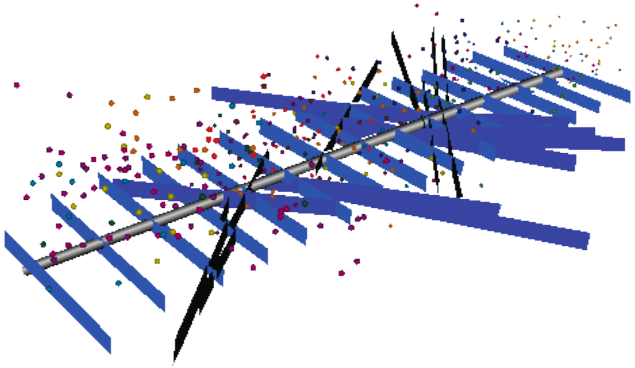


UR Add-on pack

KURC / Add-on pack

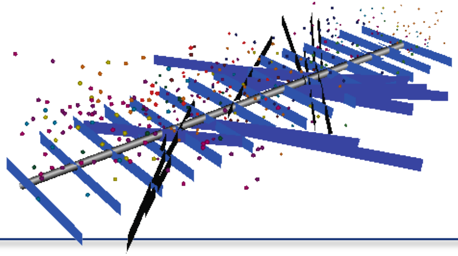
KURC – KAPPA Unconventional Resources Consortium:

- KURC-1: 2012 – 2015
- KURC-2: 2016 – 2020

UR Add-on pack:

- All former KURC-1/2 features + new developments
- Specific license privilege in Saphir, Topaze and Rubis
- Non-digressive, per stand-alone license pricing
- Available since KW v5.20.01 (2018)

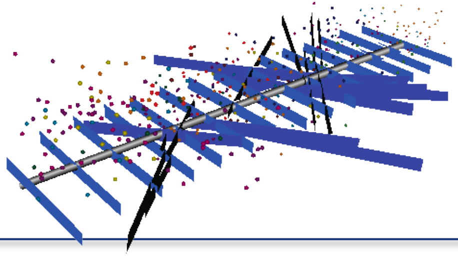
Latest update KW v5.40.05 (Dec 2021)



Add-on pack: Analytical

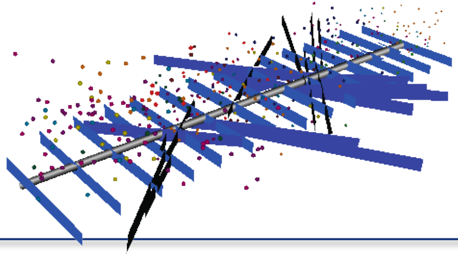
KAPPA

- 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

- 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 features

KAPPA

v5.30.03: Load from Fracturing Software

Confined PVT

Multiple KrPc

Stochastic DFN realizations

Interference with DFN: Fast Marching Method

Stimulated zones around the fractures

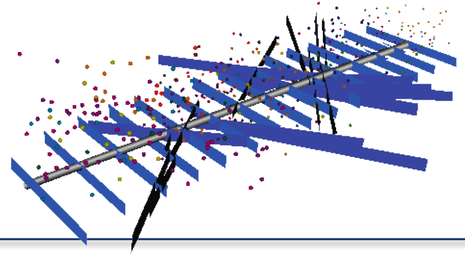
Numerical ‘butterfly’ model

v5.40.01: CSG Well Intake

v5.40.02: Fractal MFHW

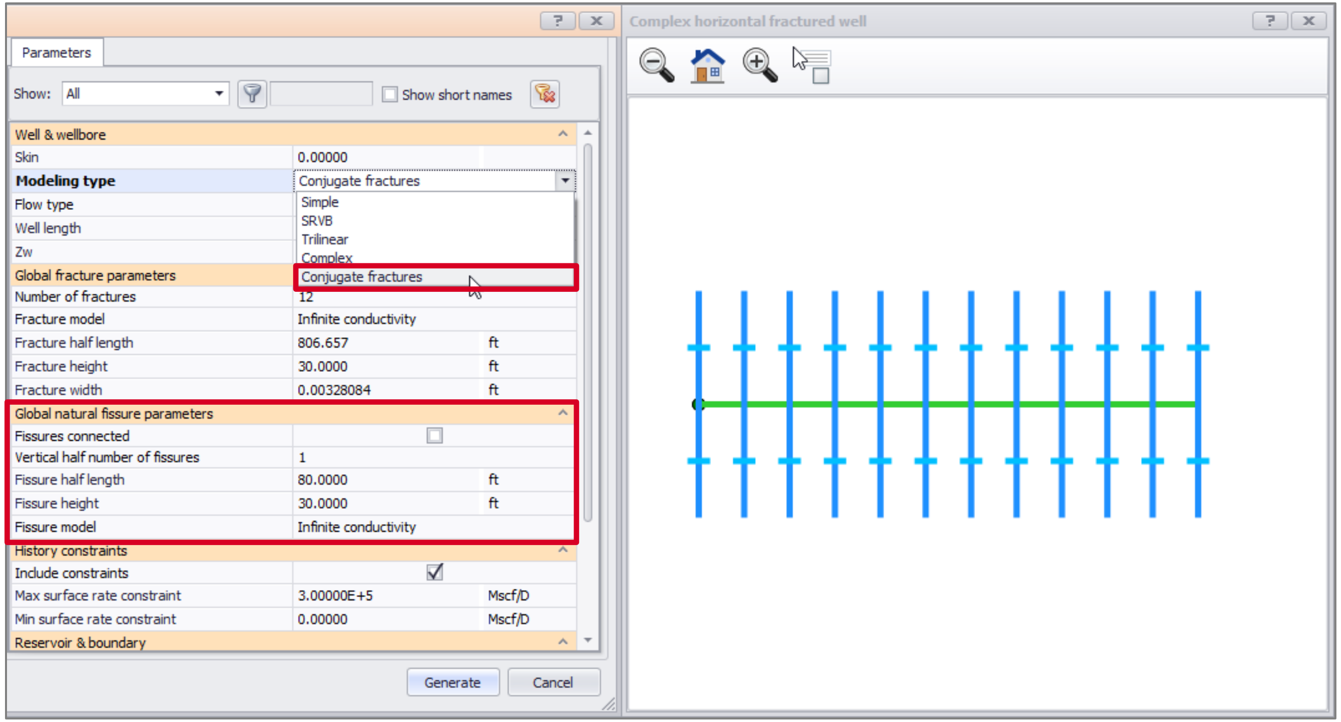
Fractional Dimension Workflow

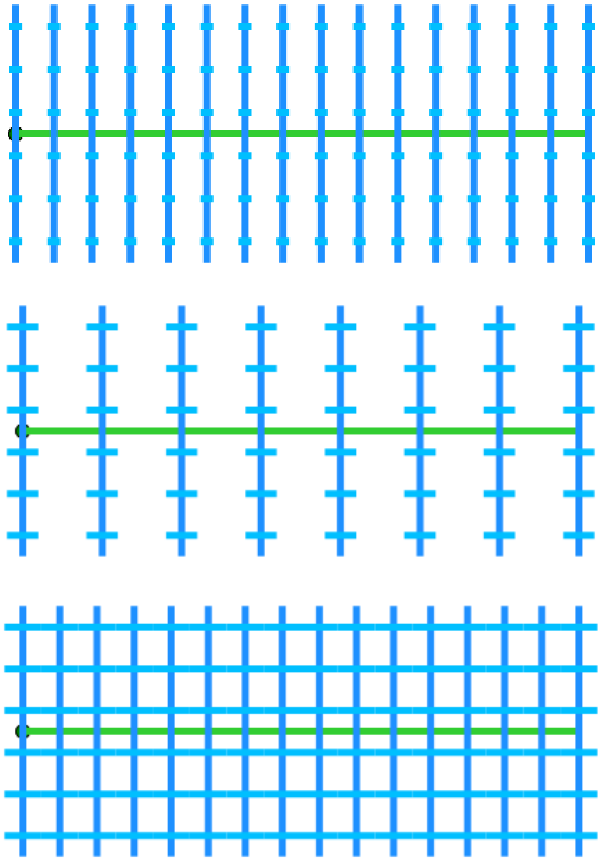
Cumulative Volume Loglog Plot

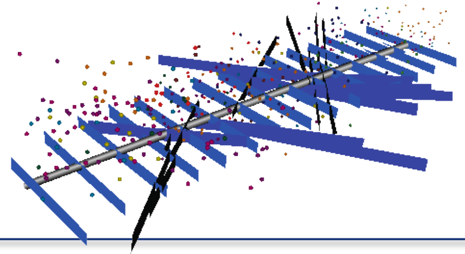


DFN analytical model

- Conjugate fractures: # fissures and geometry



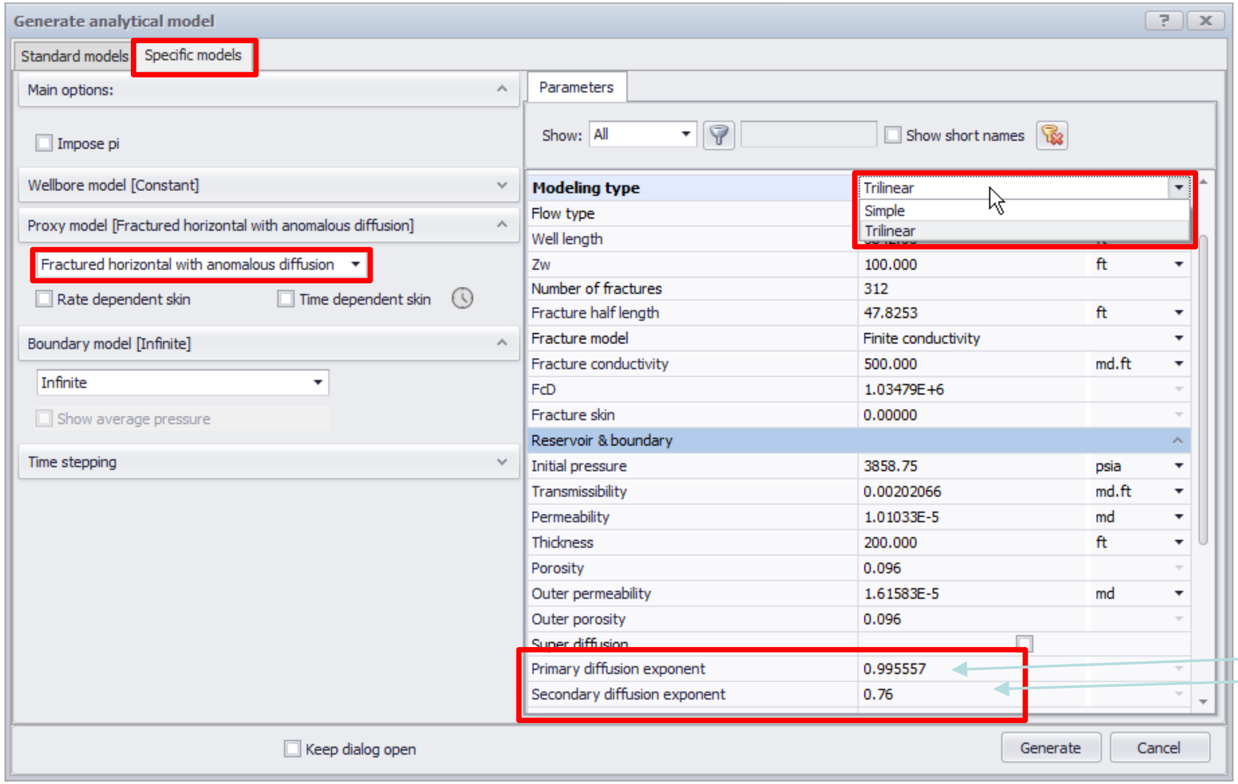




Anomalous Diffusion

KAPPA

Available under 'Specific' analytical models



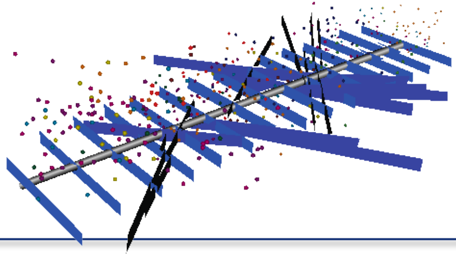
- Well+boundary:
  - Simple MFHW + infinite/rectangle
  - Trilinear + infinite/closed reservoir
- Matrix: single/double porosity
- Single layer models only
- Can include changing WBS, rate-/time-dependent skin

Additional parameters:

α_f and α_m

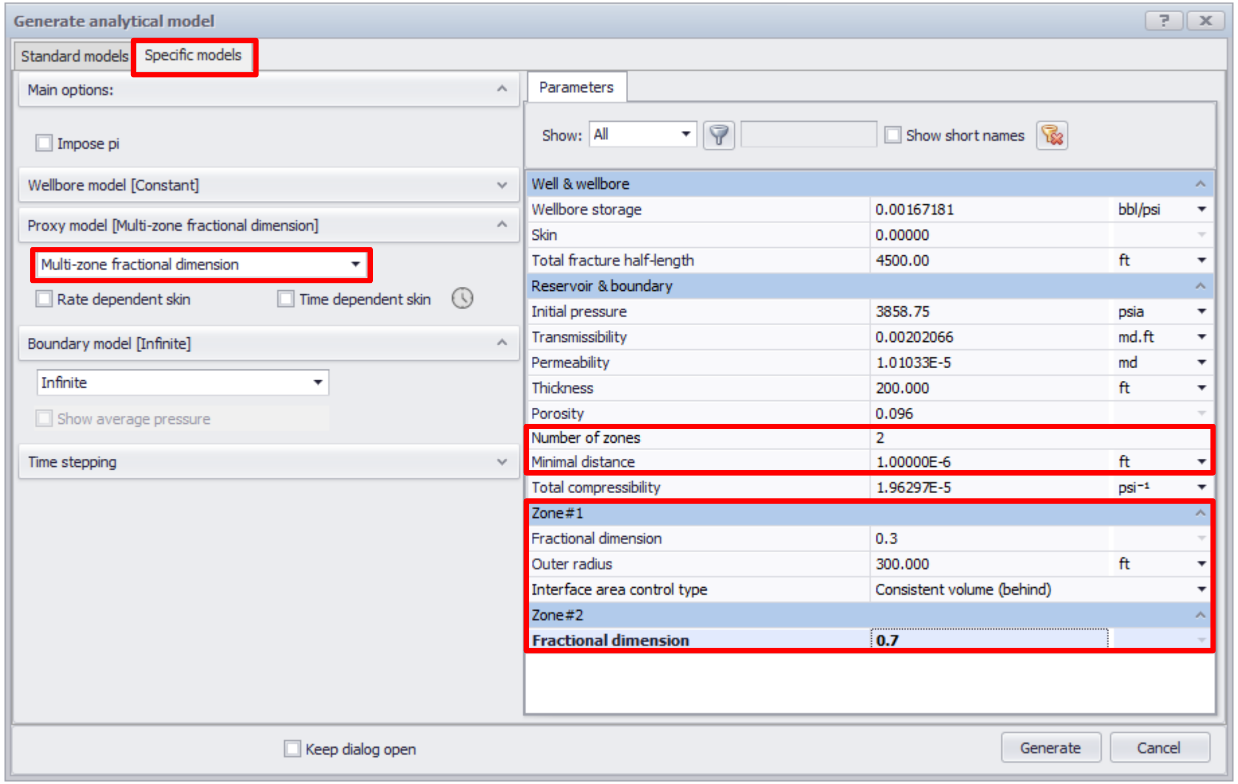
(also for outer zone in Trilinear)

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



Multi-zone fractional dimension

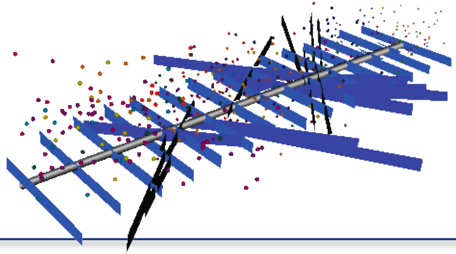
Available under ‘Specific’ analytical models



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

Also SPE-2667752, SPE-2896802, SPE-2876208.

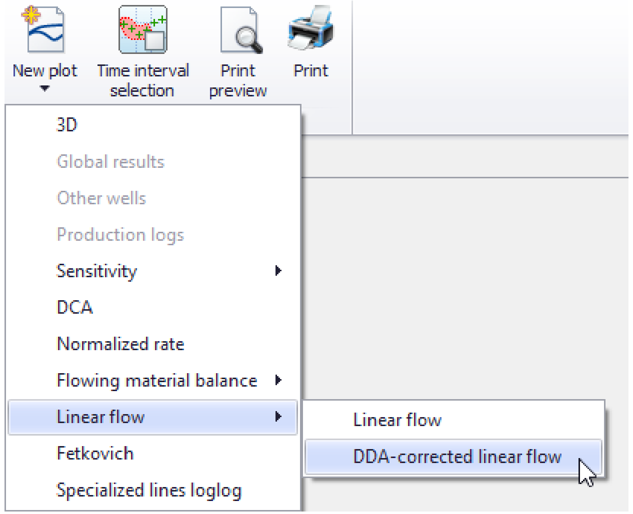
Analytical Pressure and Rate Transient Models for Analysis of Complex Fracture Networks in Tight Reservoirs, J.A. Acuña, SPE-2429710 (2016).

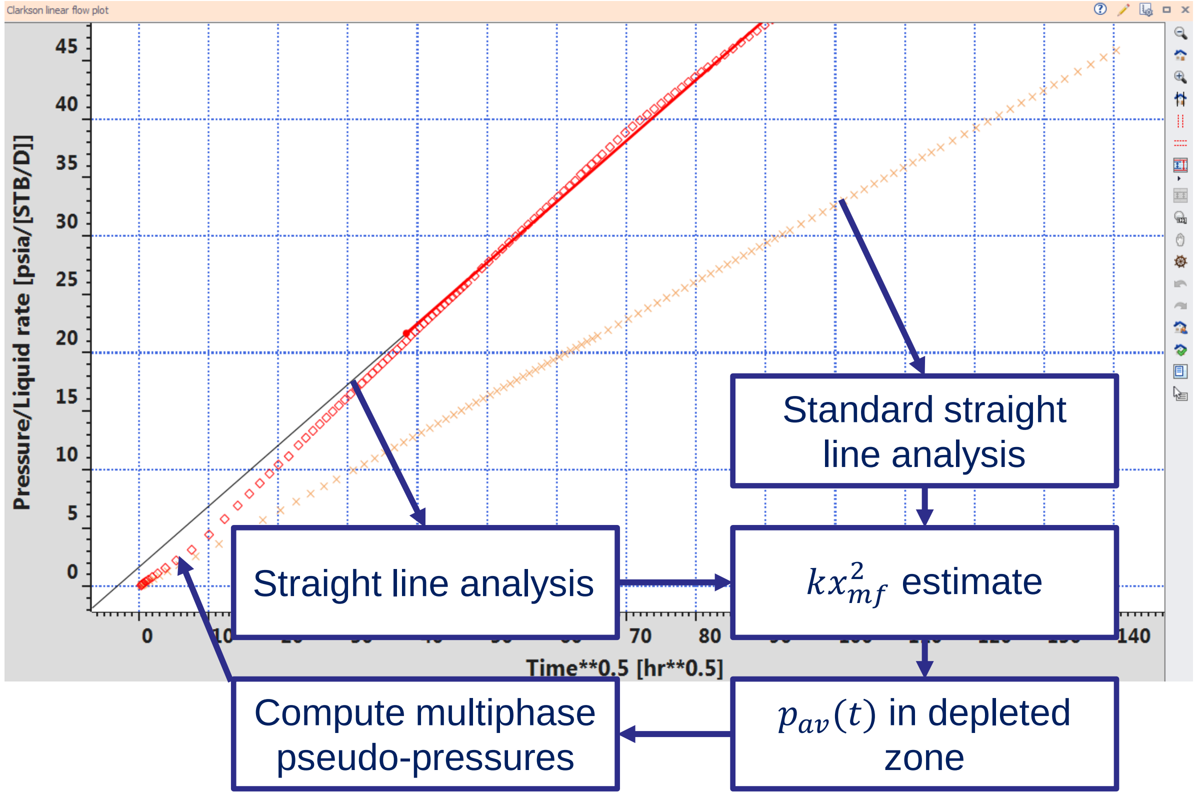


Clarkson DDA Linear Flow plot

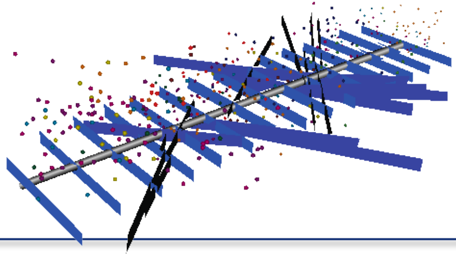
Linear flow analysis modified using pseudo-p from Dynamic Drainage Area concept

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

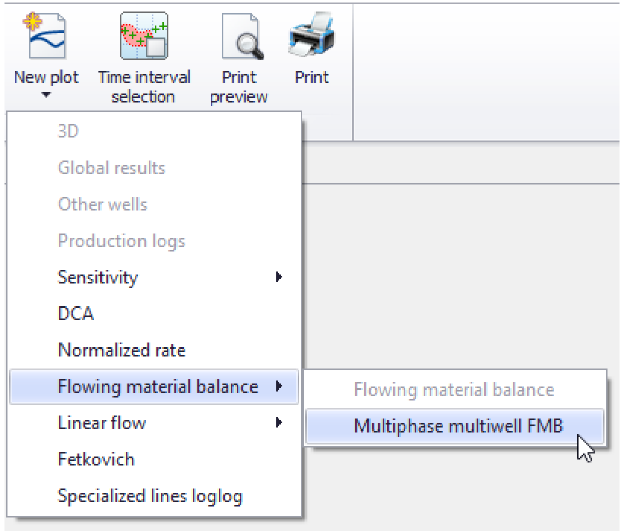
KAPPA

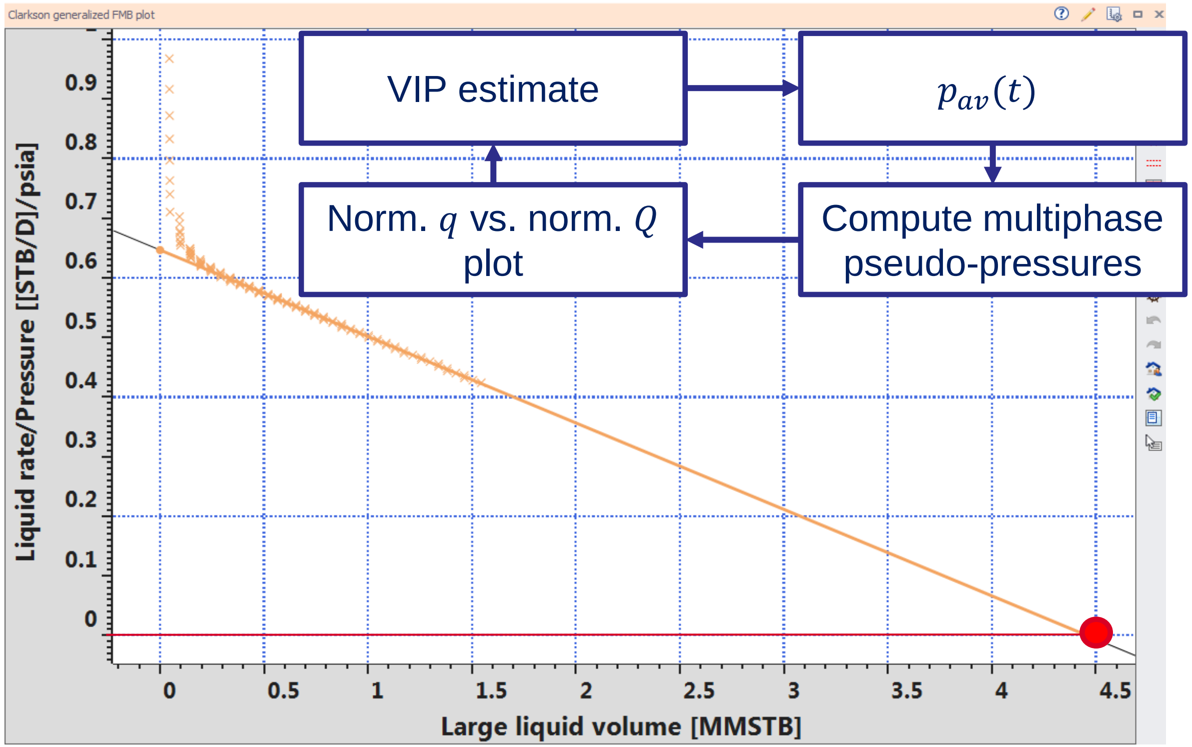
General Flowing Material Balance equation modified using pseudo-p and p_{av} from MB calculations

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

Multiphase extraction

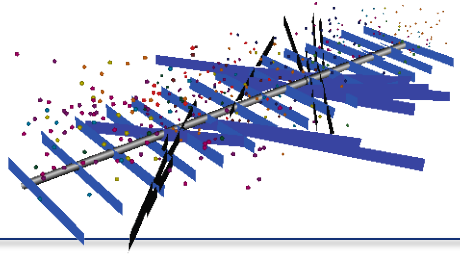
except: Dry gas + Water, Wet gas + Water, EoS + Water





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

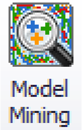
Statistical EUR



→ Single forecast

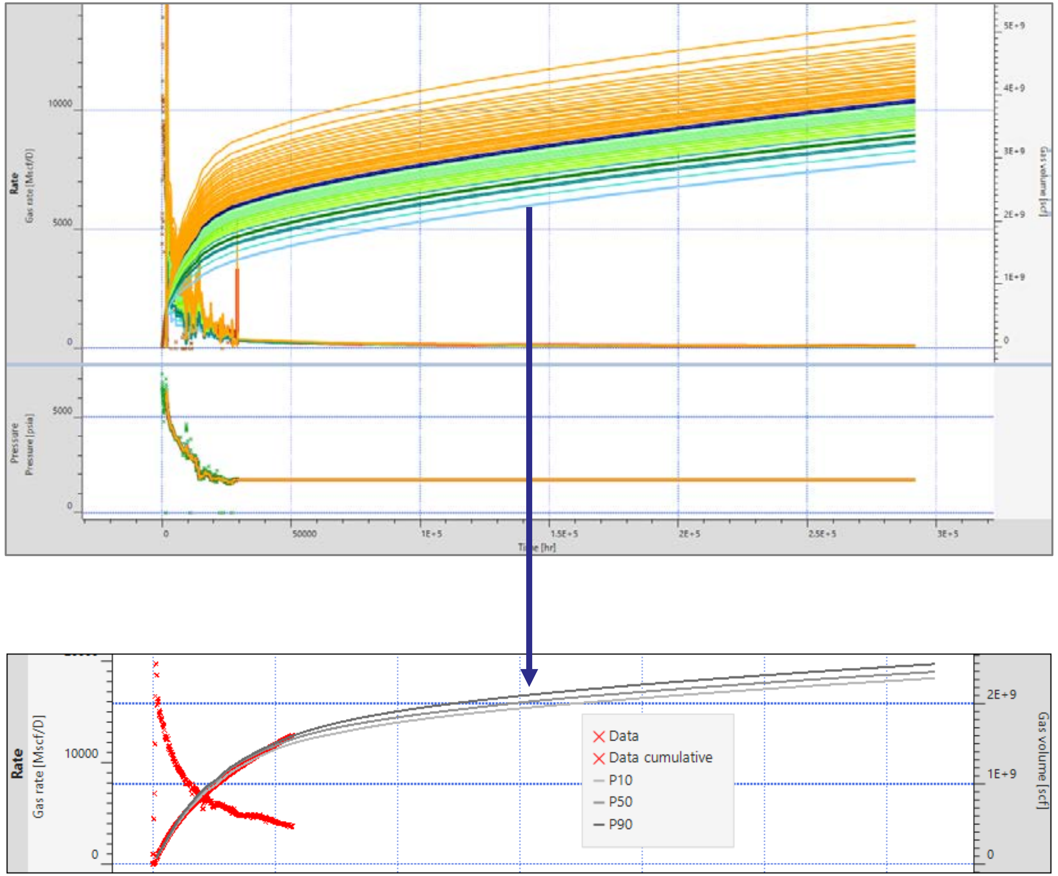
→ Monte Carlo + Improve for uncertainty estimate

