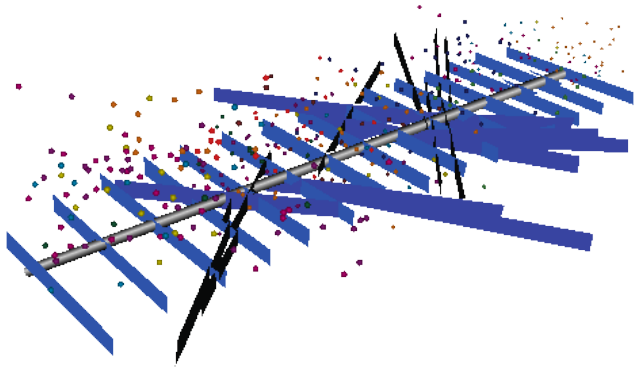


KAPPA

# UR Add-on pack

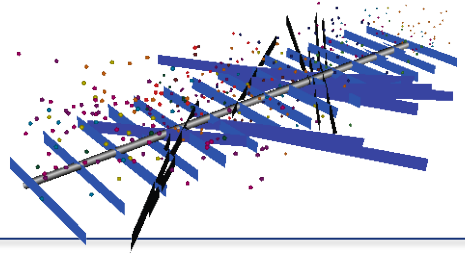
# KURC / Add-on pack

**KURC – KAPPA Unconventional Resources Consortium**

- KURC-1: 2012 – 2015 /
- KURC-2: 2016 – 2020
- KURC options are exclusive to members for 3 years since their release

**UR Add-on pack**

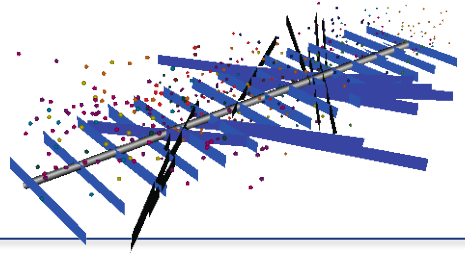
- New developments + all KURC-1/2 features post-exclusivity period
- Specific license privilege in Saphir, Topaze and Rubis
- Non-digressive, per stand-alone license
- Available since KW v5.20.01 (2018)
- Latest update KW v5.30.03 (July 2020)



# Add-on pack: Analytical

KAPPA

- DFN analytical model with conjugate fractures
- Anomalous diffusion model
- Multi-zone fractional model
  - Dynamic Drainage Area corrected Linear Flow plot
  - Flowing Material Balance plot
  - Statistical EUR



# Add-on pack: Numerical

KAPPA

- Fast numerical models for SRVB & Trilinear geometries
- Water flowback with static Initialization
- Numerical DFN model
- Numerical model with composite zones
- Load and display of microseismic data
- Simulation of Klinkenberg effect
- Fickian diffusion
- Refrac for a MFHW
- DFN Upscaling
- Loading properties of fracs

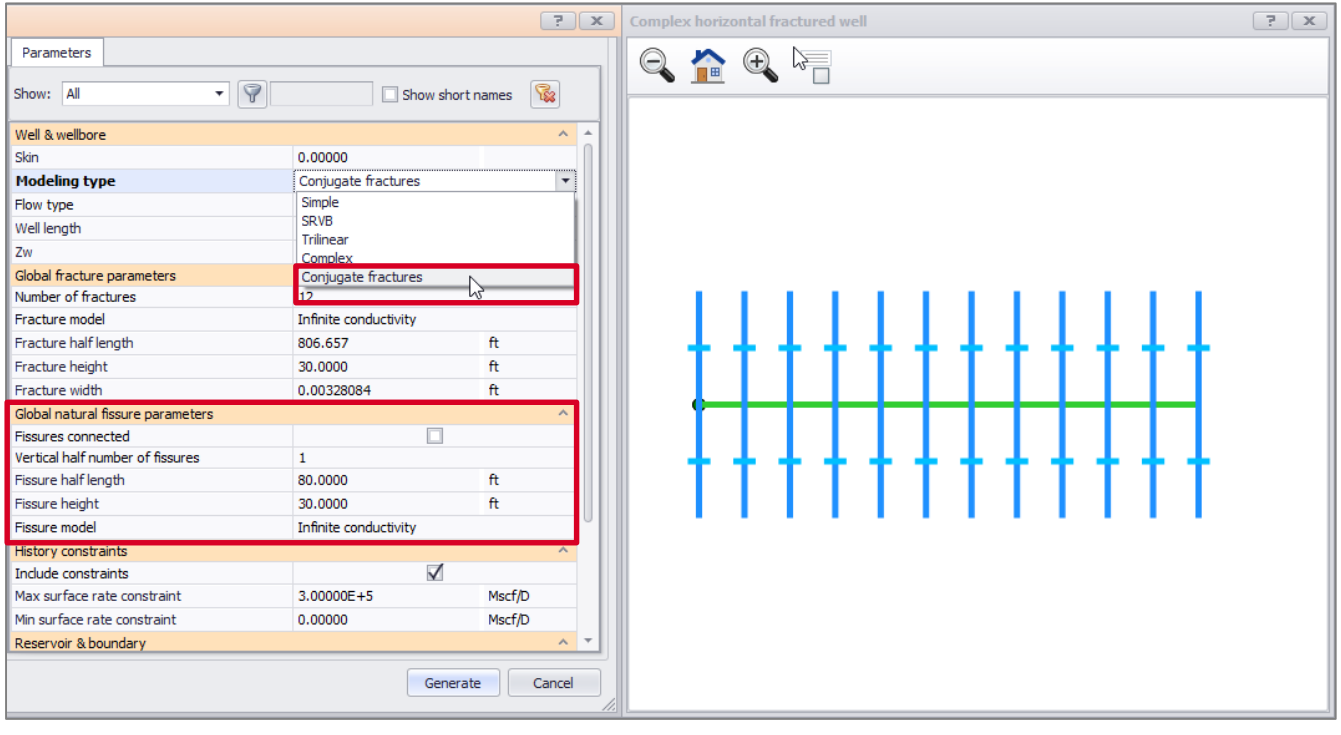
# Add-on pack: New in v5.30.03

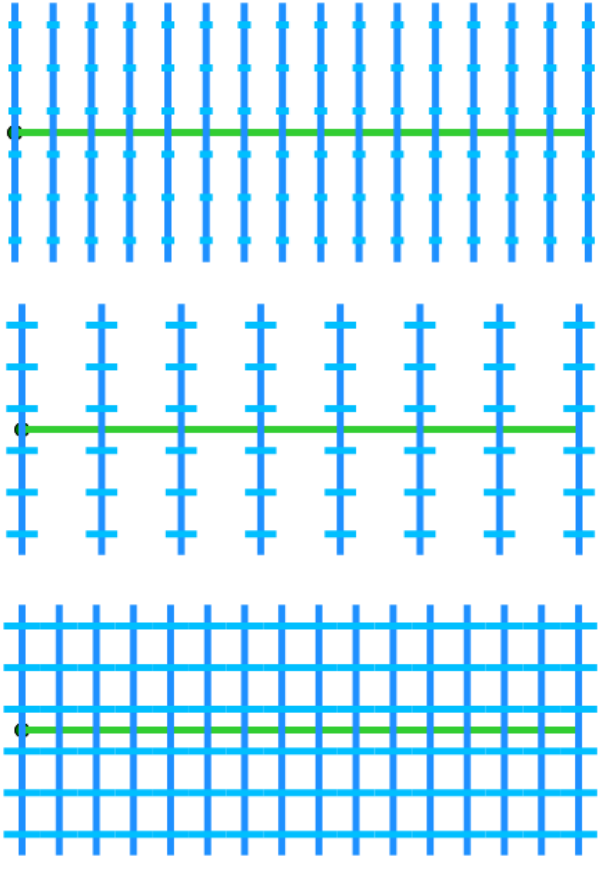
To be released by the end of July 2020:

- Load from Fracturing Software
- Confined PVT
- Multiple KrPc
- Stochastic DFN realizations
- Interference with DFN: Fast Marching Method
- Stimulated zones around the fractures
- Numerical ‘butterfly’ model

# DFN analytical model

- Conjugate fractures: # fissures and geometry



# Anomalous Diffusion

v5.30

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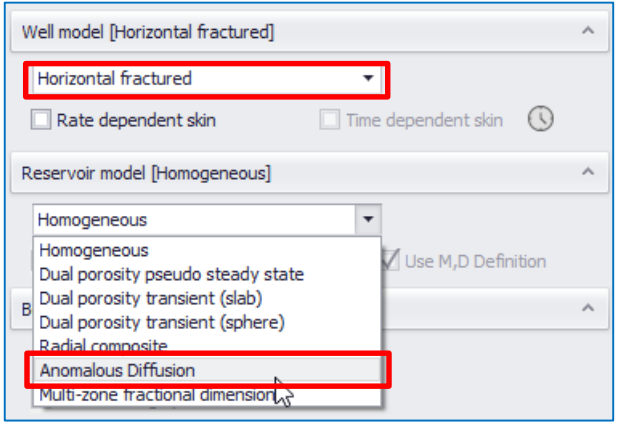
## Anomalous Diffusion analytical model is made internal




- Well: Simple MFHW or Trilinear
- Single layer models only
- Matrix: single/double porosity
- Can include changing WBS, rate-/time-dependent skin

| Well & wellbore | |
|---|---|
| Wellbore storage | 0.01 |
| Skin | 0.00000 |
| **Modeling type** | Trilinear |
| Flow type | Simple |
| Well length | SRVB |
| Zw | Trilinear |
| Number of fractures | Complex |
| | Conjugate fractures |

| Reservoir & boundary | | |
|---|---|---|
| Initial pressure | 5000.00 | psia |
| Transmissibility | 0.2 | md.ft |
| Permeability | 1.00000E-3 | md |
| Thickness | 200.000 | ft |
| Porosity | 0.1 | |
| **Primary diffusion exponent** | **0.7** | |
| **Secondary diffusion exponent** | **0.3** | |
| Reservoir | Homogeneous | |
| kz/kr | 1.00000 | |
| Total compressibility | 3.00000E-6 | $psi^{-1}$ |

Additional parameters:

$\alpha_f$ and $\alpha_m$

(also for outer zone in Trilinear)

*Fractured-Well Performance Under Anomalous Diffusion,* Raghavan and Chen, SPE-165584 (2013). Also SPE-191407, SPE-191484.

