SAND2013-10395C

Courtesy JFE Steel Corporation

Impact of hydrogeological and geomechanical properties on surface uplift at a CO_2 injection site: Parameter estimation

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09/12/2013

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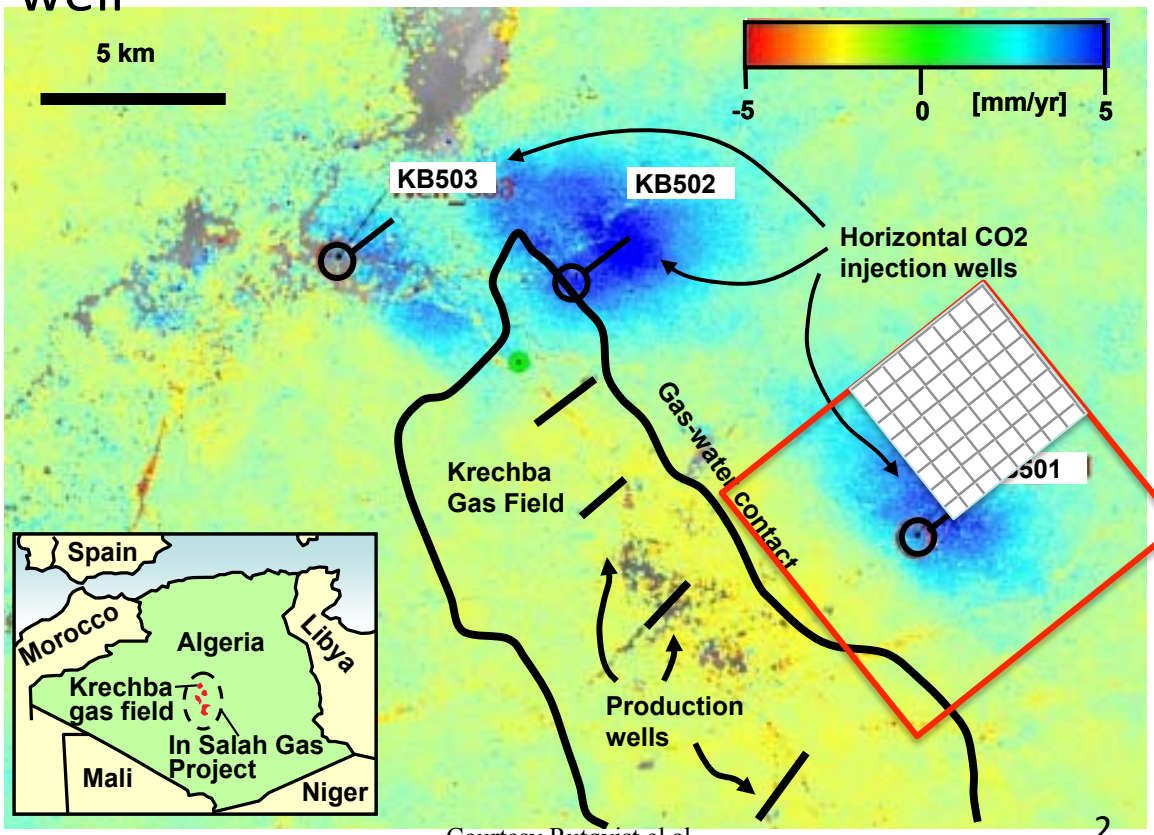
InSalah-Algeria

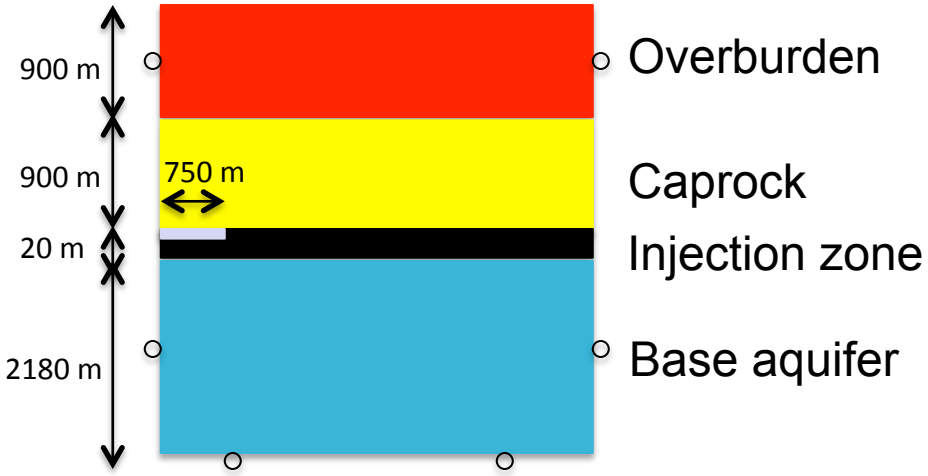
- In Salah, an industrial-scale CCS project in Algeria has been in operation since 2004.
- 3 Horizontal injection well
- 4 Production well

