

# Multiphase RTA Consortium

Which reservoir parameters change the producing GOR profile, and how?

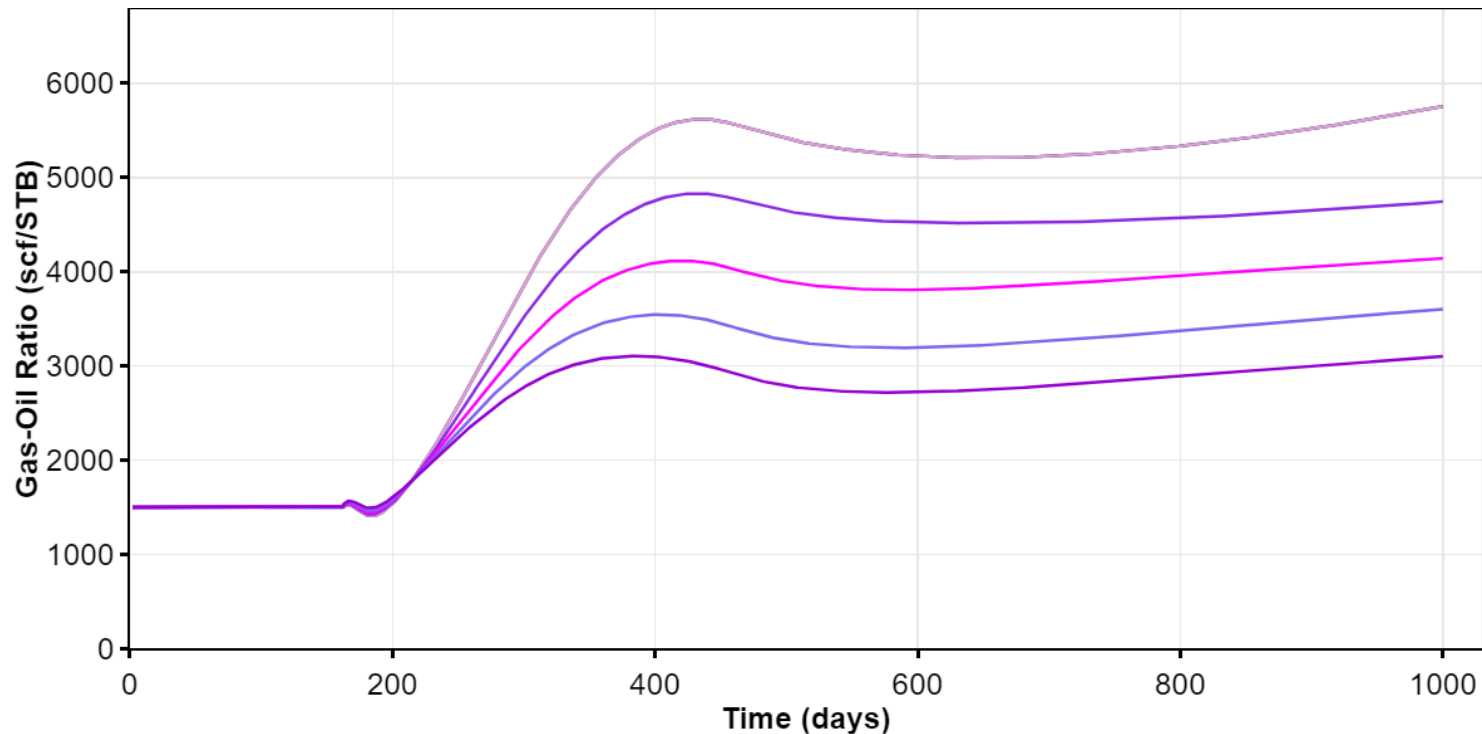
2023

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**Intro**

# Problem Statement

We observe a wide-range of producing GOR profiles in tight unconventional.



But which reservoir parameters change producing GOR when the bottomhole pressure is below the saturation pressure? And how?

# Summary:

## Which parameters change producing GOR, and how?

Parameter	Relationship to producing GOR*
Fracture conductivity, $F_{cd}$	$GOR \propto F_{cd}$
Geomechanical effects, $\gamma$	$GOR \propto 1/\gamma_{matrix}$   $GOR \propto 1/\gamma_{fracture}$
Volume beyond frac tips / height	$GOR \propto 1/x_e$   $GOR \propto 1/h$
Relative Permeability Residuals	$GOR \propto S_{wc}$   $GOR \propto S_{orw}$   $GOR \propto S_{org}$   $GOR \propto 1/S_{gc}$
Relative Permeability Exponents	$GOR \propto 1/n_w$   $GOR \propto n_{ow}$   $GOR \propto 1/n_g$   $GOR \propto n_{og}$
Relative Permeability Endpoints <sup>[2]</sup>	$GOR \propto k_{rwro}$   $GOR \propto 1/k_{rocw}$   $GOR \propto k_{rgro}$

[1] Producing GOR when  $p_{wf} < p_{sat}$

[2]  $k_{rwro}$ : Relative perm of water at  $S_w = 1 - S_{orw}$ ,  $S_g = 0$

[2]  $k_{rocw}$ : Relative perm of oil at  $S_w = S_{wc}$ ,  $S_g = 0$ .

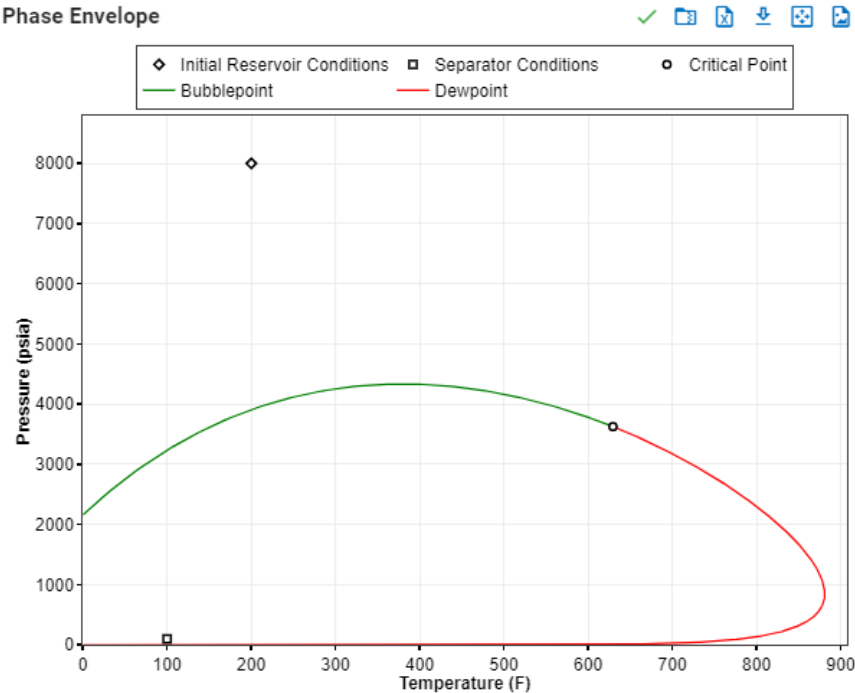
[2]  $k_{rgro}$ : Relative perm of gas at  $S_w = S_{wc}$ ,  $S_o = S_{org}$

Baker is used for three-phase relative perm.

# Sensitivities

# Base Case: Fluid System

Phase Envelope



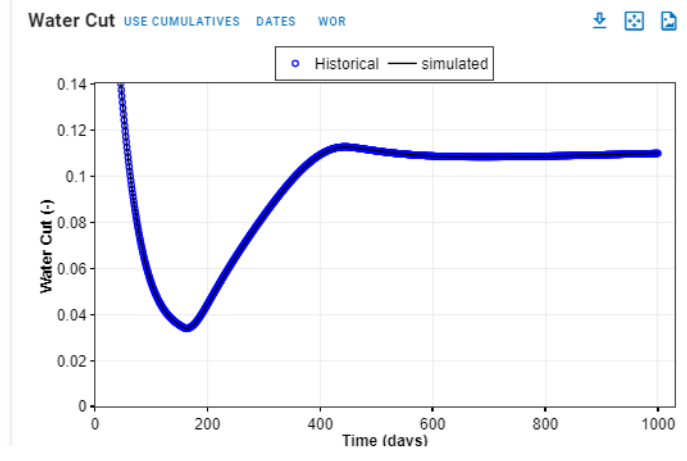
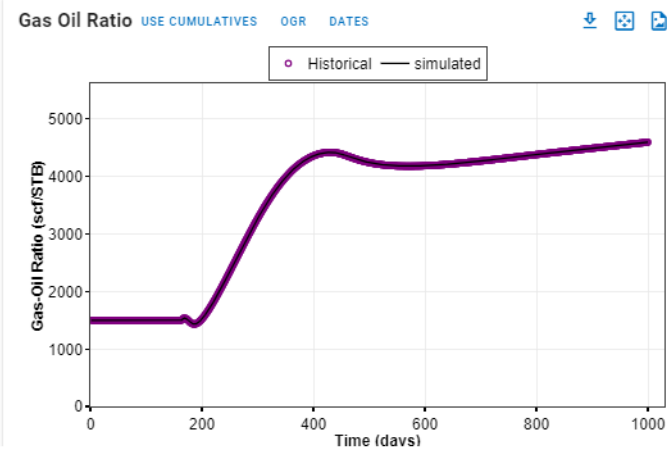
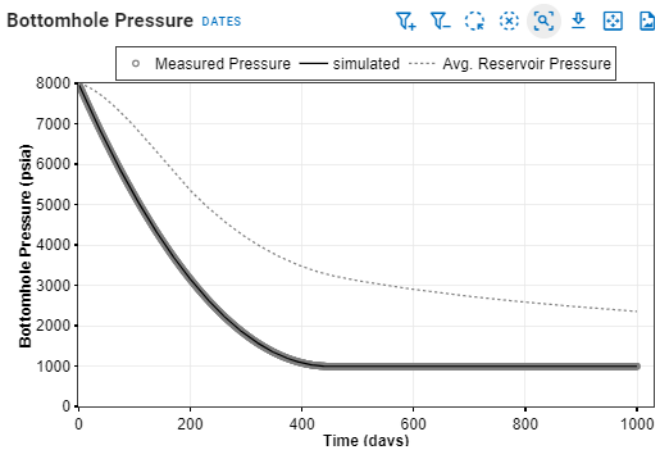
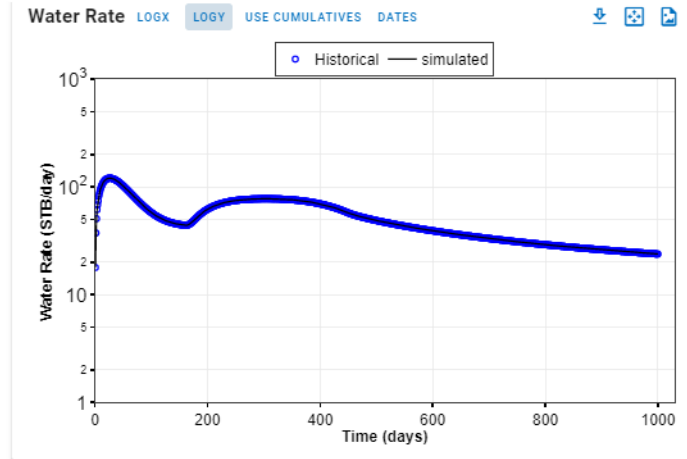
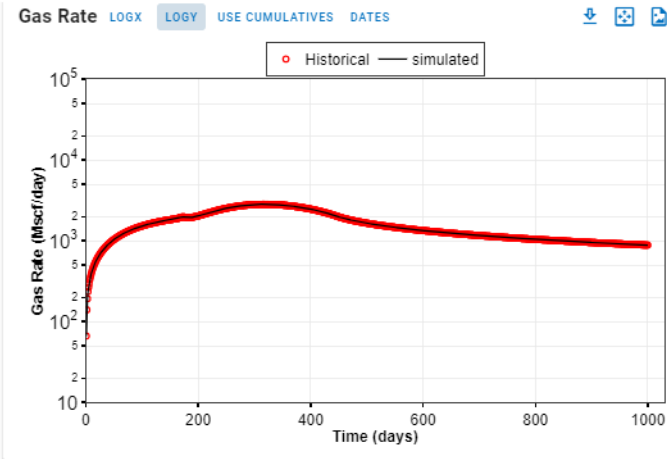
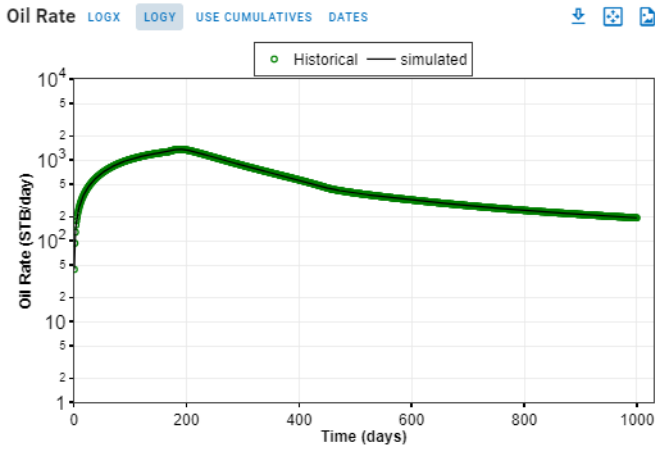
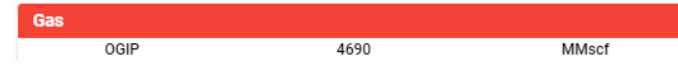
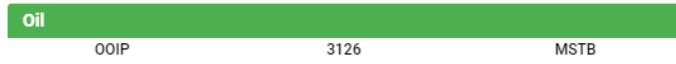
- $p_{Ri} = 8000$  psia |  $T_{res} = 200$  F
- Initially undersaturated
- Bubblepoint,  $p_{bi} = 3900$  psia
- $B_{oi} = 1.69$  RB/STB
- $R_{si} = 1500$  scf/STB
- Volatile oil