# Multi-zone fractional dimension

v5.30

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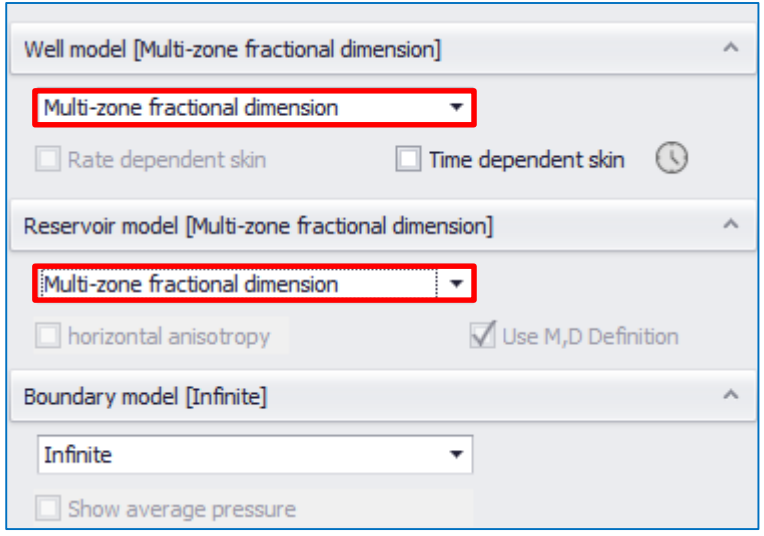
Multi-zone fractional dimension analytical model is made internal

Selected in Well or Reservoir model dialog (the two are synchronized)



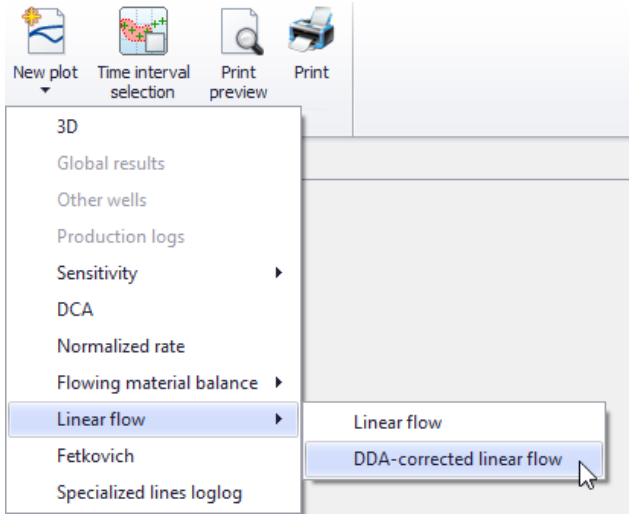

- Boundary: infinite / circular / linear
- Compatible with multilayer geometry
- Compatible with time-dependent skin
- Not available with time-dependent well mode

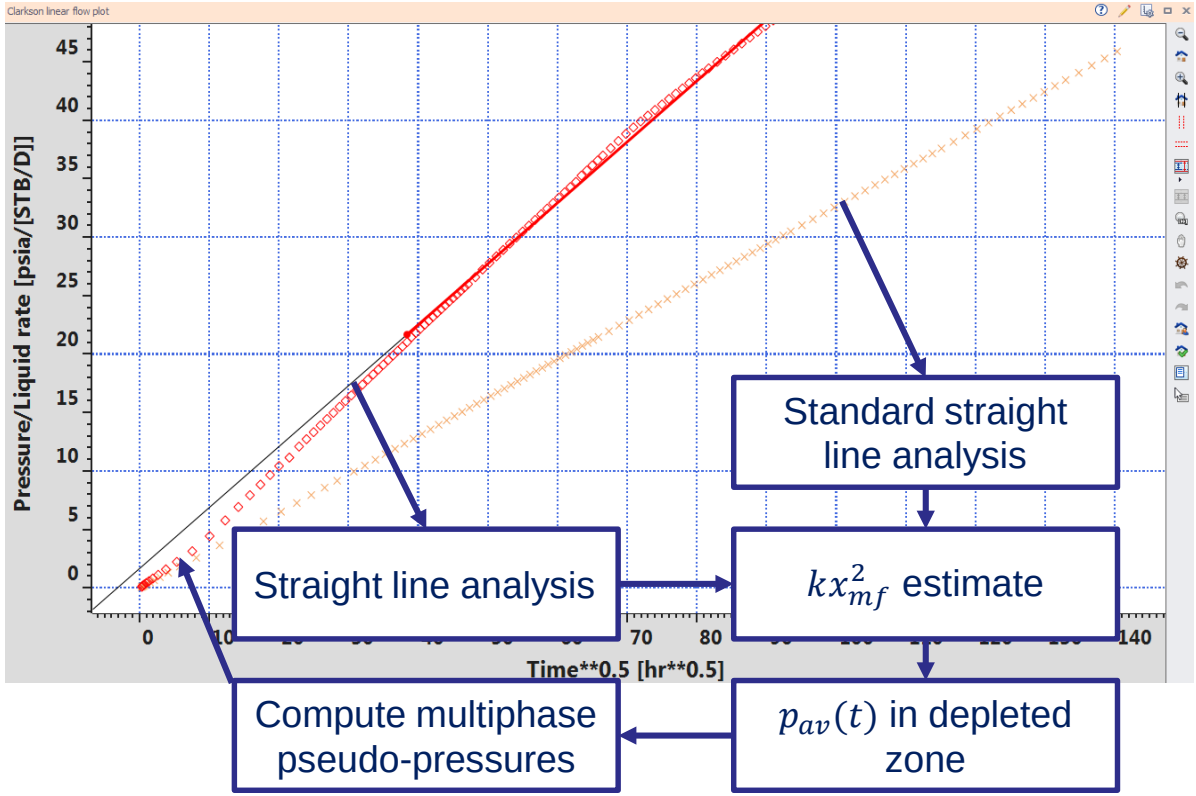
*Analytical Pressure and Rate Transient Models for Analysis of Complex Fracture Networks in Tight Reservoirs, J.A. Acuña,* URTeC paper SPE-2429710 (2016). Also SPE-2667752, SPE-2896802, SPE-2876208.

# Clarkson DDA Linear Flow plot

Linear flow analysis modified using pseudo-$p$ from Dynamic Drainage Area concept

Multiphase extraction




*Rate-transient analysis of liquid-rich tight/shale reservoirs using the dynamic drainage area concept: Examples from North American Reservoirs*, Qanbari and Clarkson, Journal of Natural Gas Science and Engineering 35 (2016)

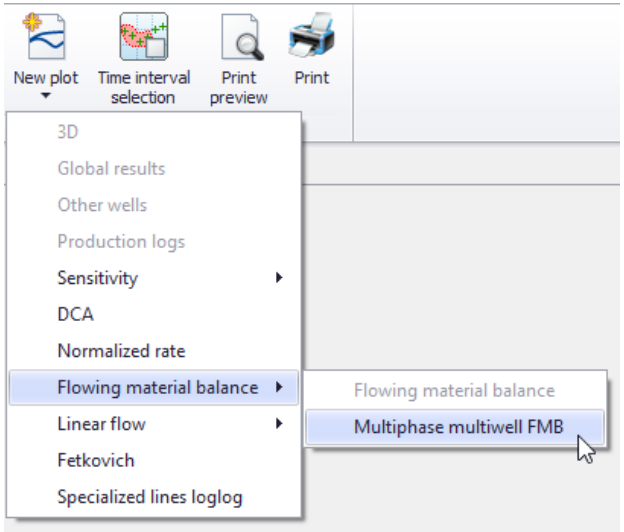
# Multiphase/multiwell FMB Plot

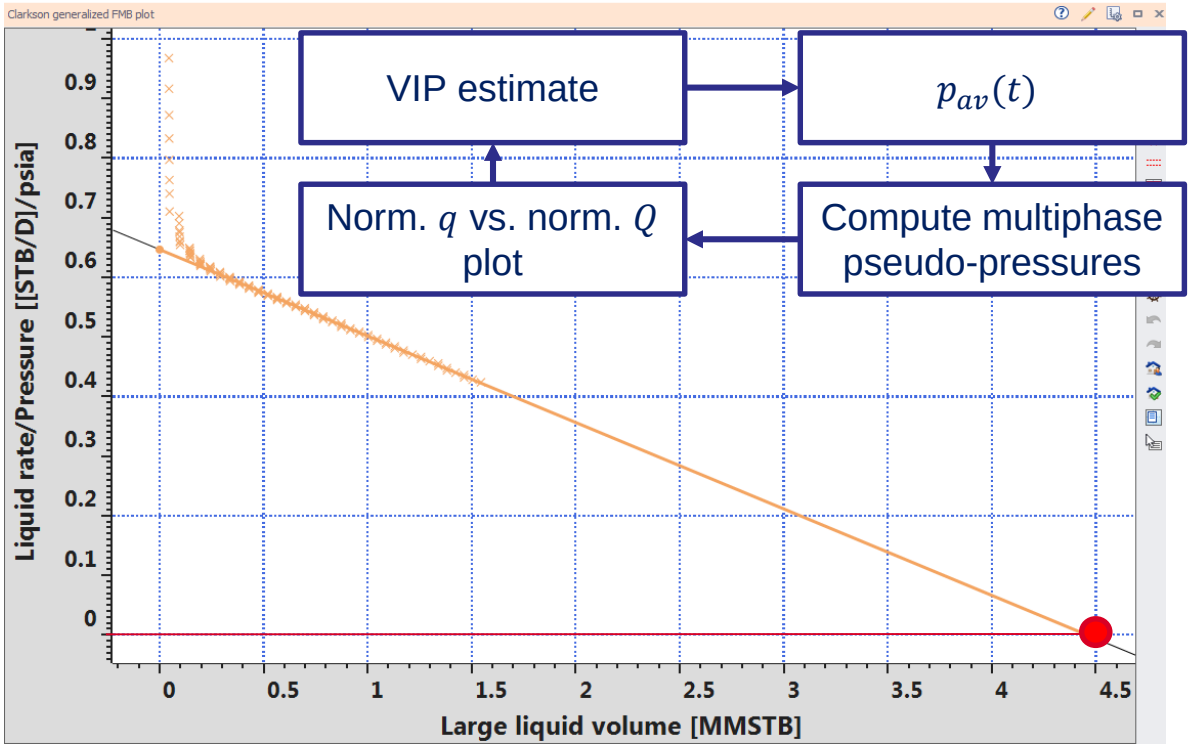
General Flowing Material Balance equation modified using pseudo-$p$ and $p_{av}$ from MB calculations

$$\frac{q_o}{\Delta p_{pw}} = \frac{1}{b} - \frac{1}{bN}\left(\frac{\Delta p_{pav} N}{\Delta p_{pw}}\right)$$

Multiphase extraction

*except:* Dry gas + Water, Wet gas + Water, EoS + Water



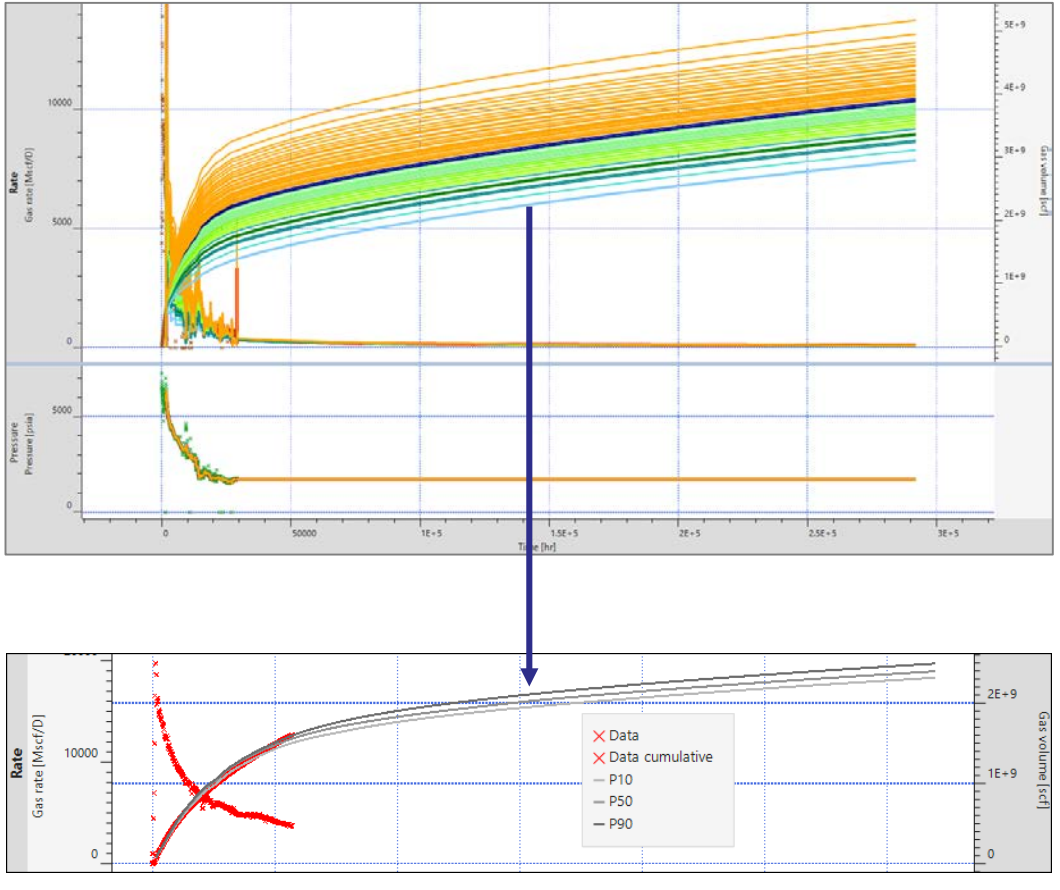

*Multi-Well, Multi-Phase flowing Material Balance* Shahamat and Clarkson, SPE 185052 (2017)

