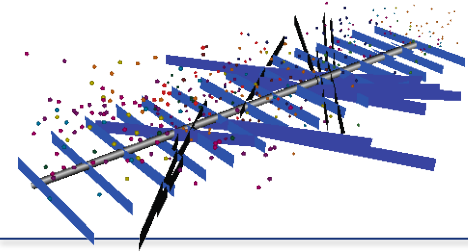


An abstract graphic in the top-left corner featuring a cluster of blue rectangular bars, some thin black lines, and a spray of small, multi-colored dots (red, yellow, green, blue, purple) emanating from the center.

# UR Add-on pack



# KURC / Add-on pack



## **KURC – KAPPA Unconventional Resources Consortium**

- KURC-1: 2012 – 2015
- KURC-2: 2016 – ...
- KURC options are exclusive to members for 3 years since their release
- KURC members get access to any Add-on features

## **UR Add-on pack**

- New developments + selected 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)



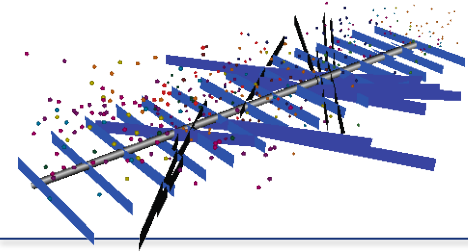
# Add-on pack features



- ◆◆ Fast numerical models for SRV & Trilinear geometries
- ◆◆ DFN analytical model with conjugate fractures
- ◆◆◆ Numerical single-well DFN model
- ◆◆◆ Numerical model with composite zones
- ◆◆◆ Load and display of microseismic data
- ◆◆◆ Simulation of Klinkenberg effect
- ◆◆◆ Fickian diffusion
  - ◆ Water flowback with static Initialization
  - ◆ Clarkson DDA Linear Flow plot
  - ◆ Flowing Material Balance plot
  - ◆ Statistical EUR

## New in KW v5.30 (2020):

- ◆◆ Anomalous diffusion model
- ◆◆ Multi-zone fractional model
- ◆◆◆ Refrac for a MFHW
- ◆◆◆ DFN Upscaling
- ◆◆◆ Loading properties of fracs



# KURC-1/2 exclusive features



Features contractually exclusive to KURC members until mid-2020:

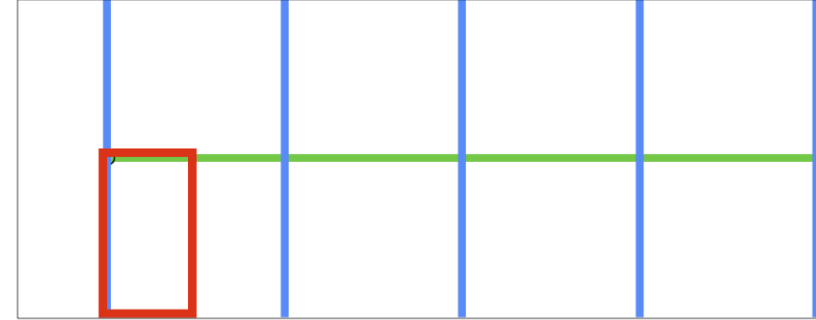
- |        |  |   |
|--------|--|---|
| KURC-1 |  | Load from Fracturing Software               |
|        |  | Confined PVT                                |
|        |  | Multiple KrPc                               |
| KURC-2 |  | Stochastic DFN realizations                 |
|        |  | Interference with DFN: Fast Marching Method |
|        |  | Stimulated zones around the fractures       |

# Fast numerical models

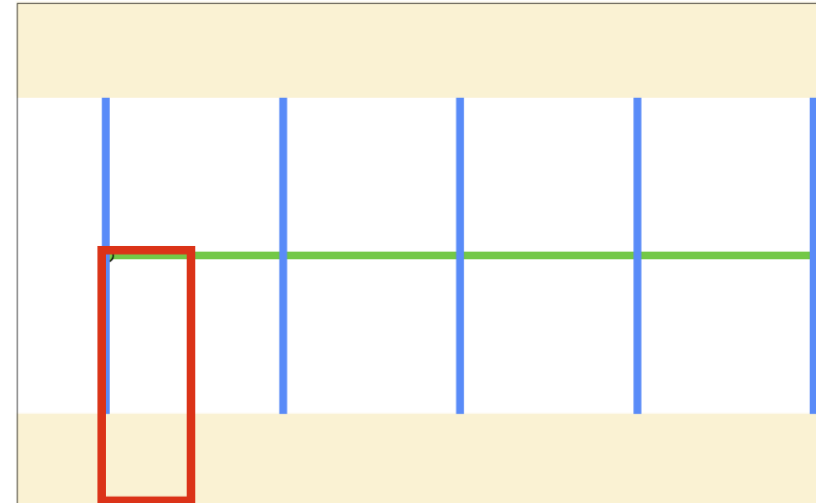


Very useful in the case of complex PVT and a simple but very long MFHW to tune the fracture properties prior to running the full numerical model

Stimulated  
Reservoir  
Volume  
bounded  
(SRVB)



Trilinear



## Well model

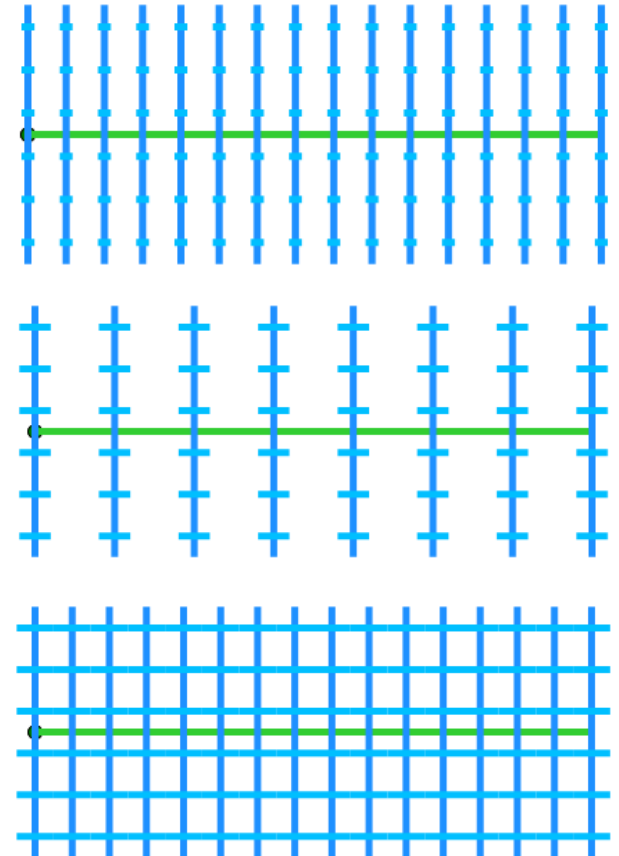
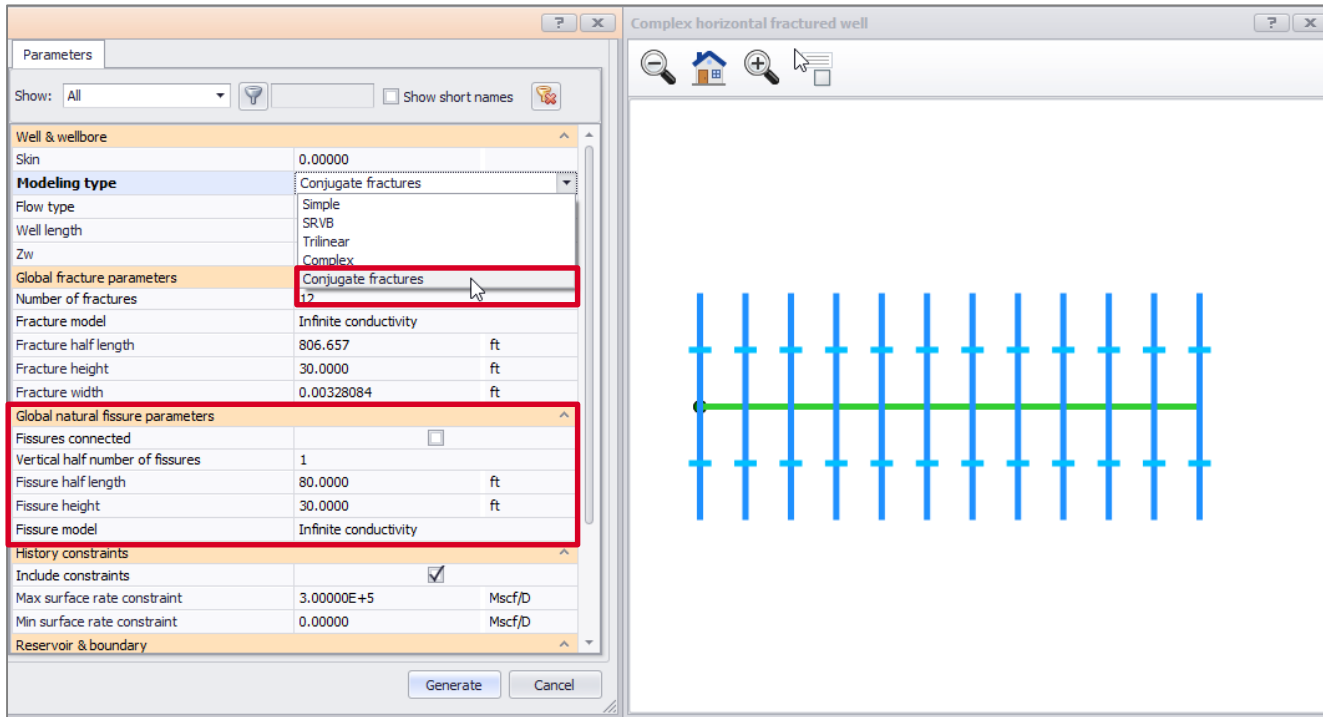
- Finite radius
- Infinite conductivity fracture
- Finite conductivity fracture
- Limited entry
- Horizontal
- Fractured horizontal
- Fractured horizontal + SRVB
- Fractured horizontal + Trilinear