Fluid Properties at Initial Reservoir Conditions

Reservoir Type	Total FVF - Bt	Total GOR - Rt	Bubblepoint - pb	Reservoir Classification
Undersaturated Oil	1.691 RB/STB	1500 scf/STB	3907.06 psia	Volatile Oil
Oil Saturation - So	Oil FVF - Bo	Solution GOR - Rs	Oil Viscosity - $\mu_o$	Reservoir Oil Density - $\rho_o$
100%	1.691 RB/STB	1500 scf/STB	0.180 cp	40.046 lbm/ft <sup>3</sup>

# Base Case: Production Data

OOIP = 3130 STB | LFP = 320,000 ft<sup>2</sup>md<sup>1/2</sup>



# Base Case: Input

OOIP = 3130 STB | LFP = 320,000 ft<sup>2</sup>md<sup>1/2</sup>

**Well data** Layers: 1 + x

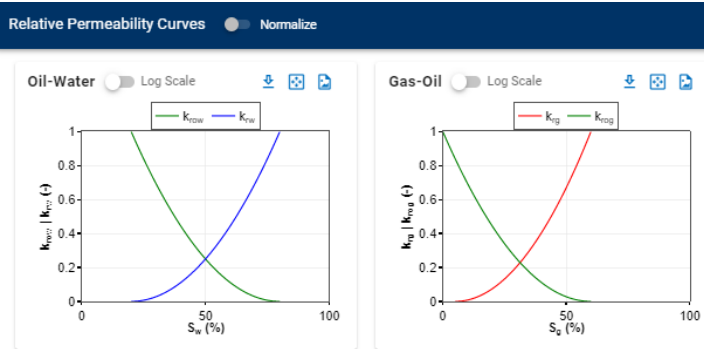
Display Only 10 Fractures  Display Entire Well Box

Well Lateral Length,  $L_w$  5280 ft  
 Number of Fractures 100  
 Dimensionless Frac Conductivity 1000

Fracture Height 200 ft  
 Fracture Half Length,  $x_f$  400 ft  
 Reservoir Half Length,  $x_e$  400 ft

Reservoir Height 200 ft  
 Matrix Permeability 100 nd  
 Matrix Porosity 0.05

Rock Compressibility 4 e-6/psia  
 Fracture Gamma,  $\gamma_f$  0 1e-4/psia  
 Matrix Gamma,  $\gamma_m$  0 1e-4/psia



**Relative Permeability**

MATRIX FRACTURE

Relative Permeability Well Specific Relative Permeability Set

Residual Saturations

Swc	Sorc	Sorg	Sgc
20 %	20 %	20 %	5 %

Exponents

nw	nog	ng	nog
2	2	2	2

Endpoint Permeabilities

kwro	krow	krro
1	1	1

SAVE

Fracture Rel. Perm:  
Straight line rel. permeabilities.

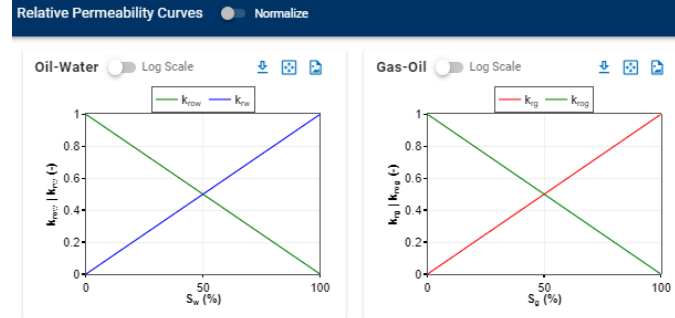
Matrix Rel. Perm:  
This is the default Corey relative permeability.

**Fluid Initialization** ⚙️ x

Initial GOR 1500 scf/STB  
 Initial Water Saturation 30 %  
 Initial Reservoir Pressure 8000 psia

Initial Solution GOR - Rs 1500 scf/STB  
 Oil Saturation - So 70.0 %  
 Saturation Pressure 3907.06 psia

Initial Solution CGR - rs - Rv 51.73 STB/MMscf  
 Gas Saturation - Sg 0.0 %  
 Reservoir Temperature 200 F