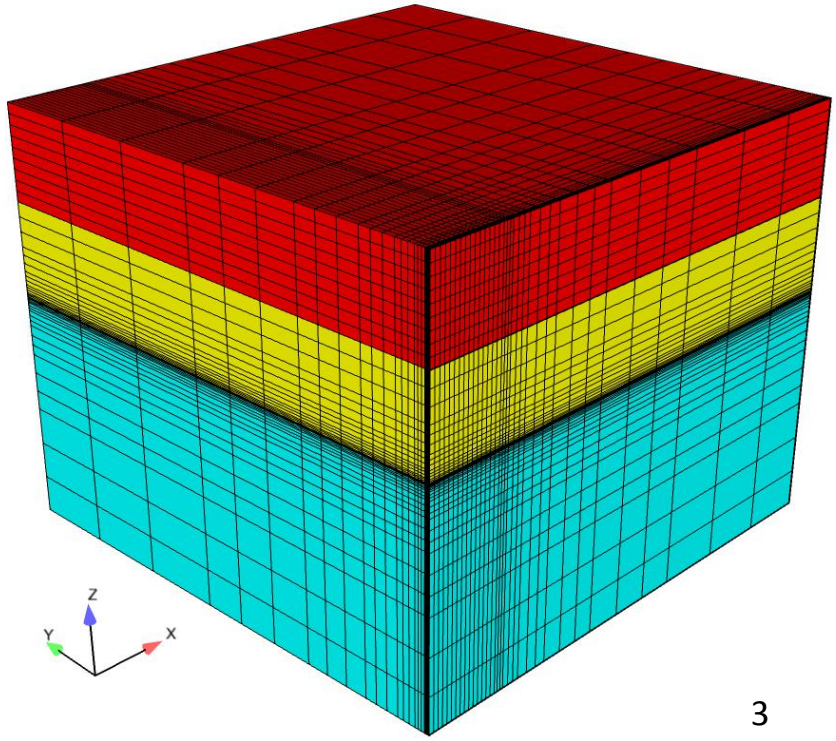


Courtesy Rutqvist el al.

Model set-up

- Q.Sym (5km x 5 km x 4 km)
- Horizontal well: 1500 m
- Coarse mesh: # of elem = 1408
- Refine mesh: # of elem = 38106
- Constant injection rate: 0.2Mt/yr
- Isothermal at 90 ^{o}C