Can be initiated from  
an analytical model  
via the Dashboard

# DFN analytical model



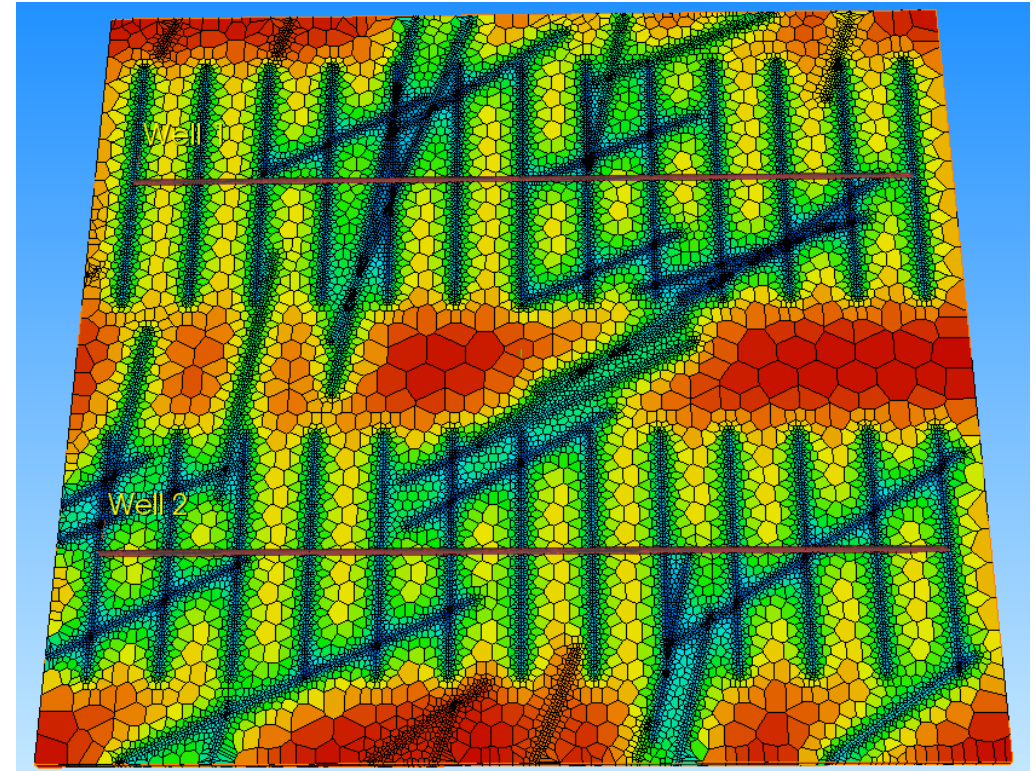
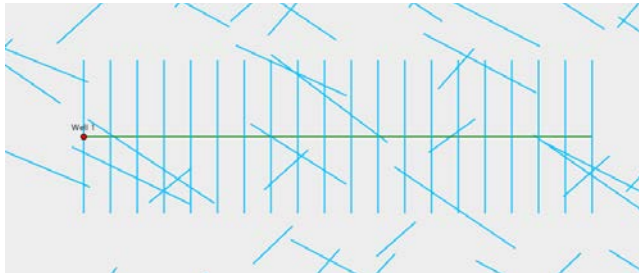
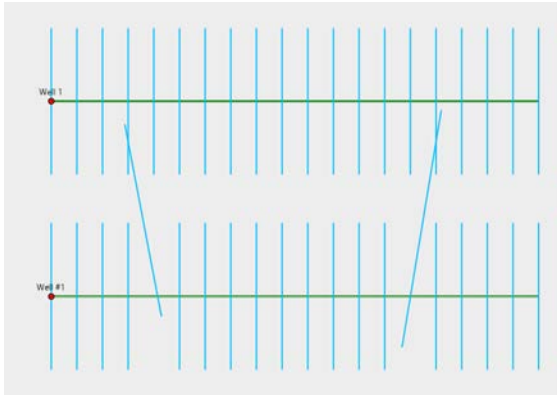
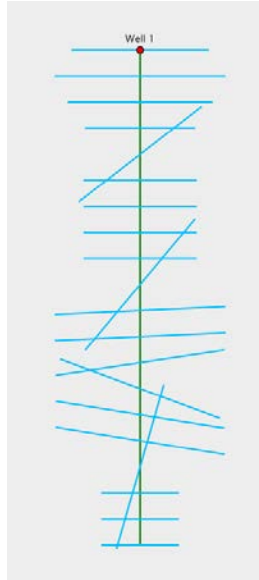
- Conjugate fractures: # fissures and geometry



# Numerical DFN



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



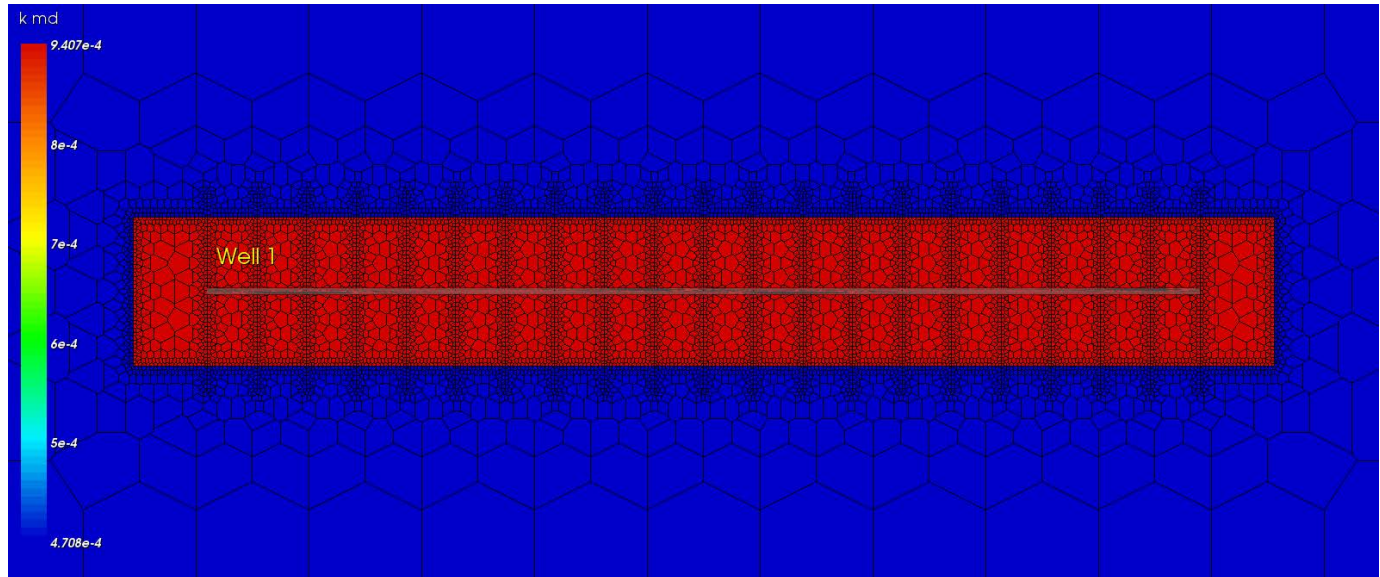
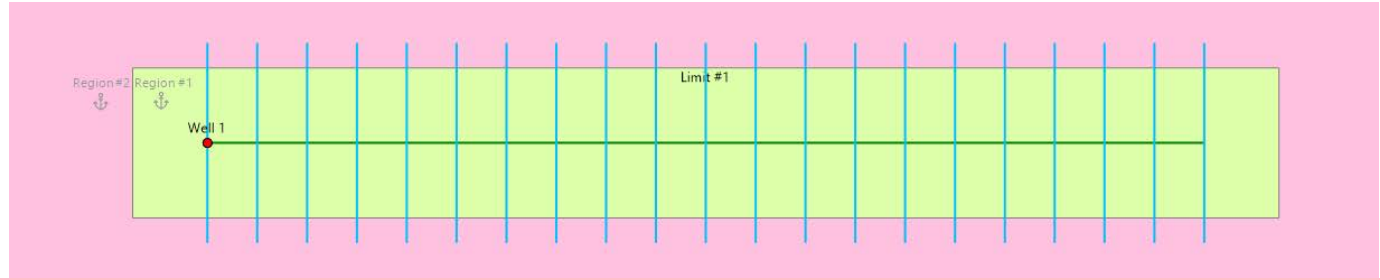


# Composite zones



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	Homogeneous
D	Dual porosity pseudo steady state
Net-to-gross	1.00000