**Relative Permeability**

MATRIX FRACTURE

Relative Permeability Well Specific Relative Permeability Set

Residual Saturations

Swc	Sorc	Sorg	Sgc
0 %	0 %	0 %	0 %

Exponents

nw	nog	ng	nog
1	1	1	1

Endpoint Permeabilities

kwro	krow	krro
1	1	1

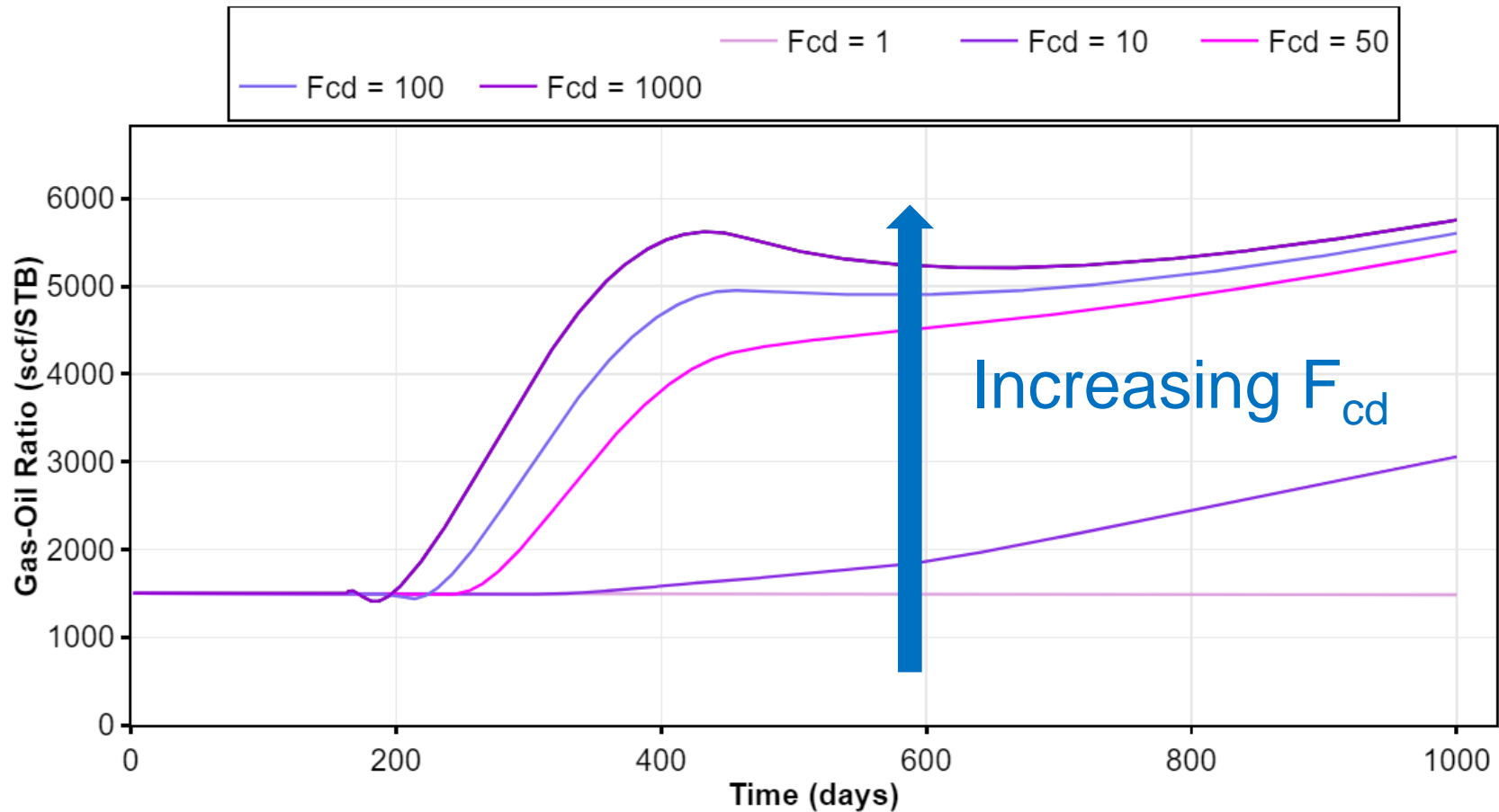
SAVE



# Fracture Conductivity: $F_{cd}$

$GOR \propto F_{cd}$ : When  $F_{cd}$  goes up, GOR goes up\*

Gas Oil Ratio USE CUMULATIVES OGR DATES

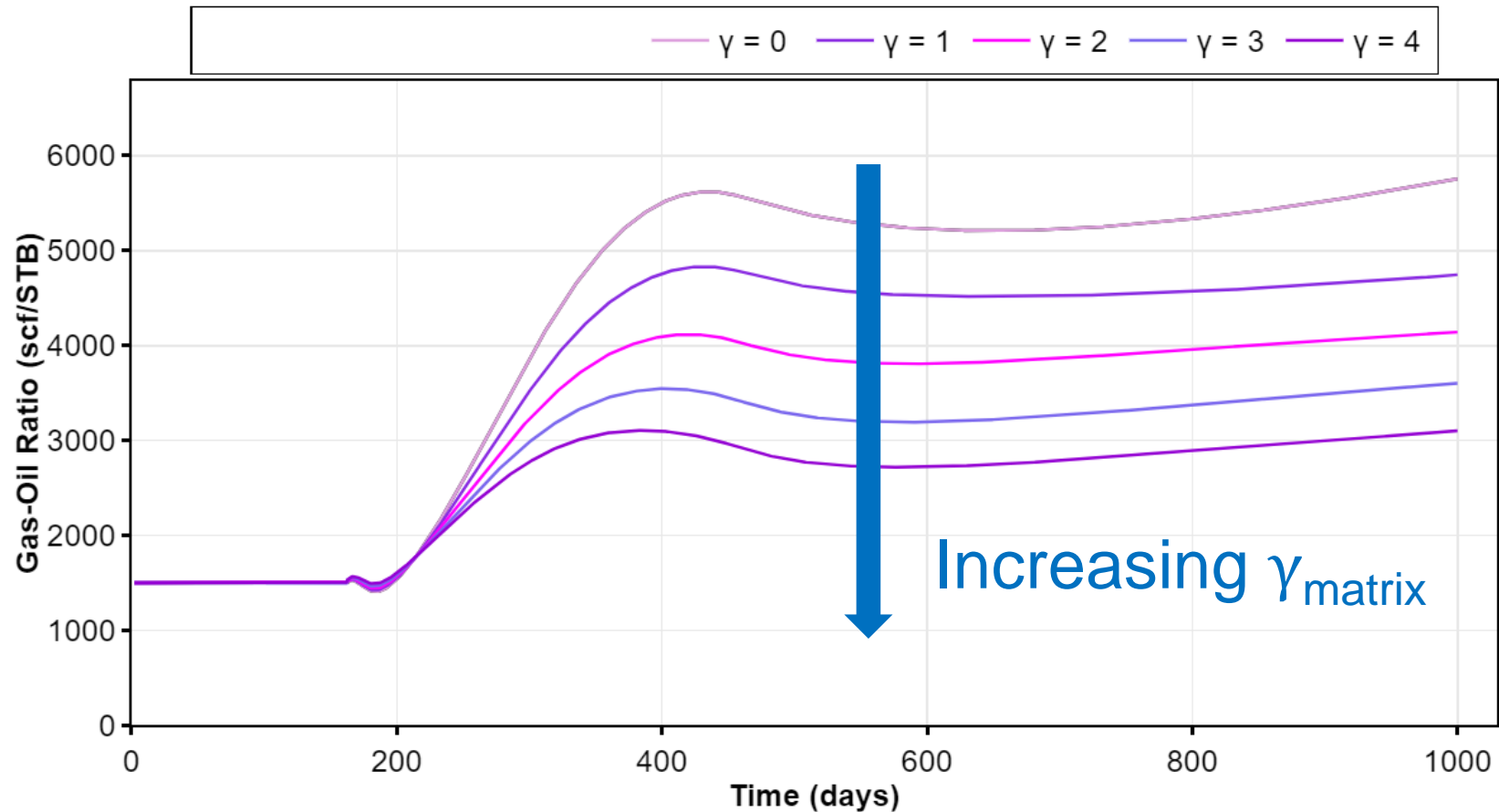


\*The GOR does not go up more when  $F_{cd}$  starts to behave infinite conductive.

# Geomechanical Effects: $\gamma_{matrix}$

$GOR \propto 1/\gamma_{matrix}$ : When  $\gamma_{matrix}$  goes up, GOR goes down

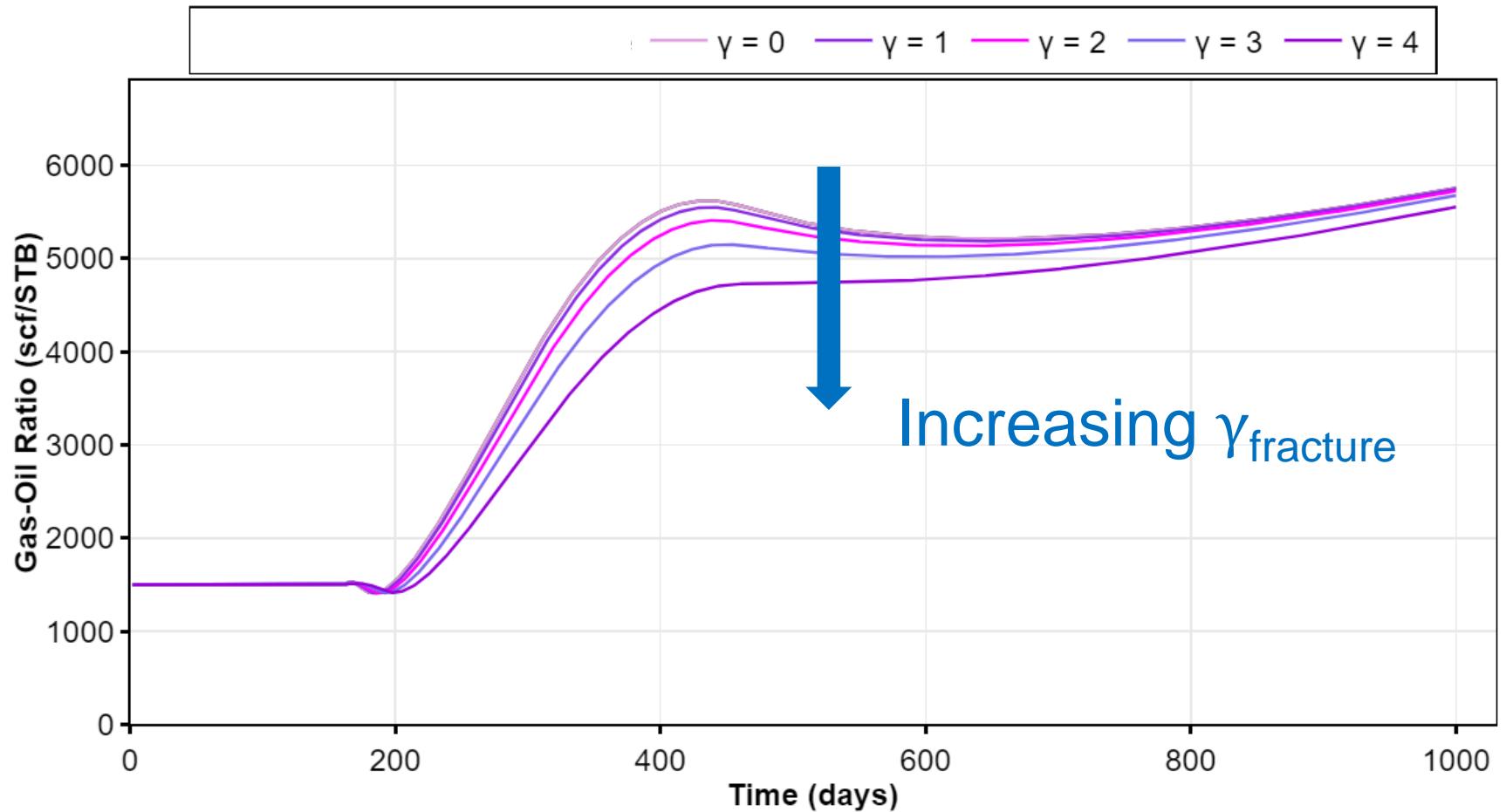
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# Geomechanical Effects: $\gamma_{fracture}$

$GOR \propto 1/\gamma_{fracture}$ : When  $\gamma_{fracture}$  goes up, GOR goes down

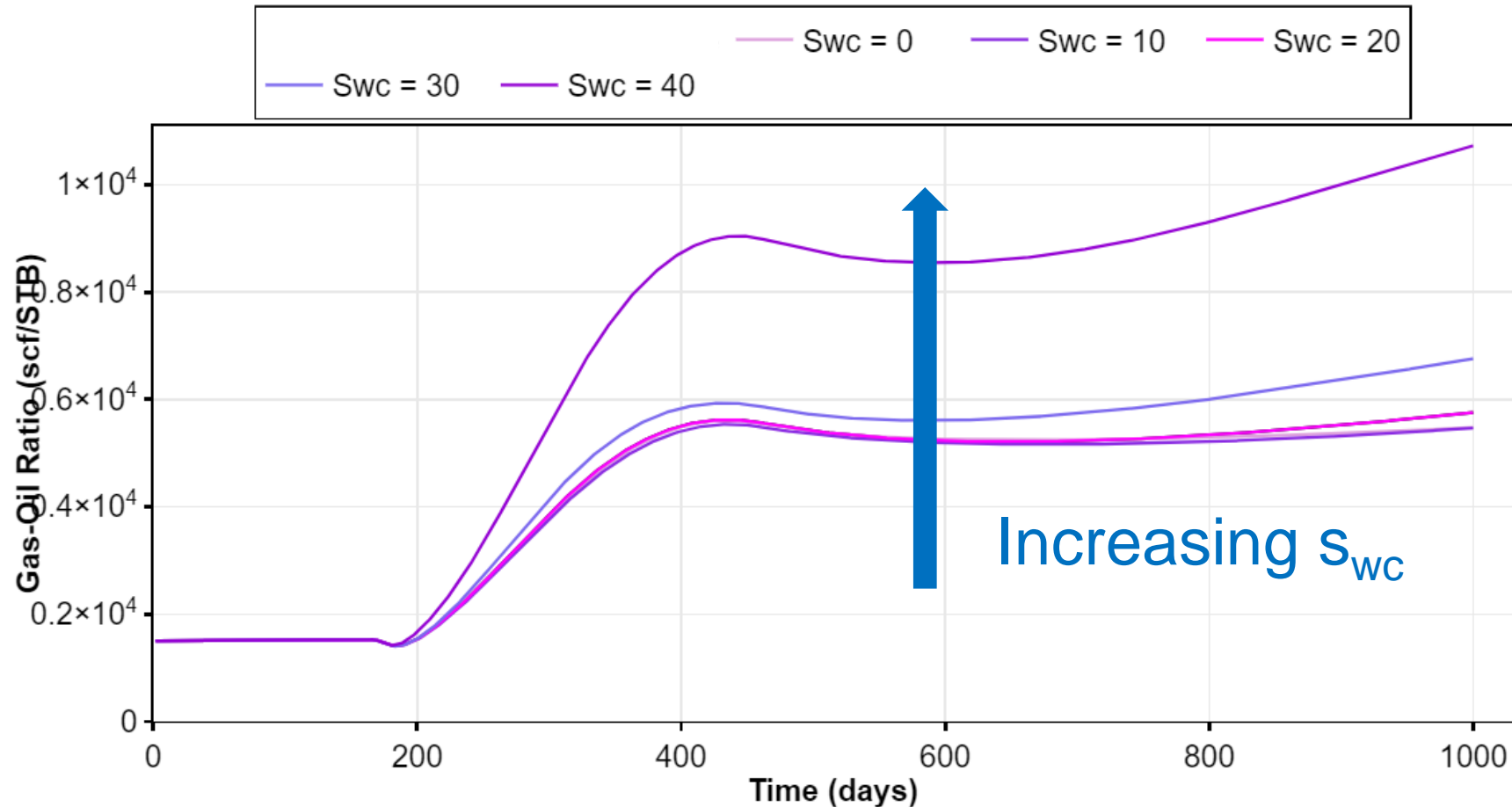
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# Relative Permeability: $S_{wc}$