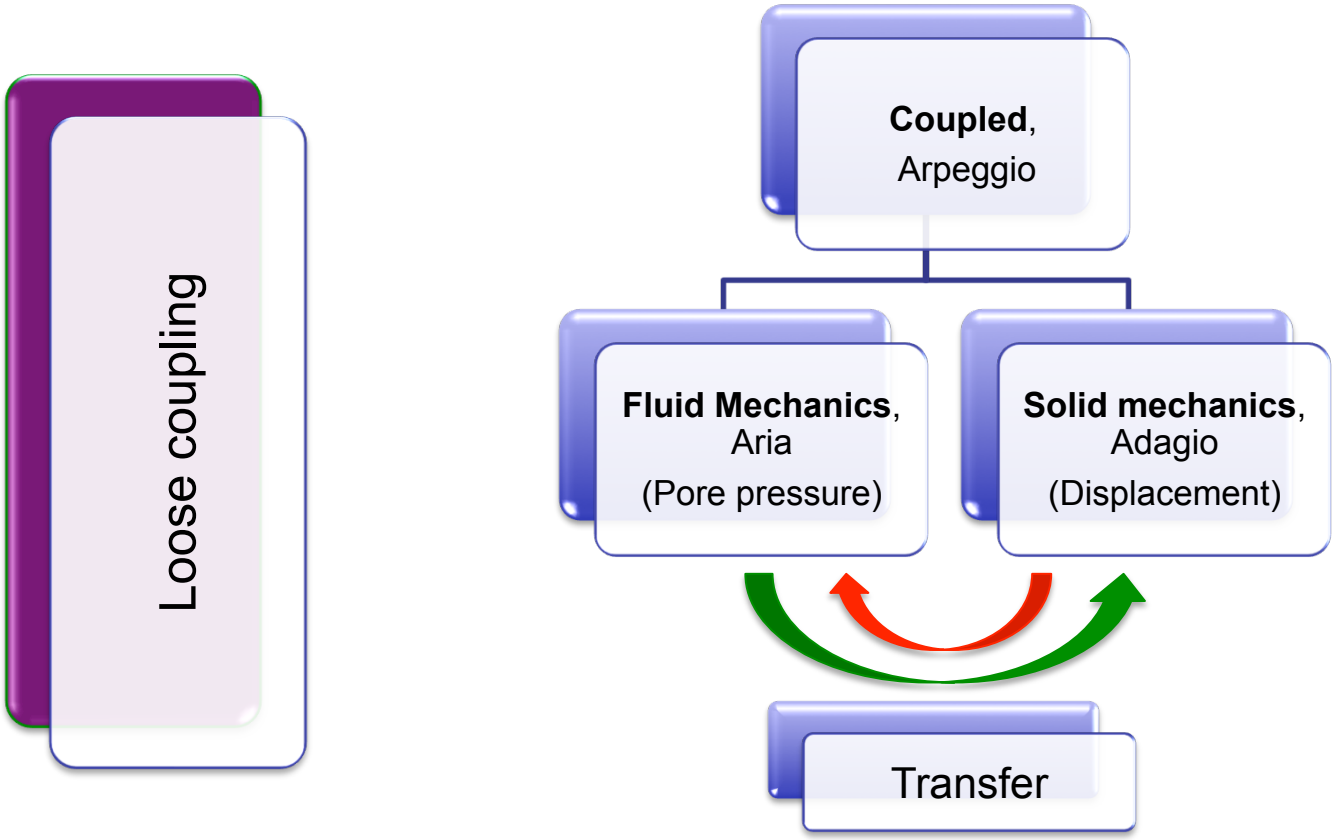




Material properties

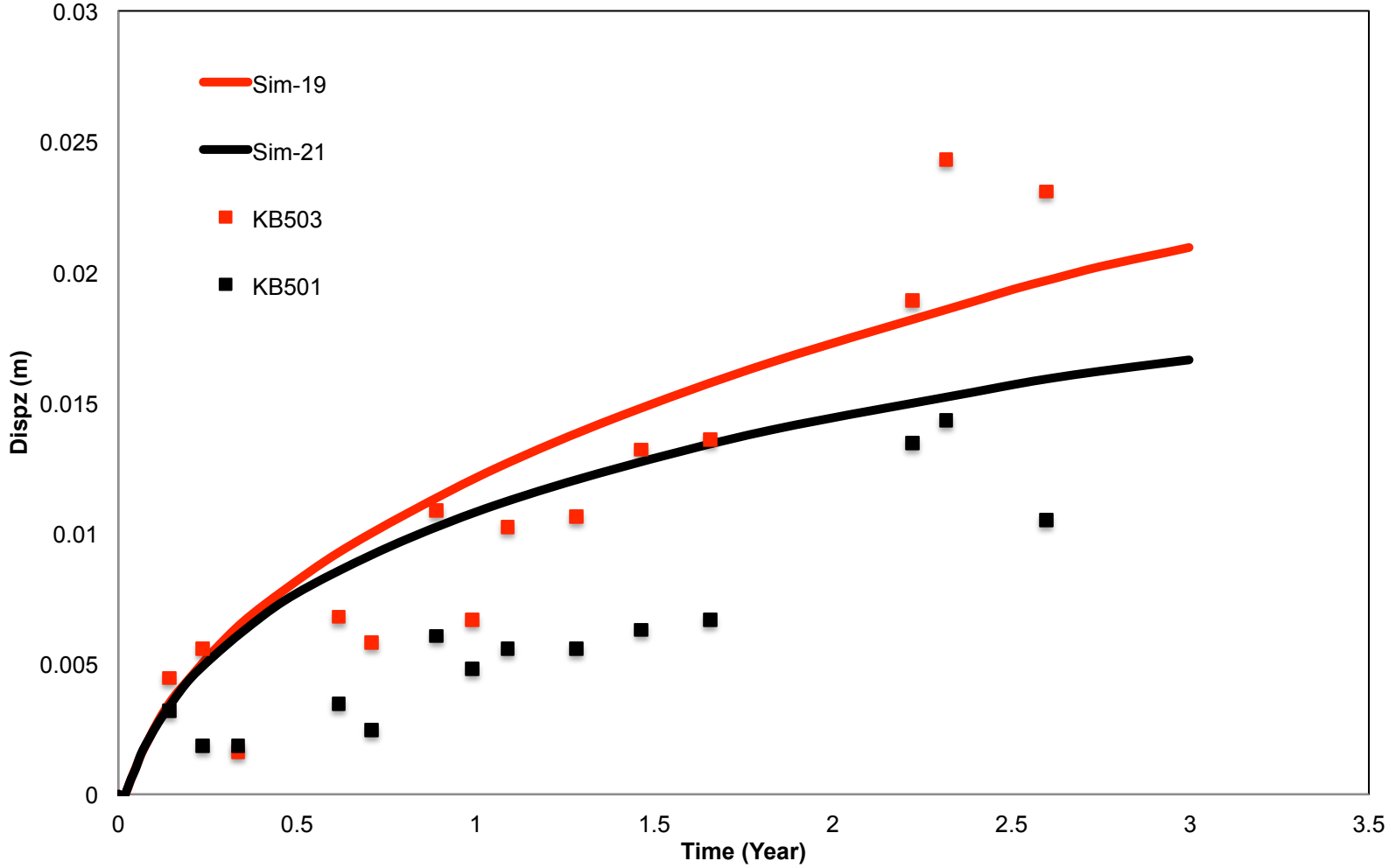
Property	Overburden	Caprock	Injection zone	Initial porosity	Units
Density	2260	2260	2260	2260	kg/m^3
Young modulus	1.5	20	6	20	GPa
Poisson's ratio	0.2	0.15	0.2	0.15	
Initial porosity	0.1	0.01	0.17	0.01	
Intrinsic permeability	1.0×10^{-17}	1.0×10^{-19} 1.0×10^{-21}	1.3×10^{-14}	1.0×10^{-19}	m^2
Biot's Coefficient	1.0	1.0	1.0	1.0	
Van Genuchten, P_0	19.9	19.9	19.9	19.9	kPa
Van Genuchten, b	1.8416	1.8416	1.8416	1.8416	m

Sierra Mechanics

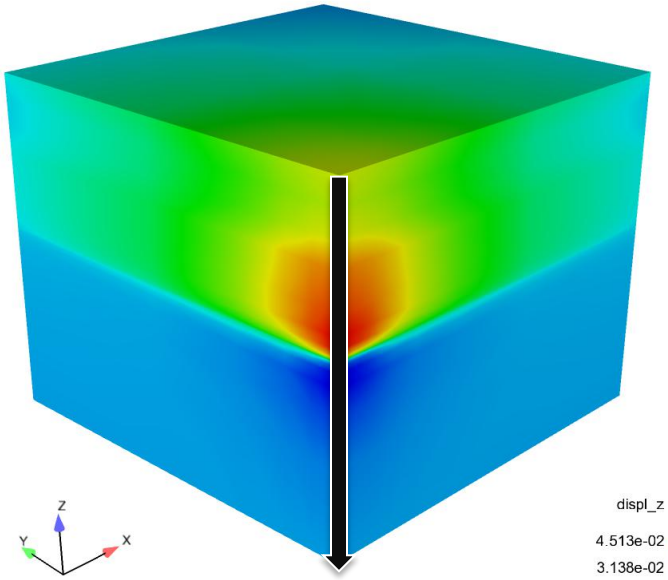


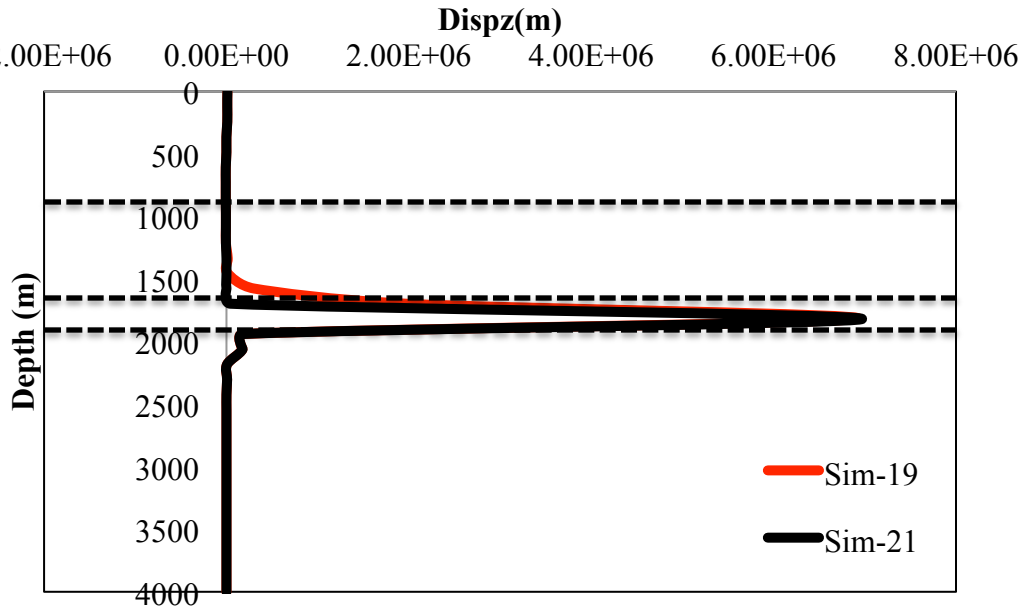
Aria: Galerkin FE program for coupled-physics problems described by systems of coupled PDEs
Adagio: 3-D, implicit, nonlinear Quasi-Statics; dynamics code
Arpeggio: Couples the Adagio, Aria Sierra Mechanics modules.