# Statistical EUR

- → Single forecast
- → Monte Carlo + Improve for uncertainty estimate
- → **Monte Carlo + Model Mining**: replacing the CPU expensive nonlinear regression step by a data mining proxy


**Model Mining** is activated when:

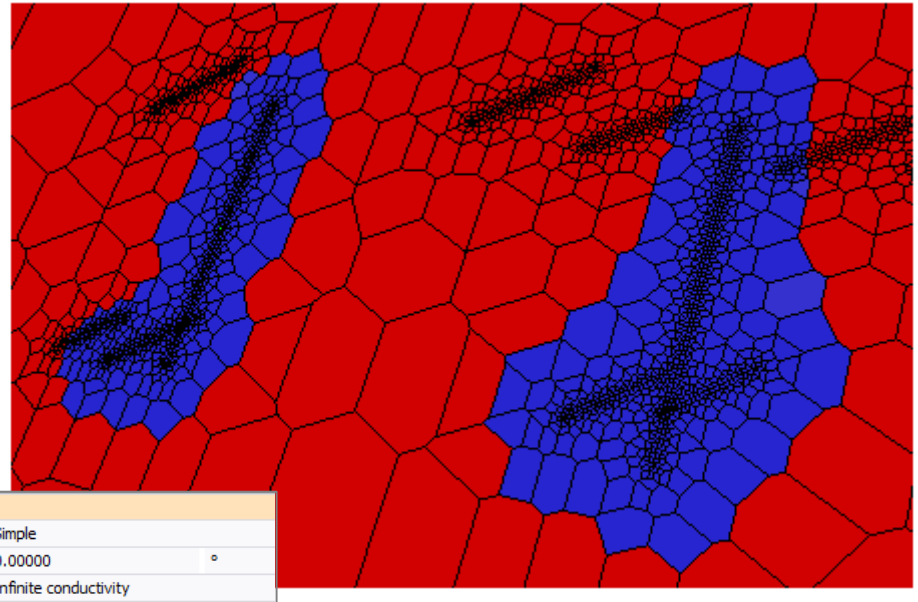
- Model forecast in done
- There are multiple Monte Carlo sensitivity runs on the forecast
- The sensitivity runs ‘bracket’ historical $Q_{cum}$



# Water flowback

To model the post fracture treatment water flowback:

- The user inputs the total injected water volume
- The injected volume is divided between the connected hydraulic and natural fractures (accounts for Kr end points)
- The local pressure increase is not modeled



Available in the numerical model:

- Multiphase PVT includes water
- Real PVT are used
- Well is set to MFHW

| Well 1 | | |
|---|---|---|
| Modeling type | Simple | |
| Drain angle | 0.00000 | ° |
| Fracture model | Infinite conductivity | |
| Number of fractures | 15 | |
| Fracture half length | 300.000 | ft |
| Fracture height | 30.0000 | ft |
| Fracture mid-point height | 15.0000 | ft |
| Width | 0.00328084 | ft |
| Fracture angle | 90.0000 | ° |
| Zw | 15.0000 | ft |
| Well length | 1000.00 | ft |
| Stimulated zones around fractures | ☐ | |
| Include injected water | ☑ | |
| Injected water | 5000.00 | MMSTB |
| Rate dependent skin | ☐ | |

# Klinkenberg effect

For gas observed permeability can be higher than the true/absolute permeability of the rock due to slippage

Available in the numerical model:

- PVT is set to dry gas
- Real PVT are used
- Reservoir type: homogeneous

| Well 1 | | |
|---|---|---|
| Zw | 15.0000 | ft |
| Perforation length | 30.0000 | ft |
| Well length | 30.0000 | ft |
| Rate dependent skin | ☐ | |
| Skin | 0.00000 | |
| Wellbore model | None | |
| Bottomhole MD | 6000.00 | ft |
| Include constraints | ☐ | |
| **Reservoir** | | |
| Initial pressure | 7246.55 | psia |
| Reservoir type | Homogeneous | |
| Transmissibility | 1000.000 | md.ft |
| Permeability | 33.3333 | md |
| Thickness | 30.0000 | ft |
| Porosity | 0.1 | |
| Klinkenberg | ☑ | |
| Klinkenberg b | 200.000 | psia |
| Net-to-gross | 1.00000 | |
| kz/kr | 1.00000 | |

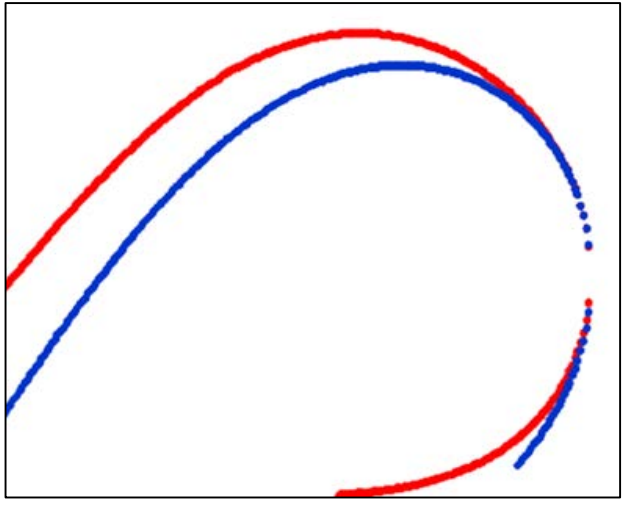
# Confined PVT

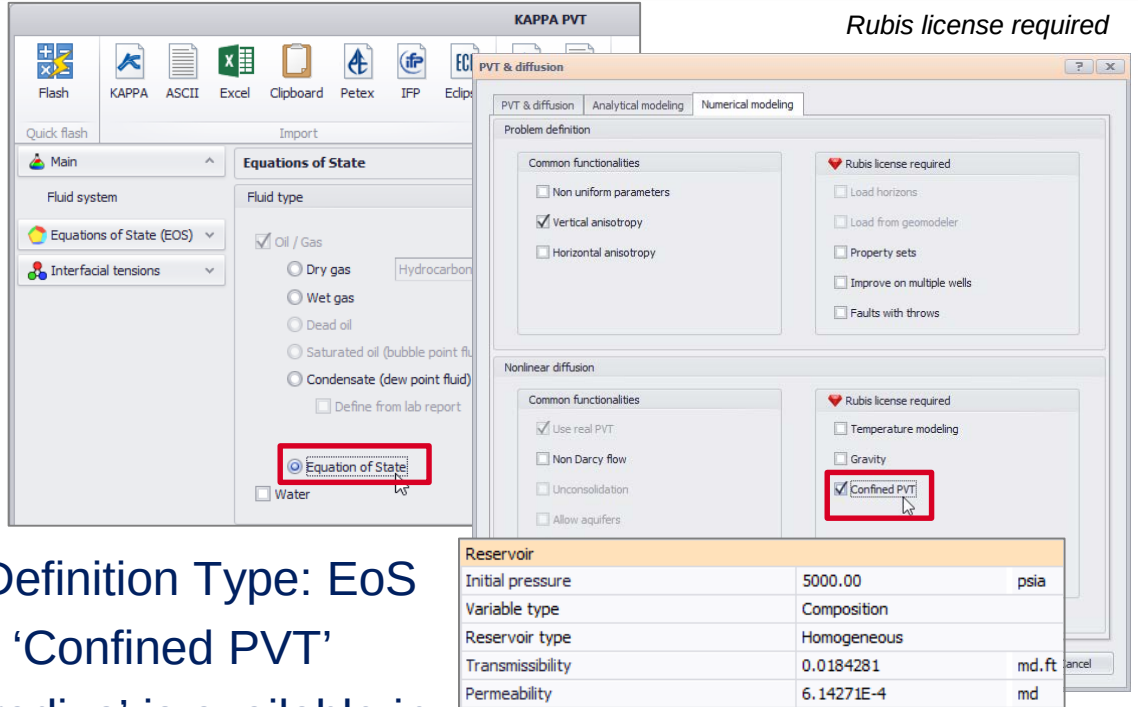
*New in v5.30.03*

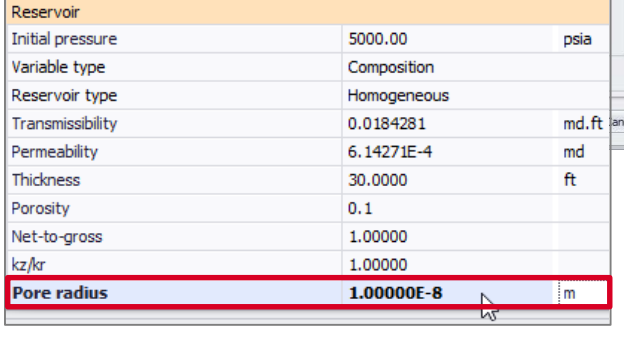
KAPPA

*Rubis license required*

The size of the pores ~ the size of hydrocarbon molecules (‘confined’)
→ PVT is different from the phase behavior in a laboratory cell