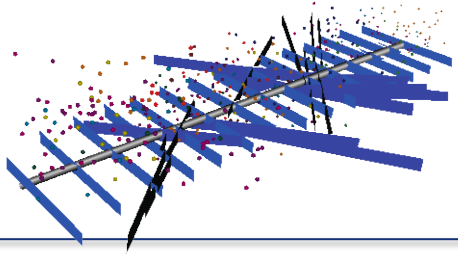
→ **Monte Carlo + Model Mining**: replacing the CPU expensive nonlinear regression step by a data mining proxy



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}



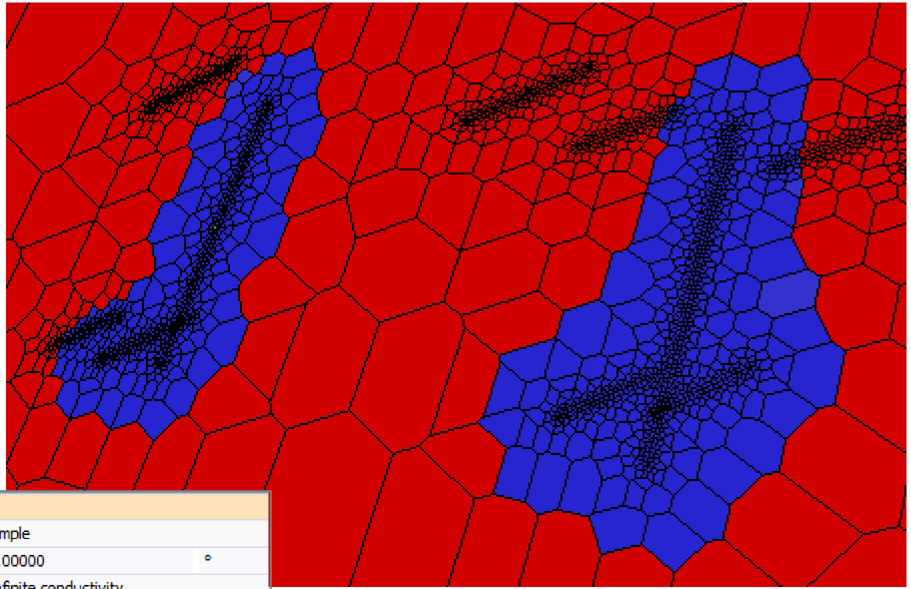


Water flowback

KAPPA

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	☐	

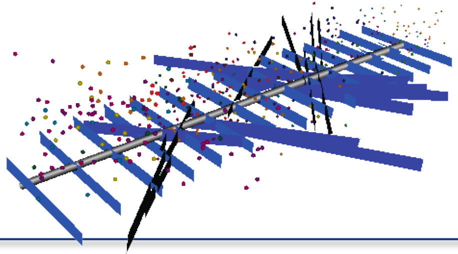
Klinkenberg effect

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

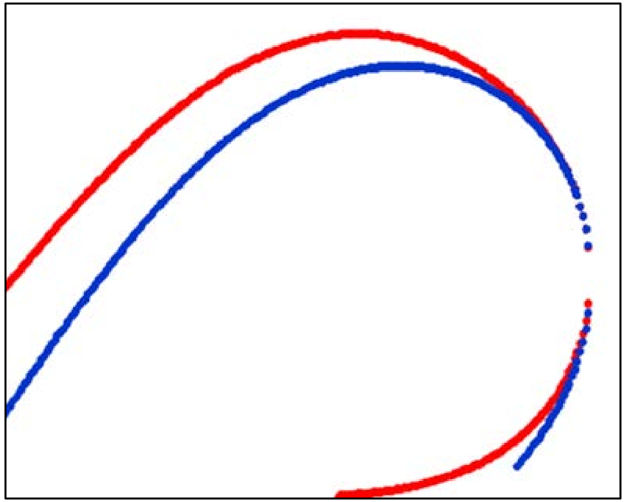
Well 1		
Zw	15.0000	ft
Perforation length	30.0000	ft
Well length	30.0000	ft
Rate dependent skin	☐	
Skin	0.00000	
Wellbore model	None	
Bottomhole MD	6000.00	ft
Include constraints	☐	
Reservoir		
Initial pressure	7246.55	psia
Reservoir type	Homogeneous	
Transmissibility	1000.000	md.ft
Permeability	33.3333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



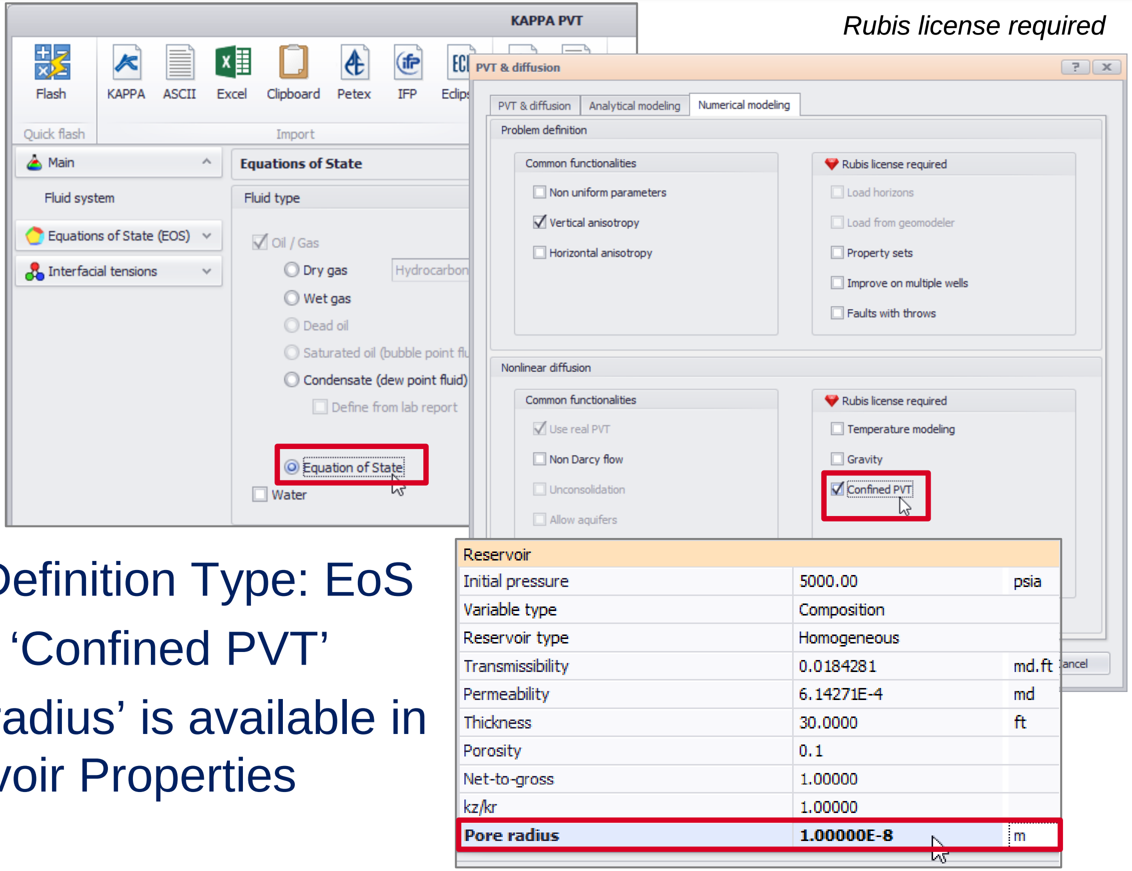
Confined PVT

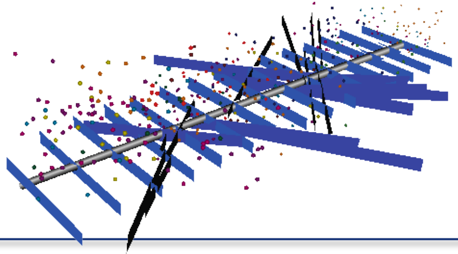
Rubis license required

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

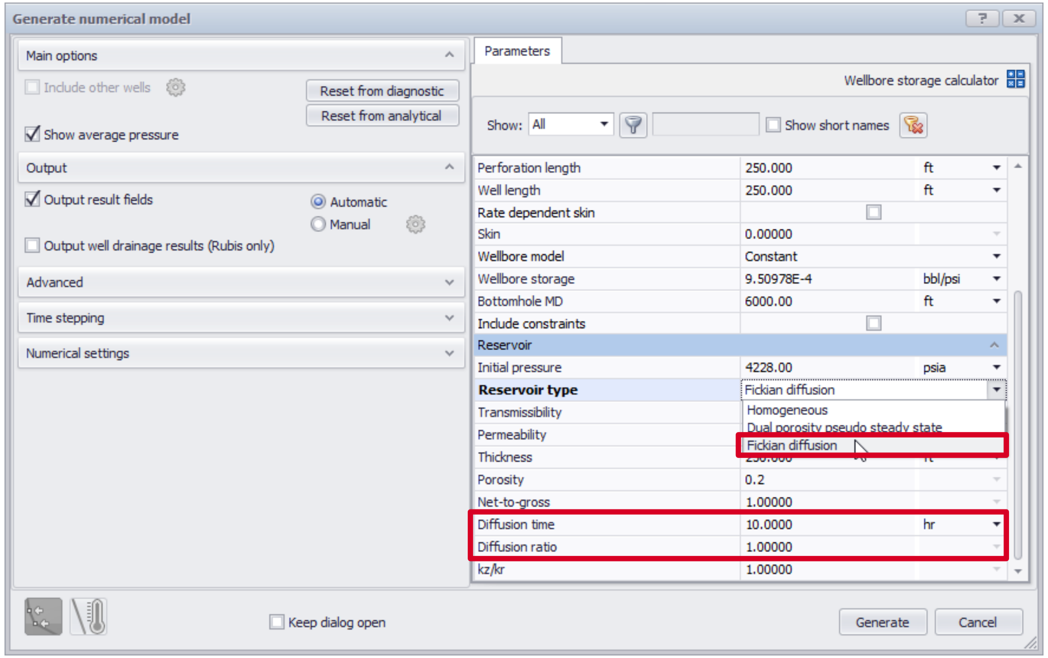




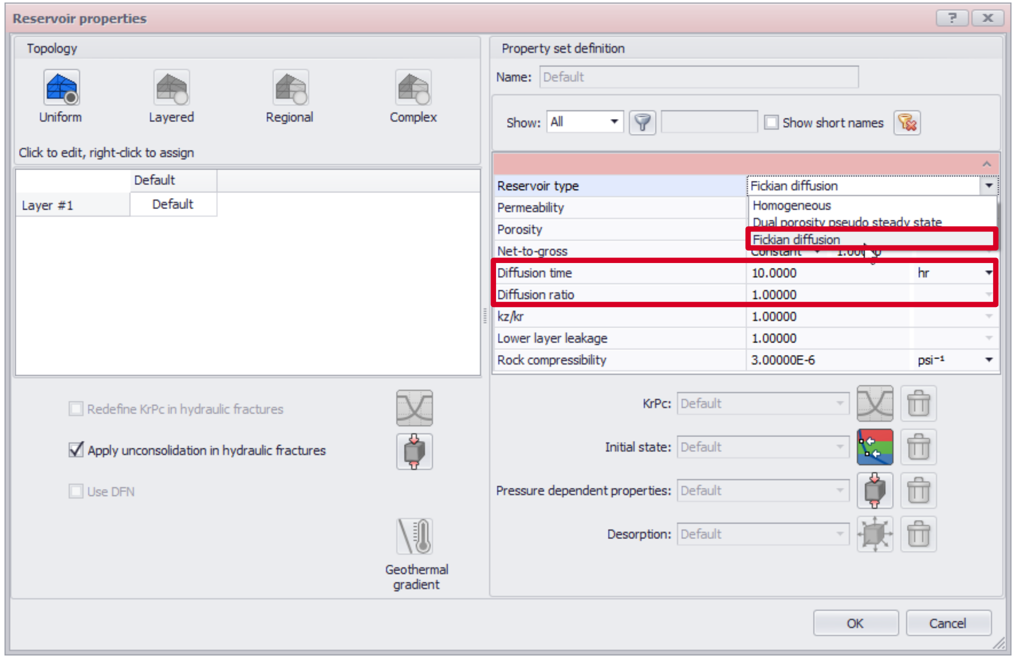
Fickian diffusion

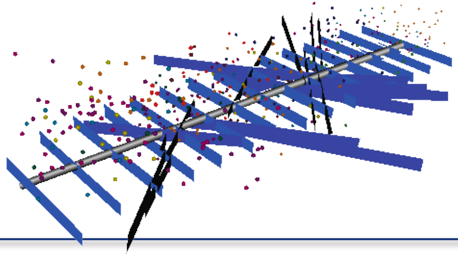
PVT includes gas & Real PVT are used

Available under ‘Reservoir type’



