

**SPE-215349**

**Coupled Numerical Simulation Modelling of  
Depleted Gas Reservoir for Carbon Dioxide  
Sequestration**

Presenter: Marco Misenta, CMG

On behalf of:

Seyed Mousa (Pouria) Mousavi Mirkalaei, Mark Edmonson  
**Computer Modelling Group Ltd.**

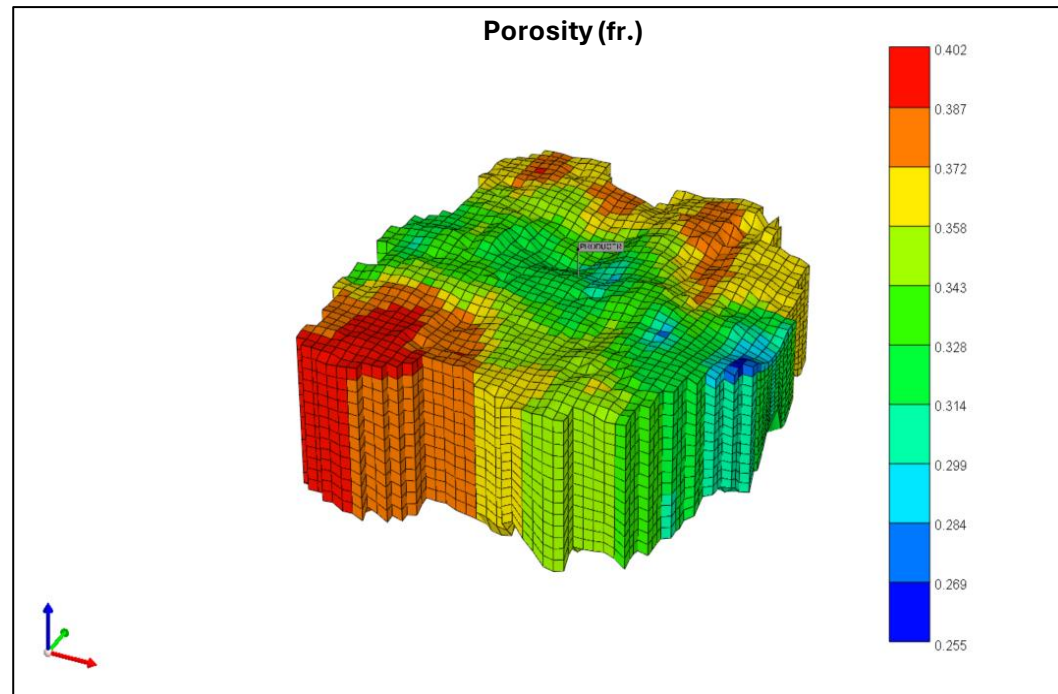
Ahmad Khanifar, **PETRONAS**

# CASE STUDY – DEPLETED GAS RESERVOIR

RESERVOIR PROPERTIES	
Porosity	34%
Permeability	200 mD
Depth	850-1100 m

SIMULATION MODEL (GEM, CMG)	
4 Components	EOS (SRK)
Solubility / Diffusion	CO <sub>2</sub> Dissolution
Hysteresis	CO <sub>2</sub> Trapping
Geomechanics	Stress / Strain / Displacement
Geochemistry	Mineralization

OPERATIONAL DATA	
Production	1 MMSCF/D - 10 Years
CO <sub>2</sub> Injection	0.5 MMSCF/D - 25 Years
Extended Forecast	1000 Years



**3D Reservoir Model**

# GEOCHEMISTRY MODEL

## AQUEOUS REACTIONS

### Reaction Stoichiometry (for **EQUILIBRIUM MODEL**)

Water Dissociation	'OH' + 'H+' = 'H <sub>2</sub> O'
CO <sub>2</sub> / Water Interaction	'H <sub>2</sub> O' + 'CO <sub>2</sub> ' = 'HCO <sub>3</sub> <sup>-</sup> ' + 'H <sup>+</sup> '
Bicarbonate Ion Link	'CO <sub>3</sub> <sup>-</sup> ' + 'H <sup>+</sup> ' = 'HCO <sub>3</sub> <sup>-</sup> '

Pre/post-CO<sub>2</sub> soaking experiments show prevalence of 5 mineral species, and related reactions:

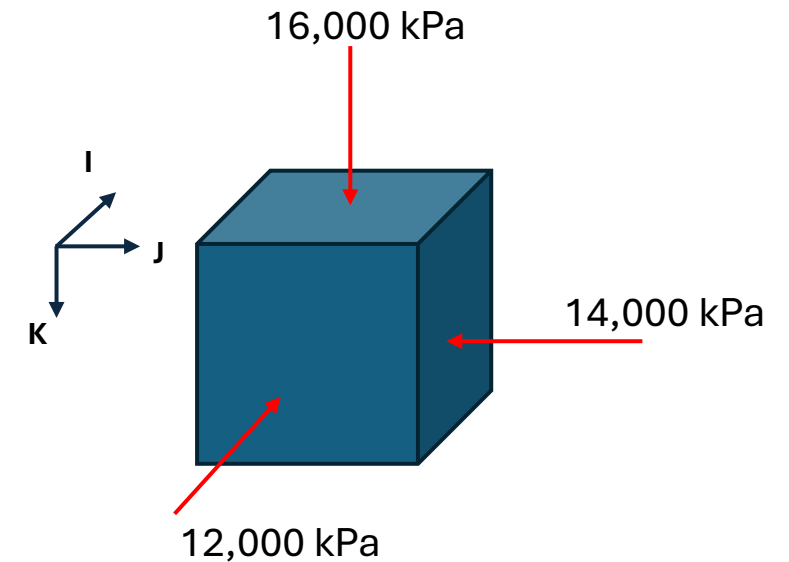
MINERALS LIST	Volume Fr.	Reaction Stoichiometry (for <b>KINETIC MODEL</b> )
Siderite	0.008	'Siderite' + 'H+' = 'HCO <sub>3</sub> <sup>-</sup> ' + 'Fe <sup>++</sup> '
Muscovite	0.061	'Muscovite' + 10 'H+' = 3 'SiO <sub>2</sub> ' + 3 'Al <sup>+++</sup> ' + 'K+' + 6 'H <sub>2</sub> O'
Smectite	0.0246	'Smectite' + 8 'H+' = 0.2 'Fe <sup>+++</sup> ' + 3.5 'SiO <sub>2</sub> ' + 0.5 'Fe <sup>++</sup> ' + 1.25
Kaolinite	0.0342	'Kaolinite' + 6 'H+' = 2 'SiO <sub>2</sub> ' + 2 'Al <sup>+++</sup> ' + 5 'H <sub>2</sub> O'
Dolomite	0.024	'Dolomite' + 2 'H+' = 2 'HCO <sub>3</sub> <sup>-</sup> ' + 'Mg <sup>++</sup> ' + 'Ca <sup>++</sup> '

# GEOMECHANICS MODEL

Two geo-rock types differentiate the mechanical response of Reservoir and Over/Under/Side-burden regions

GEO-ROCK DATA	RESERVOIR	NON-RESERVOIR
Constitutive Model	MOD CAM CLAY	MOHR-COULOMB
Young Modulus	114500.0 kPa	600000.0 kPa
Poisson Ratio	0.27	0.35
Cohesion	-	730e6 kPa
Biot Coefficient	1	0
Friction Angle	26.0 degree	19.0 degree
Swelling Index	0.1	-
Compression Index	0.2	-
Preconsolidated Pressure	200.0 kPa	-
Ratio of Critical State	1.0	-
Bulk Mod. Exponential	1.002	-