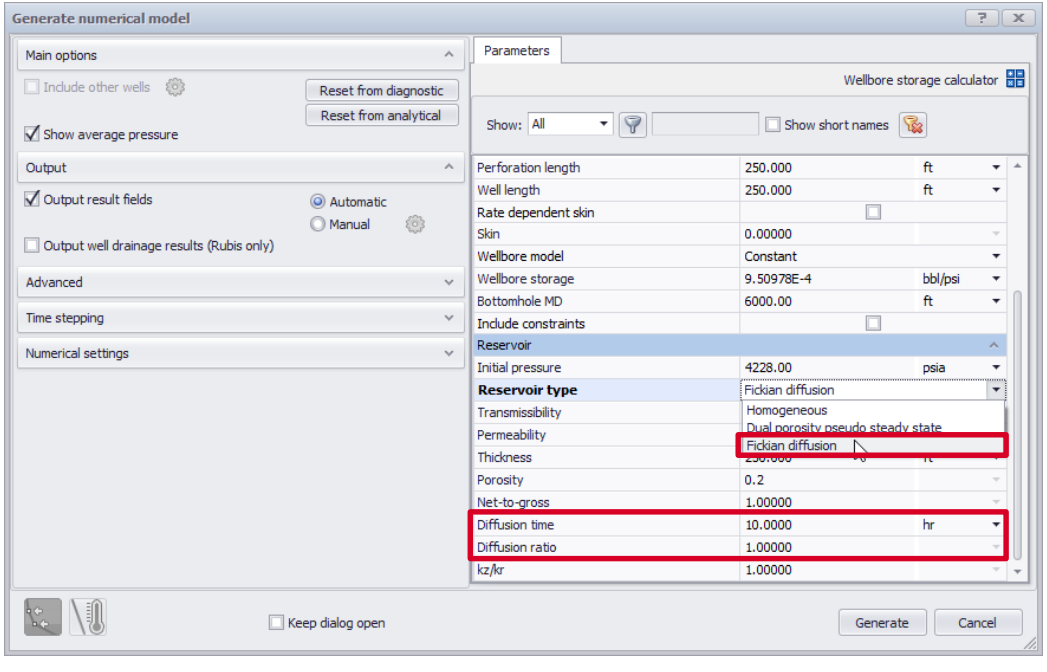




- Fluid Definition Type: EoS
- Check ‘Confined PVT’
- ‘Pore radius’ is available in Reservoir Properties

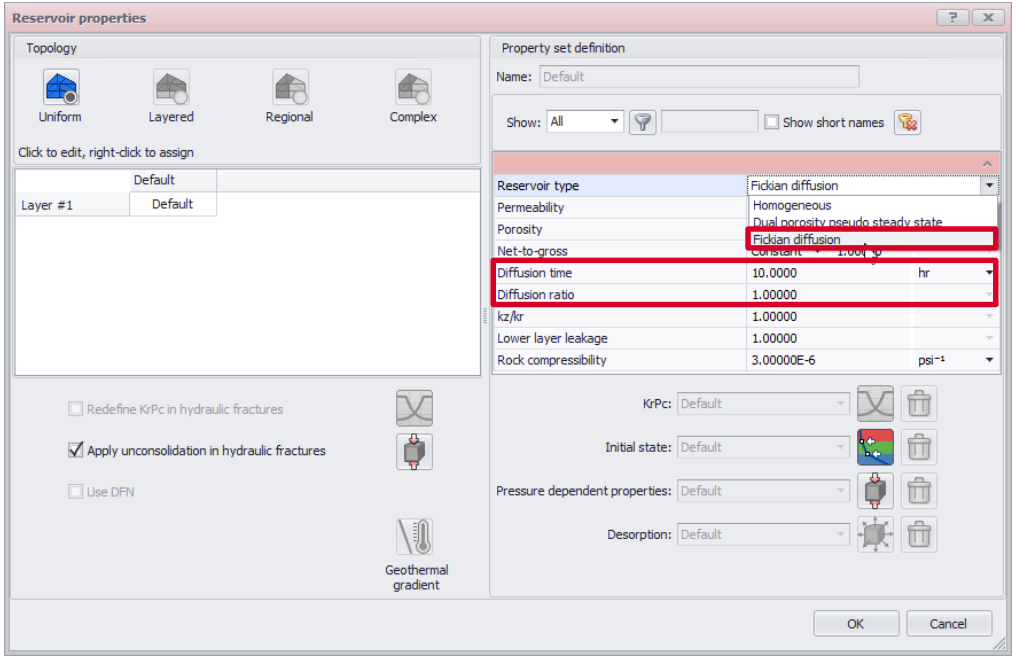
# Fickian diffusion

PVT includes gas & Real PVT are used

Available under ‘Reservoir type’

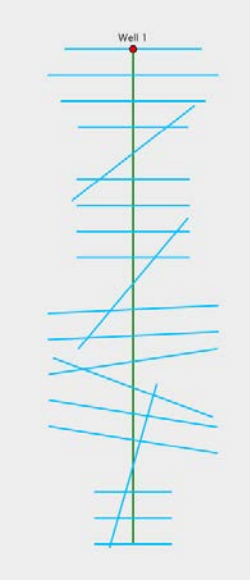


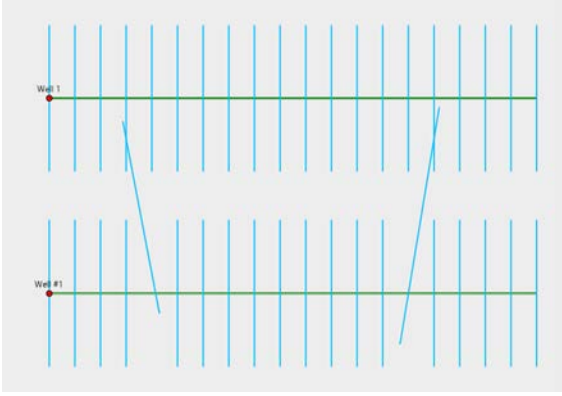

or ‘Reservoir properties’

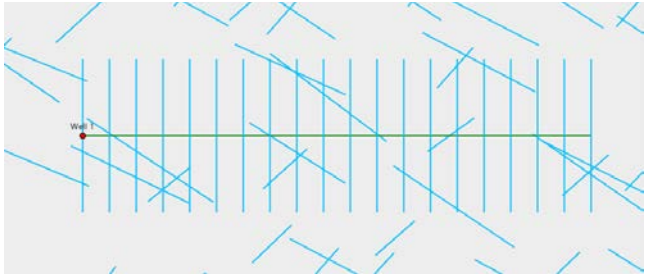


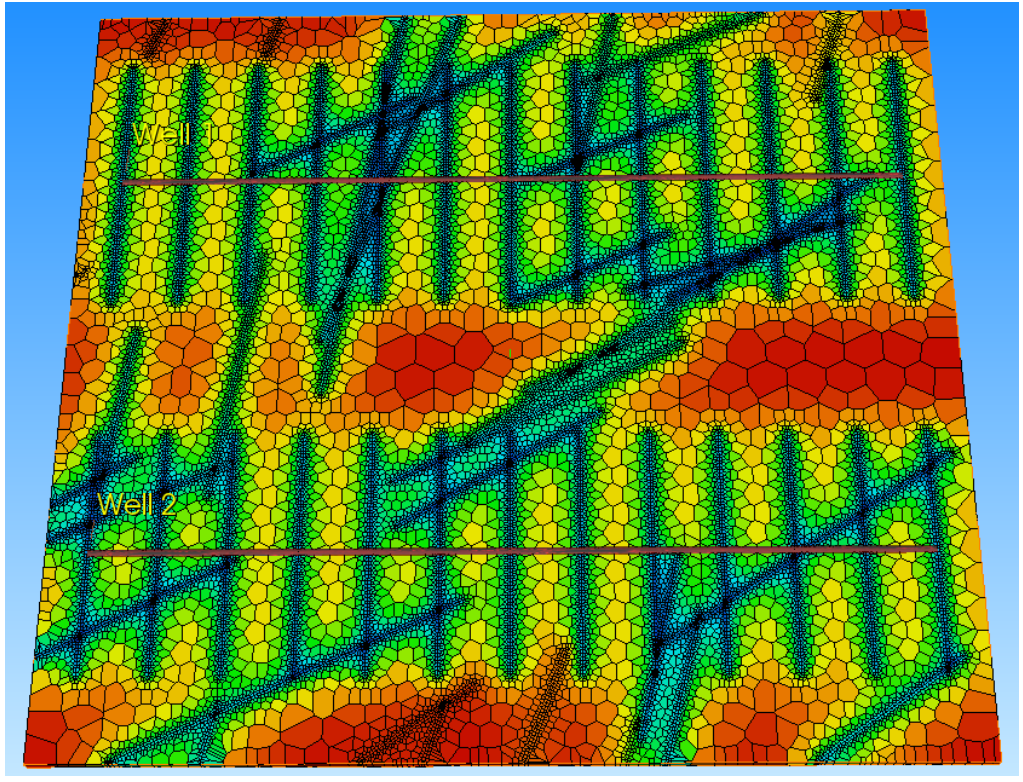
# Numerical DFN

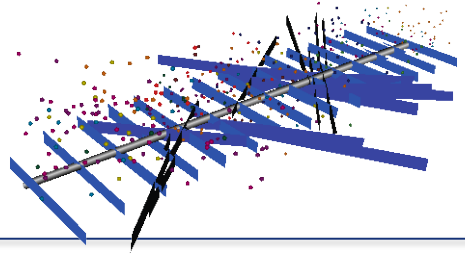
DFN and well fractures have distinct properties, including relative permeabilities and $k(p)$.



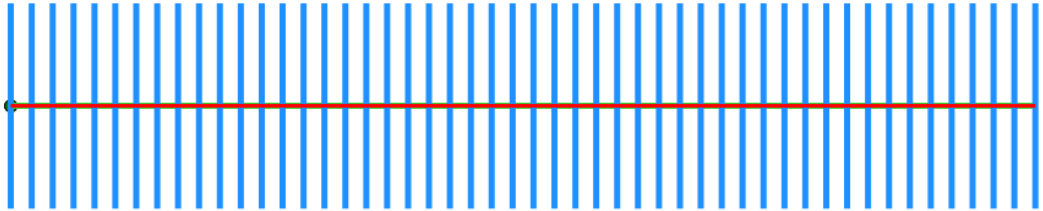



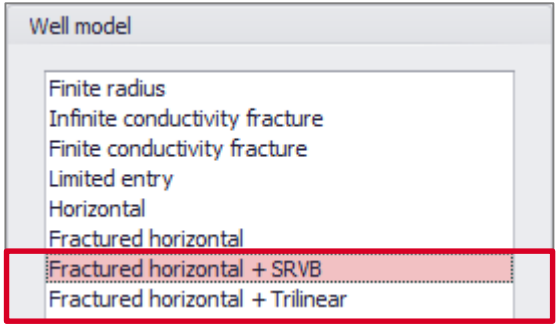





# Fast numerical models

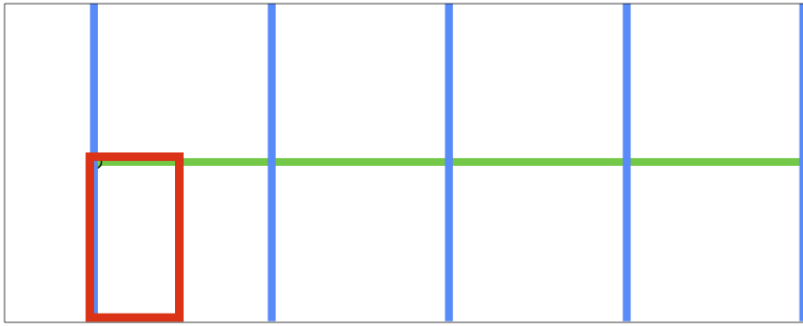
Very useful in the case of complex PVT and a simple but very long MFHW to tune the fracture properties prior to running the full numerical model