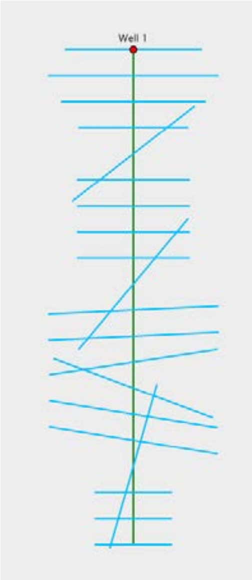
or ‘Reservoir properties’

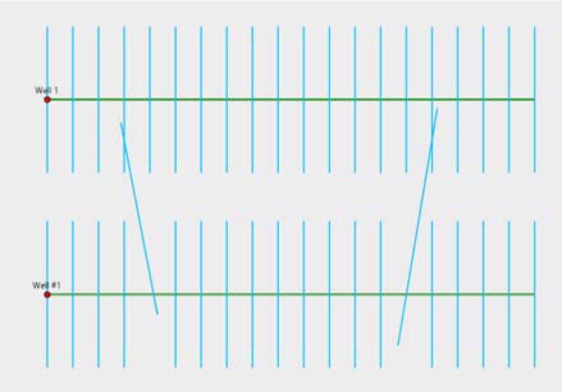


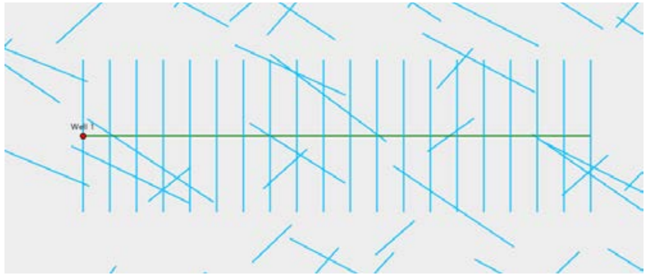


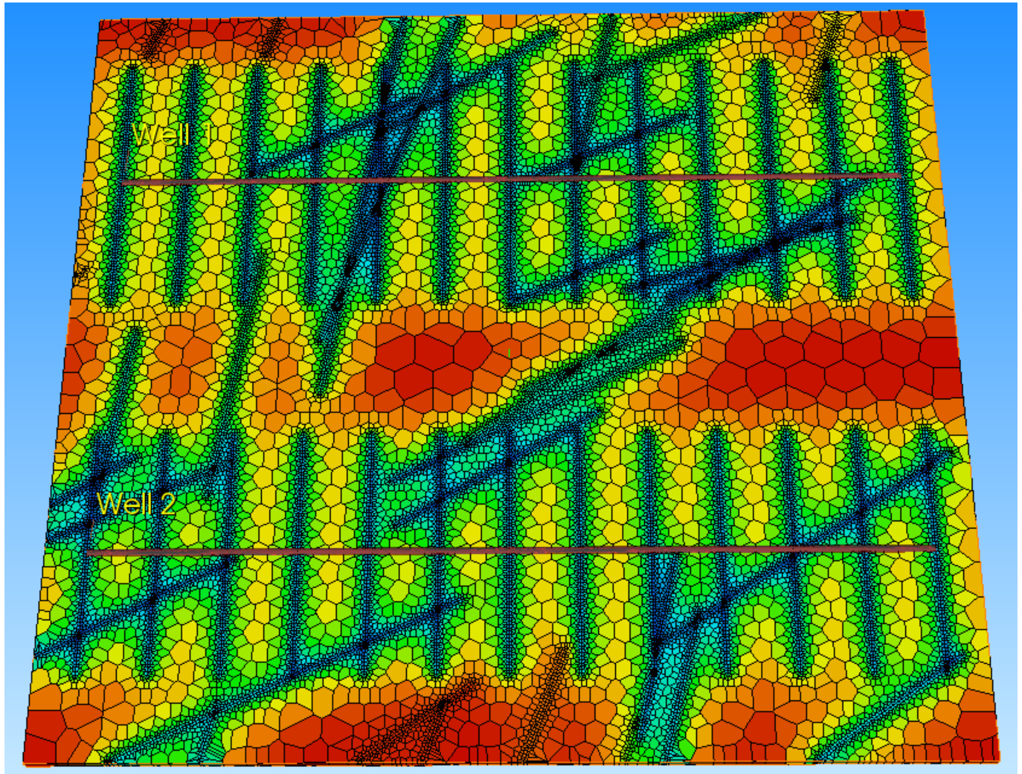
Numerical DFN

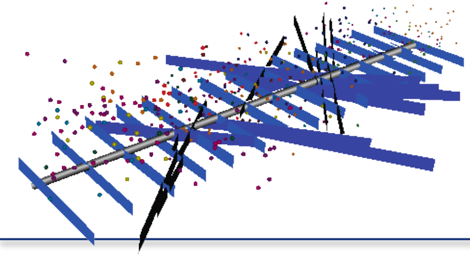
DFN and well fractures have distinct properties, including relative permeabilities and $k(p)$.





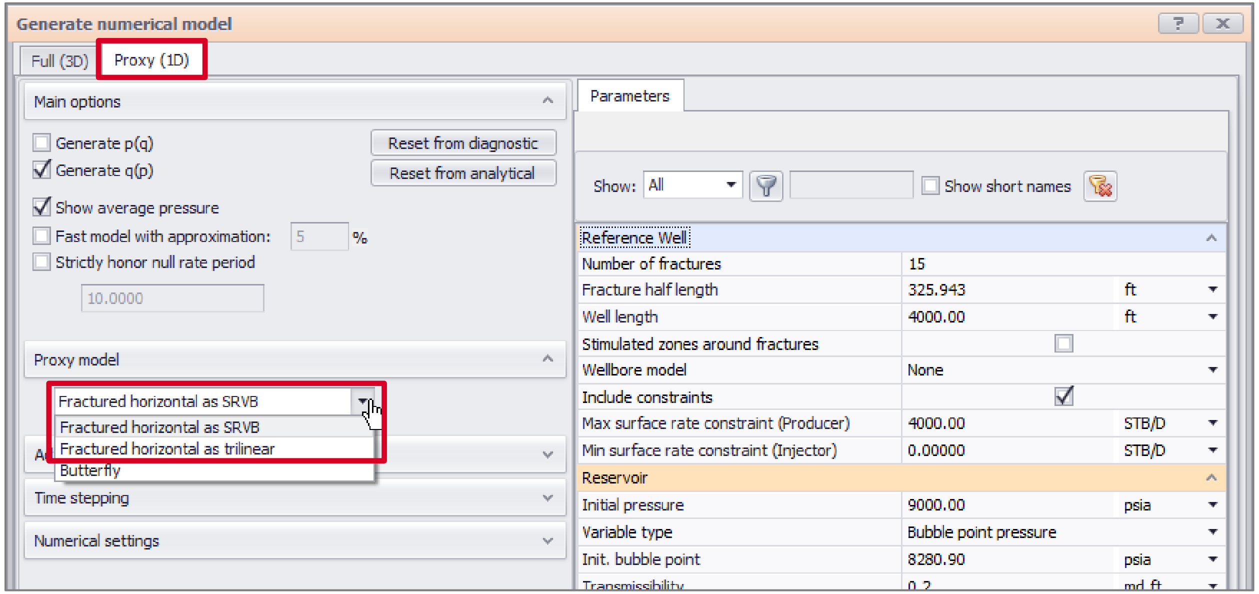




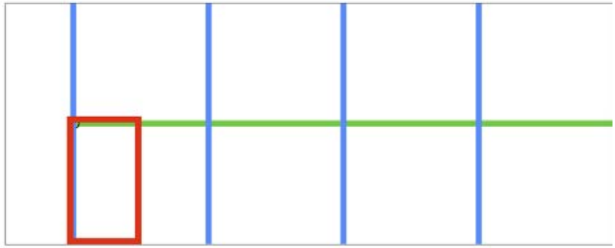


Numerical Proxy models

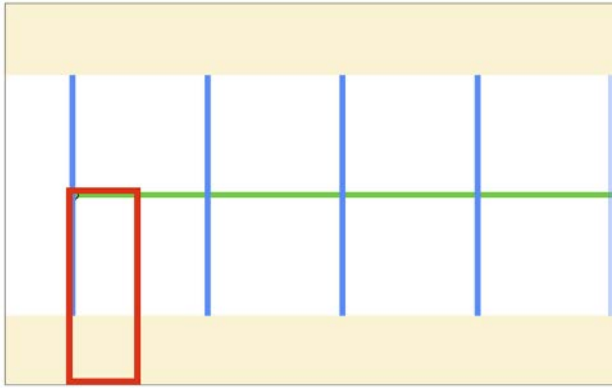
Useful in the case of complex PVT and a simple very long MFHW to tune the fracture properties prior to running the full numerical model



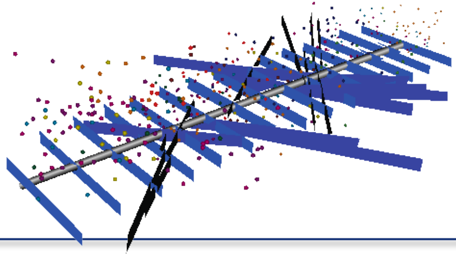
Stimulated Reservoir Volume bounded (SRVB)



Trilinear



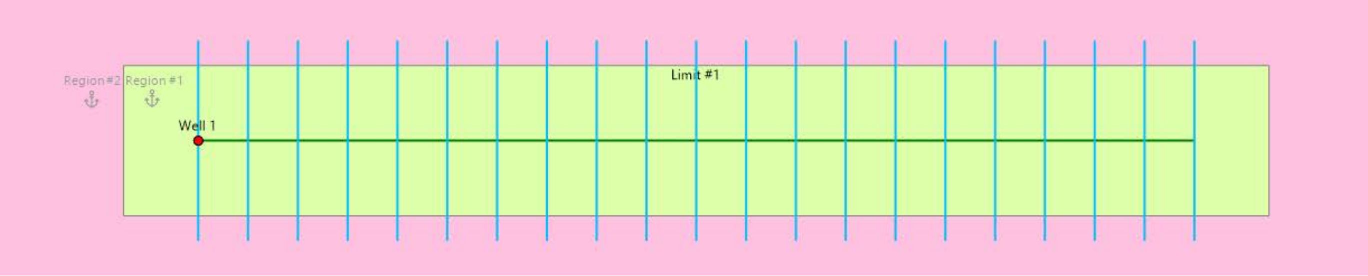
Efficient Proxies for Numerical Simulation of Unconventional Resources, Artus et al., 1896873-MS URTEC Conference Paper (2014)