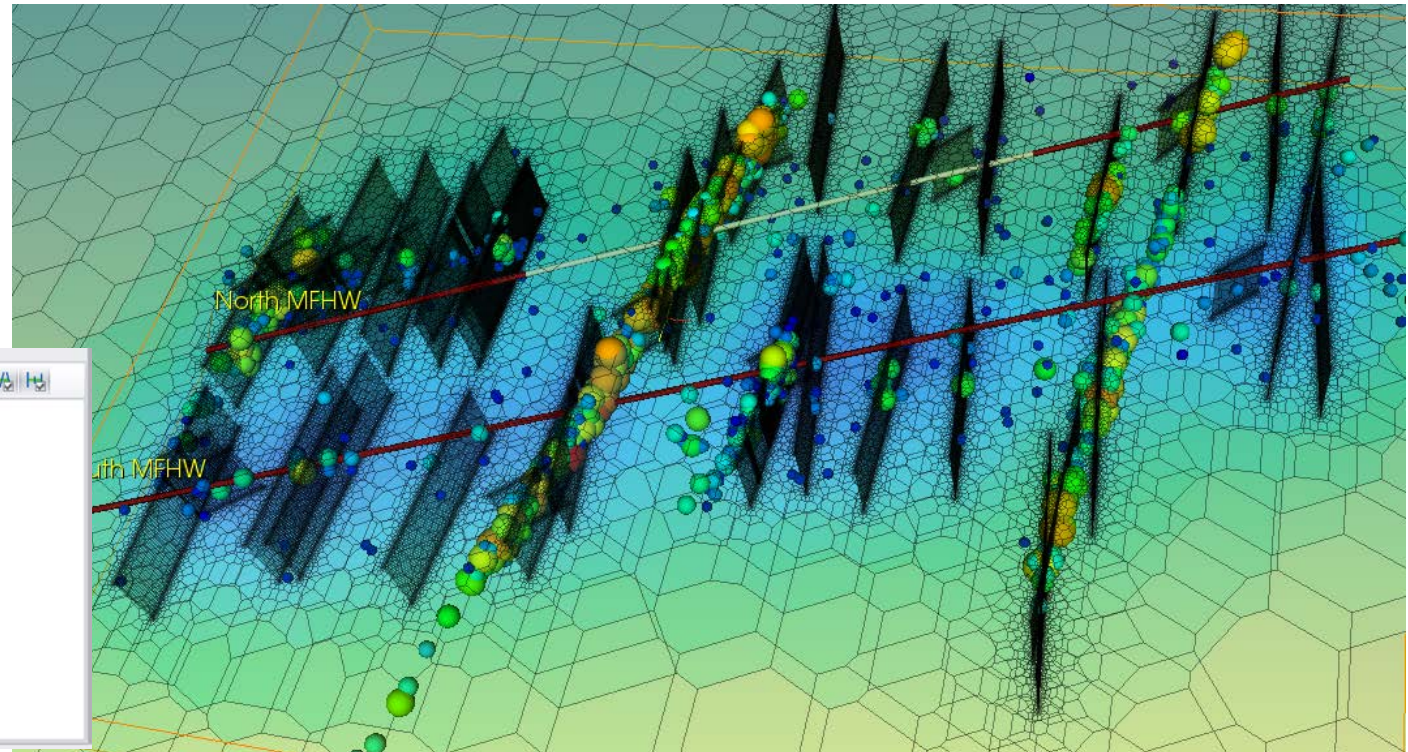
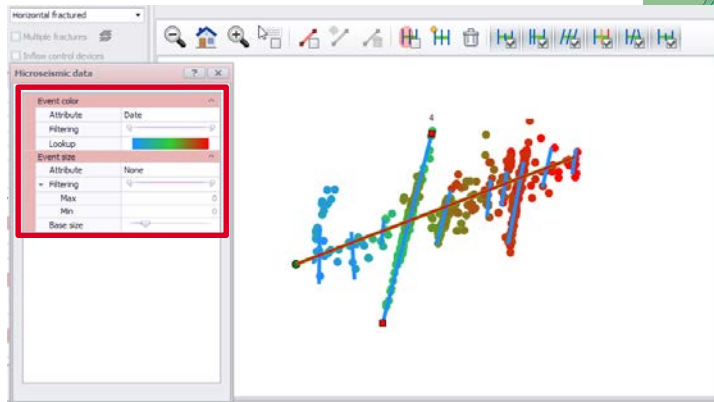


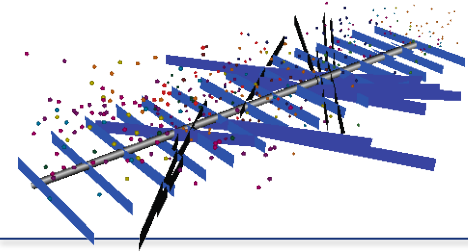
# Microseismics



Load and display of microseismic events to constrain the MFHW configuration

Visualizing attributes:  
date, amplitude, stage index

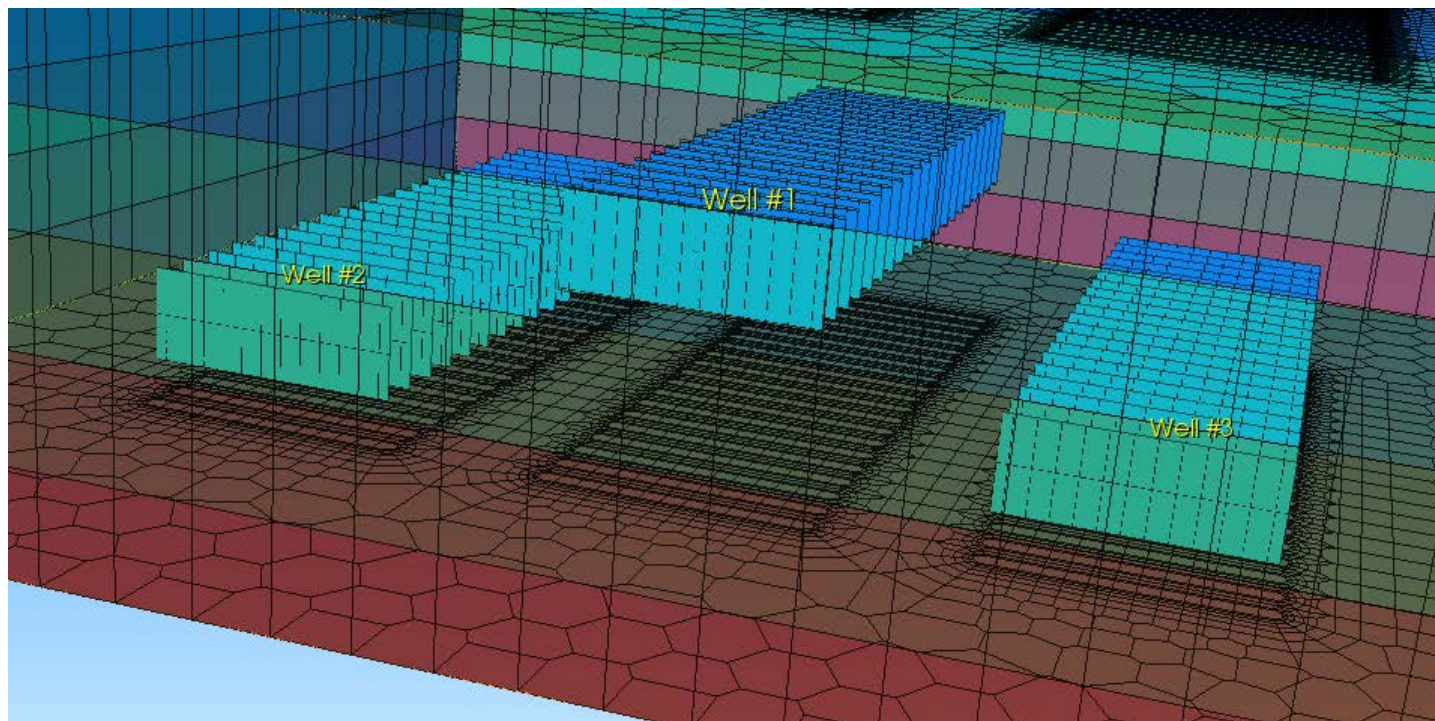




# Accelerated initialization



Large models with multiple MFHWs are initialized using specific faster procedures





# 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	<input type="checkbox"/>	
Skin	0.00000	
Wellbore model	None	
Bottomhole MD	6000.00	ft
Include constraints	<input type="checkbox"/>	
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	<input checked="" type="checkbox"/>	
Klinkenberg b	200.000	psia
Net-to-gross	1.00000	
kz/kr	1.00000	

# Water flowback

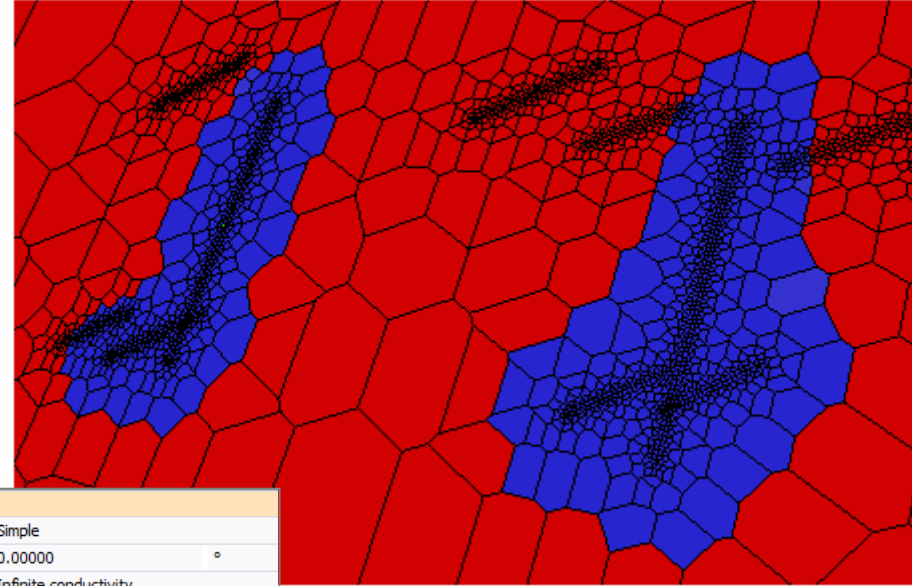


To model the post fracture treatment water flowback:

- 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



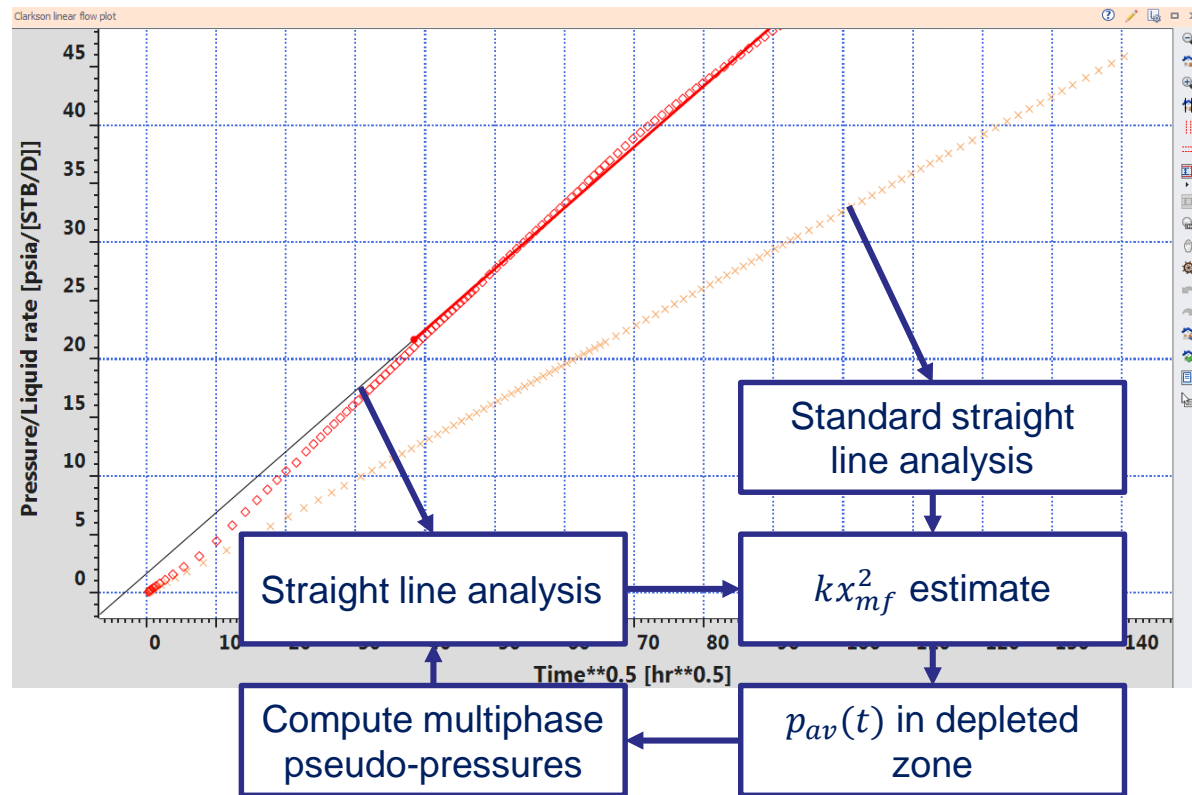
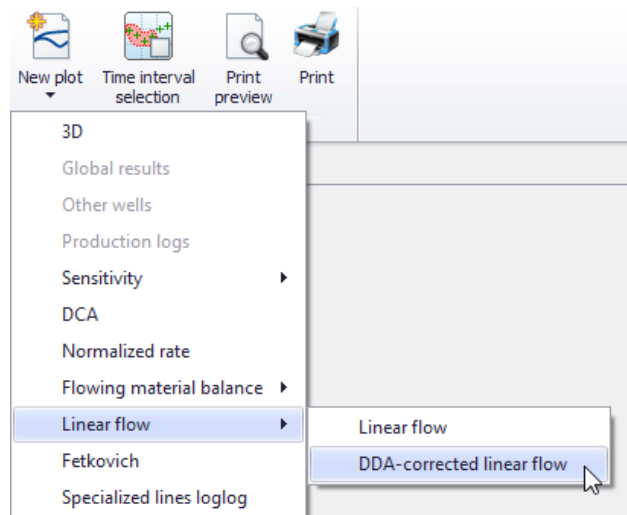
Well 1		
Modeling type	Simple	
Drain angle	0.00000	°
Fracture model	Infinite conductivity	
Number of fractures	15	
Fracture half length	300.000	ft
Fracture height	30.0000	ft
Fracture mid-point height	15.0000	ft
Width	0.00328084	ft
Fracture angle	90.0000	°
Zw	15.0000	ft
Well length	1000.00	ft
Stimulated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

# 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)*

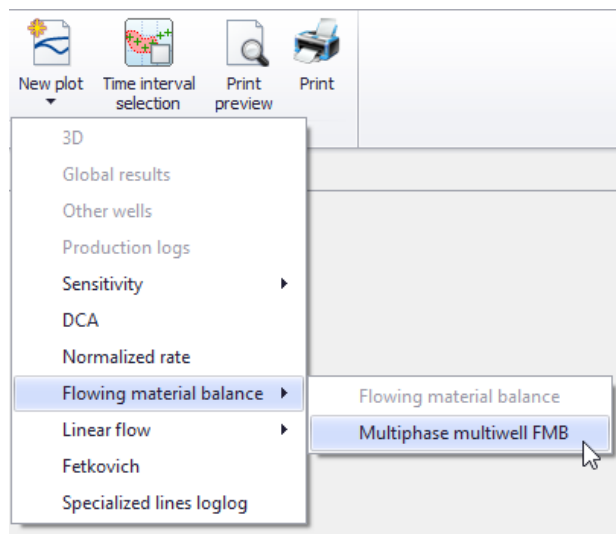
# Multiphase/multiwell FMB Plot



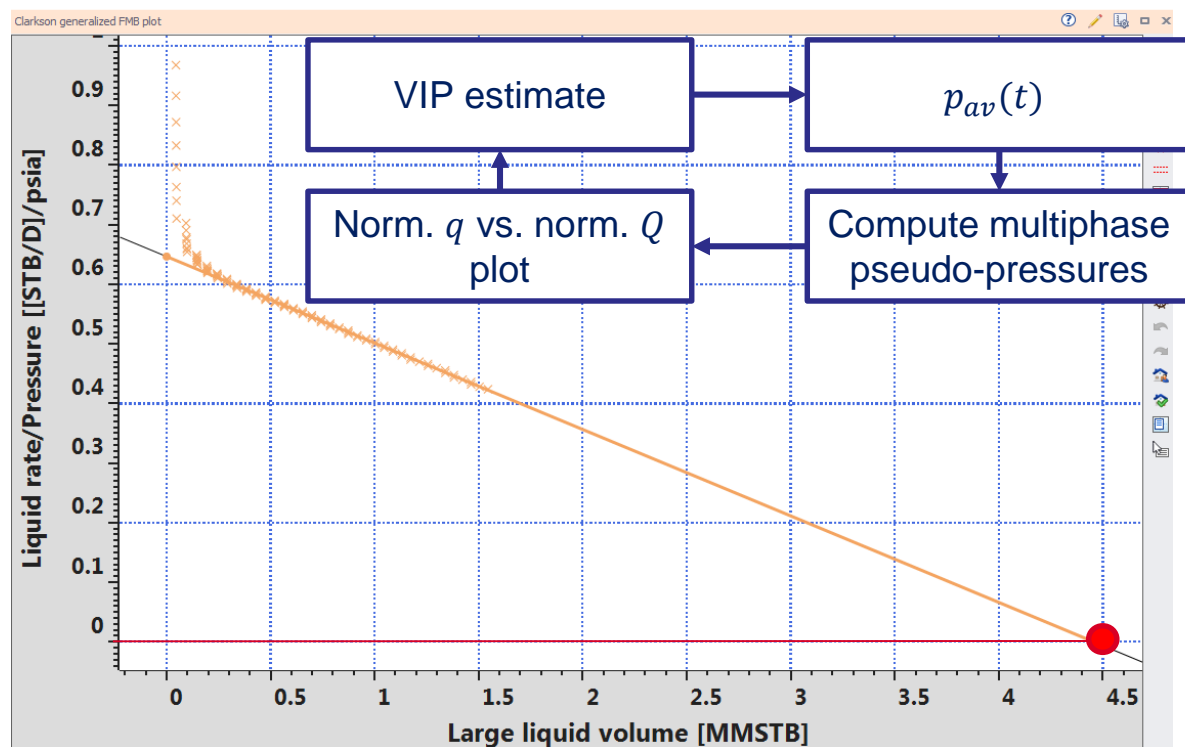
General Flowing Material Balance equation modified using pseudo- $p$  and  $p_{av}$  from MB calculations