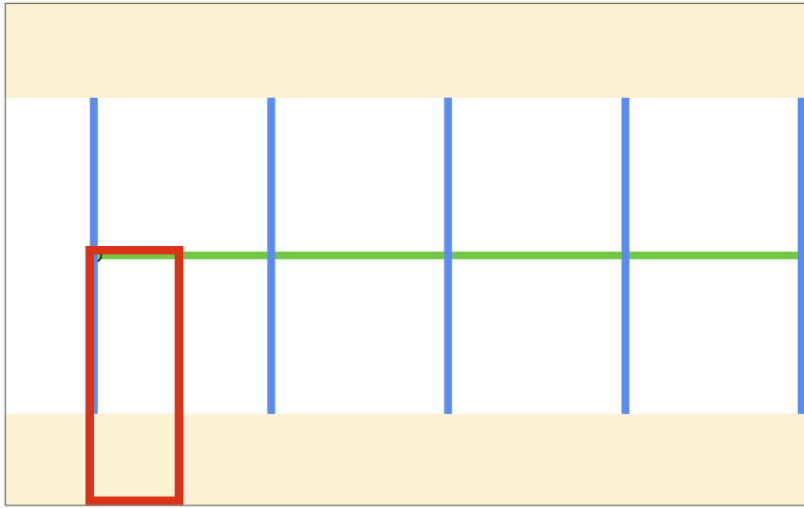



Can be initiated from an analytical model via the Dashboard

Stimulated Reservoir Volume bounded (SRVB)



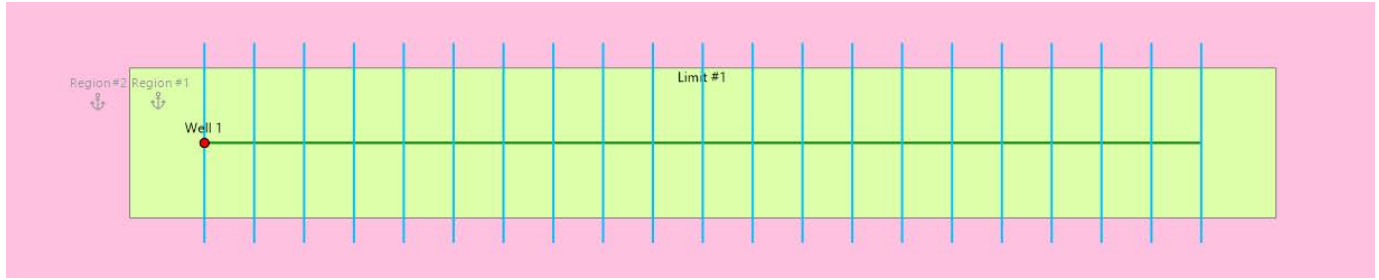
Trilinear



*Efficient Proxies for Numerical Simulation of Unconventional Resources,* Artus et al., 1896873-MS URTEC Conference Paper (2014)

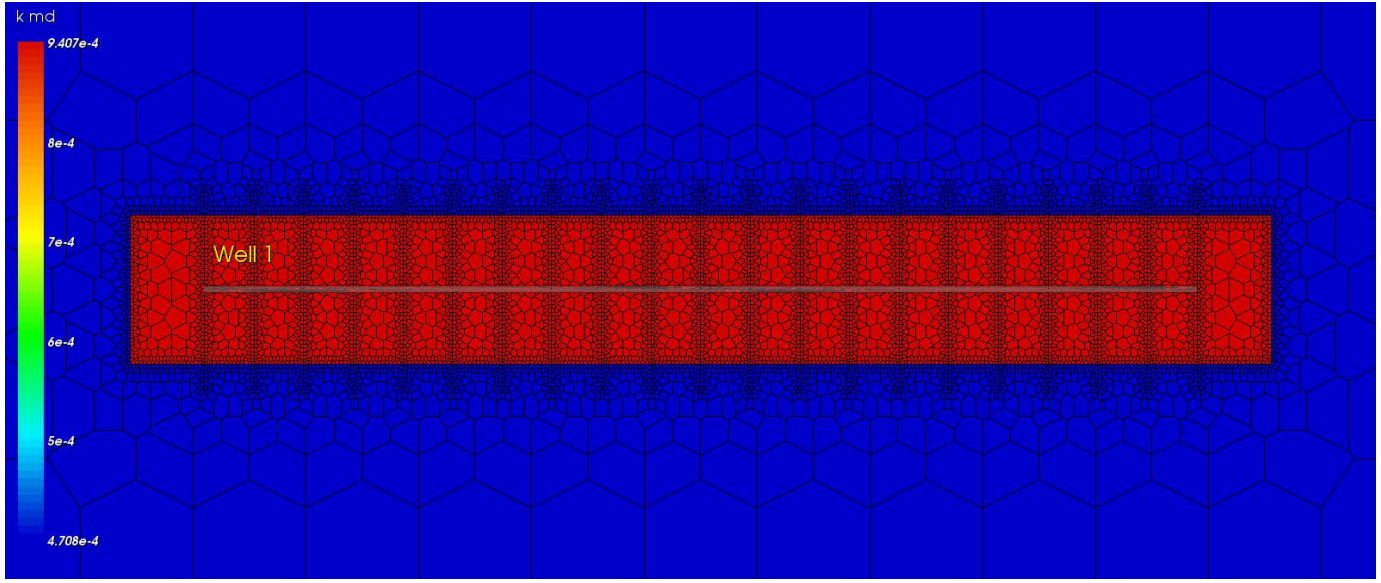
# Composite zones

Composite limits are now allowed to cross fractures to simulate enhanced area close to the well




| Region #1 | |
|---|---|
| Reservoir type | Homogeneous |
| M | 1.00000 |
| D | 1.00000 |
| Net-to-gross | 1.00000 |
| Region #2 | |
| **Reservoir type** | Homogeneous |
| M | |
| D | |
| Net-to-gross | 1.00000 |

Homogeneous
Dual porosity pseudo steady state



# DFN Upscaling

v5.30

KAPPA

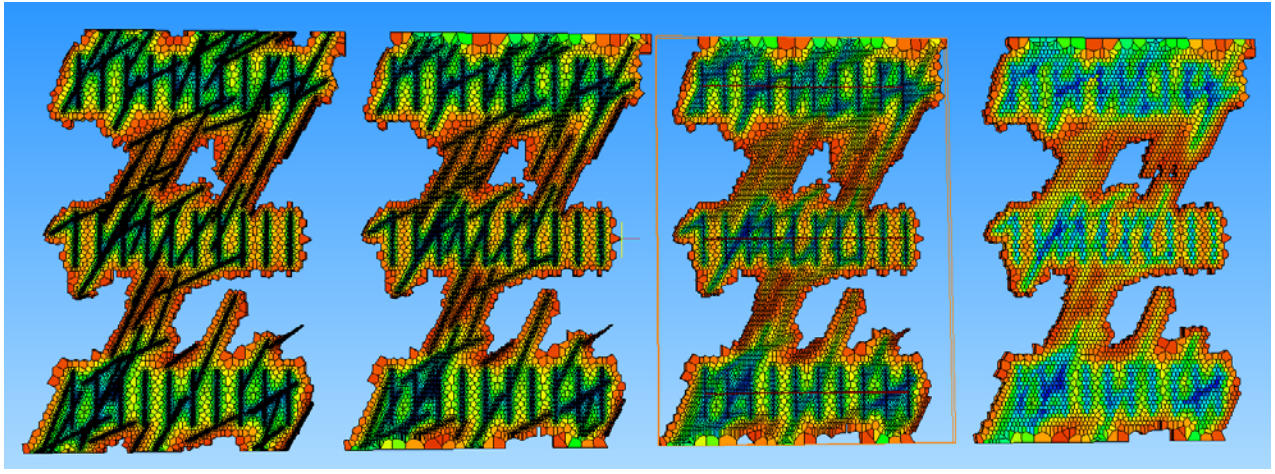
DFN upscaling reduces the refinement of the grid (and gridblock count), correctly accounting for the matrix-to-fracture flow and interaction

- DFN added in Map 

- Upscaling parameters are available in Grid 

- Min gridblock size changes from ‘DFN resolution’ to ‘DFN coarse resolution’

| | | |
|---|---|---|
| DFN upscaling | ☑ | |
| DFN resolution | 4.00000 | ft |
| DFN coarse resolution | 50.0000 | ft |

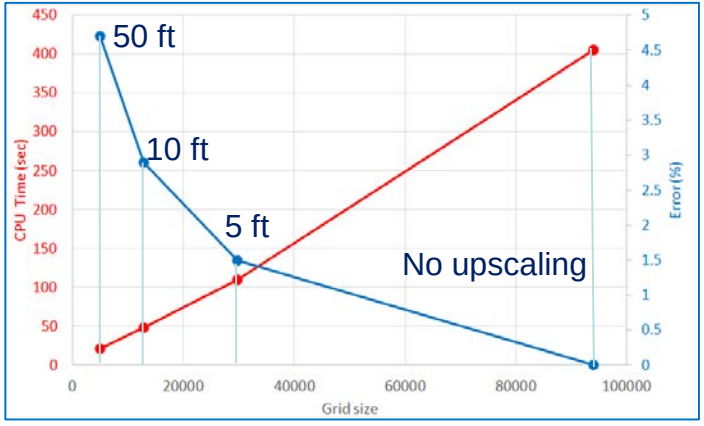


No upscaling
~94,000 cells

5 ft upscaling
~30,000 cells

10 ft
~13,000 cells

50 ft
~5,000 cells



# Stochastic DFN realizations

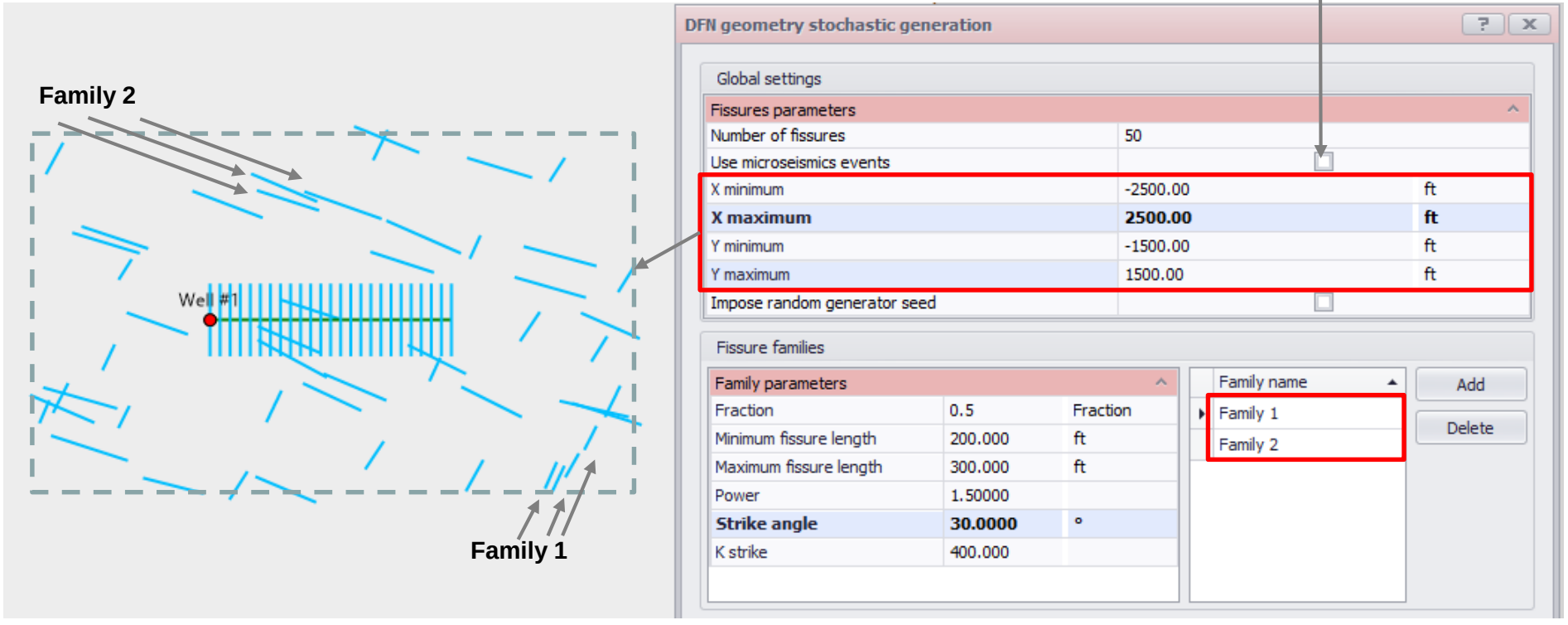
*New in v5.30.03*

KAPPA

DFN

'Map' → 'DFN' → 'Generate'

