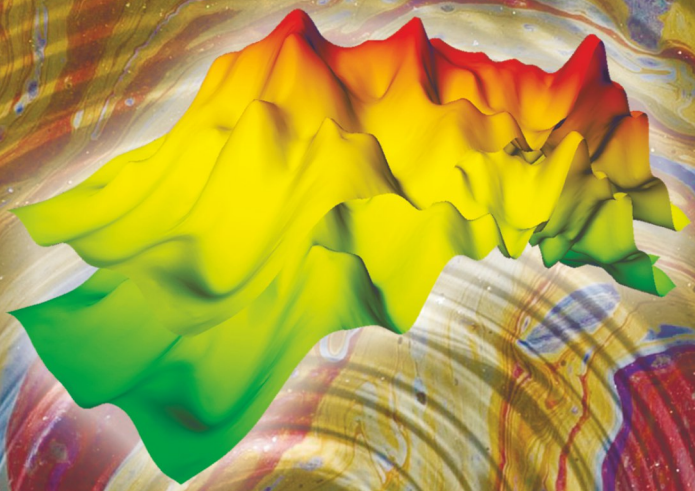
sofoil

Pressure pulse Code Test



PULSE-CODE TESTING

DEFINITION

Pulse-Code Testing (PCT) is an innovative implementation of cross-well pressure interference testing based on bottom-hole pressure response at one well to the rate variation at another well.

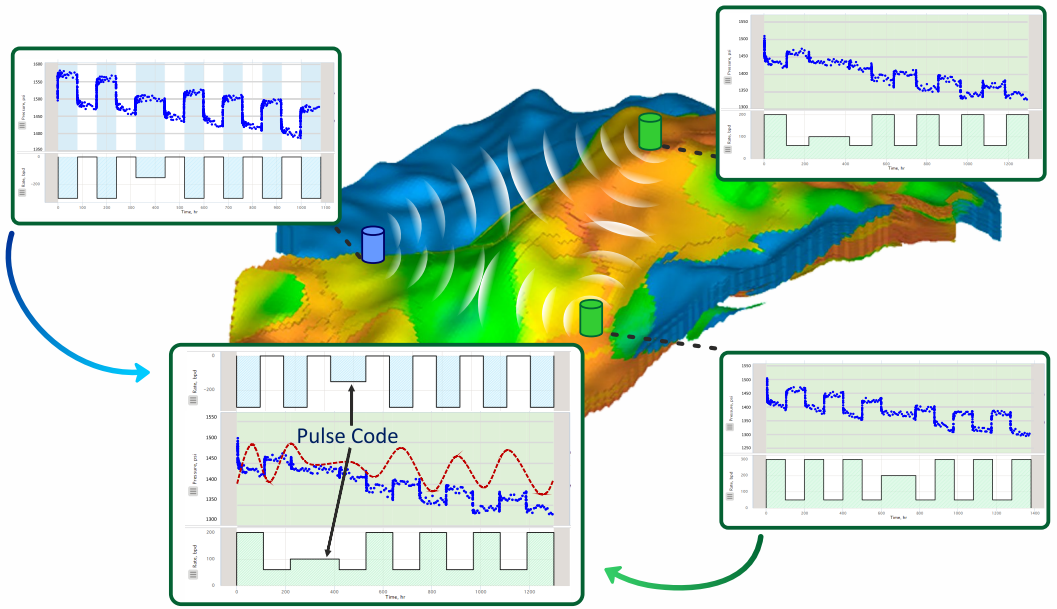
Unlike a conventional interference test which is based on step-response analysis while receivers and surrounding wells are shut-in the **PCT** procedure assigns a generating well to change flow rate in a certain pre-calculated sequence and does not require shutting in other wells. This creates coded pressure pulsations propagating throughout the formation which are captured by downhole gauges and decoded at the surface.

This allows conducting the cross-well scanning in the group of highly interfering wells without punishing production losses.

The PCT engine is based on modern parallel signal decoding algorithms, multi-core workstations and high resolution of downhole quartz gauges and flowmeters.