Multiphase extraction

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



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



# Statistical EUR



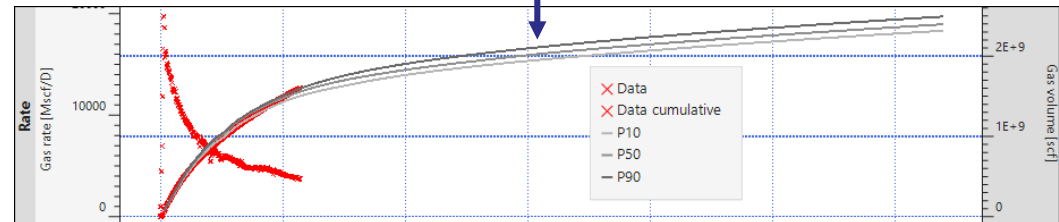
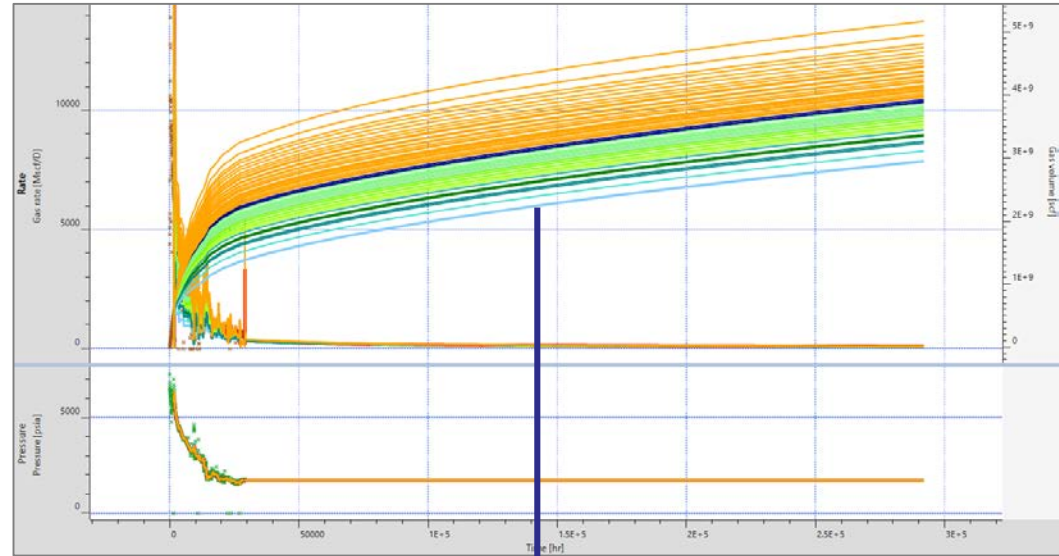
- Single forecast
- Monte Carlo + Improve for uncertainty estimate
- **Monte Carlo + Model Mining**: replacing the CPU expensive nonlinear regression step by a data mining proxy



Model Mining

**Model Mining** is activated when:

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





# Fickian diffusion



PVT includes gas & Real PVT are used

Available under 'Reservoir type'

or 'Reservoir properties'

Generate numerical model

Main options

- ☐ Include other wells
- ☒ Show average pressure
- ☒ Output result fields
- ☐ Output well drainage results (Rubis only)

Advanced

- Time stepping
- Numerical settings

Parameters

Wellbore storage calculator

Show: All

Show short names

Perforation length	250.000	ft
Well length	250.000	ft
Rate dependent skin	<input type="checkbox"/>	
Skin	0.00000	
Wellbore model	Constant	
Wellbore storage	9.50978E-4	bbl/psi
Bottomhole MD	6000.00	ft
Include constraints	<input type="checkbox"/>	
Reservoir		
Initial pressure	4228.00	psia
Reservoir type	Fickian diffusion	
Transmissibility	Homogeneous	
Permeability	Dual porosity pseudo steady state	
Thickness	25.00000	ft
Porosity	0.2	
Net-to-gross	1.00000	
Diffusion time	10.0000	hr
Diffusion ratio	1.00000	
kz/kr	1.00000	

Generate Cancel

Reservoir properties

Topology

- Uniform
- Layered
- Regional
- Complex

Click to edit, right-click to assign

Layer #1	Default
	Default

Property set definition

Name: Default

Show: All

Show short names

Reservoir type	Fickian diffusion
Permeability	Homogeneous
Porosity	Dual porosity pseudo steady state
Net-to-gross	Constant porosity
Diffusion time	10.0000 hr
Diffusion ratio	1.00000
kz/kr	1.00000
Lower layer leakage	1.00000
Rock compressibility	3.00000E-6 psi <sup>-1</sup>

KrPc: Default

Initial state: Default

Pressure dependent properties: Default

Desorption: Default

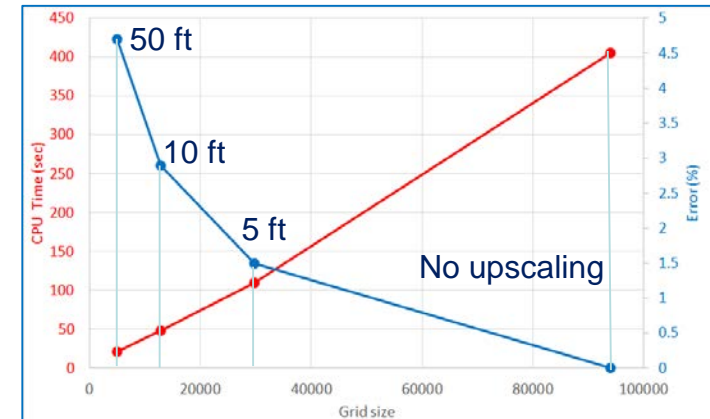
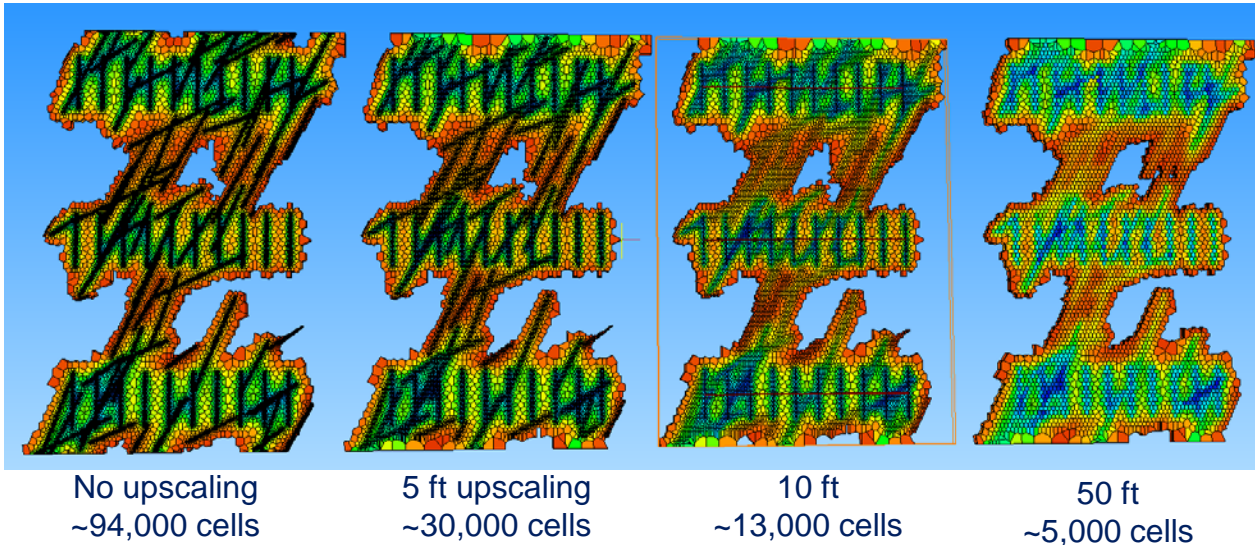
OK Cancel

# DFN Upscaling

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	<input checked="" type="checkbox"/>
DFN resolution	4.00000 ft
DFN coarse resolution	50.0000 ft



# Refrac



New in v5.30




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	<input checked="" type="checkbox"/>
Refrac elapsed time	18.0000 Month $\rightarrow T$
Number of fractures at t0	12 $\rightarrow a$
Refrac ratio	4 $\rightarrow b$
Infill	<input type="checkbox"/>

(b) **Irregular** refrac pattern:

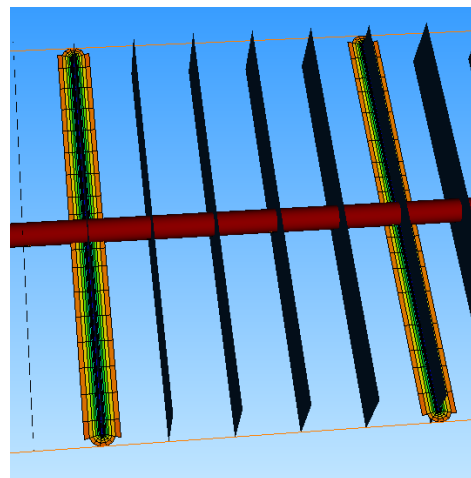
- Complex MFHW + indiv.properties 
- Each fracture has its own refrac time  $T$

(c) **Infill** option:

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

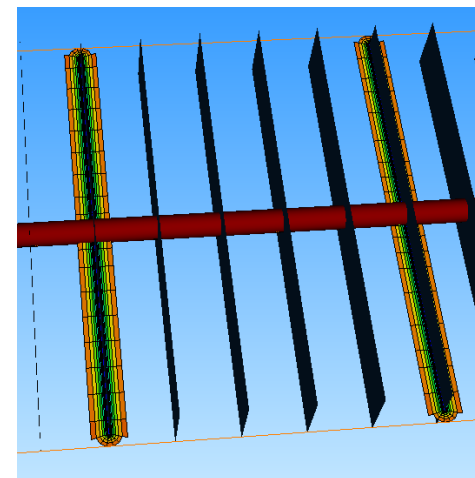
Before refrac (time = 0):

$$N_f = a$$



After refrac (time =  $T$ ):