Surface uplift-KB501 and KB503

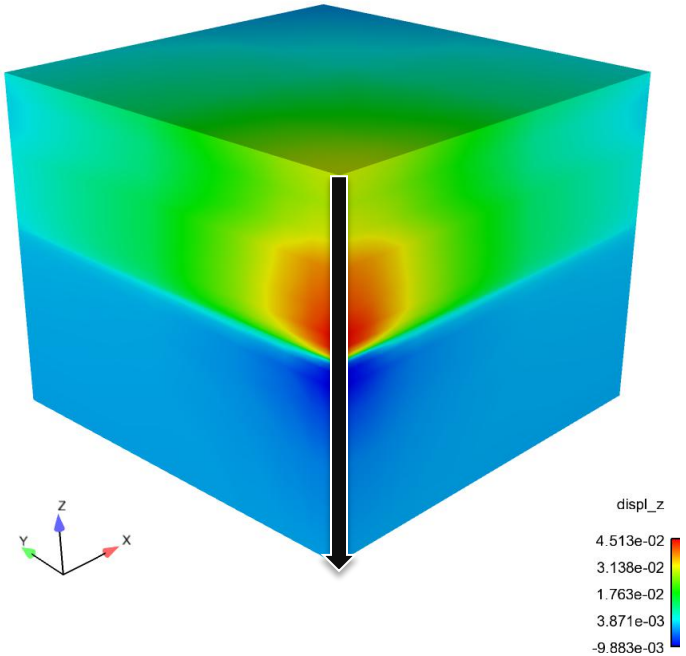


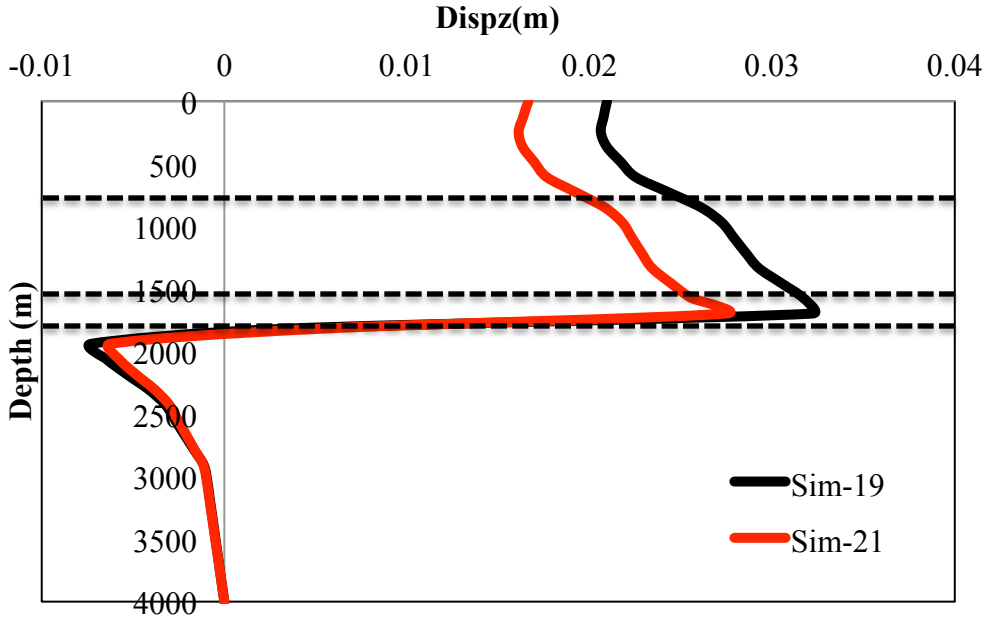
Change in the pore pressure though the depth at year 3