KEY ADVANTAGES

- Multi-well scanning
- No requirements to shut-in the test well and off-set wells
- High tolerance to all kinds of background inference
- May alert well underperformance beforehand



WIPO
WORLD
INTELLECTUAL PROPERTY
ORGANIZATION

INTERNATIONAL PATENT PCT/RU2016/000430

ASSESING RESERVOIR PARAMETERS WITH MULTI-WELL PRESSURE PULSE-CODE TESTING (PCT)

PULSE-CODE TESTING

APPLICATIONS

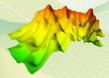
Production Enhancement:

#1 Reveal suitable priority zones for the new wells and side-tracks

#2 Organise priority candidates for workovers
(water shut-off, stimulation, fracturing)

#3 Optimize production targets

#4 Control displacement efficiency during waterflood



APPLICATIONS

Reservoir Study:

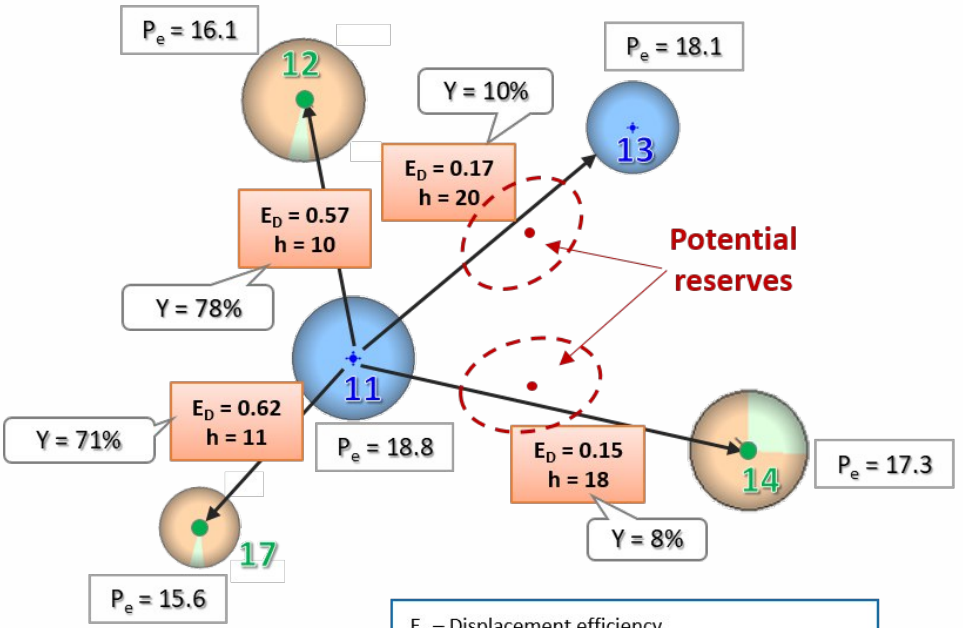
- #5 Assess the length and direction of hydraulic fractures
- #6 Identify spontaneous fractures
- #7 Localise barriers and pinch outs
- #8 Calibrate shale breaks
- #9 Quantify reservoir properties in the cross-well interval
- #10 Quantify reservoir properties in near-well area
- #11 Assess formation permeability
- #12 Assess formation compressibility

APPLICATIONS –

#1 Reveal suitable priority zones for the new wells and side-tracks

PCT in cross-well interval **11** → **12**, **11** → **17** indicates low effective thickness and high degree of oil displacement by water which disqualifies this area from priority drilling.

PCT in cross-well intervals **11** → **13** and **11** → **14** show much higher effective thickness and lesser degree of oil displacement by water which makes them a better choice for the infill drilling.