$GOR \propto S_{wc}$ : When  $S_{wc}$  goes up, GOR goes up

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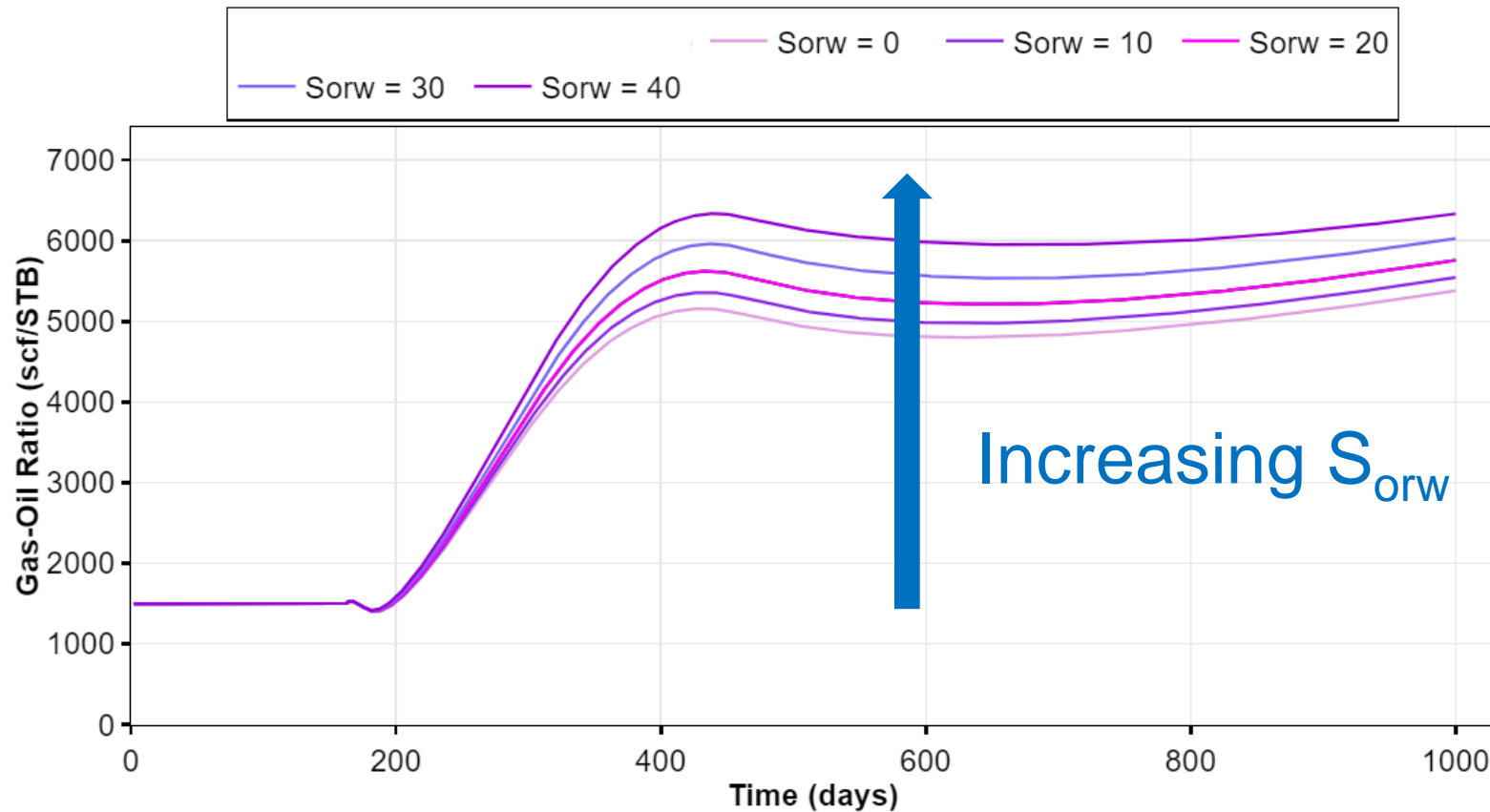


\* $S_{wi} = 30\%$  (if  $S_{wc} \geq S_{wi}$ , no water flowing). Just a little water flow changes the GOR a lot (most likely a three-phase rel. perm model item).

# Relative Permeability: $S_{orw}$

$GOR \propto S_{orw}$ : When  $S_{orw}$  goes up, GOR goes up

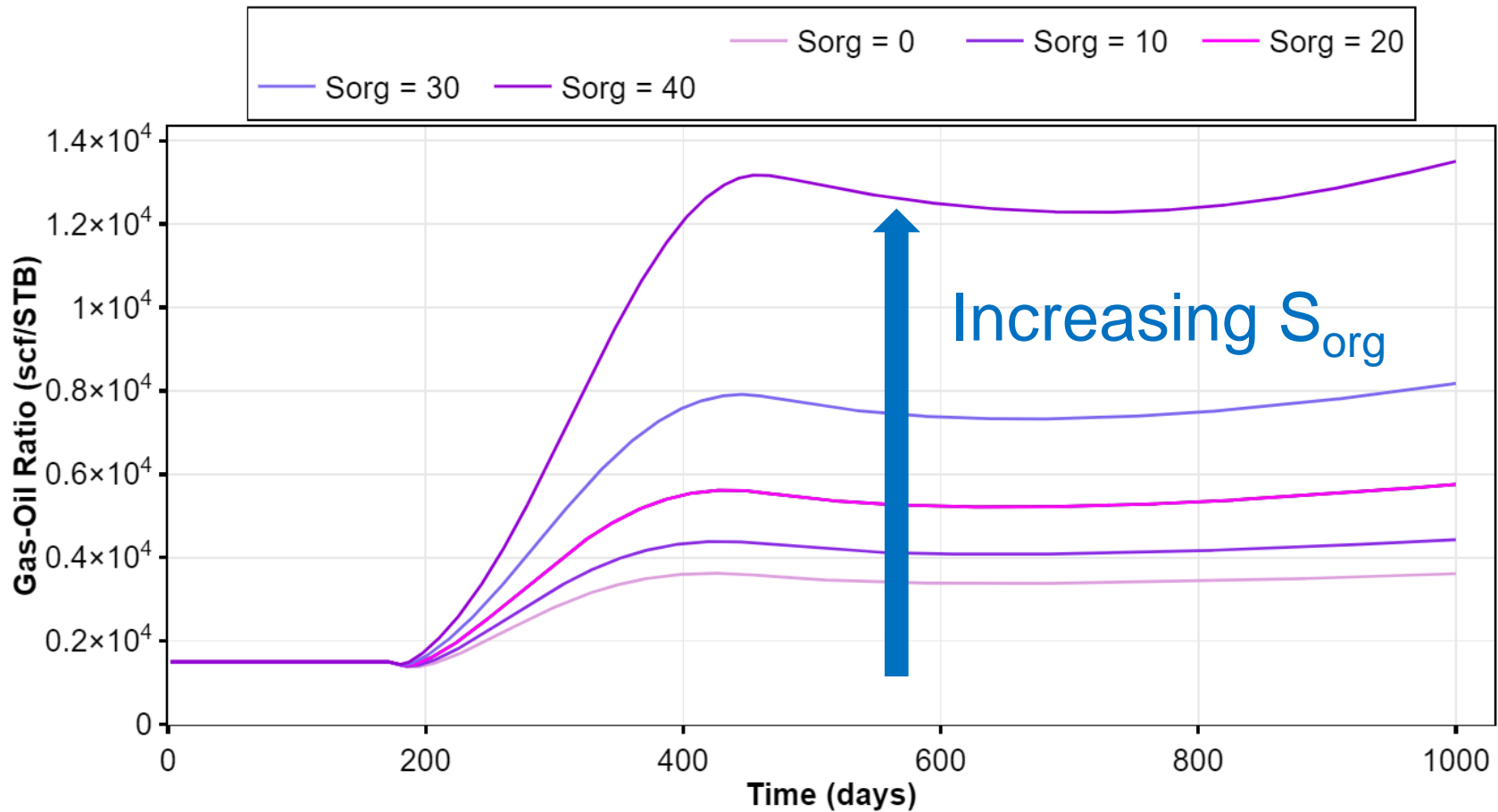
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# Relative Permeability: $S_{org}$

$GOR \propto S_{org}$ : When  $S_{org}$  goes up, GOR goes up

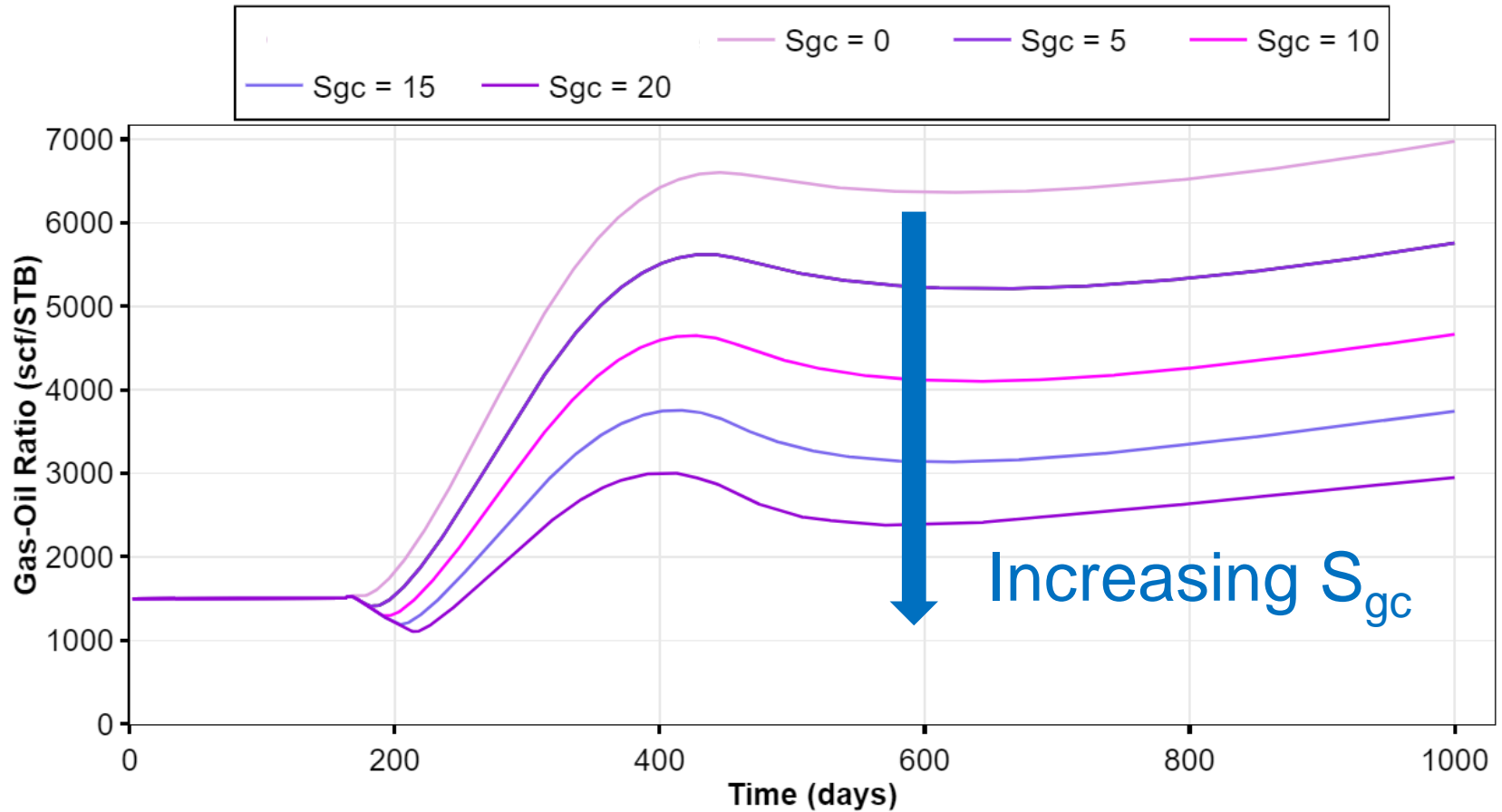
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# Relative Permeability: $S_{gc}$