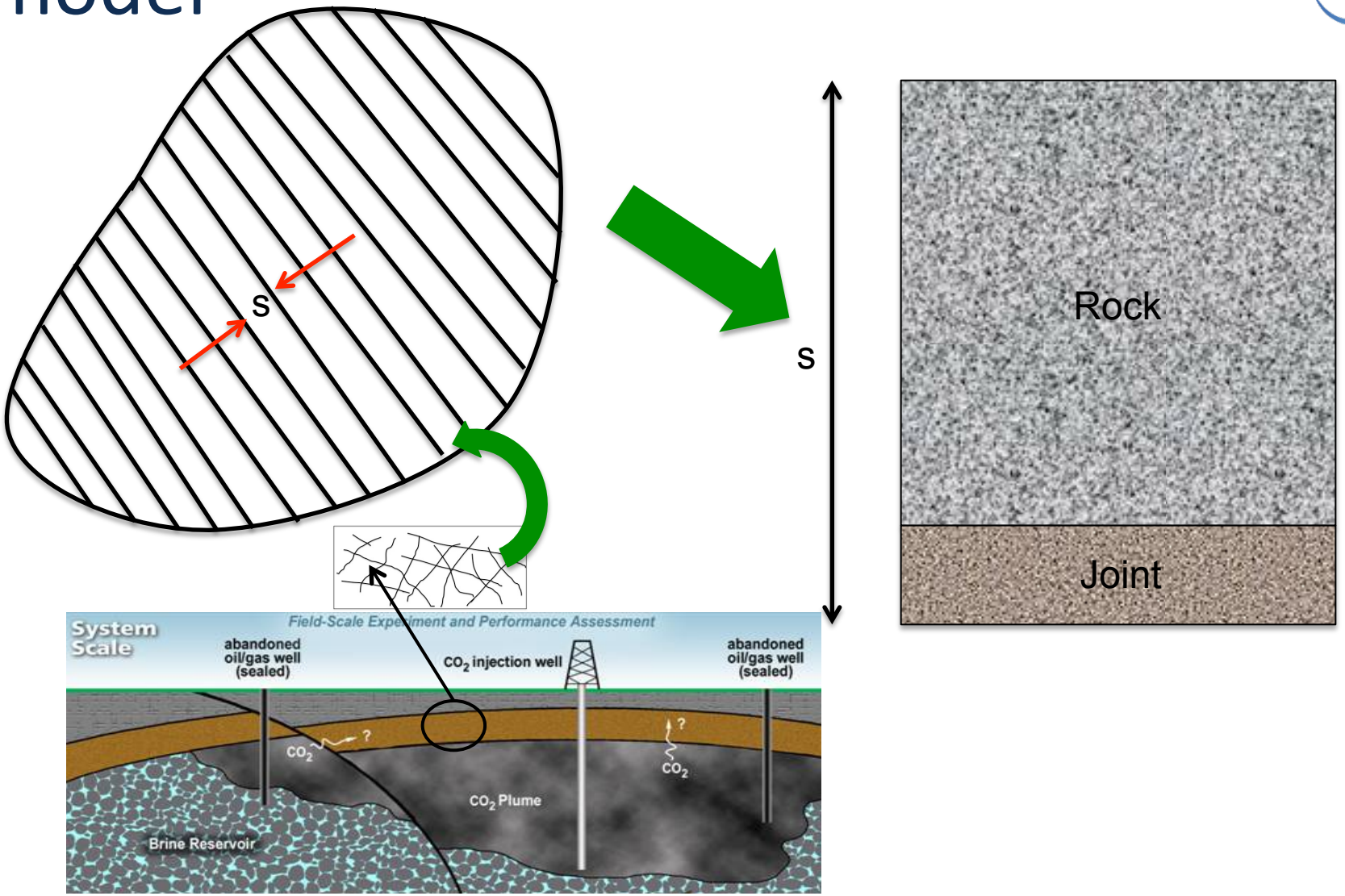


Change in the vertical displacement though the depth at year 3





Equivalent continuum model-Geo model



Coupling formulation

Coupling

$$K_{eff} = K_R + \sum_{J=1}^{n} K_J$$

$$n_1 = \sin\alpha \sin\beta$$

$$n_2 = \sin\alpha \cos\beta$$

$$n_3 = \cos\alpha$$

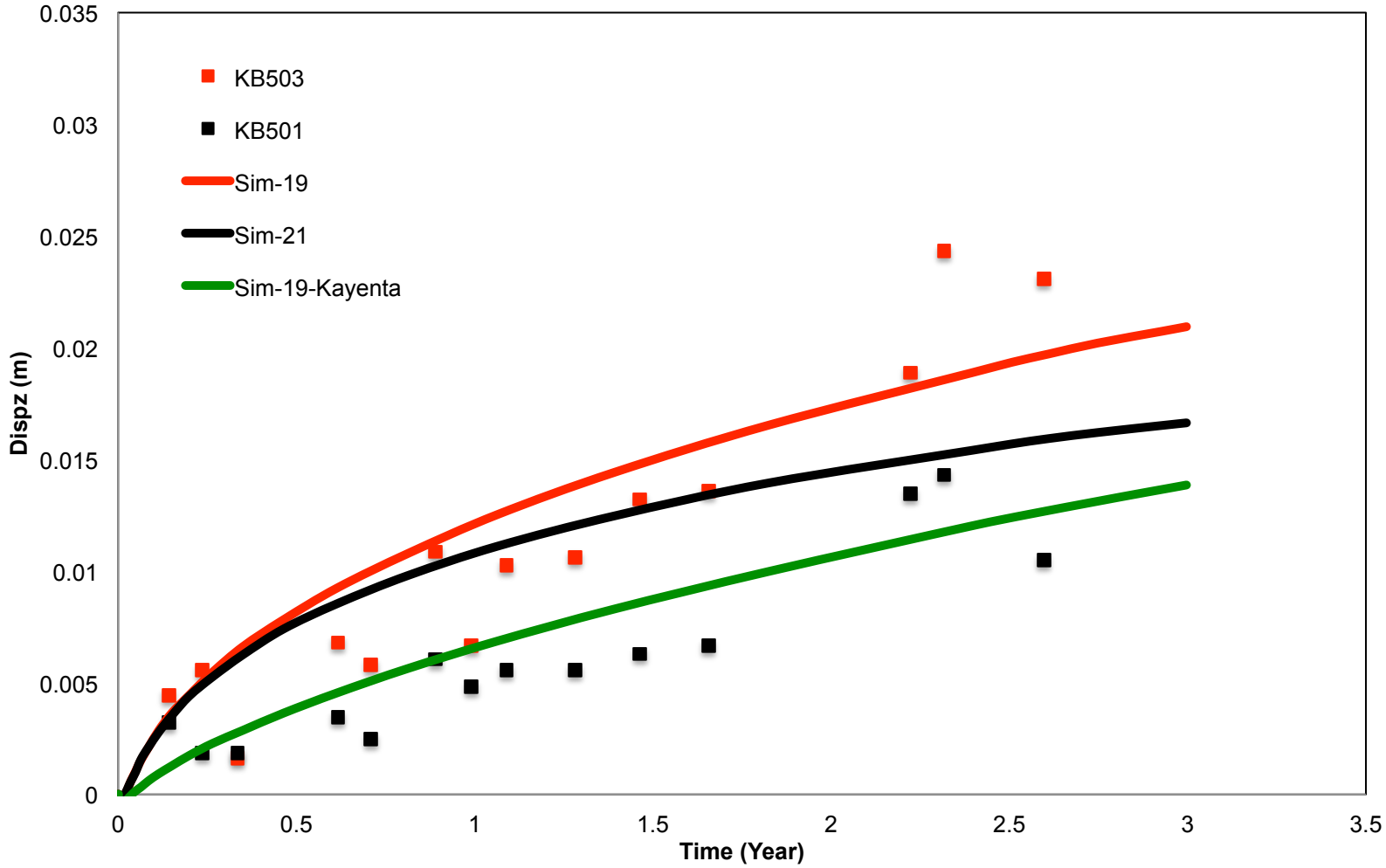
Joint opening

Joint spacing

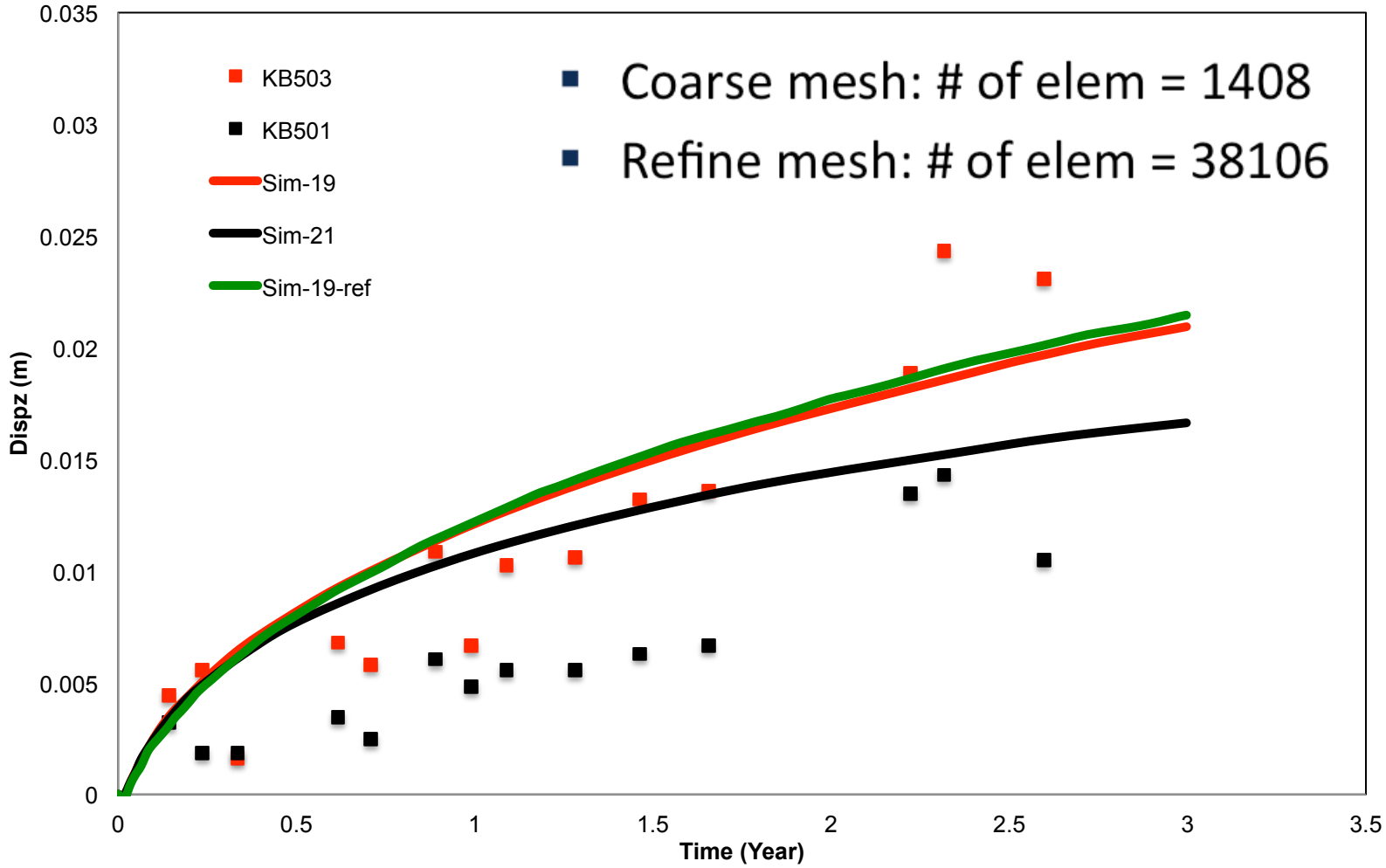
$$K_J = \frac{b^3}{12s} \begin{bmatrix} 1-n_1^2 & -n_1 n_2 & -n_1 n_3 \\ -n_1 n_2 & 1-n_2^2 & -n_2 n_3 \\ -n_1 n_3 & -n_2 n_3 & 1-n_3^2 \end{bmatrix}$$

- **Kayenta (Geo-material model)**
  - Joint opening
- **Adagio (Solid mechanics)**
  - K_J
- **Aria (Fluid mechanics)**
  - K_R
- **Effective permeability**
  - K_{eff}

Kayenta material model-Reservoir



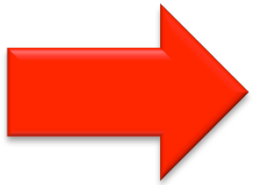
Mesh refinement



Why sensitivity analysis?