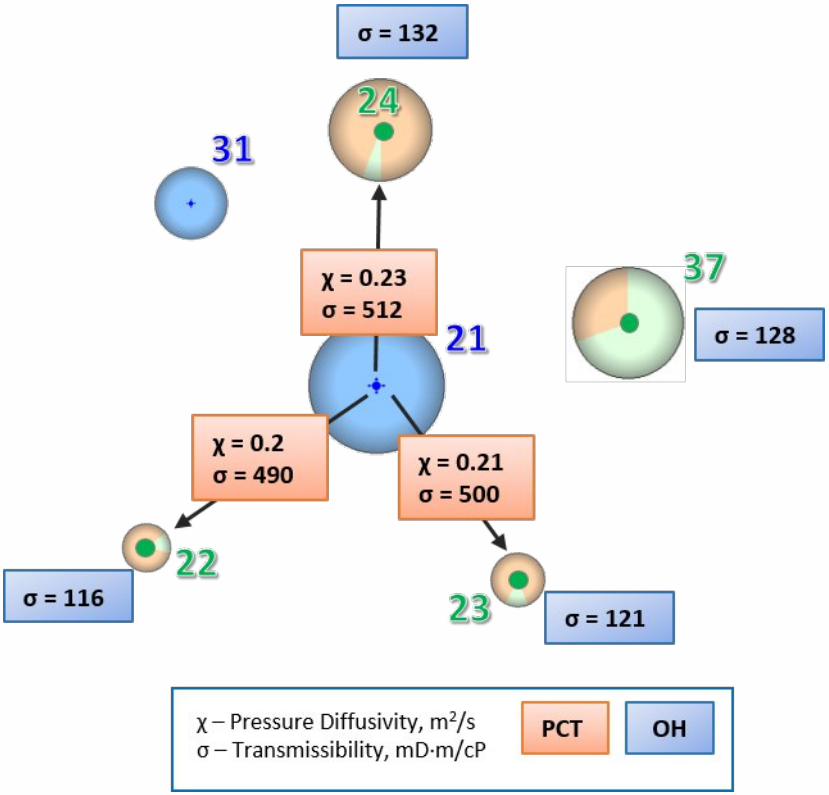


Production Enhancement

#2 Organise priority candidates for workovers

PCT intervals **21** → **22**, **21** → **24** and **21** → **23** show a weak influence and anomalously high transmissibility value, which is probably caused by thief injection in well **21**.

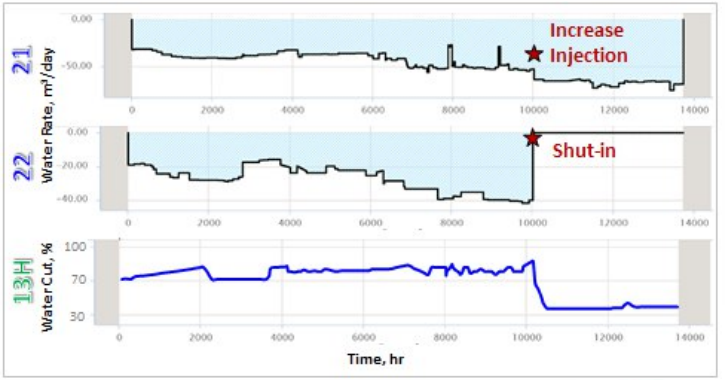
It is recommended to perform logging survey (**21**) to locate thief injection.

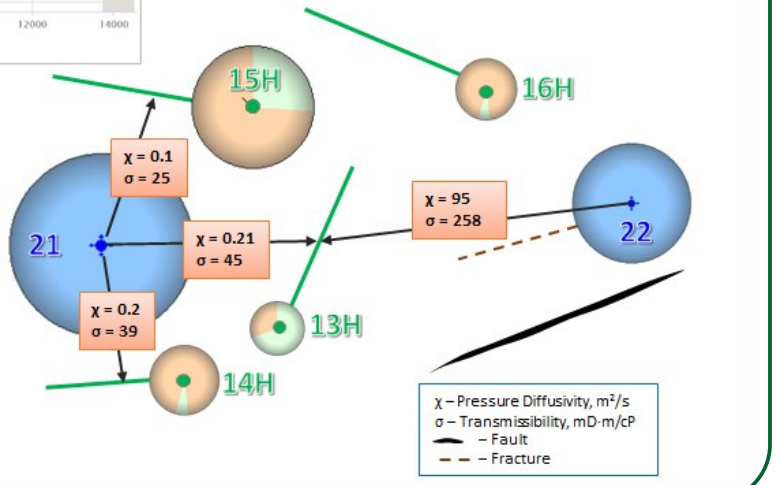


APPLICATIONS –

#3 Optimize production targets

PCT Interval between wells **21** → **13H** shows anomalous high influence in relation to intervals **22** → **13H**, which is also accompanied by anomalous pressure diffusivity (95 m²/s), which presence of abnormal improvement of formation properties between wells **21** and **13H**, probably caused by auto-fracture in the direction of well **13H**. Further operation at the current production target can lead to premature water breakthrough and a decrease in vertical sweep efficiency towards this direction. It is recommended to limit injection in well **21** and increase injection in well **22**.





Production Enhancement

#4 Control displacement efficiency during waterflood

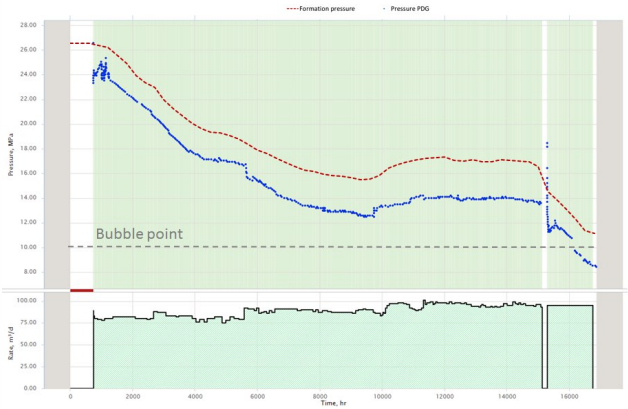
The area is lacking pressure support.