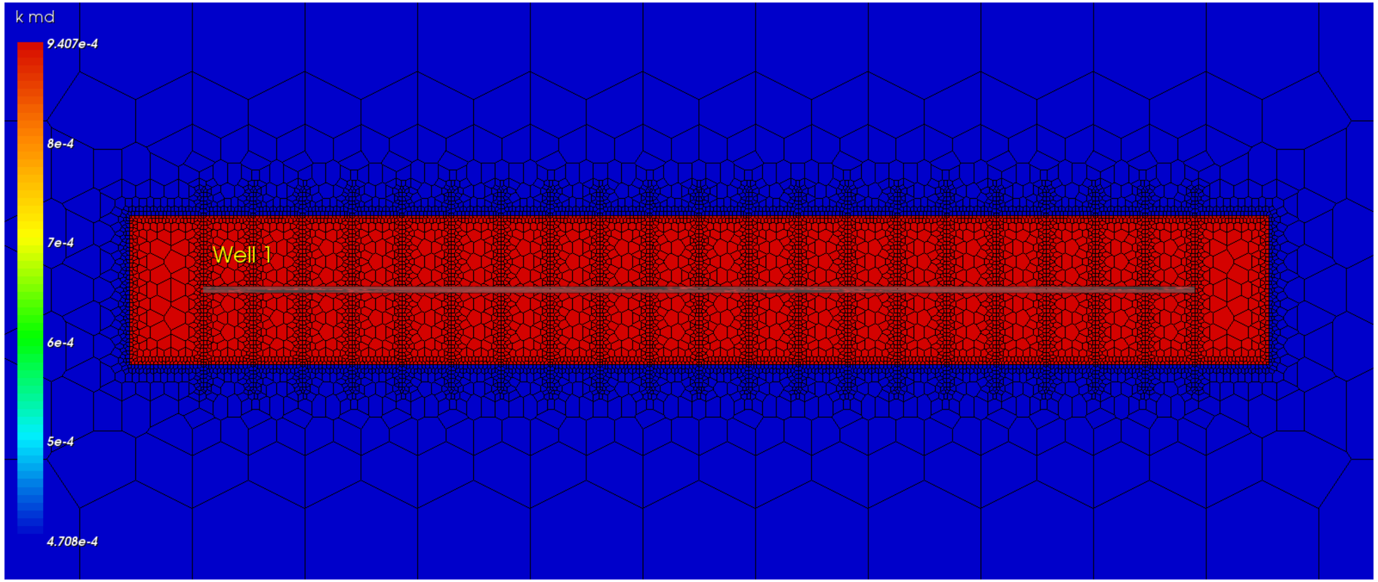


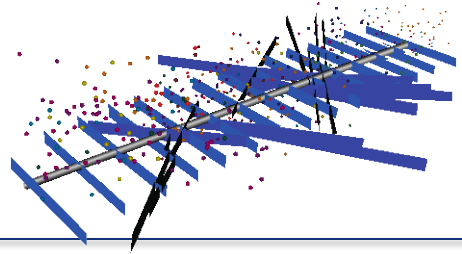
Composite zones

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

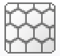




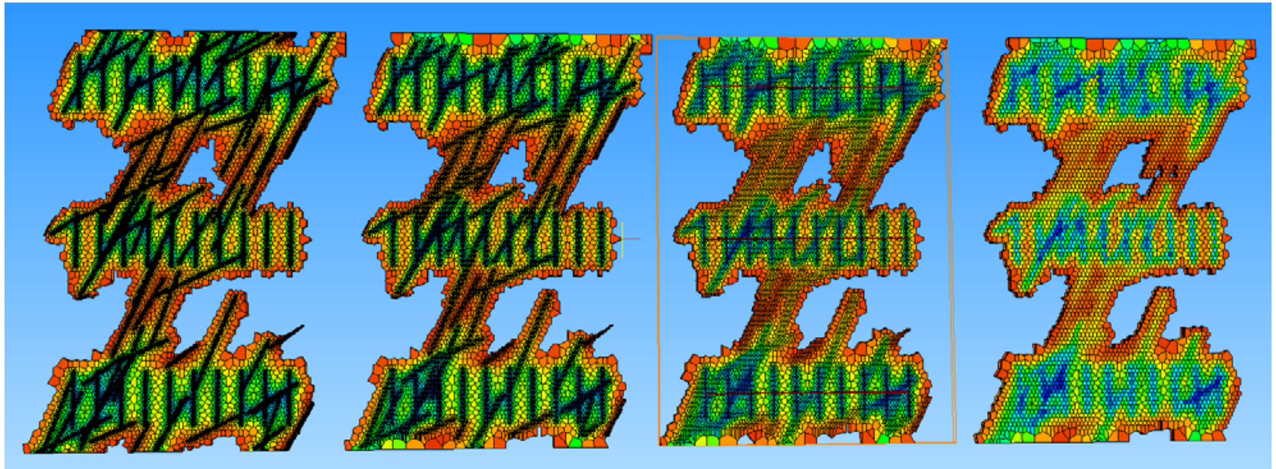


DFN Upscaling

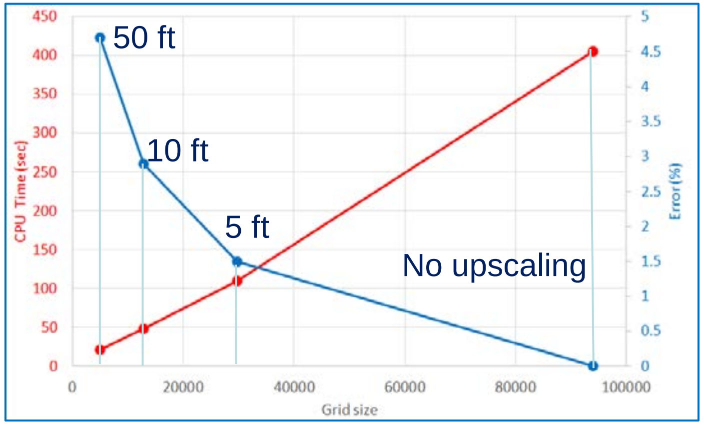
DFN upscaling reduces the refinement of the grid (and gridblock count), correctly accounting for the matrix-to-fracture flow and interaction

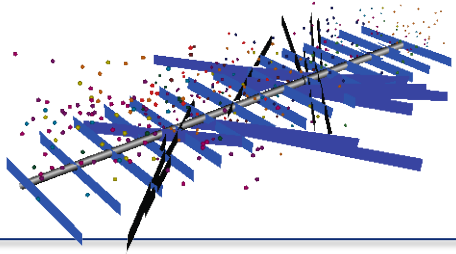
- DFN added in Map 
- Upscaling parameters are available in Grid 
- Min gridblock size changes from ‘DFN resolution’ to ‘DFN coarse resolution’

DFN upscaling	☑	
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



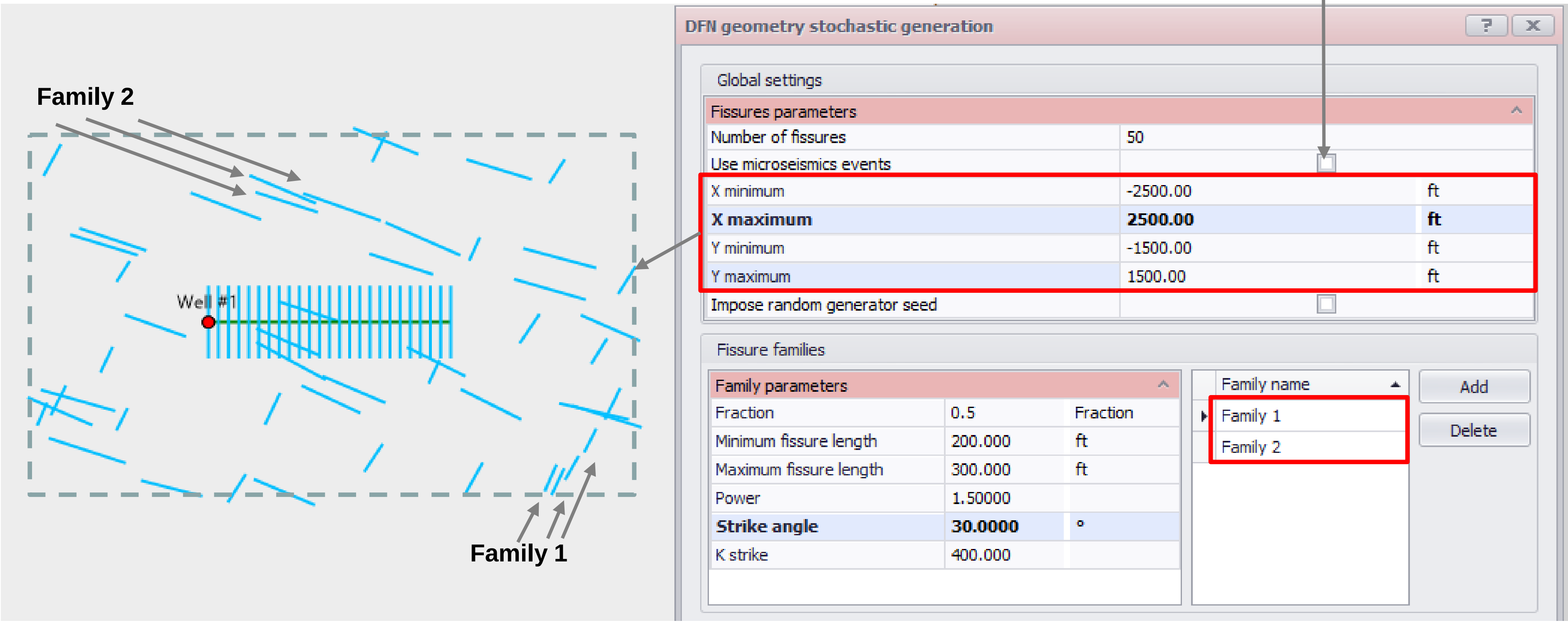


Stochastic DFN realizations

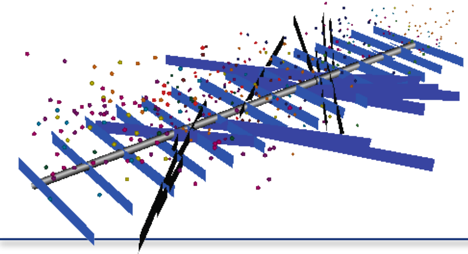
DFN

'Map' → 'DFN' → 'Generate'

Location can be defined μ-seismic, if loaded



Interference with DFN: FMM



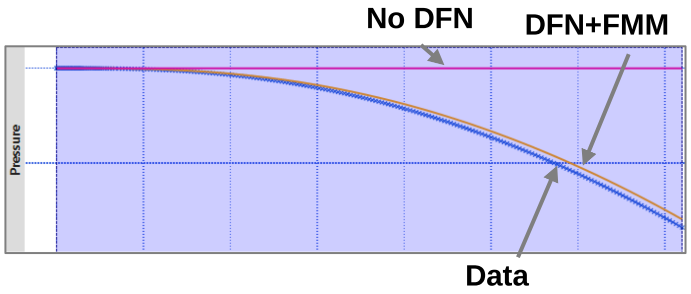
At least 2 wells must exist in the map

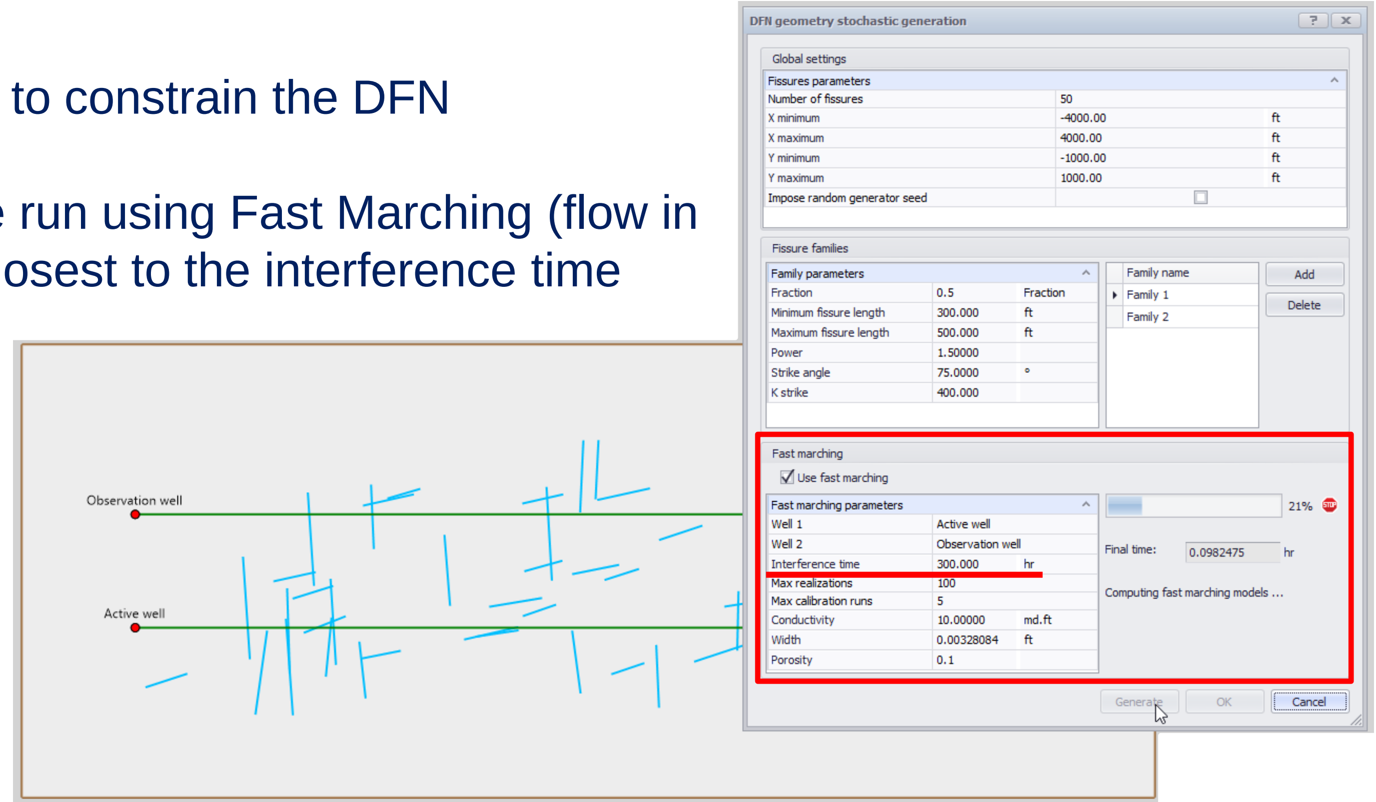
'Map' → 'DFN' → 'Generate'

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

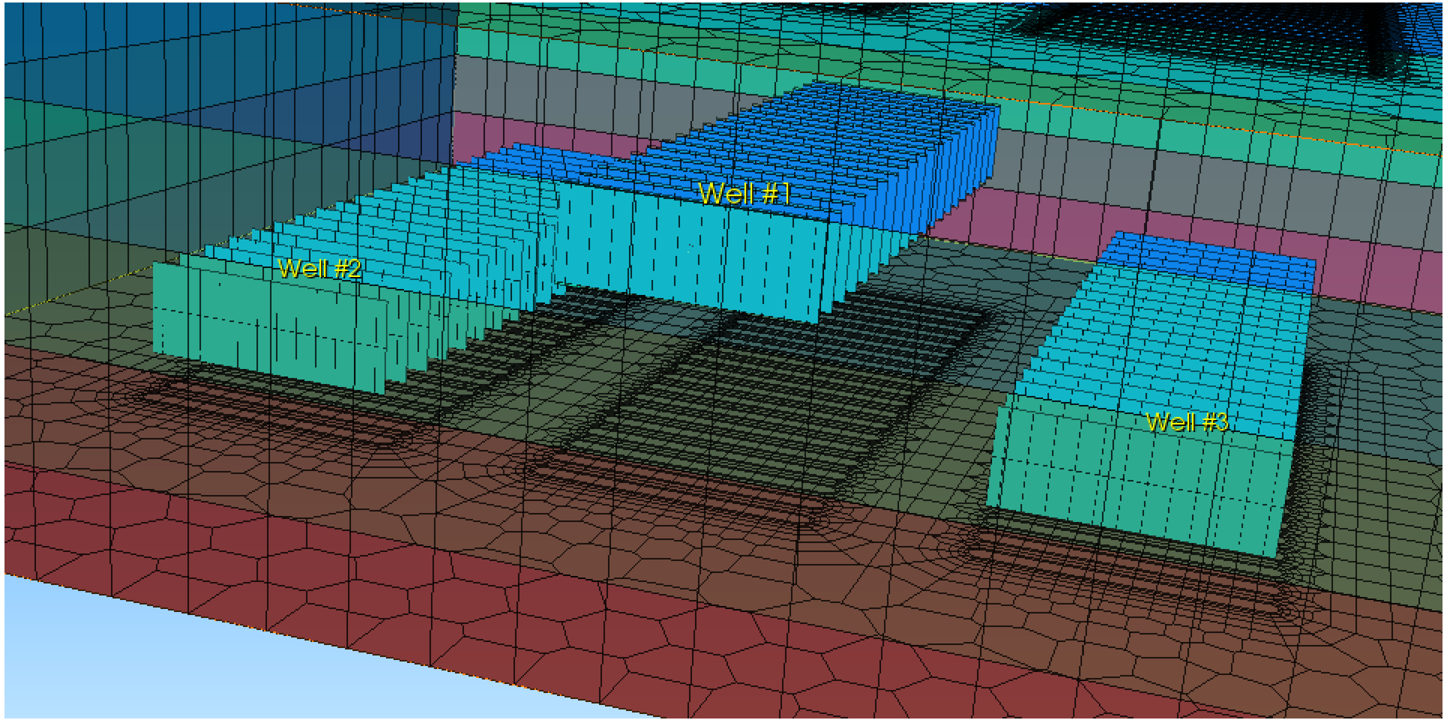
Then a full model is run in Analysis



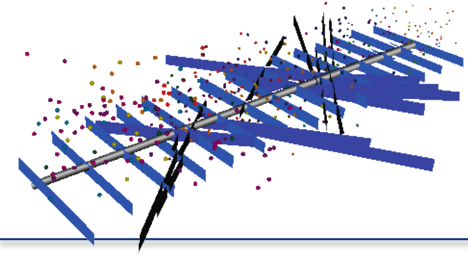


Accelerated initialization

Large models with multiple MFHWs are initialized using specific faster procedures