Location can be defined $\mu$-seismic, if loaded



# Interference with DFN: FMM

*New in v5.30.03*

KAPPA

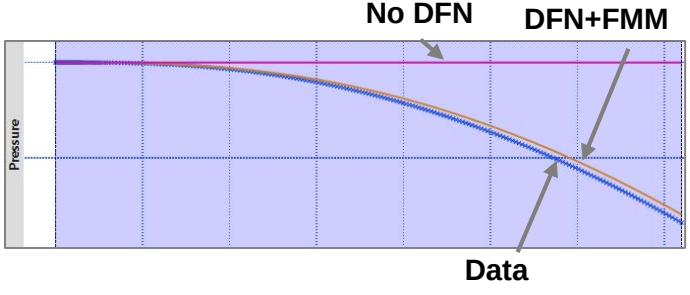
At least 2 wells must exist in the map

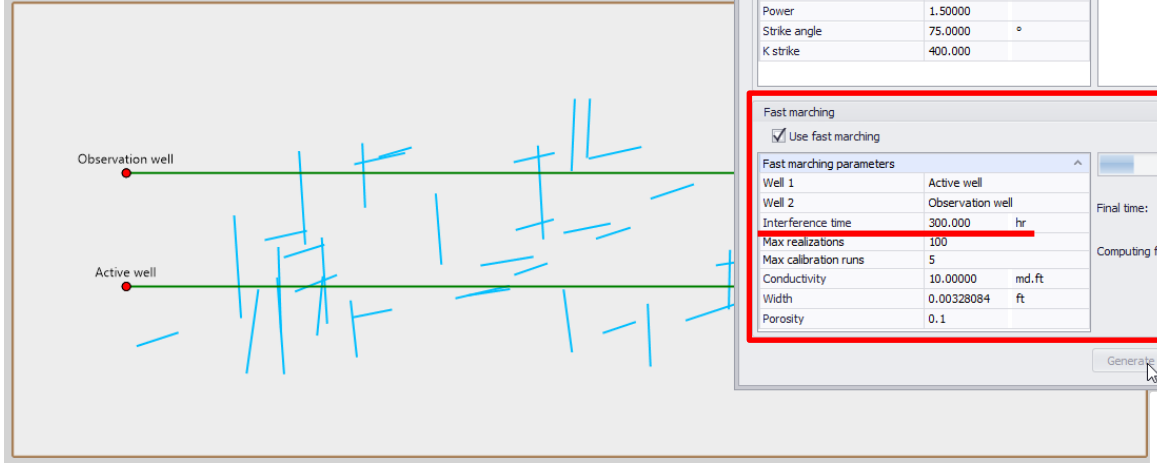

'Map' → 'DFN' → 'Generate'

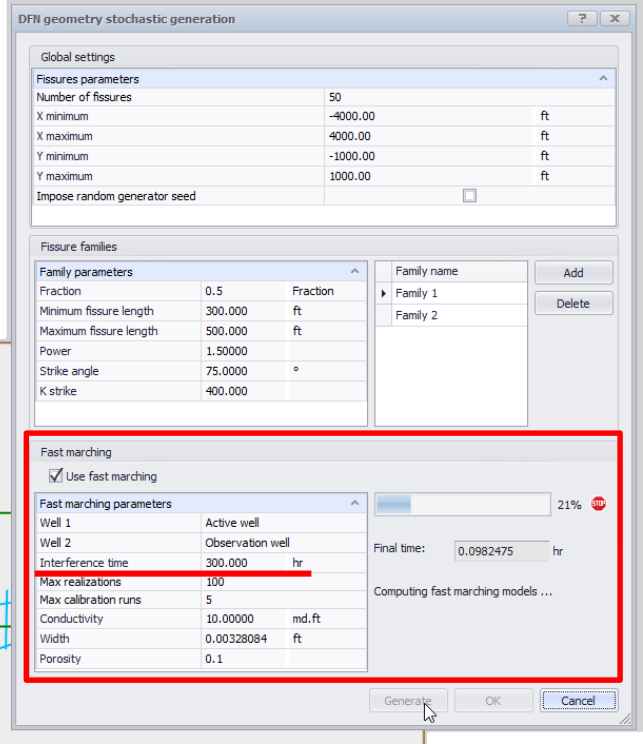
Interference time is an input to constrain the DFN

A number of realizations are run using Fast Marching (flow in fractures only) to pick one closest to the interference time

Then a full model is run in Analysis

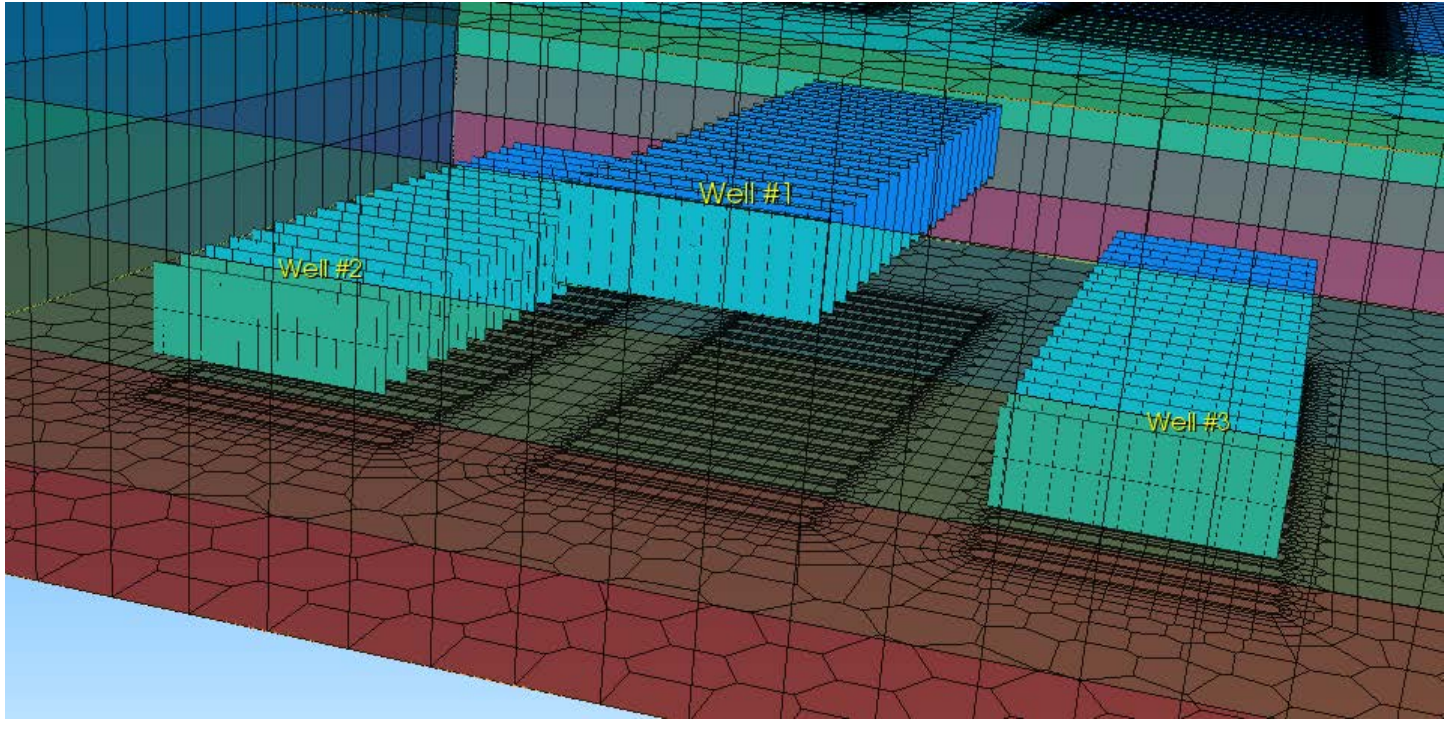


# Accelerated initialization

Large models with multiple MFHWs are initialized using specific faster procedures



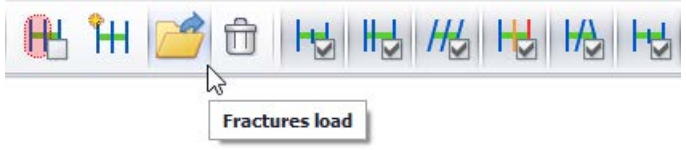
# Loading properties of fracs

v5.30

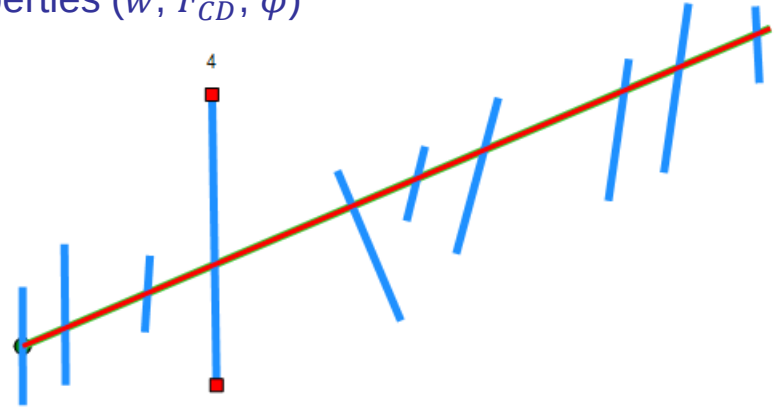
KAPPA

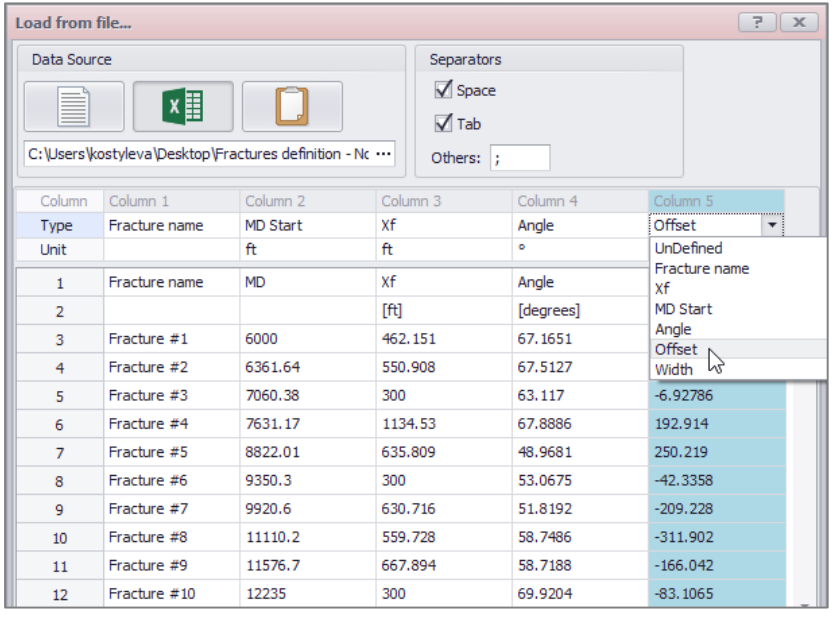
The option allows loading individual fracture properties for a complex MFHW from a file