$GOR \propto 1/S_{gc}$ : When  $S_{gc}$  goes up, GOR goes down

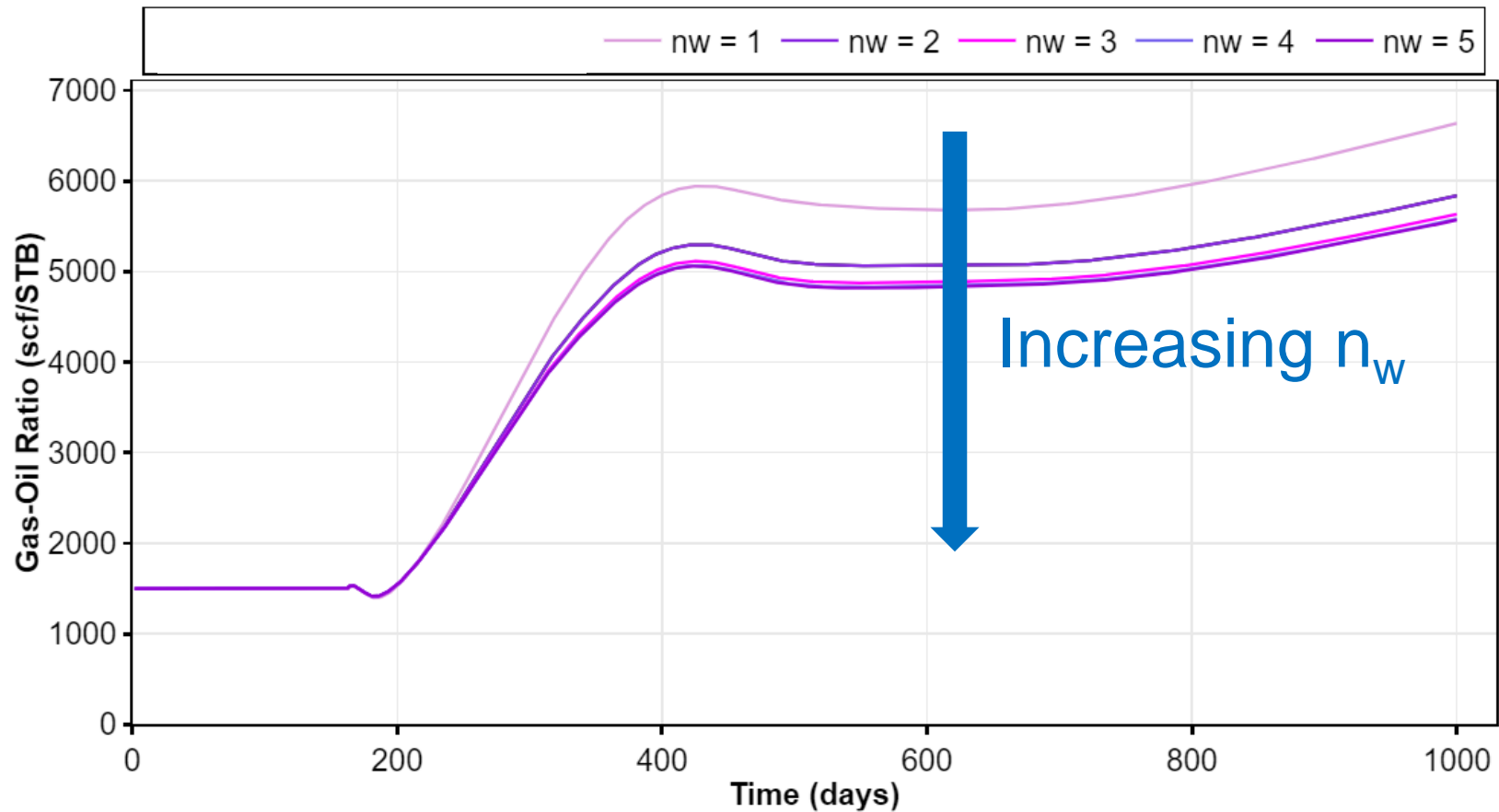
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# Relative Permeability: $n_w$

$GOR \propto 1/n_w$ : When  $n_w$  goes up, GOR goes down

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# Relative Permeability: $n_{ow}$

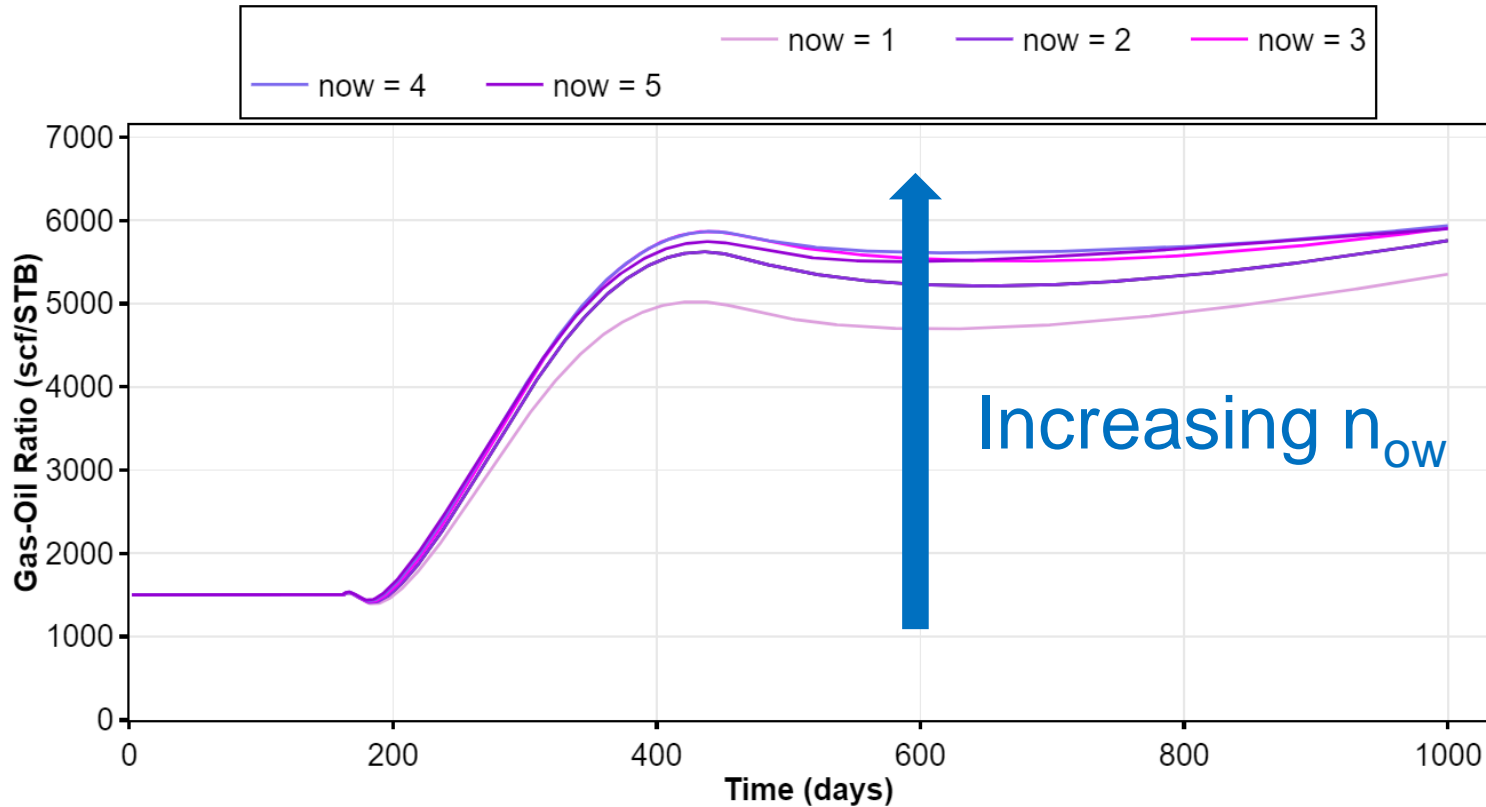
$GOR \propto n_{ow}$ : When  $n_{ow}$  goes up, GOR goes up