Lack of certainty in:

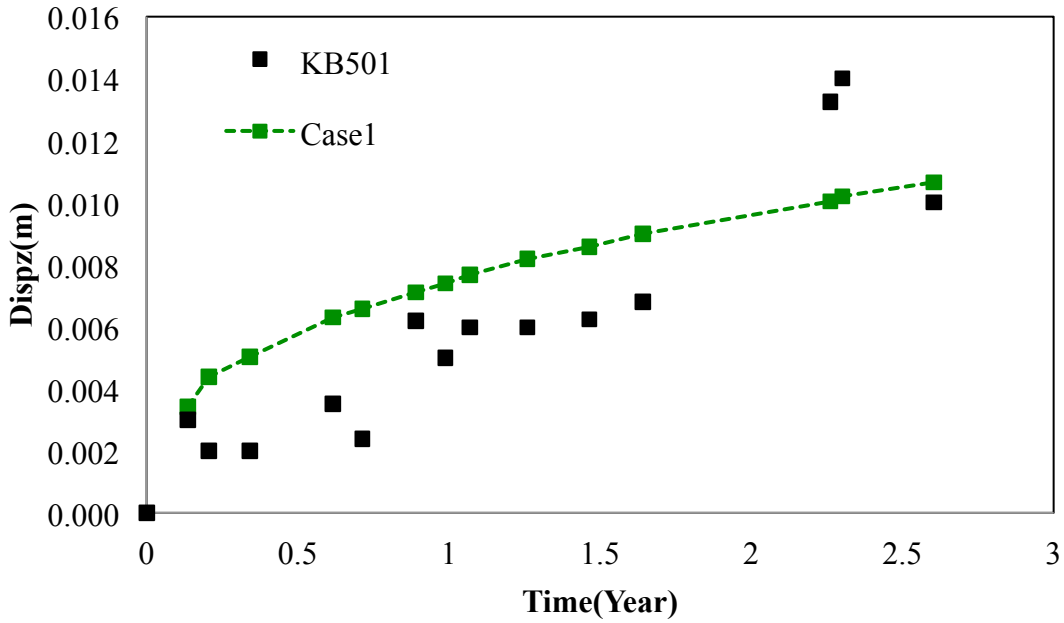
- Mechanical properties
  - Young's modulus
- Fluid properties
  - Permeability of injection zone
    - Isotropic permeability
    - Anisotropic Permeability
  - Permeability of caprock
    - Isotropic permeability
    - Anisotropic Permeability
- Coupling properties
  - Biot's coefficient



Gain better understanding of CCS process. Maximizes the probability of some good thing happening, or minimizes the probability of some bad thing happen.

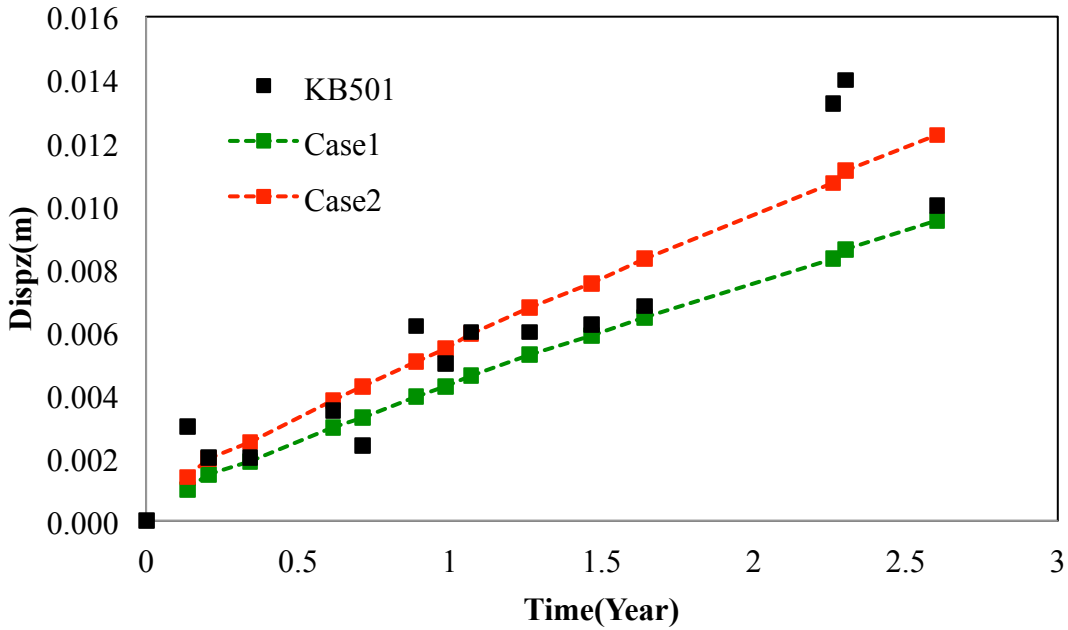
Permeability-Reservoir and Caprock

Parameter	Case1
kzz_cap	1.0E-19
kzz_res	1.0E-13
α_cap	1.0
α_res	1.0
Biot's coefficient	1.0
Residual	1.00E-04



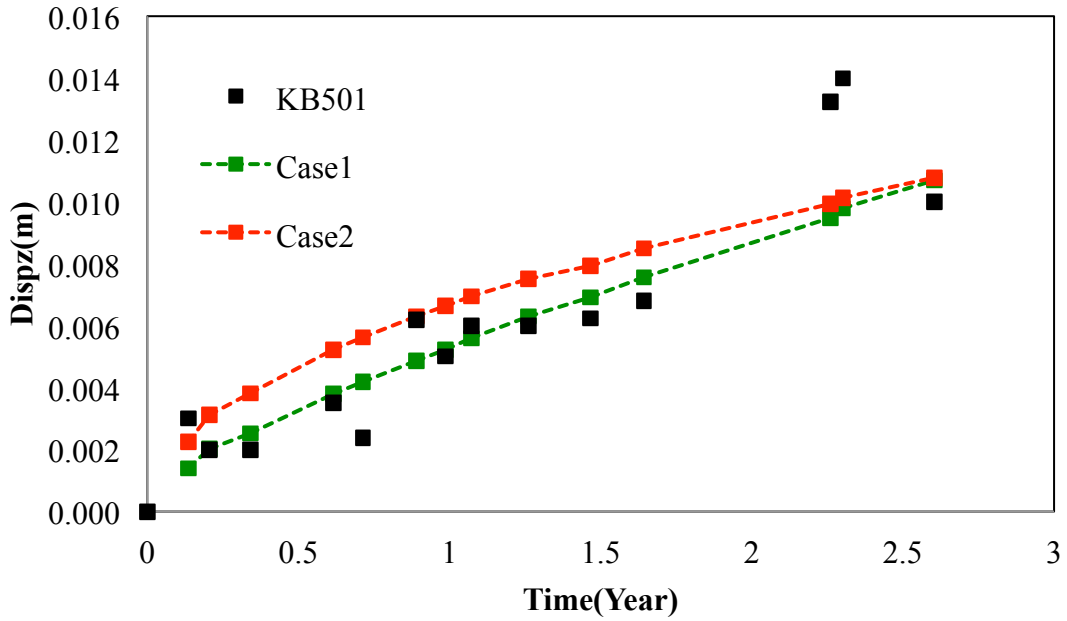
Permeability-Reservoir and Caprock

Parameter	Case1	Case2
kzz_cap	1.0E-17	1.0E-17
kzz_res	1.0E-14	1.0E-14
α_cap	0.5	0.2
α_res	17.5	50
Biot's coefficient	1.0	1.0
Residual	7.17E-05	3.55E-05