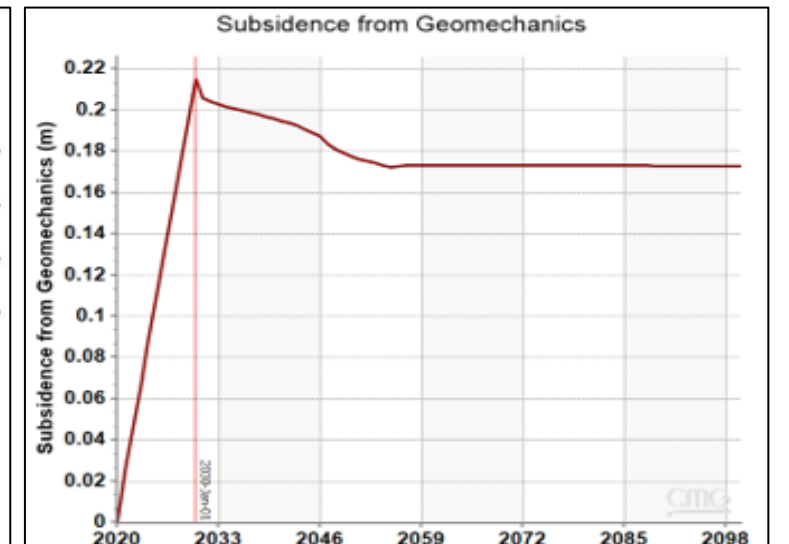
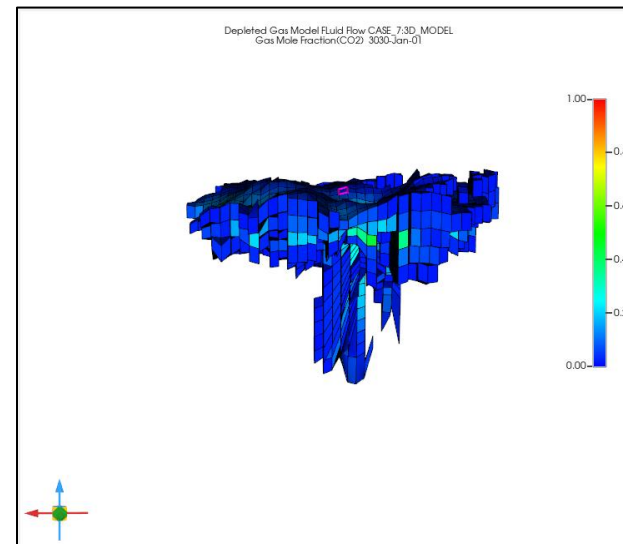
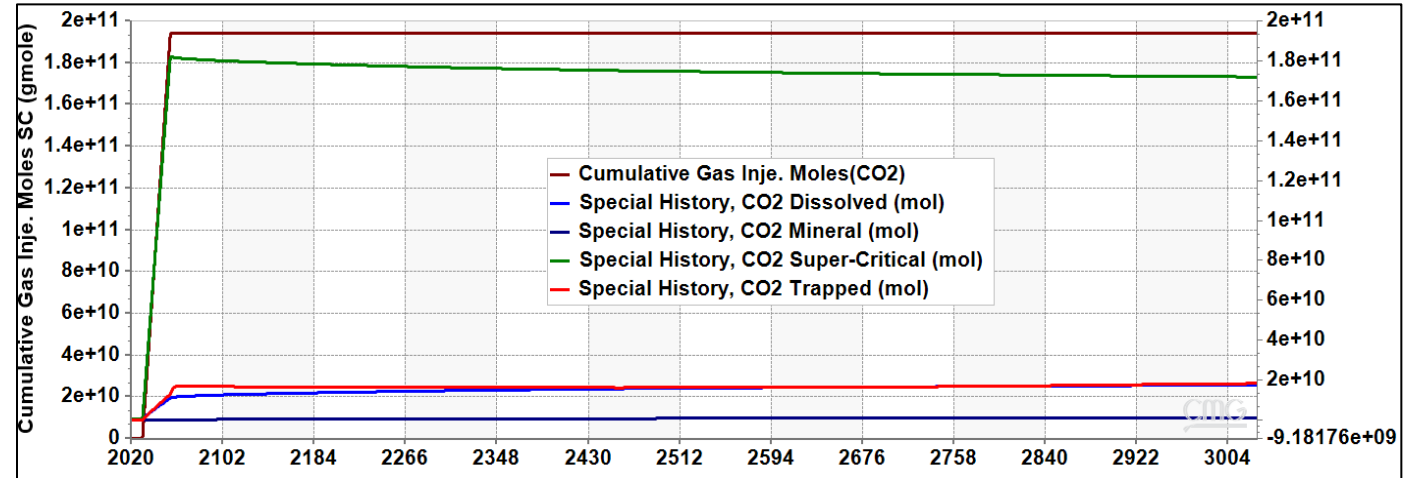
## Principal Stresses:



Stress Gradient  $\sim 10$  kPa/m

# RESULTS

- Trapping mechanisms ranking:
  - **Structural** (SC CO<sub>2</sub>)
  - **Solubility** (Water)
  - **Residual** (Hysteresis)
  - **Mineral**
- Convective Flow of CO<sub>2</sub> drives the CO<sub>2</sub> **Plume Evolution** (shown here at end simulation)
- Production and Injection cause rock Compaction and Dilation with 4 cm elastic **Displacement** in the vertical direction



# CONCLUSIONS

- Successful Coupled **Geochemistry / Geomechanics / Fluid Flow** in **Depleted Gas Reservoir**
- Accurate CO<sub>2</sub> **Plume Migration** prediction with Geochemistry and Geomechanics
- Rock **Deformation** estimation at reservoir top and surface



**Thank You**