Gas Oil Ratio

USE CUMULATIVES

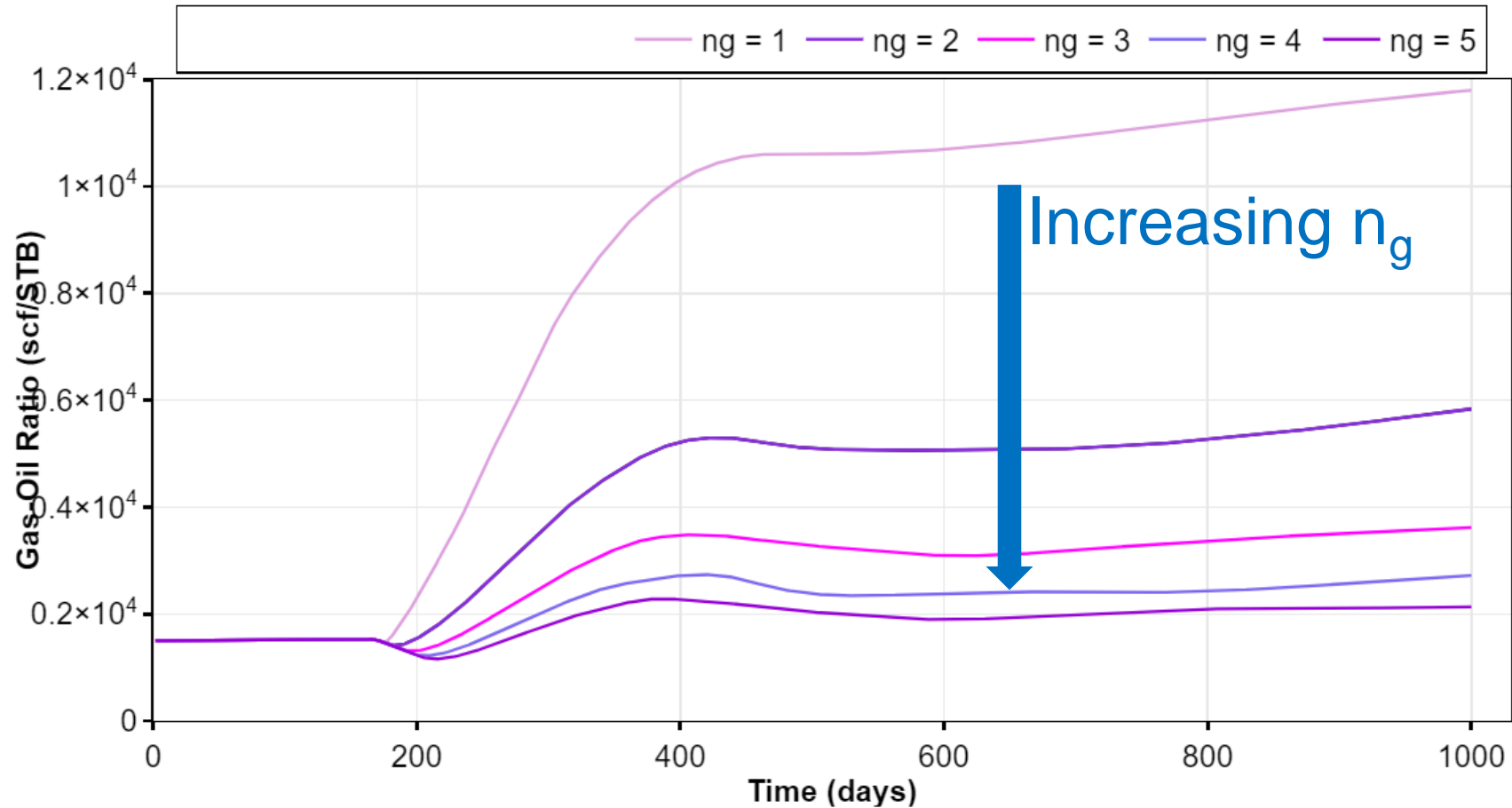
OGR

DATES



# Relative Permeability: $n_g$

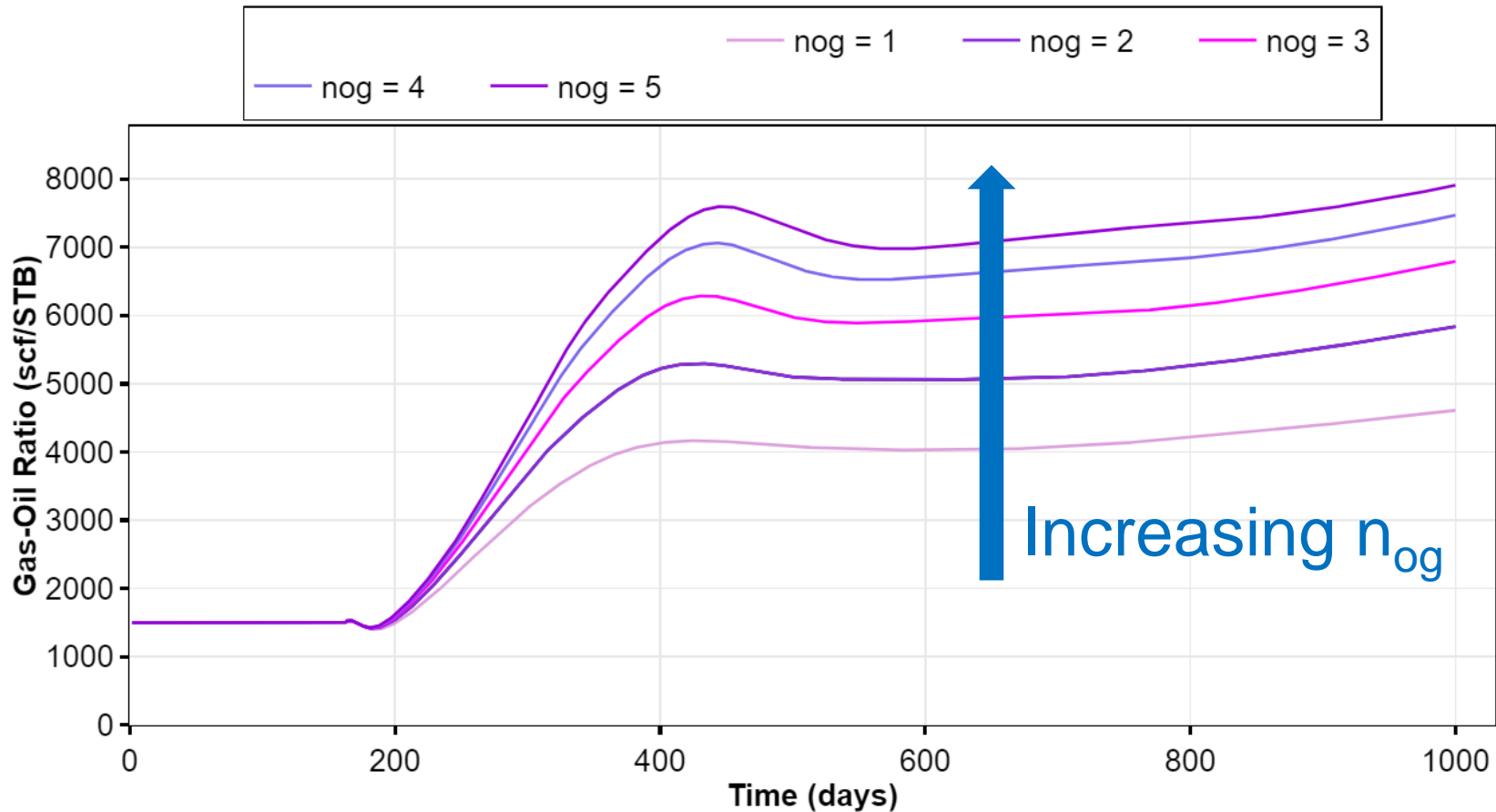
$GOR \propto 1/n_g$ : When  $n_g$  goes up, GOR goes down



# Relative Permeability: $n_{og}$

$GOR \propto n_{og}$ : When  $n_{og}$  goes up, GOR goes up

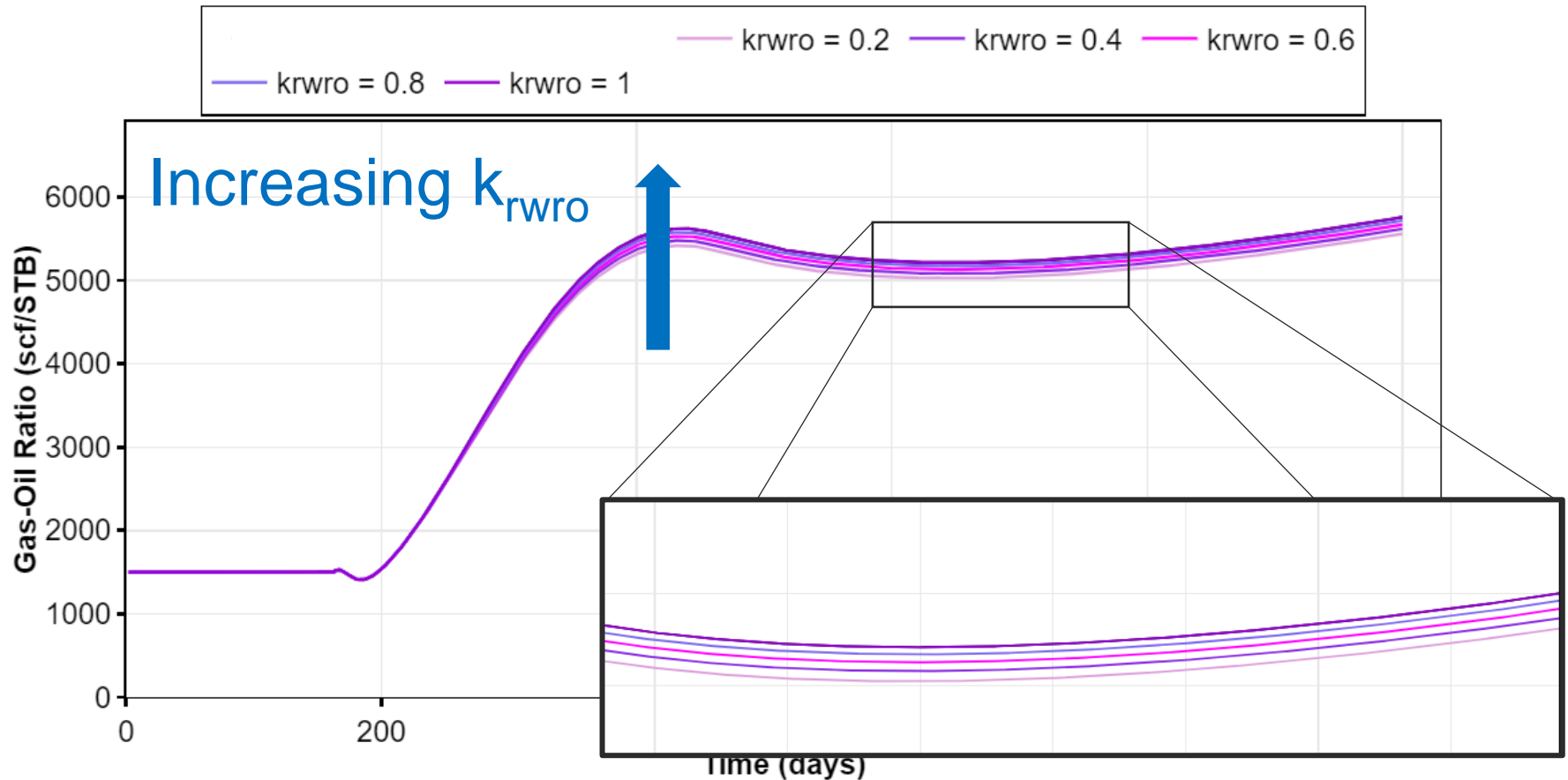
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# Relative Permeability: $k_{rwro}$