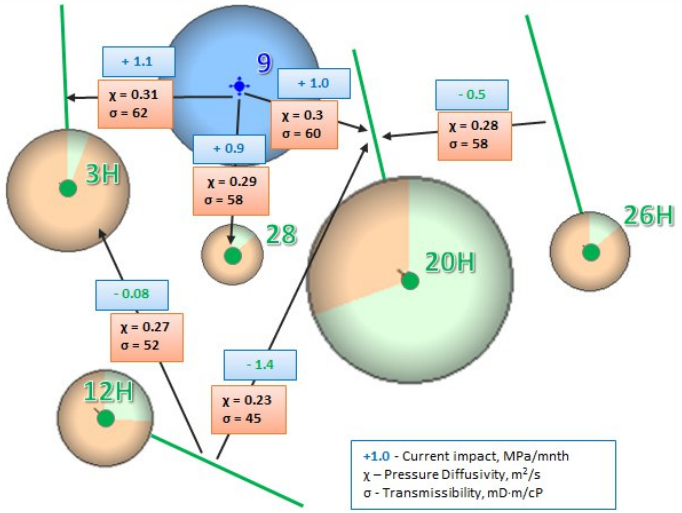
The **PCT** forecast on formation pressure dynamic in horizontal producer **20H** was suggesting it would go below bubble point in the next 10 months.

The cross-well analysis is showing that horizontal producer **12H** is depleting **20H** more efficiently (-1.4 MPa/month) than horizontal producer **26H** (-0.5 MPa/month) despite of a much further location.

This priorities **12H** as a fair choice for pressure support.

ⓘ Converting **12H** to injection resulted in pressure and production increase from **20H** with oil gain overweighting production loss from **12H**.





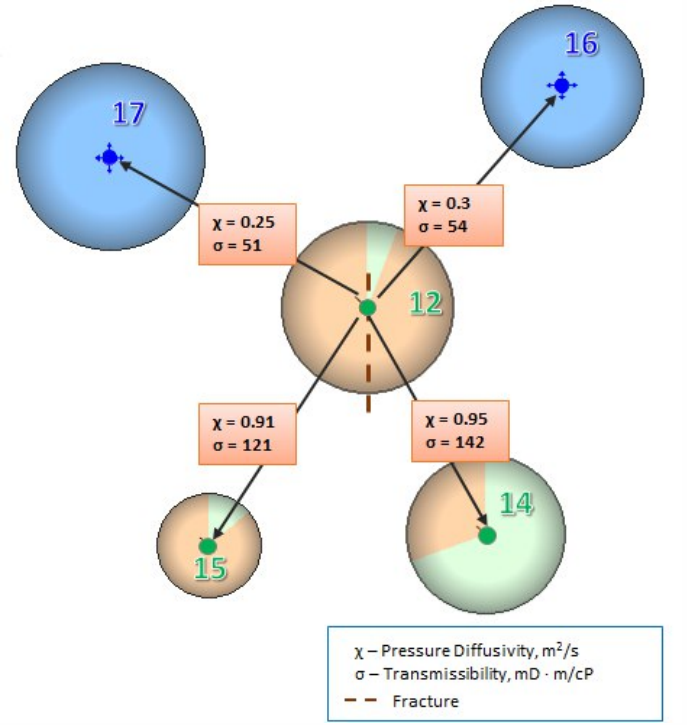
APPLICATIONS –

#5 Assess the length and direction of hydraulic fractures

The **PCT** analysis was performed around producer **12** which was hydraulically fractured one year ago. The objective was to identify the orientation and length of the fracture.

The PCT-based transmissibility between **12** → **16** and **12** →**17** are in a good correlation with OH data which verifies high quality vertical sweep in these intervals. The transmissibility between **12**→ **14** and **12**→ **15** turned to be twice higher which indicates that hydraulic fracture has extended in a sector between **14** and **15**.

Numerical modelling in **PolyGon** software estimated the fracture length as 70 m which is 20 % of the distance towards the offset wells.