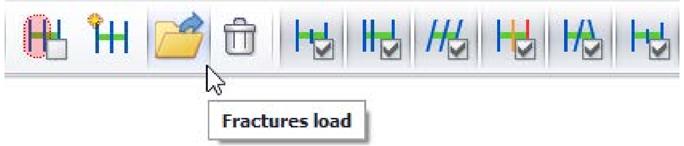


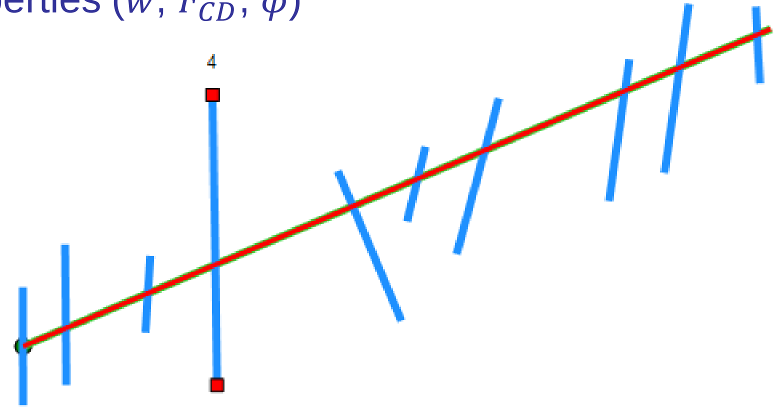
Loading properties of fracs



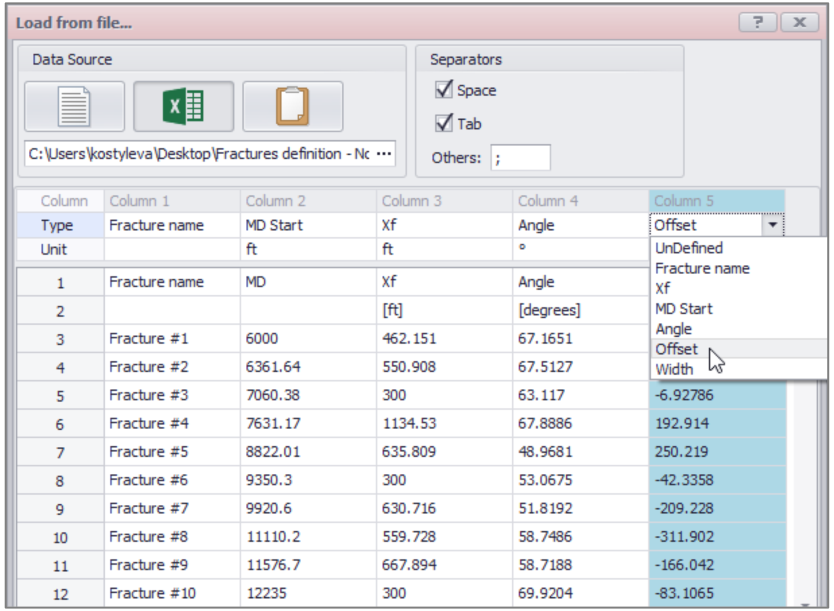
The option allows loading individual fracture properties for a complex MFHW well from a file

- 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}, ϕ)
  - 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

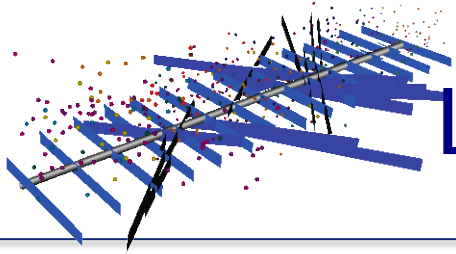
Space

Tab

Others: ;

Column	Column 1	Column 2	Column 3	Column 4	Column 5
Type	Fracture name	MD Start	Xf	Angle	Offset
Unit		ft	ft	°	
1	Fracture name	MD	Xf	Angle	
2			[ft]	[degrees]	
3	Fracture #1	6000	462.151	67.1651	
4	Fracture #2	6361.64	550.908	67.5127	
5	Fracture #3	7060.38	300	63.117	-6.92786
6	Fracture #4	7631.17	1134.53	67.8886	192.914
7	Fracture #5	8822.01	635.809	48.9681	250.219
8	Fracture #6	9350.3	300	53.0675	-42.3358
9	Fracture #7	9920.6	630.716	51.8192	-209.228
10	Fracture #8	11110.2	559.728	58.7486	-311.902
11	Fracture #9	11576.7	667.894	58.7188	-166.042
12	Fracture #10	12235	300	69.9204	-83.1065

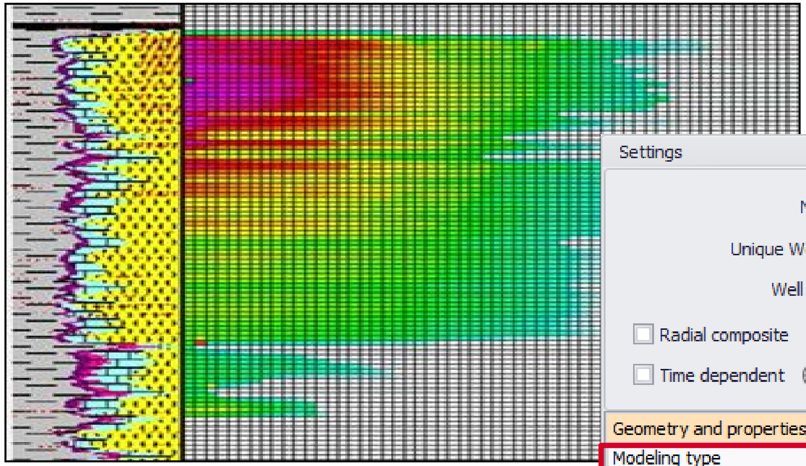
UnDefined
Fracture name
Xf
MD Start
Angle
Offset
Width

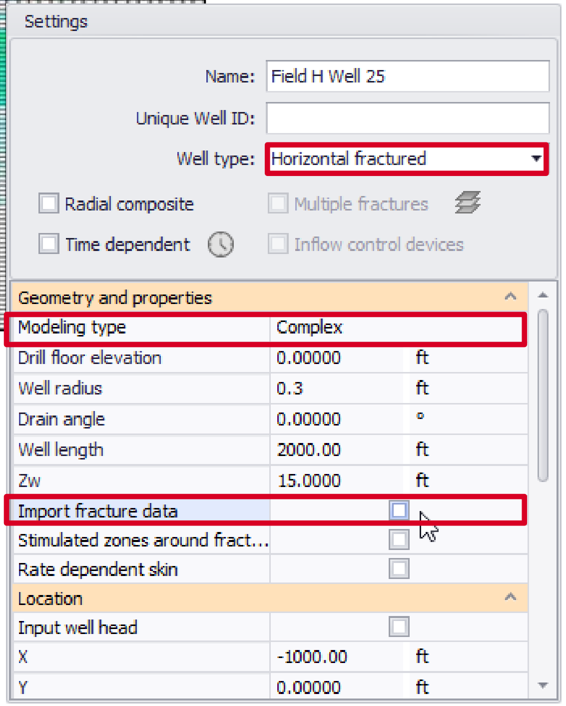


Load from fracturing software

KAPPA

Fracture properties can be non-uniform along the fracture plane



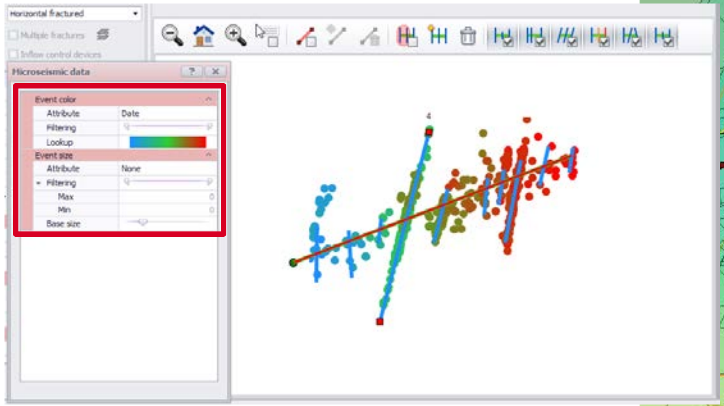


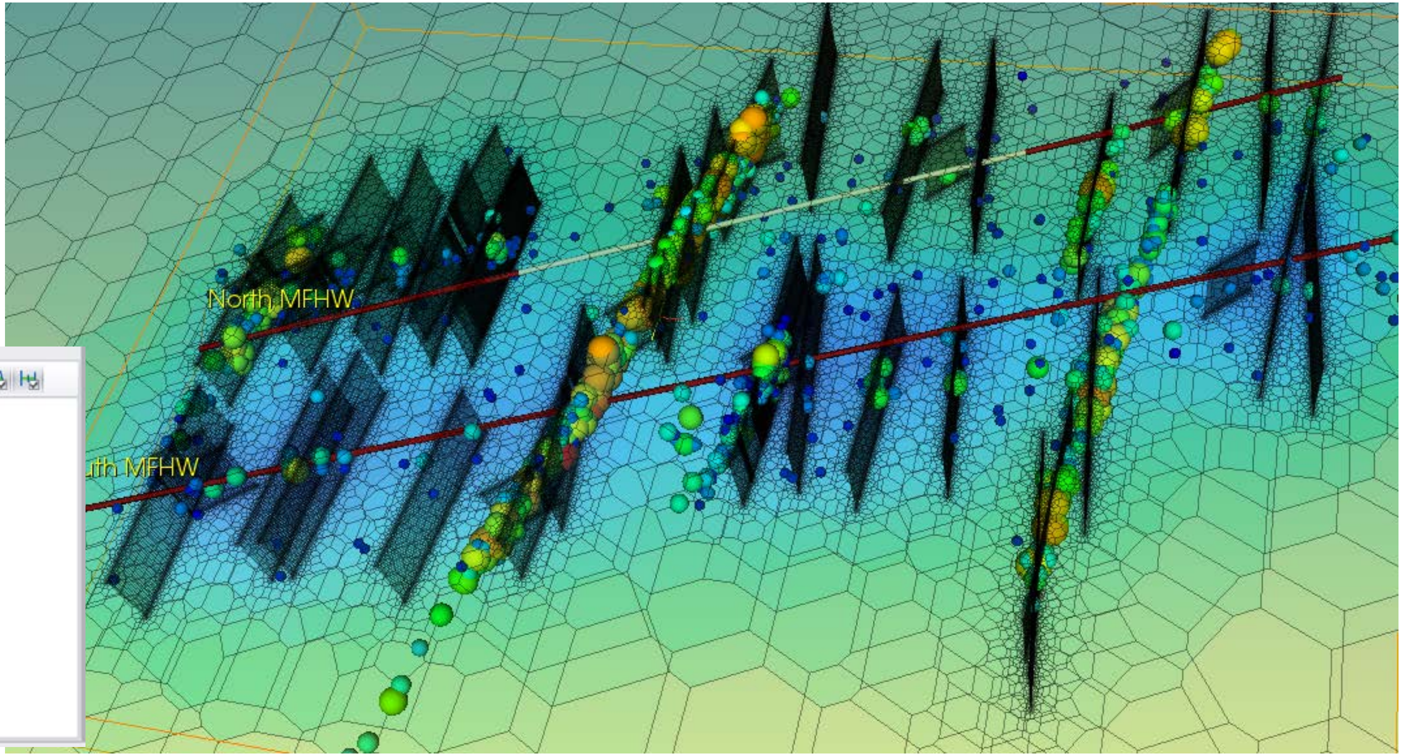
- Define a MFHW as 'Complex'
- Activate 'Import fracture data'
- Load properties from *.csv or *.xml:
  - Index, TVD and location at the well
  - (X,Z): w_f, k_f, F_{CD}, φ, β
- Define fracture MD and angles

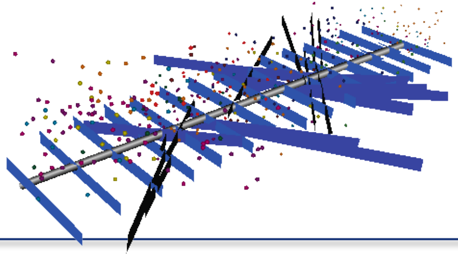
Microseismics

Load and display of microseismic events to constrain the MFHW configuration

Visualizing attributes:
date, amplitude, stage index







Stimulated zones

Stimulated zones around fractures of a MFHW

- Available for both Simple and Complex well types
- Defined by radius of the zone, k and φ 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