$GOR \propto k_{rwro}$ : When  $k_{rwro}$  goes up, GOR goes up

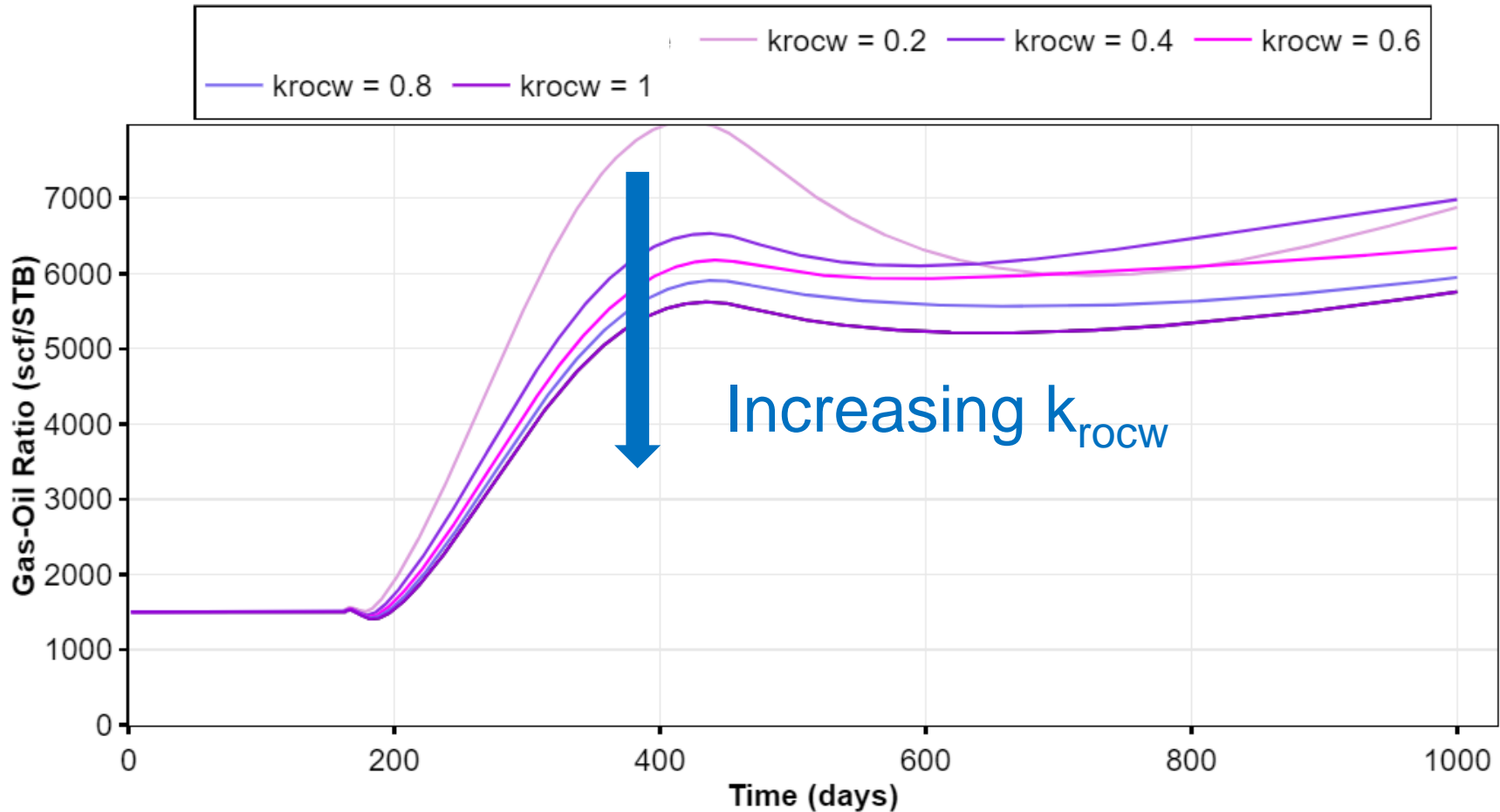
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# Relative Permeability: $k_{rocw}$

$GOR \propto 1/k_{rocw}$  : When  $k_{rocw}$  goes up, GOR goes down

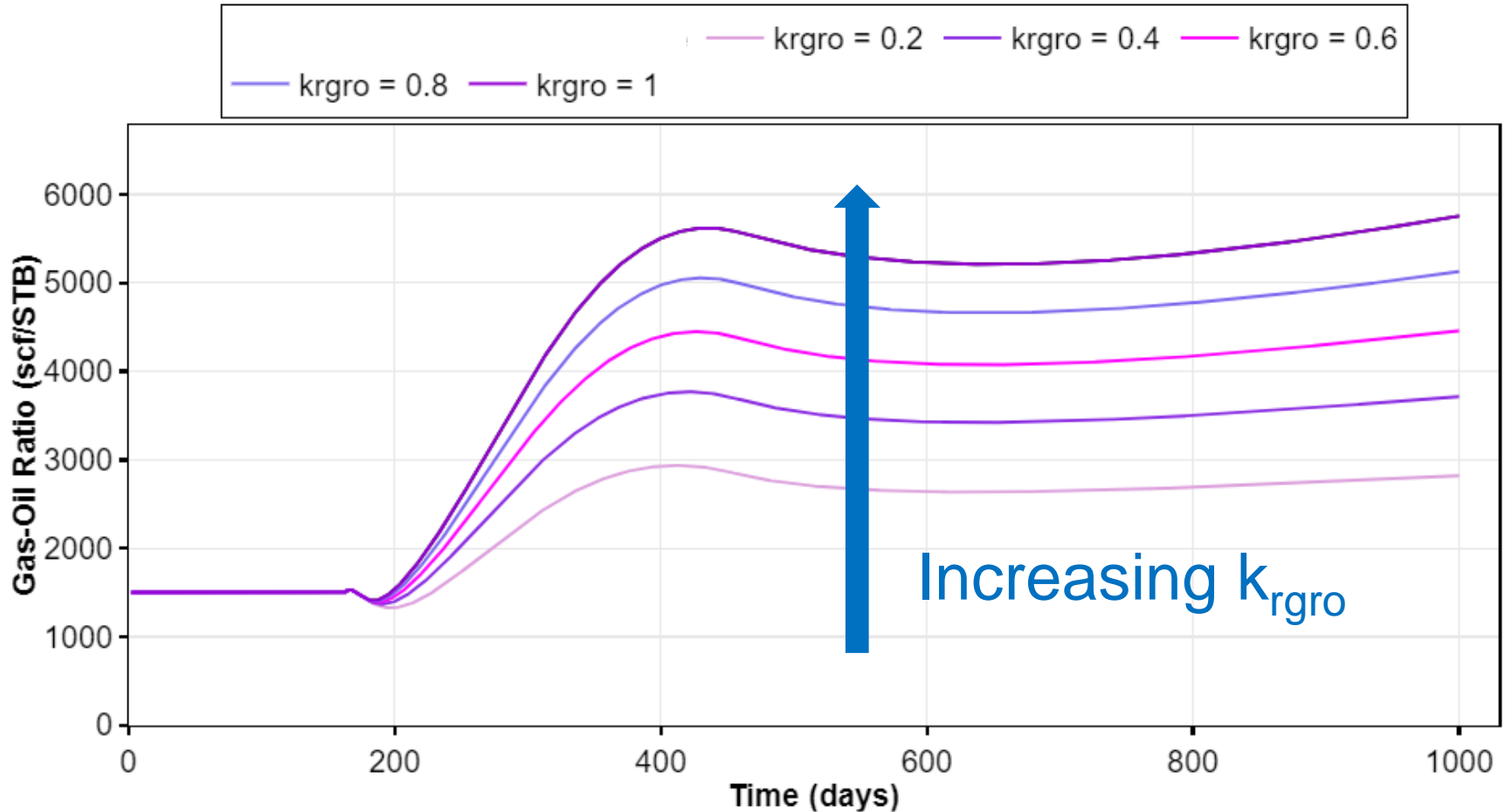
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# Relative Permeability: $k_{rgro}$

$GOR \propto k_{rgro}$ : When  $k_{rgro}$  goes up, GOR goes up

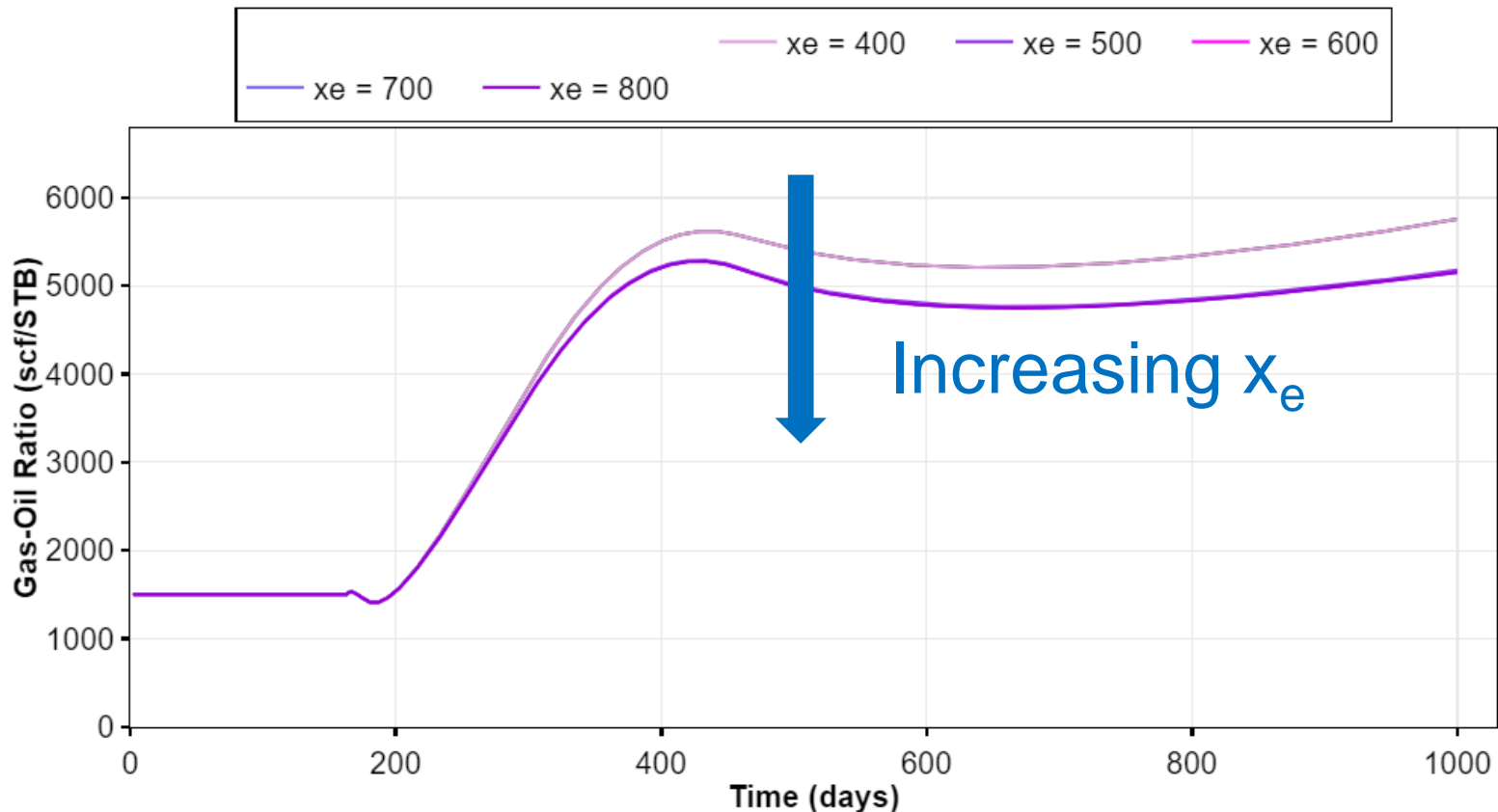
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# Reservoir extent > Frac length ( $k = 100 \text{ nd}$ )