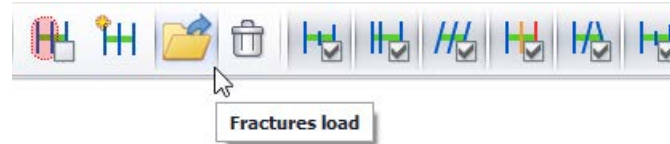
$$N_f = a + b(a - 1)$$



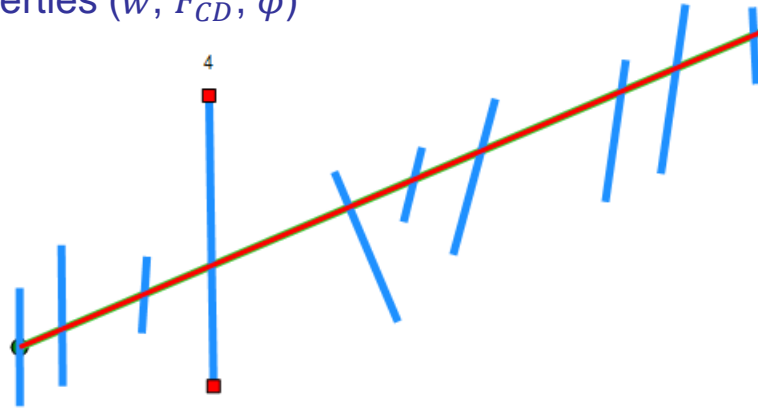
# Loading properties of fracs

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

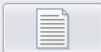



Geometry and properties - Fracture #4		
Measured depth	7631.17	ft
Fracture half length	1134.53	ft
Fracture angle	67.8886	°
Fracture offset	192.914	ft
Fracture height	400.000	ft
Fracture conductivity	150.000	md.ft
Fracture width	0.01	ft
Fracture porosity	0.1	




Load from file...

Data Source







C:\Users\kostyleva\Desktop\Fractures definition - Nc ...

Separators

☒ Space

☒ Tab

Others: ;

Column	Column 1	Column 2	Column 3	Column 4	Column 5
Type	Fracture name	MD Start	Xf	Angle	Offset
Unit		ft	ft	°	Undefined
1	Fracture name	MD	Xf	Angle	Fracture name
2			[ft]	[degrees]	Xf
3	Fracture #1	6000	462.151	67.1651	MD Start
4	Fracture #2	6361.64	550.908	67.5127	Angle
5	Fracture #3	7060.38	300	63.117	Offset
6	Fracture #4	7631.17	1134.53	67.8886	Width
7	Fracture #5	8822.01	635.809	48.9681	-6.92786
8	Fracture #6	9350.3	300	53.0675	250.219
9	Fracture #7	9920.6	630.716	51.8192	-42.3358
10	Fracture #8	11110.2	559.728	58.7486	-209.228
11	Fracture #9	11576.7	667.894	58.7188	-311.902
12	Fracture #10	12235	300	69.9204	-166.042
					-83.1065

# Anomalous Diffusion



New in v5.30



Anomalous Diffusion analytical model is made internal

Well model [Horizontal fractured]

Horizontal fractured

☐ Rate dependent skin ☐ Time dependent skin

Reservoir model [Homogeneous]

Homogeneous

Homogeneous  
Dual porosity pseudo steady state  
Dual porosity transient (slab)  
Dual porosity transient (sphere)  
Radial composite  
**Anomalous Diffusion**  
Multi-zone fractional dimension

Use M,D Definition

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

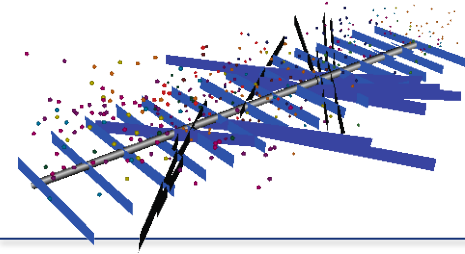
Well & wellbore	
Wellbore storage	0.01
Skin	0.00000
<b>Modeling type</b>	Trilinear
Flow type	Simple
Well length	SRV
Zw	Trilinear
Number of fractures	Conjugate fractures

Reservoir & boundary		
Initial pressure	5000.00	psia
Transmissibility	0.2	md.ft
Permeability	1.00000E-3	md
Thickness	200.000	ft
Porosity	0.1	
<b>Primary diffusion exponent</b>	<b>0.7</b>	
<b>Secondary diffusion exponent</b>	<b>0.3</b>	
Reservoir	Homogeneous	
kz/kr	1.00000	
Total compressibility	3.00000E-6	psi <sup>-1</sup>

Additional parameters:

$\alpha_f$  and  $\alpha_m$

(also for outer zone in Trilinear)



# Multi-zone fractional dimension



New in v5.30

Multi-zone fractional dimension analytical model is made internal  
Selected in Well or Reservoir model dialog (the two are synchronized)

Well model [Multi-zone fractional dimension]

Multi-zone fractional dimension

☐ Rate dependent skin ☐ Time dependent skin

Reservoir model [Multi-zone fractional dimension]

Multi-zone fractional dimension

☐ horizontal anisotropy ☒ Use M,D Definition

Boundary model [Infinite]

Infinite

☐ Show average pressure

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

A decorative graphic in the top-left corner consisting of several blue diagonal lines, a thin black line, and a cluster of small, multi-colored dots.

# THANK YOU



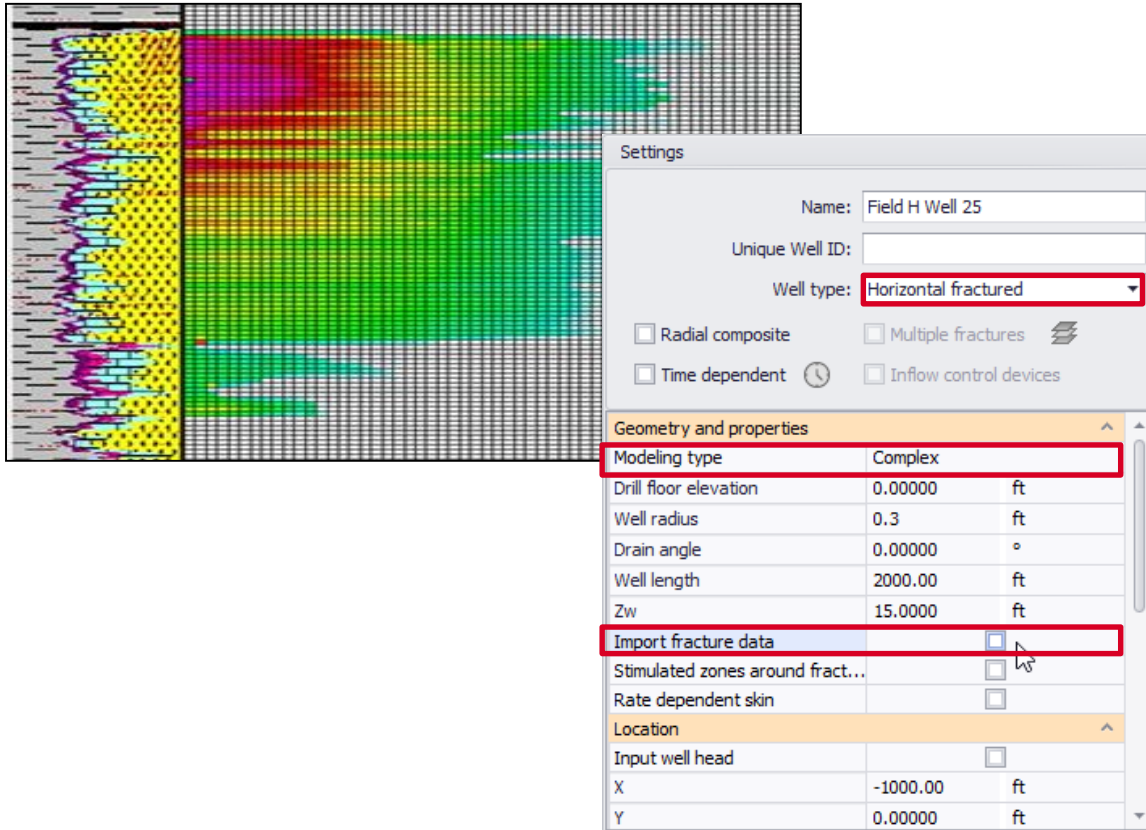
[kappaeng.com/ur](http://kappaeng.com/ur)



# Load from fracturing software



Fracture properties can be non-uniform along the fracture plane



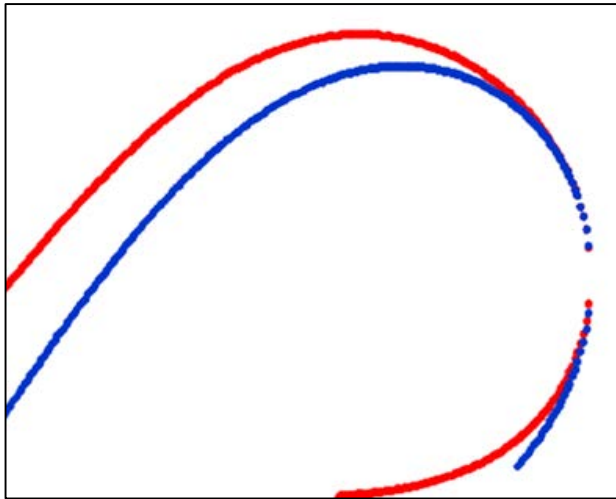
The image shows a software interface with a fracture visualization on the left and a 'Settings' dialog box on the right. The visualization displays a wellbore with a complex fracture network, color-coded by property. The 'Settings' dialog box is titled 'Settings' and contains the following sections:

- General:**
  - Name: Field H Well 25
  - Unique Well ID:
  - Well type: Horizontal fractured (selected in a dropdown menu)
  - ☐ Radial composite
  - ☐ Multiple fractures
  - ☐ Time dependent
  - ☐ Inflow control devices
- Geometry and properties:**
  - Modeling type: Complex (selected in a dropdown menu)
  - Drill floor elevation: 0.00000 ft
  - Well radius: 0.3 ft
  - Drain angle: 0.00000 °
  - Well length: 2000.00 ft
  - Zw: 15.0000 ft
  - Import fracture data: ☒ (checked)
  - Stimulated zones around fract...: ☐
  - Rate dependent skin: ☐
- Location:**
  - Input well head: ☐
  - X: -1000.00 ft
  - Y: 0.00000 ft

- 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

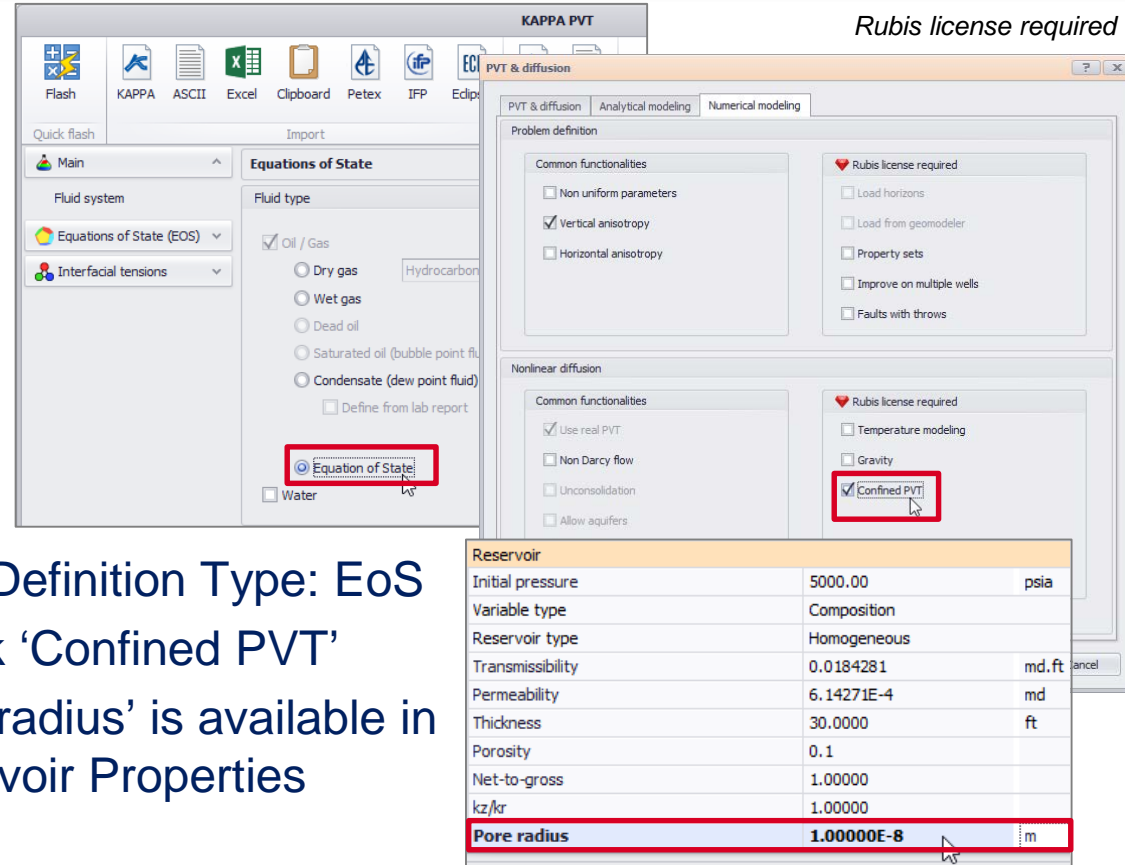
# Confined PVT

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

*Rubis license required*



**Equations of State**

Fluid type

- ☒ Oil / Gas
- ☐ Dry gas
- ☐ Wet gas
- ☐ Dead oil
- ☐ Saturated oil (bubble point fluid)
- ☐ Condensate (dew point fluid)
- ☐ Define from lab report
- ☐ Water

**Nonlinear diffusion**

Common functionalities

- ☒ Use real PVT
- ☐ Non Darcy flow
- ☐ Unconsolidation
- ☐ Allow aquifers

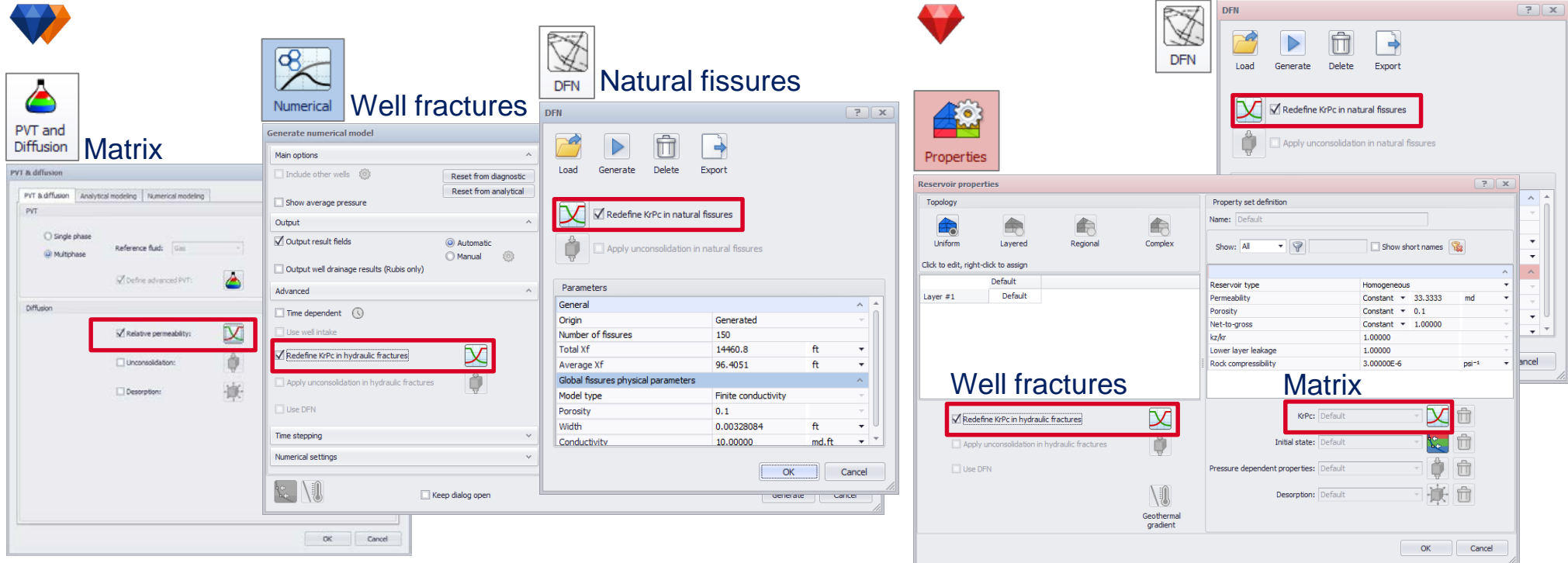
**Reservoir**

Property	Value	Unit
Initial pressure	5000.00	psia
Variable type	Composition	
Reservoir type	Homogeneous	
Transmissibility	0.0184281	md.ft
Permeability	6.14271E-4	md
Thickness	30.0000	ft
Porosity	0.1	
Net-to-gross	1.00000	
kz/k <sub>r</sub>	1.00000	
<b>Pore radius</b>	<b>1.00000E-8</b>	<b>m</b>

# Multiple KrPc

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

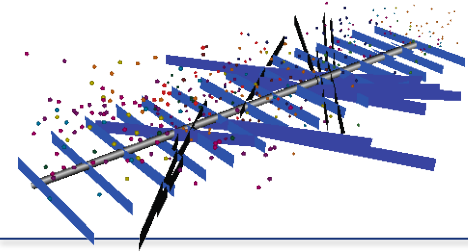
- Multiphase PVT is defined & real PVT are used



The screenshot displays three overlapping software windows from a reservoir simulation package, illustrating the configuration of independent KrPc (Relative Permeability-Capillary Pressure) for different geological features.

- Matrix Window:** Located in the bottom-left, it shows the 'PVT & diffusion' tab. Under the 'Diffusion' section, the 'Relative permeability' checkbox is checked and highlighted with a red box. Below it, the 'Unconsolidation' and 'Desorption' checkboxes are unchecked.
- Well fractures Window:** Located in the bottom-center, it shows the 'Reservoir properties' tab. Under the 'Global fissures physical parameters' section, the 'Redefine KrPc in hydraulic fractures' checkbox is checked and highlighted with a red box.
- Natural fissures Window:** Located in the bottom-right, it shows the 'Reservoir properties' tab. Under the 'Global fissures physical parameters' section, the 'Redefine KrPc in natural fissures' checkbox is checked and highlighted with a red box.

Additionally, a 'Natural fissures' window is visible in the top-right, showing the 'DFN' (Discrete Fracture Network) tab with the 'Redefine KrPc in natural fissures' checkbox checked and highlighted with a red box.