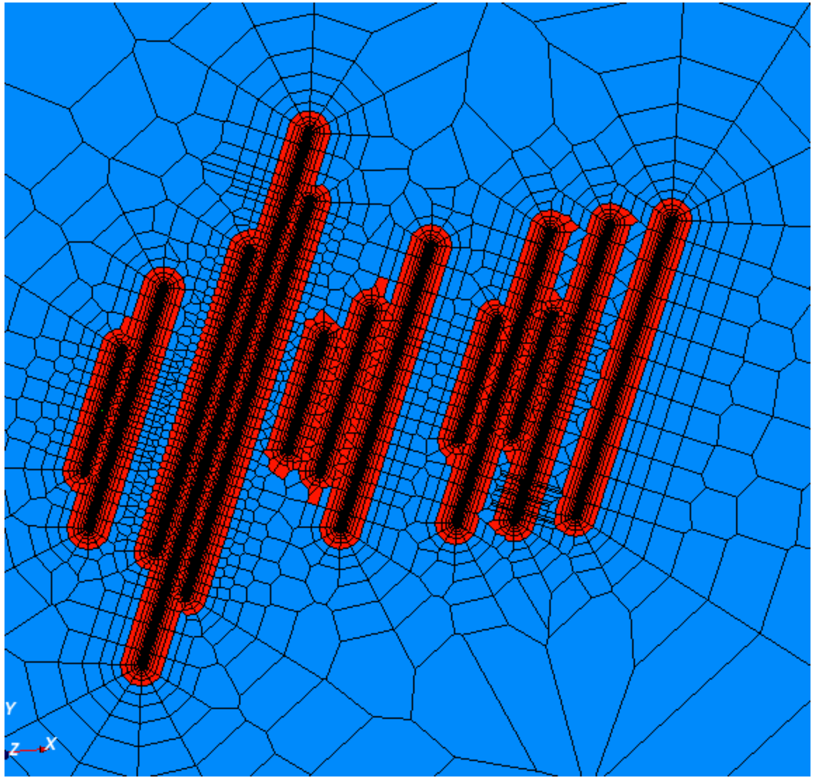
These parameters can be regressed upon in 'Improve'

Improve

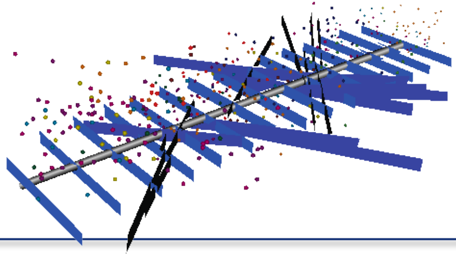
Parameters | Targets

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

KAPPA

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:

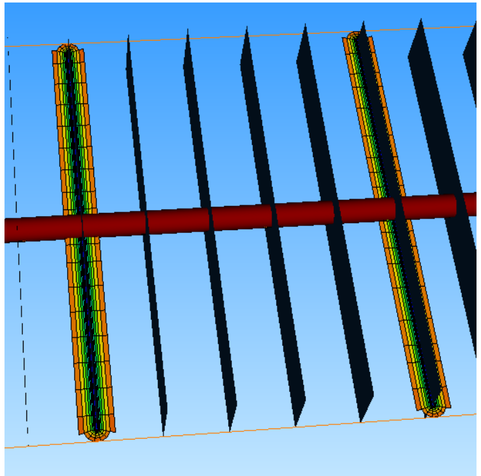
Refrac	☑		
Refrac elapsed time	18.0000	Month	T
Number of fractures at t0	12		a
Refrac ratio	4		b
Infill	☐		

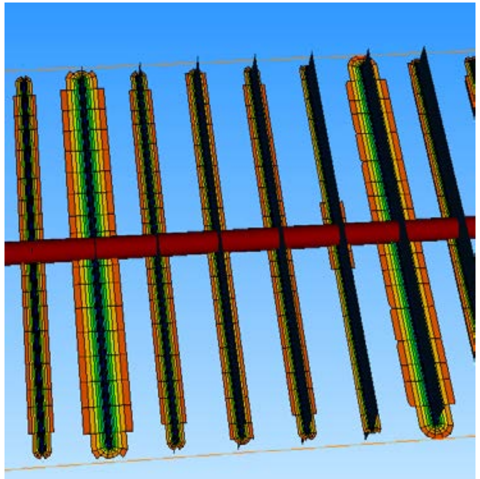
Before refrac (time = 0):

$$N_f = a$$

After refrac (time = T):

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





(b) **Irregular** refrac pattern:

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

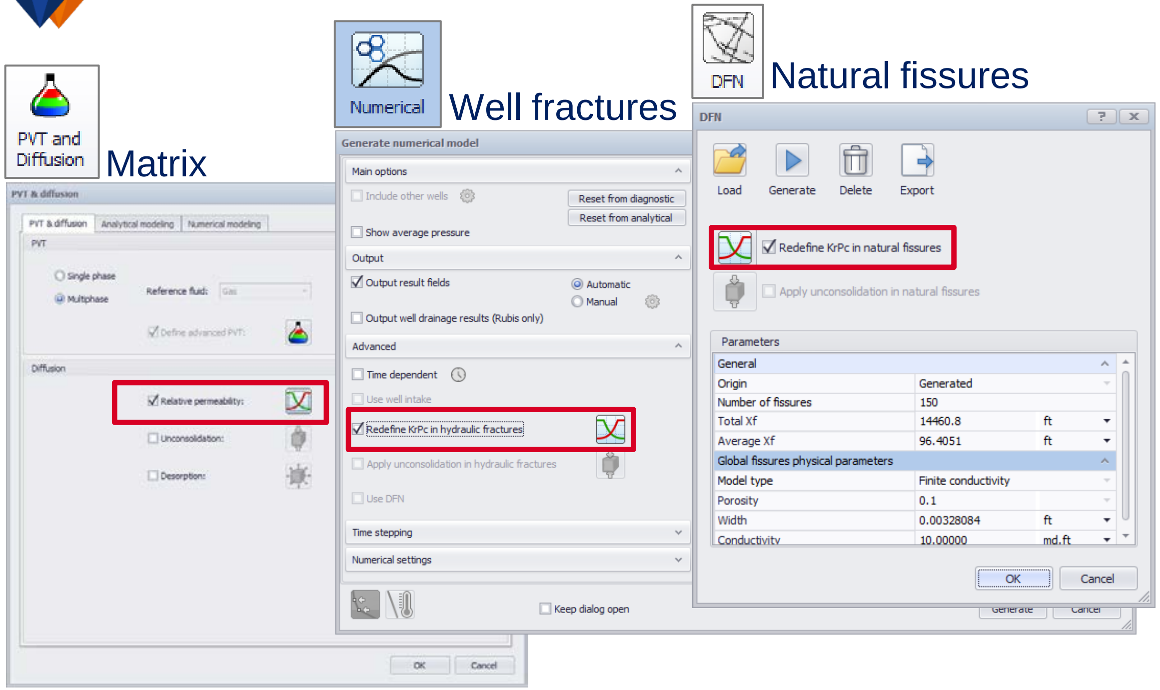
(c) **Infill** option:

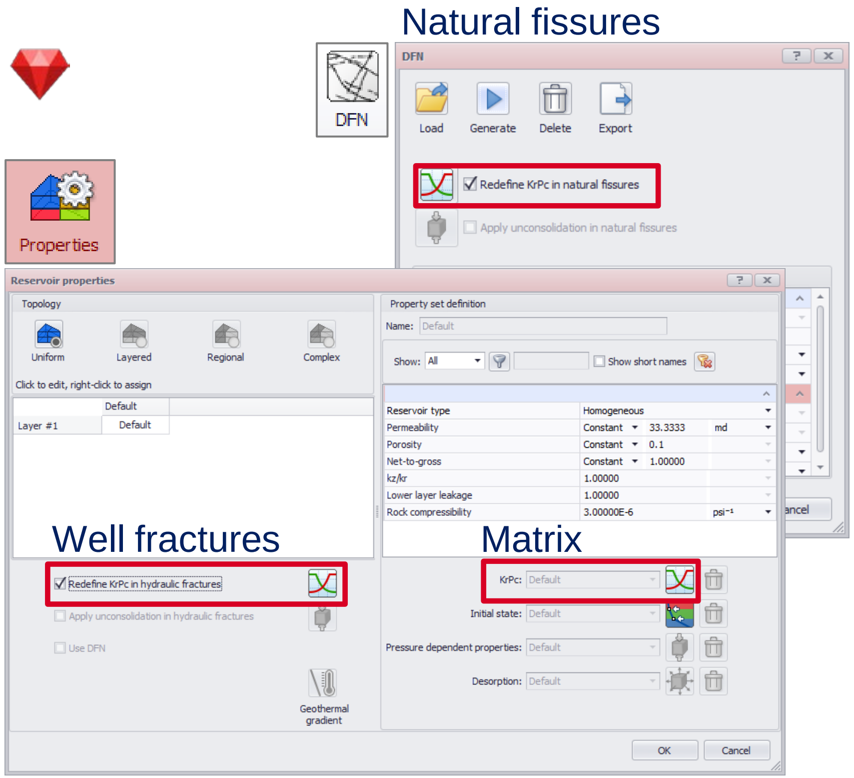
- All fractures start with matrix properties and switch to high conductivity at refrac elapsed time T