$\text{GOR} \propto 1/x_e$  : When  $x_e$  goes up, GOR goes down\*

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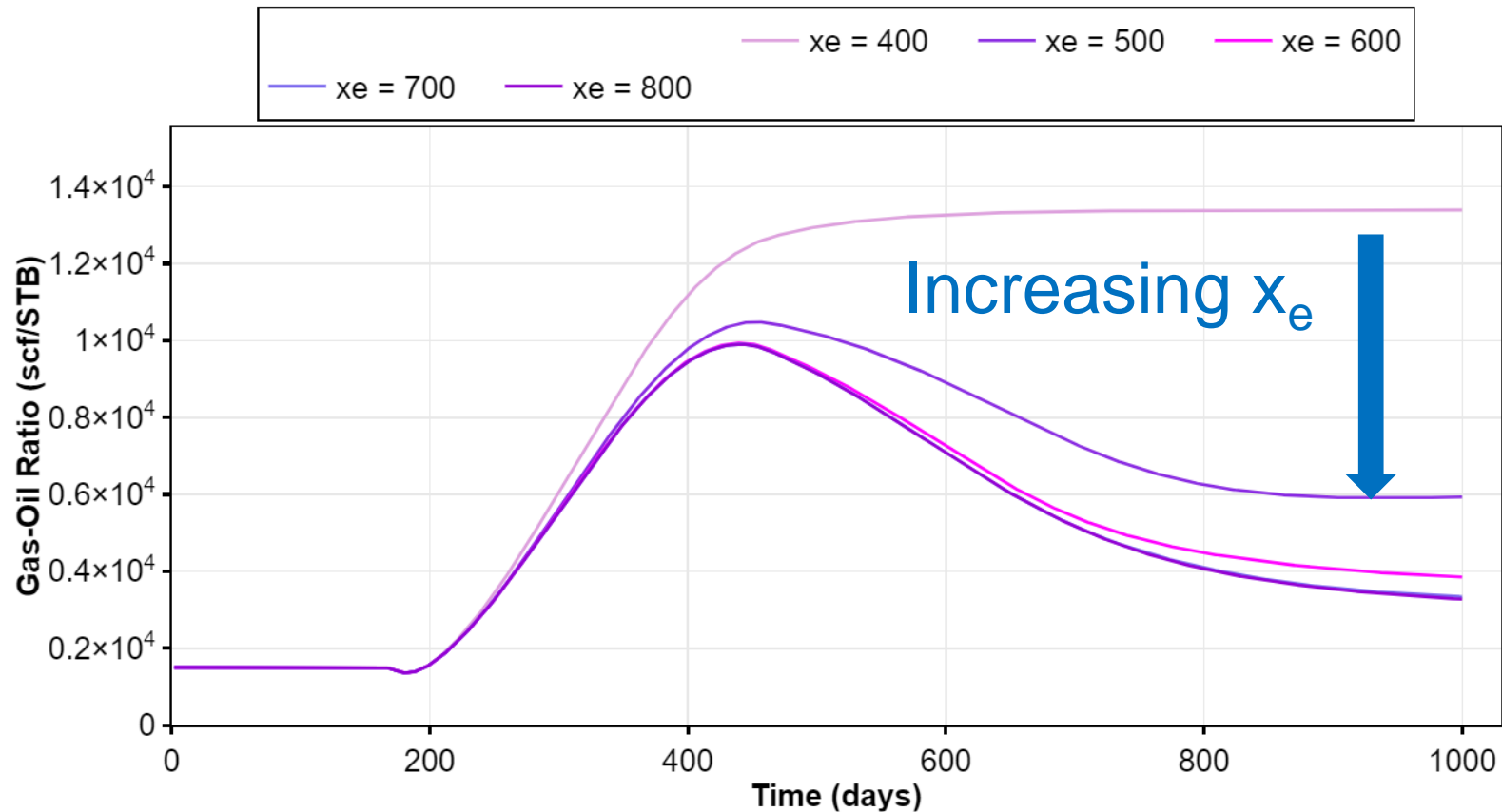


\*This is a strong function of permeability.

# Reservoir extent > Frac length ( $k = 1000 \text{ nd}$ )

$\text{GOR} \propto 1/x_e$  : When  $x_e$  goes up, GOR goes down\*

Gas Oil Ratio USE CUMULATIVES OGR DATES



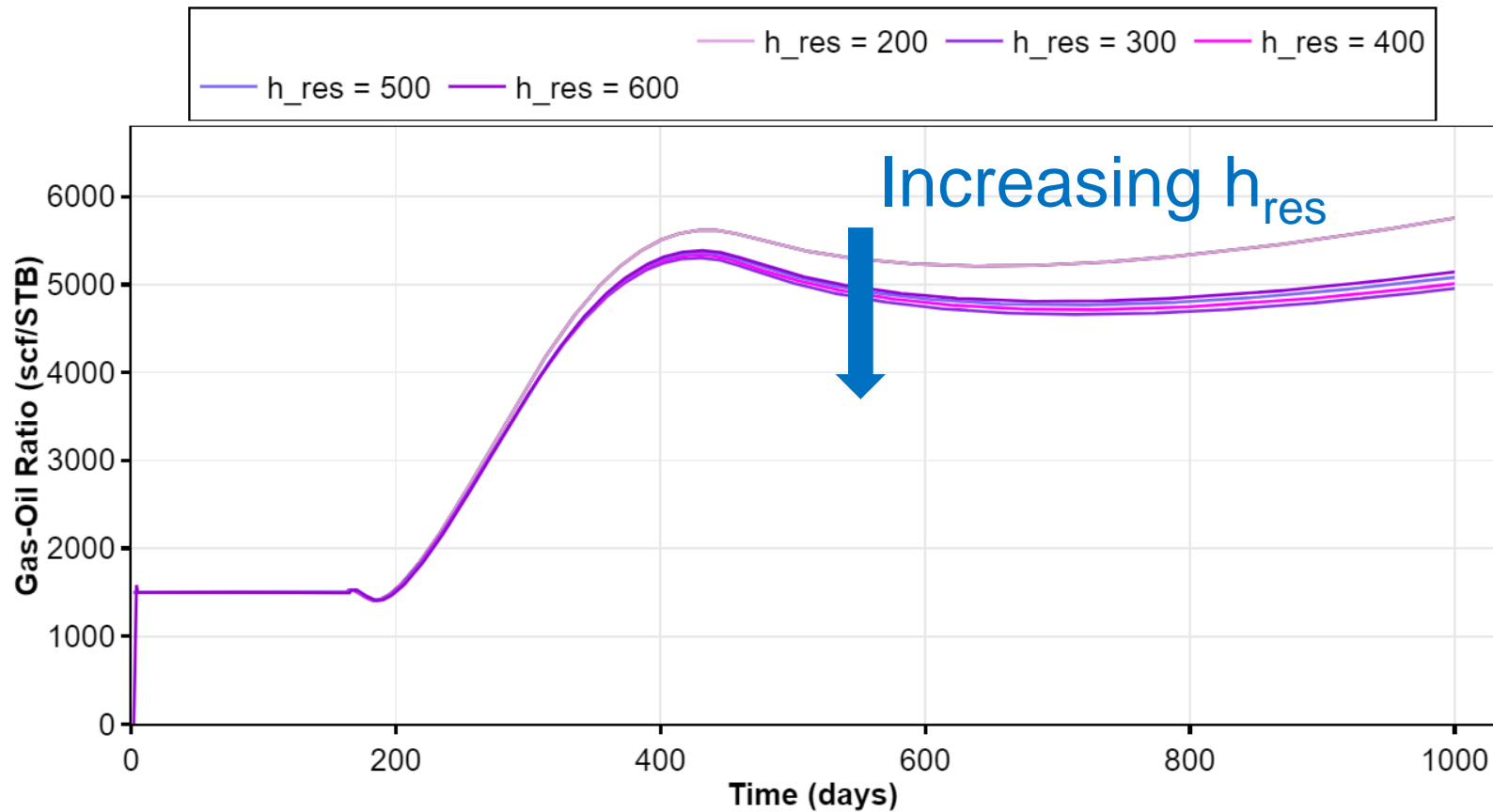
\*This is a strong function of permeability.



# Reservoir height > Frac height ( $k = 100 \text{ nd}$ )

$\text{GOR} \propto 1/h_{\text{res}}$  : When  $h_{\text{res}}$  goes up, GOR goes down\*

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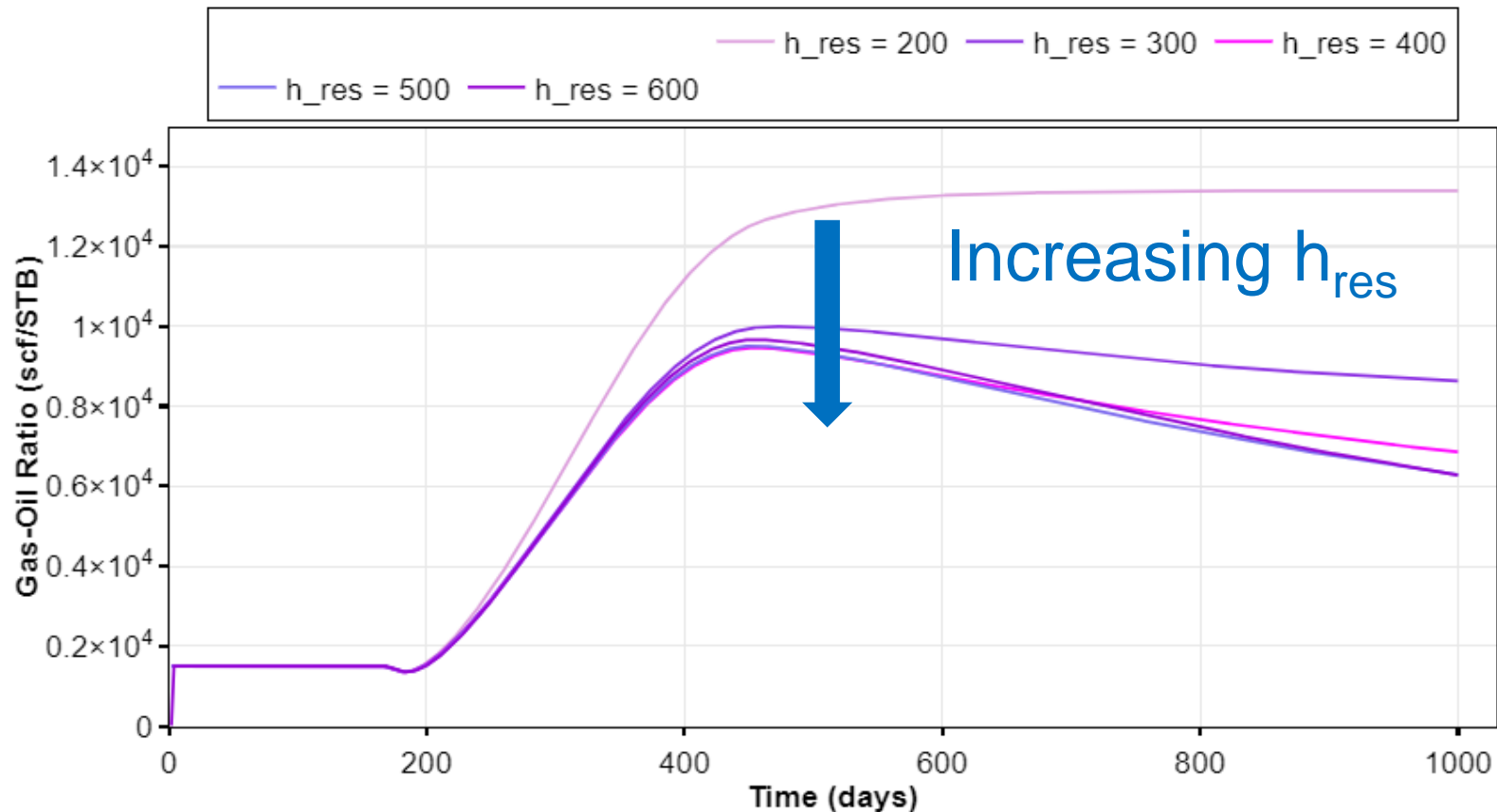


\*This is a strong function of permeability.

# Reservoir height > Frac height ( $k = 1000 \text{ nd}$ )

$\text{GOR} \propto 1/h_{\text{res}}$  : When  $h_{\text{res}}$  goes up, GOR goes down\*

Gas Oil Ratio USE CUMULATIVES OGR DATES



\*This is a strong function of permeability.

# Appendix