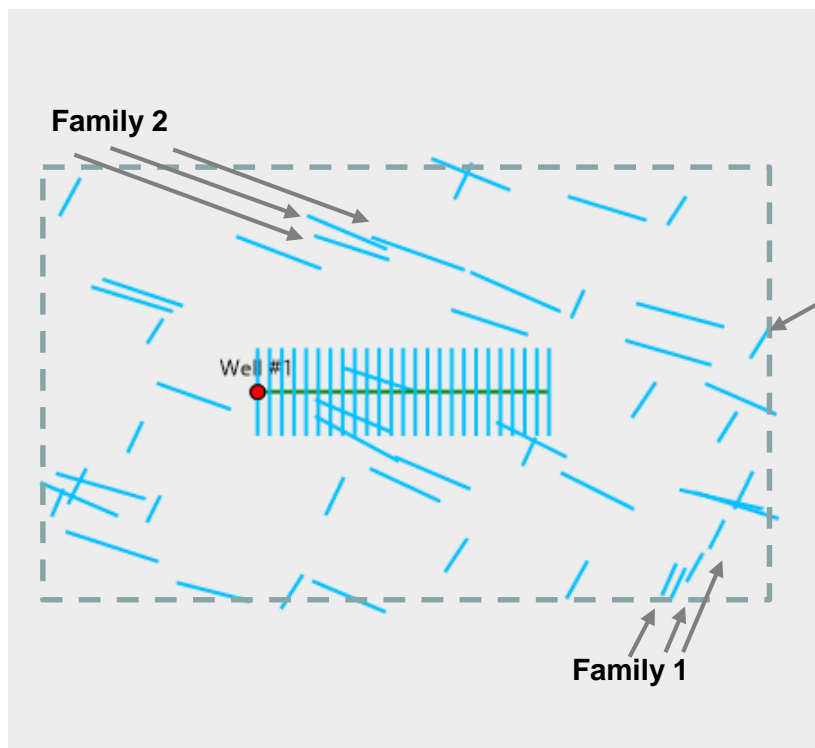


# Stochastic DFN realizations



'Map' → 'DFN' → 'Generate'

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



DFN geometry stochastic generation

Global settings

Fissures parameters

Number of fissures	50	
Use microseismics events	<input type="checkbox"/>	
X minimum	-2500.00	ft
<b>X maximum</b>	<b>2500.00</b>	<b>ft</b>
Y minimum	-1500.00	ft
Y maximum	1500.00	ft
Impose random generator seed	<input type="checkbox"/>	

Fissure families

Family parameters

Fraction	0.5	Fraction
Minimum fissure length	200.000	ft
Maximum fissure length	300.000	ft
Power	1.50000	
<b>Strike angle</b>	<b>30.0000</b>	<b>°</b>
K strike	400.000	

Family name

- Family 1
- Family 2

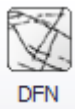
Add

Delete

# Interference with DFN: FMM



At least 2 wells must exist in the map

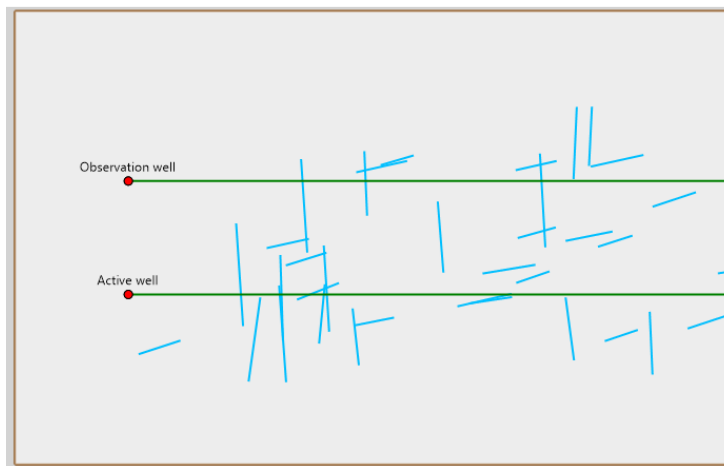
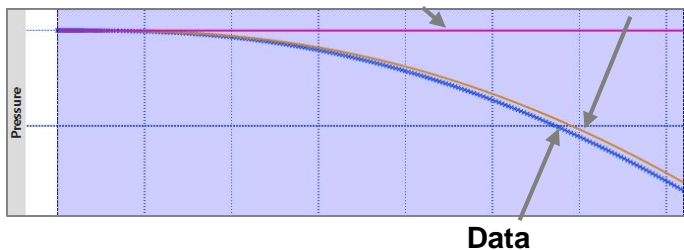


‘Map’ → ‘DFN’ → ‘Generate’

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



DFN geometry stochastic generation

Global settings

Fissures parameters		
Number of fissures	50	
X minimum	-4000.00	ft
X maximum	4000.00	ft
Y minimum	-1000.00	ft
Y maximum	1000.00	ft
Impose random generator seed	<input type="checkbox"/>	

Fissure families

Family parameters		
Fraction	0.5	Fraction
Minimum fissure length	300.000	ft
Maximum fissure length	500.000	ft
Power	1.50000	
Strike angle	75.0000	°
K strike	400.000	

Family name

Family 1	Add
Family 2	Delete

Fast marching

☒ Use fast marching

Fast marching parameters

Well 1	Active well
Well 2	Observation well
Interference time	300.000 hr
Max realizations	100
Max calibration runs	5
Conductivity	10.00000 md.ft
Width	0.00328084 ft
Porosity	0.1

Final time: 0.0982475 hr

Computing fast marching models ...

Generate OK Cancel

# Stimulated zones



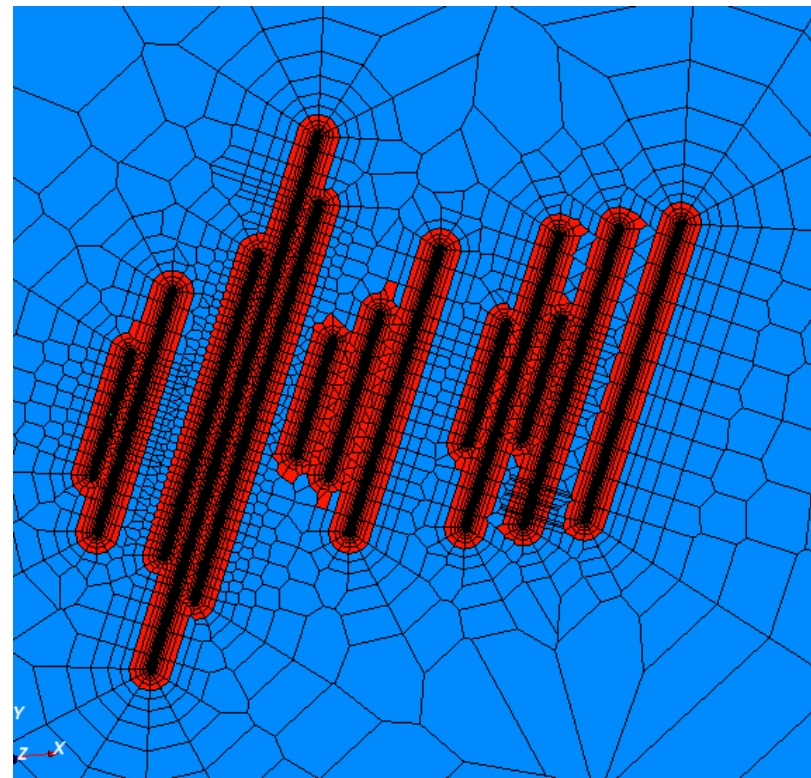
Stimulated zones around fractures of a MFHW

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

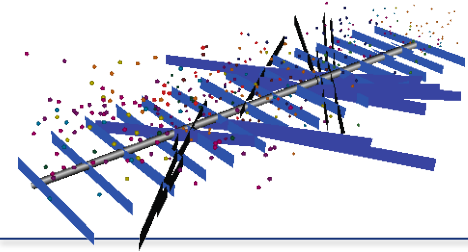
Parameters		
Show: All <input type="checkbox"/> Show short names		
Well 1		
Modeling type	Simple	
Drain angle	0.00000	°
Fracture model	Infinite conductivity	
Number of fractures	13	
Fracture half length	360.000	ft
Fracture height	30.0000	ft
Fracture mid-point height	15.0000	ft
Width	0.00328084	ft
Fracture angle	90.0000	°
Zw	15.0000	ft
Well length	2000.00	ft
Stimulated zones around fractures	<input checked="" type="checkbox"/>	
Stimulation radius	50.0000	ft
Permeability multiplier	4.00000	
Porosity multiplier	1.00000	
Rate dependent skin	<input type="checkbox"/>	
Wellbore model	None	
Bottomhole MD	6000.00	ft

These parameters can be regressed upon in 'Improve'

Improve	
Parameters	Targets
Constant parameters	
Well 1	
<input type="radio"/>	Theta
<input type="radio"/>	N
<input type="radio"/>	Xf
<input type="radio"/>	Hf
<input type="radio"/>	Zf
<input type="radio"/>	Width
<input type="radio"/>	Beta
<input type="radio"/>	Zw
<input type="radio"/>	Lw
<input checked="" type="radio"/>	Stimulation radius
<input checked="" type="radio"/>	k multiplier
<input checked="" type="radio"/>	phi multiplier



Compatible with numerical SRVB/Trilinear models



# KURC-2 future developments



- ◆ ◆ ◆ MFHW with deviated drain trajectory
- ◆ ◆ ◆ Coupling with geomechanics
- ◆ ◆ ◆ Stimulated zones around the fractures with  $k(p)$  and  $\varphi(p)$