- MFHW well modeling type should be set as ‘Complex’
- ‘Load’ button is available in the well dialog
- Tick the options prior to loading a file:
  - Half-length
  - Fracture position (MD)
  - Angle to the wellbore
  - Individual properties ($w$, $F_{CD}$, $\phi$)
  - Offset




| Geometry and properties - Fracture #4 | | |
|---|---|---|
| Measured depth | 7631.17 | ft |
| Fracture half length | 1134.53 | ft |
| Fracture angle | 67.8886 | ° |
| Fracture offset | 192.914 | ft |
| Fracture height | 400.000 | ft |
| Fracture conductivity | 150.000 | md.ft |
| Fracture width | 0.01 | ft |
| Fracture porosity | 0.1 | |



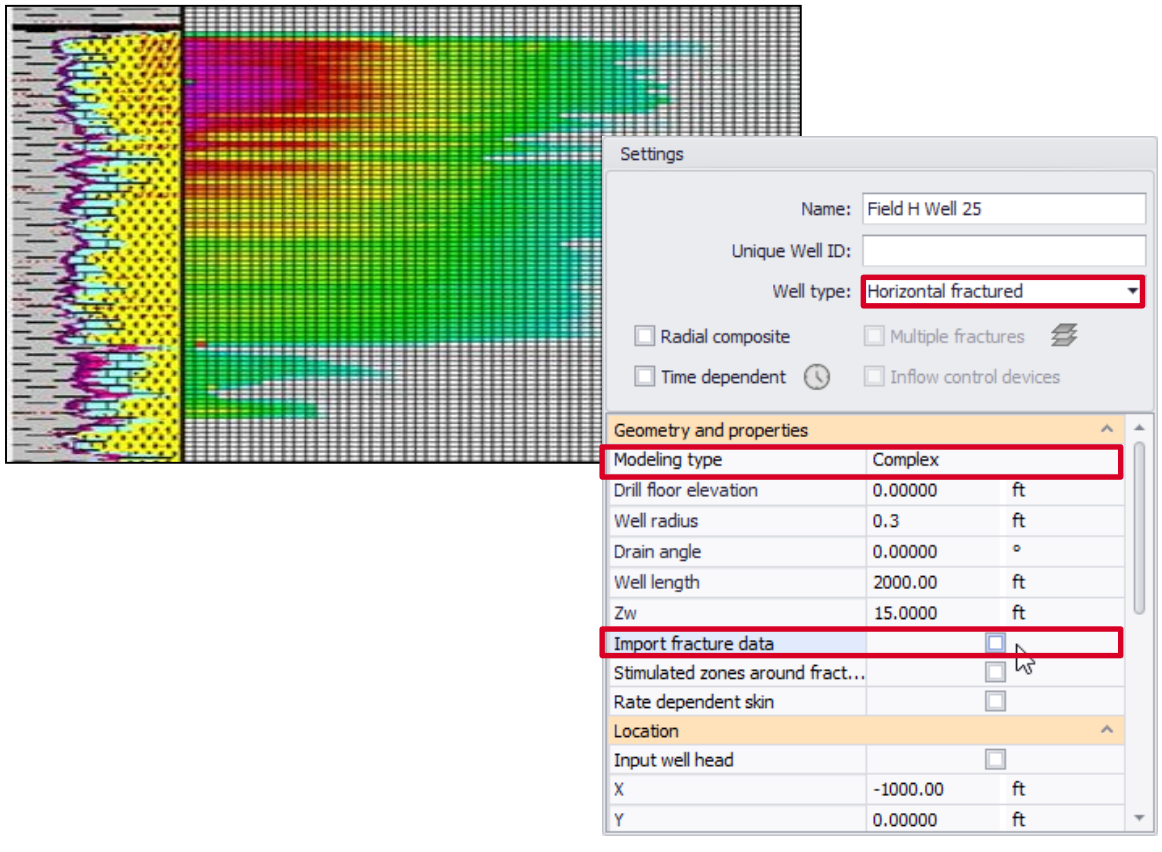



# Load from fracturing software

*New in v5.30.03*

KAPPA

Fracture properties can be non-uniform along the fracture plane

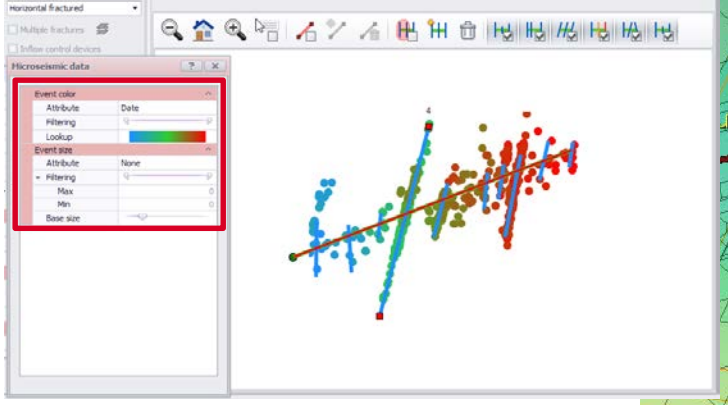


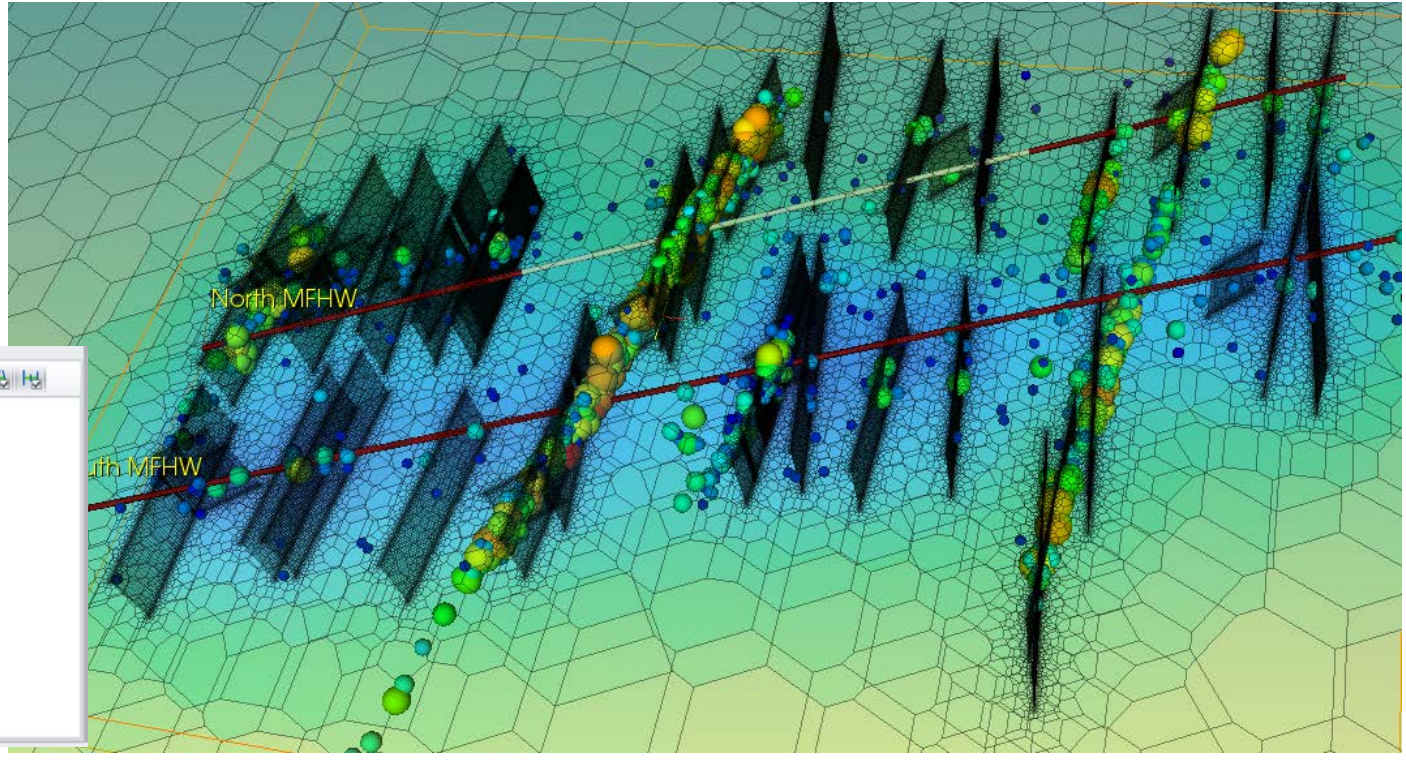

- Define a MFHW as ‘Complex’
- Activate ‘Import fracture data’
- Load properties from *.csv or *.xml:
  - Index, TVD and location at the well
  - (X,Z): $w_f$, $k_f$, $F_{CD}$, $\varphi$, $\beta$
- Define fracture MD and angles

# Microseismics

Load and display of microseismic events to constrain the MFHW configuration

Visualizing attributes:
date, amplitude, stage index



# Stimulated zones

*New in v5.30.03*

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Stimulated zones around fractures of a MFHW

- Available for both Simple and Complex well types
- Defined by radius of the zone, $k$ and $\varphi$ multipliers

Parameters

Show: All  Show short names

| Well 1 | | |
|---|---|---|
| Modeling type | Simple | |
| Drain angle | 0.00000 | ° |
| Fracture model | Infinite conductivity | |
| Number of fractures | 13 | |
| Fracture half length | 360.000 | ft |
| Fracture height | 30.0000 | ft |
| Fracture mid-point height | 15.0000 | ft |
| Width | 0.00328084 | ft |
| Fracture angle | 90.0000 | ° |
| Zw | 15.0000 | ft |
| Well length | 2000.00 | ft |
| Stimulated zones around fractures | ☑ | |
| Stimulation radius | 50.0000 | ft |
| Permeability multiplier | 4.00000 | |
| Porosity multiplier | 1.00000 | |
| Rate dependent skin | ☐ | |
| Wellbore model | None | |
| Bottomhole MD | 6000.00 | ft |

These parameters can be regressed upon in 'Improve'