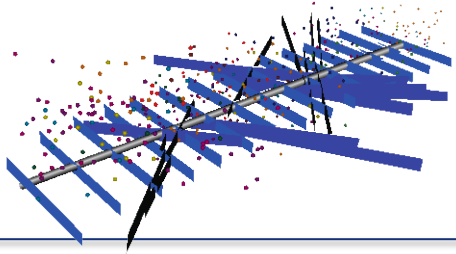
Multiple KrPc

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

- Multiphase PVT is defined & real PVT are used





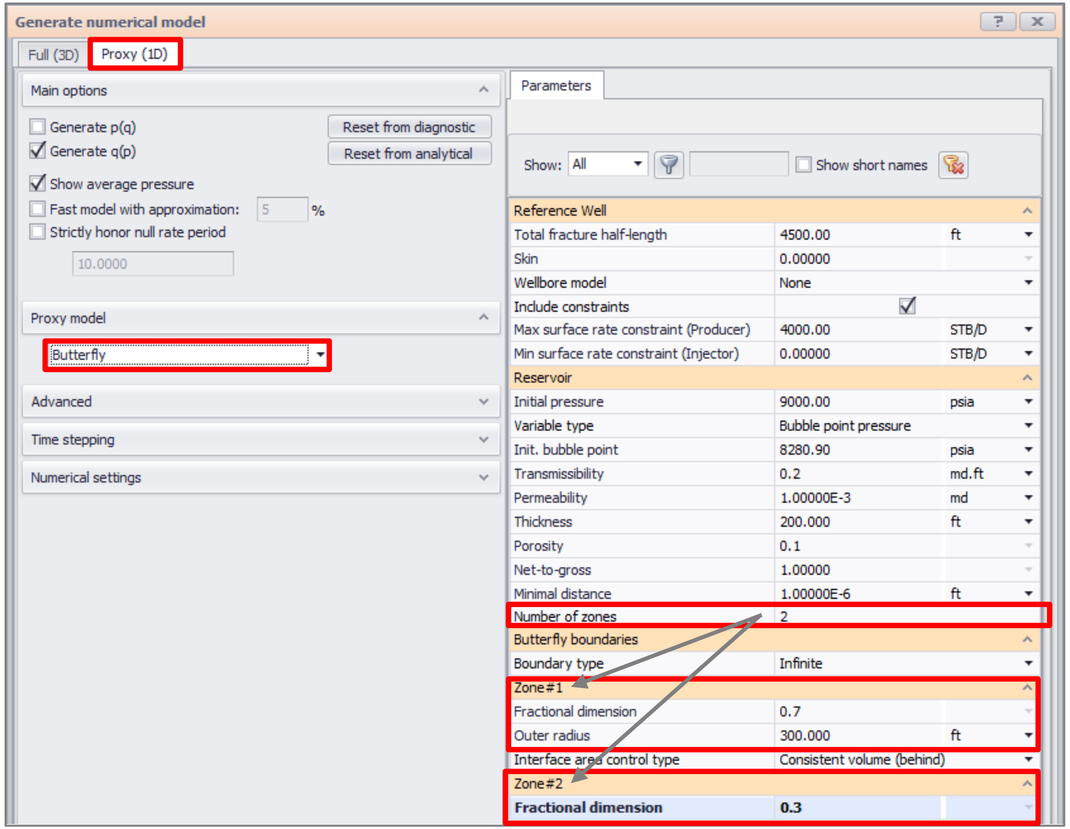


Numerical 'butterfly' model

KAPPA

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



SPE-2429710, SPE-2667752, SPE-2896802, SPE-2876208

CSG Well Intake

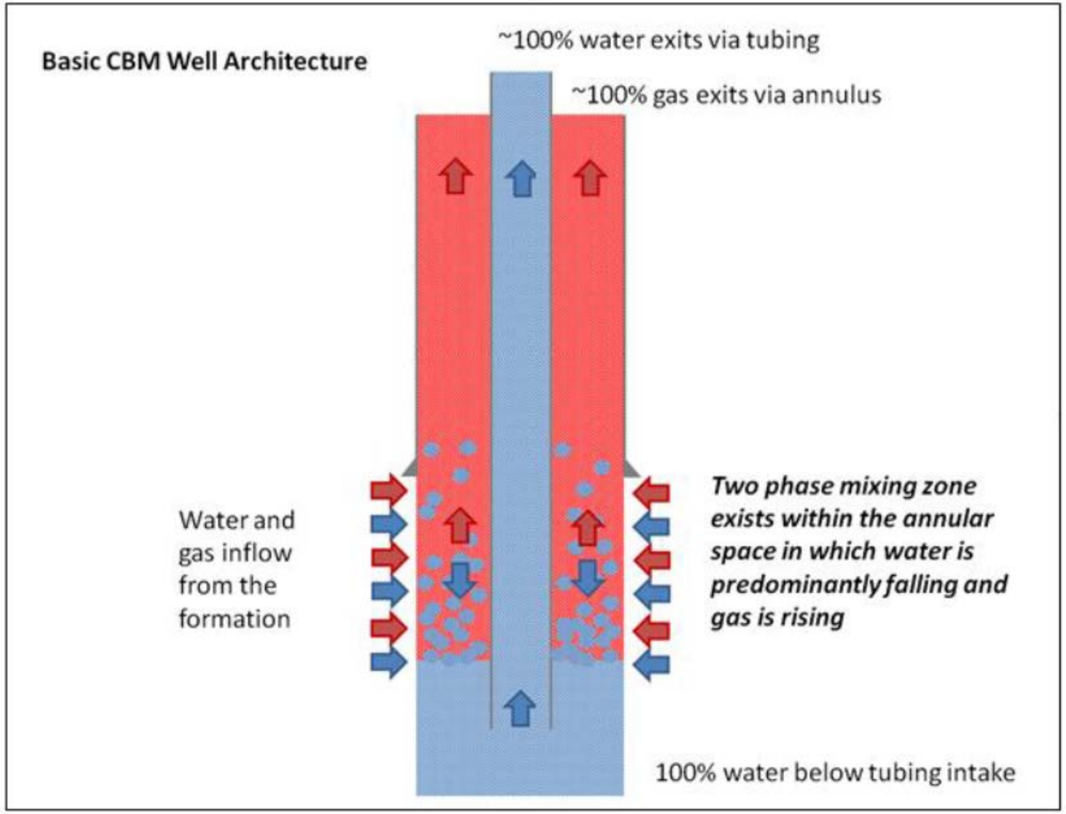
v5.40.01

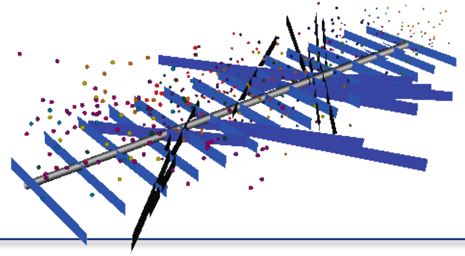
Available when:

- PVT is defined as ‘Dry gas + Water’
- Annular well intake

Assumptions:

- Steady-state flow
- Water level is an input



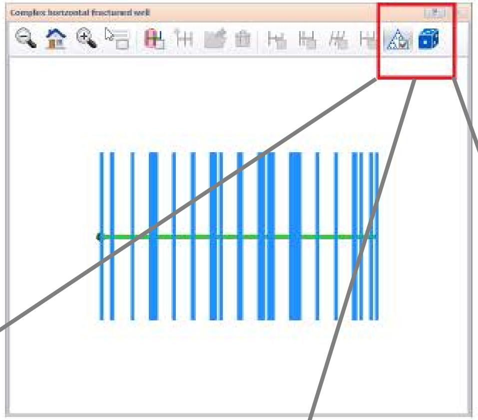


Fractal MFHW

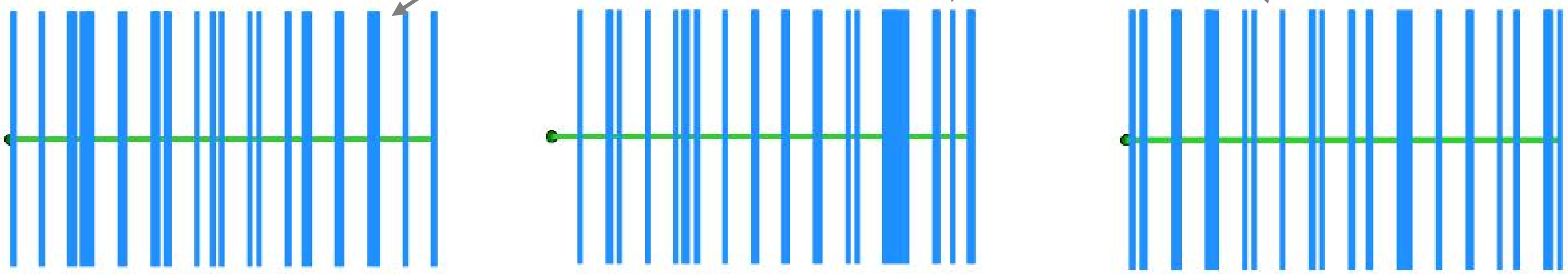
New in v5.40.02

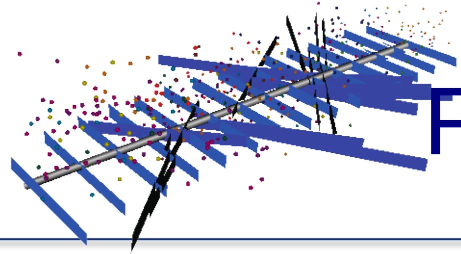
KAPPA

Geometry and properties - Global fracture parameters		
Number of fractures	76	
Fracture model	Infinite conductivity	
Fracture half length	300.000	ft
Fracture height	30.0000	ft
Fracture width	0.00328084	ft
Geometry and properties - Fractal MFHW parameters		
Flow dimension	0.3	
Maximum size	50.0000	ft
Minimum size	2.00000	ft
Number of sizes	8	



MZFD model parameters are used to generate a fractal MFHW with an equivalent response



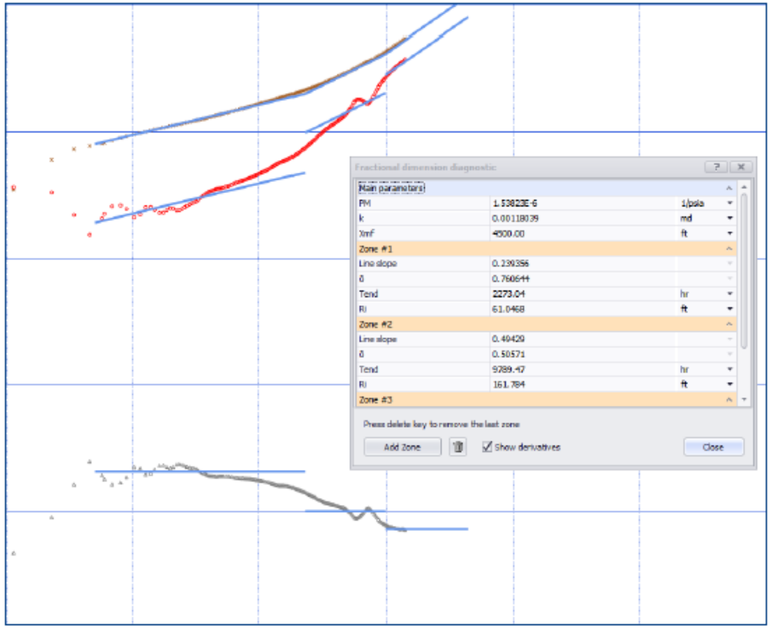


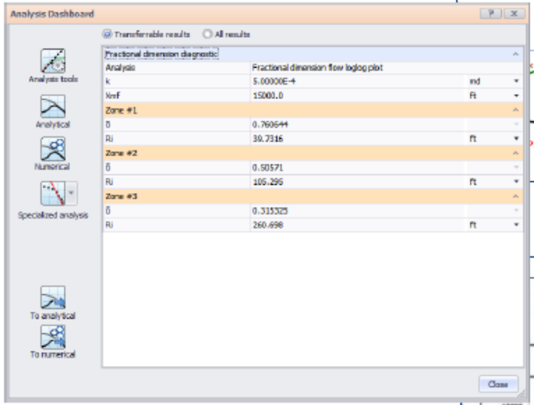
Fractional Dimension Workflow

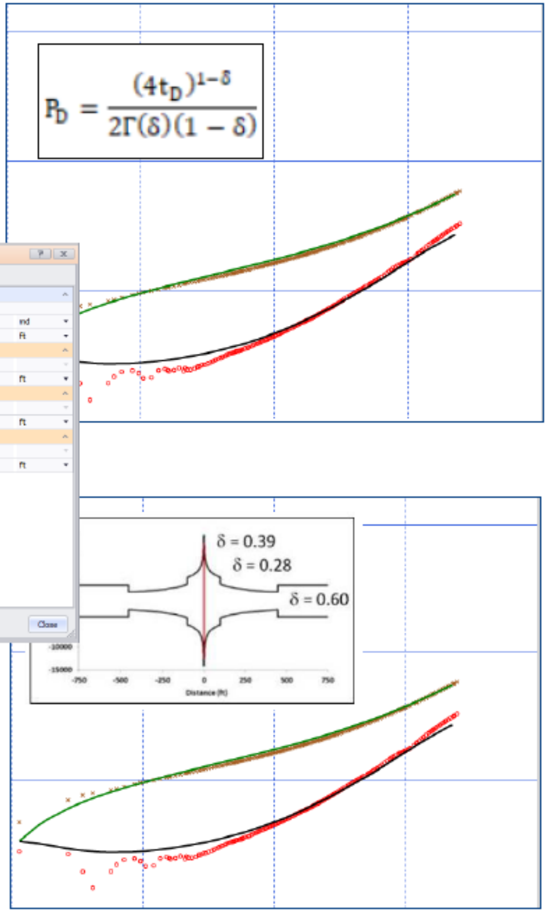
New in v5.40.02

KAPPA

Integrated MZFD model workflow: parameters read from diagnostic lines on the loglog plot used to initialize the model



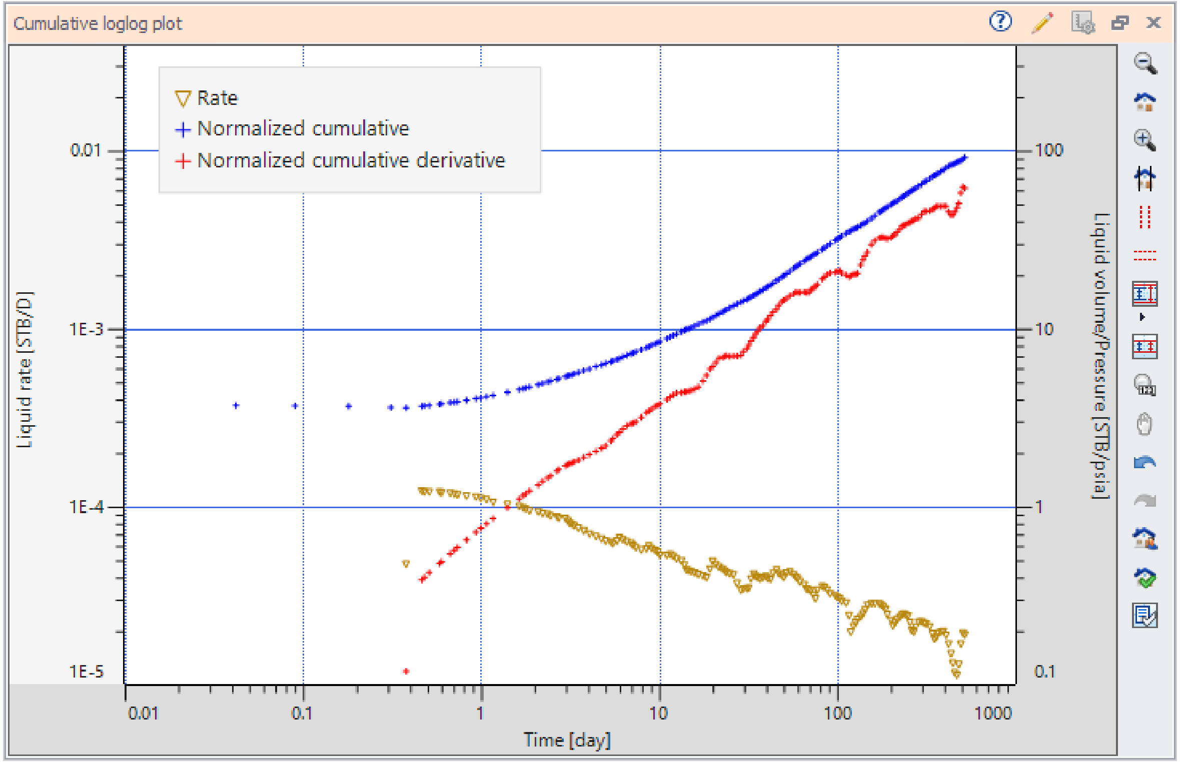




Cumulative Volume Loglog Plot

New in v5.40.02

An additional diagnostic plot for the 'butterfly' model behavior:

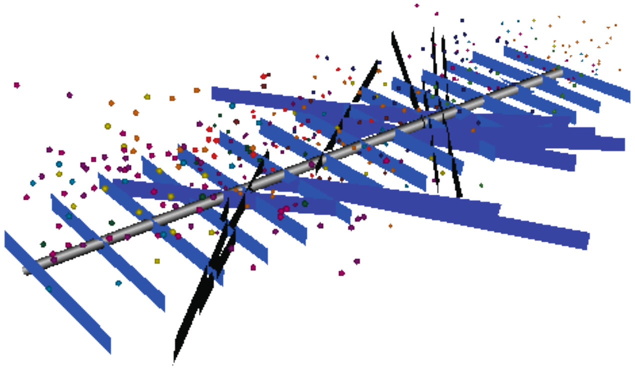


Time on production

$$\frac{Q(t)}{P_i - P(t)}$$

$$\frac{t\,\dfrac{dQ}{dt}}{P_i - P(t)}$$

$$q(t)$$



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THANK YOU

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