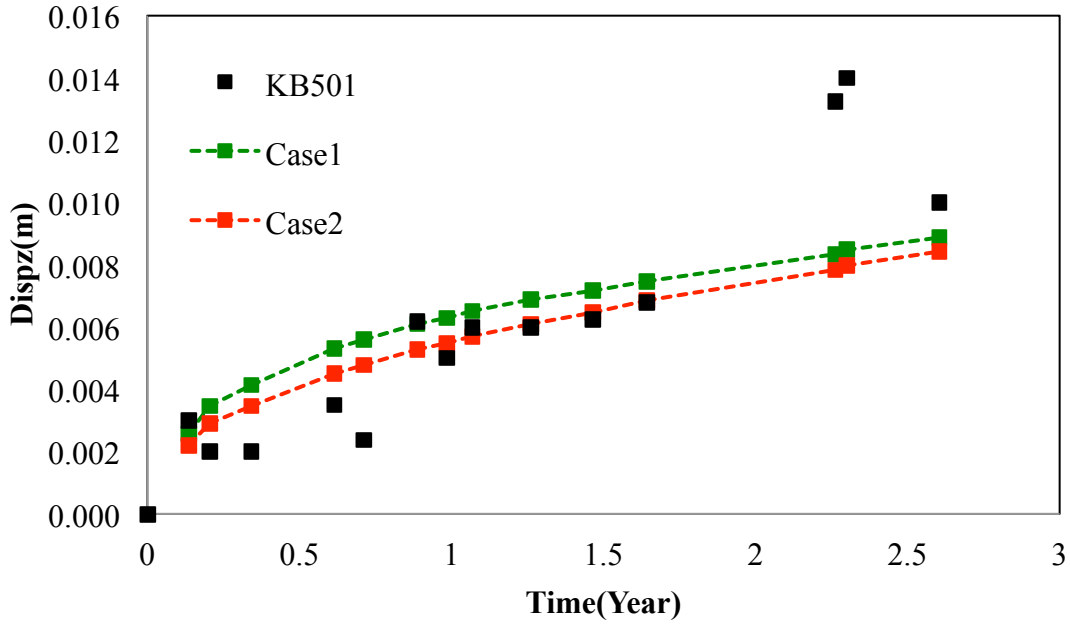
Biot's coefficient

Parameter	Case1	Case2
kzz_cap	1.0E-17	1.0E-18
kzz_res	1.0E-14	1.0E-15
α_cap	1.9	1.2
α_res	24.3	14.0
Biot's coefficient	0.63	0.57
Residual	4.64E-05	6.49E-05



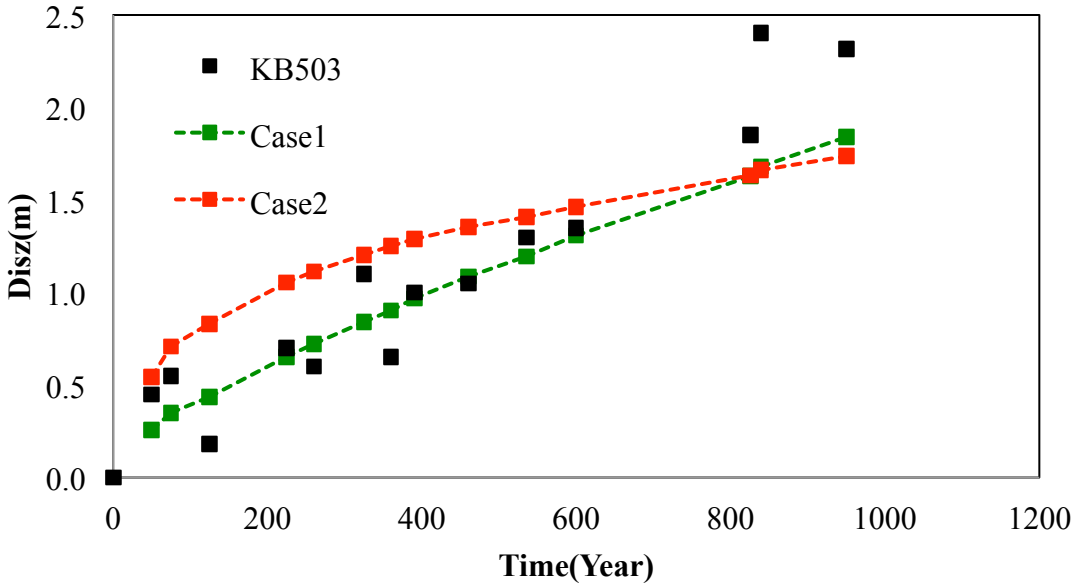
Young's modulus-Reservoir

Parameter	Case1	Case2
kzz_cap	1.0E-22	1.0E-19
kzz_res	1.0E-15	1.0E-15
α_cap	1.9	1.2
α_res	24.3	14.0
Biot's coefficient	0.8	0.7
E_res	10	9.8
Residual	4.64E-05	6.49E-05



Optimization KB503

Parameter	Case1	Case2
kzz_cap	1.0E-17	1.0E-17
kzz_res	1.0E-14	1.0E-14
alpha_cap	0.5	0.2
alpha_res	17.5	50
Biot's coefficient	1.0	1.0
Residual	7.17E-05	3.55E-05



Acknowledgment

- This work is supported as part of the ***Center for Frontiers of Subsurface Energy Security***, an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Award Number DE-SC0001114. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.