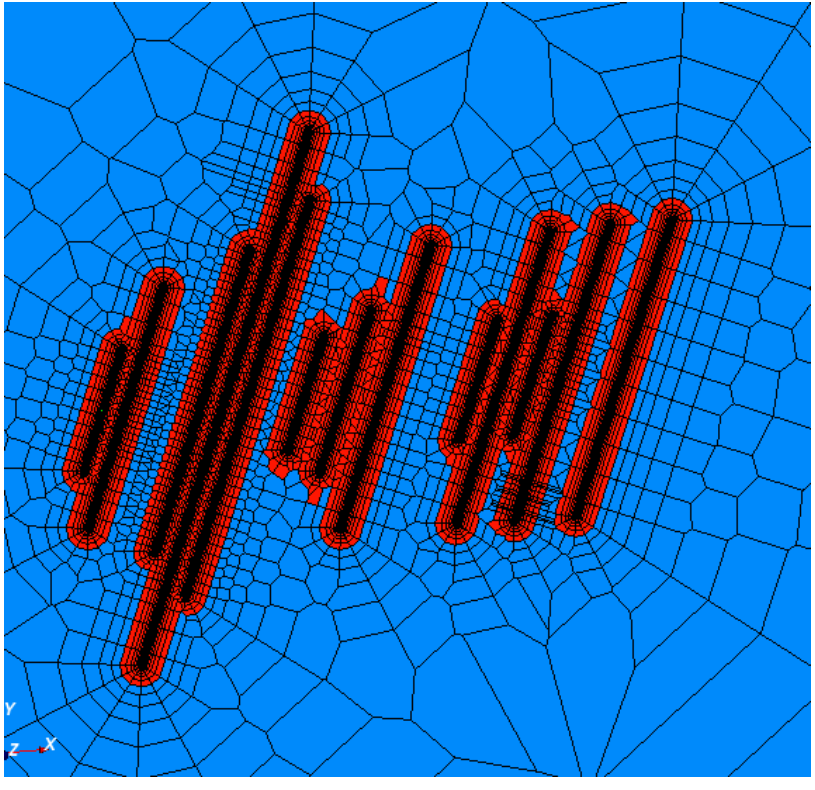
Improve

Parameters | Targets

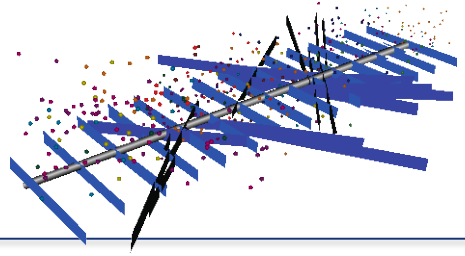
Constant parameters

Well 1

- Theta
- N
- Xf
- Hf
- Zf
- Width
- Beta
- Zw
- Lw
- Stimulation radius
- k multiplier
- phi multiplier




Compatible with numerical SRVB/Trilinear models



# Refrac

v5.30

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The option allows opening some MFHW fractures at a later time

- Well is set as a MFHW
- Fractures are Finite conductivity

(a) **Regular** refrac pattern:

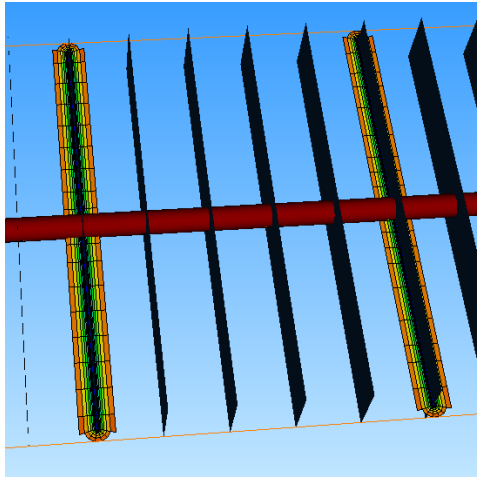
| | | |
|---|---|---|
| Refrac | ☑ | |
| Refrac elapsed time | 18.0000 | Month → $T$ |
| Number of fractures at t0 | 12 | → $a$ |
| Refrac ratio | 4 | → $b$ |
| Infill | ☐ | |

(b) **Irregular** refrac pattern:

- Complex MFHW + indiv.properties 
- Each fracture has its own refrac time $T$

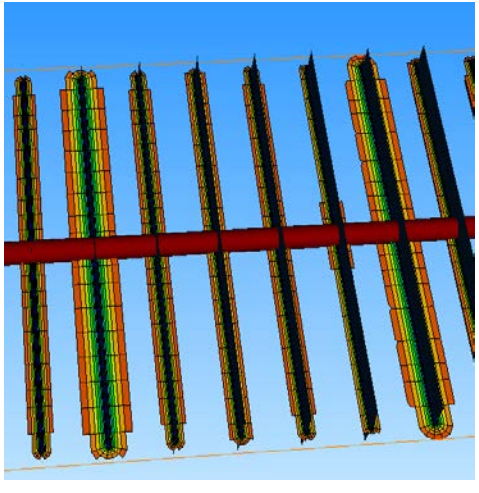
Before refrac (time = 0):

$$N_f = a$$



After refrac (time = $T$):

$$N_f = a + b\,(a - 1)$$



(c) **Infill** option:

- All fractures start with matrix properties and switch to high conductivity at refrac elapsed time $T$

# Multiple KrPc

*New in v5.30.03*

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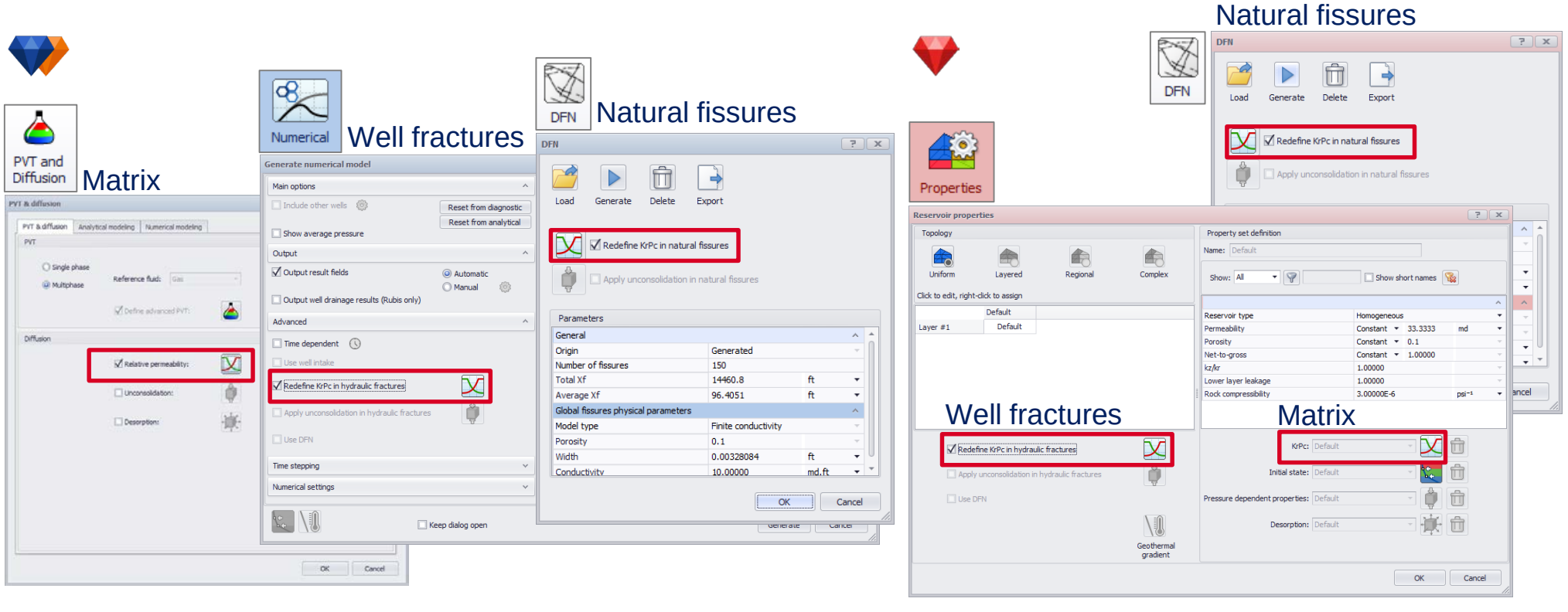
Matrix, well fractures and natural fissures can have independent sets of KrPc

- Multiphase PVT is defined & real PVT are used



# Numerical ‘butterfly’ model

*New in v5.30.03*

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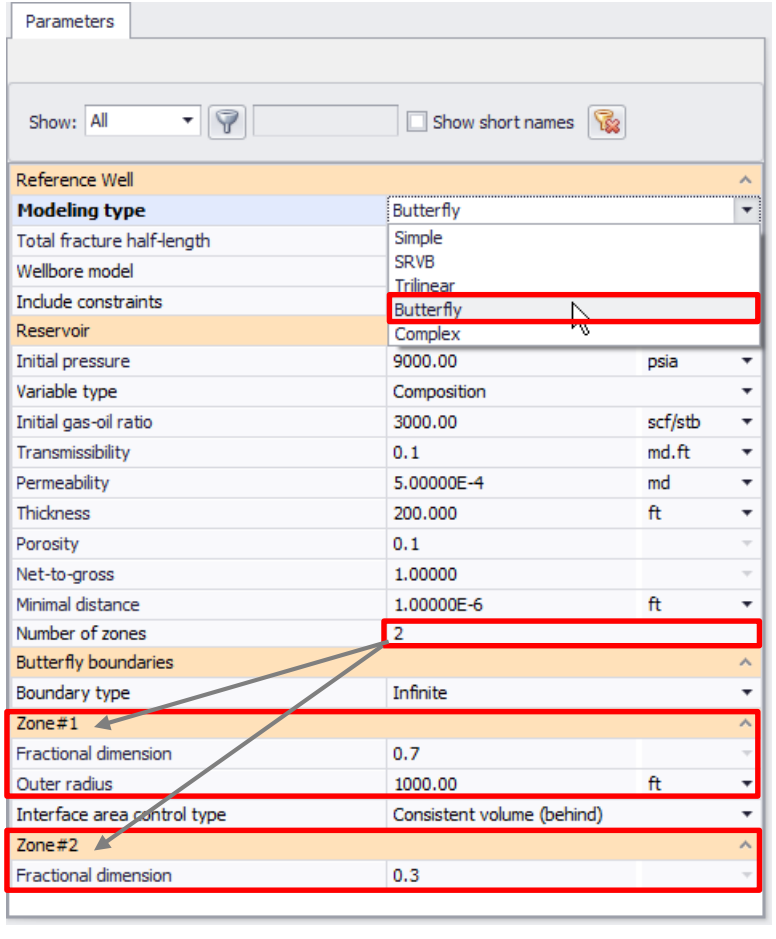
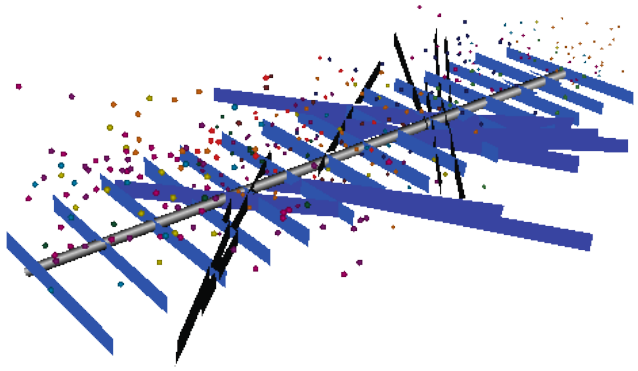
The butterfly model is the numerical counterpart of the multi-zone fractional dimension (MZFD) analytical model. The model solves on a 1D simplified geometry, but benefits from accounting for the non-linearities.

- Constant thickness geometry
- The width of the area perpendicular to the flux varies with a power-law relationship
- Wellbore: constant / changing
- Boundary: infinite / circular / linear





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# THANK YOU

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