Reservoir Study

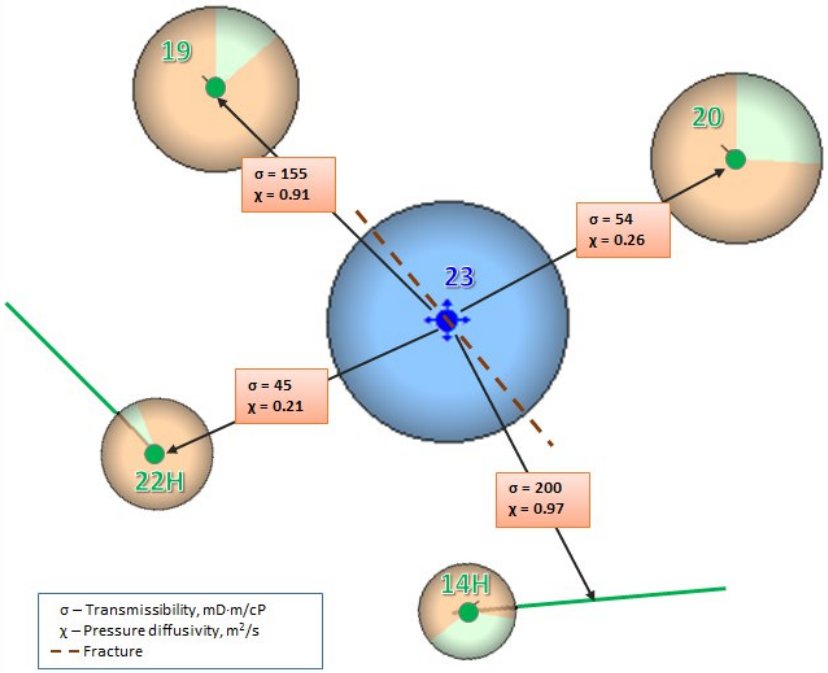
#6 Identify spontaneous fractures

The history of injector **23** shows a short period of high infectivity in the past which was followed by water cut growth in vicinity and consequent constrain of injection rate.

The **PCT** analysis was performed around injector **23** in order to assess the presence of spontaneous fracture.

The cross-well pressure diffusivity and transmissibility between **14H** → **23** and **19** → **23** turned to be much higher than other directions which indicates a presence of fracture communication.

Numerical modelling in **PolyGon** software estimated the fracture length as 120 m which is 30 % of the distance towards producers **19** and **14H**.

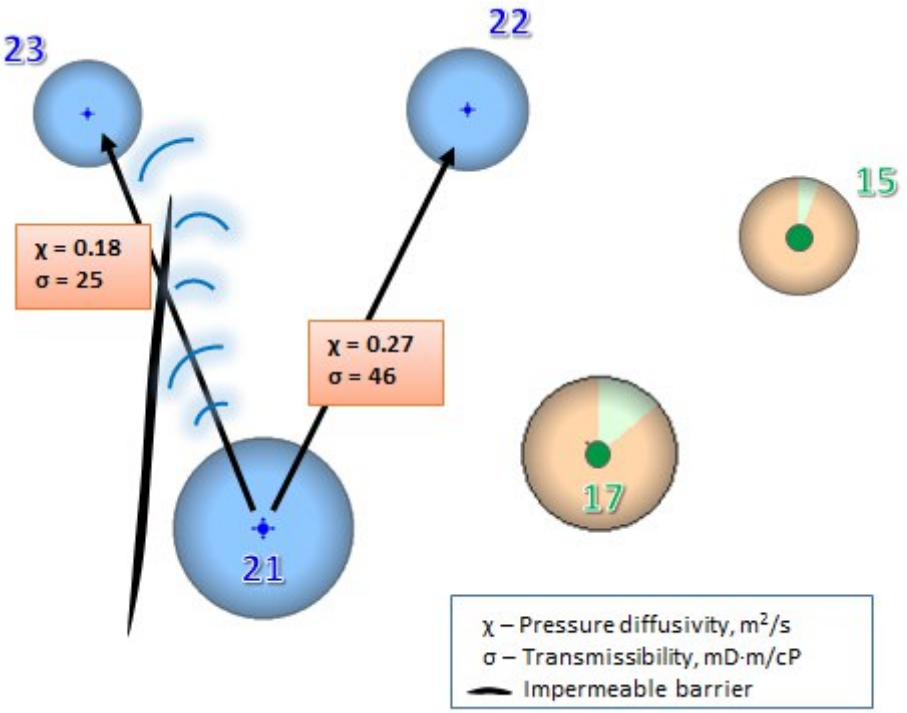


APPLICATIONS –

#7 Localise barriers and pinch outs

The wells block operates with continuous high production rates. **PCT** survey were conducted between injection wells during the planned operation of the surrounding wells. The main goal – to assess conductivity of the seismic fault in this zone.

According **PCT** results, the pressure diffusivity between the wells **21** → **23** turned out to be abnormally low (when compared to the interval **21** → **22**) , which indicates as Impermeable barrier. Nevertheless, the presence of a weak influence between wells **21** and **23** confirms the limitation of the extent of fault in the north.



Reservoir Study

#8 Calibrate shale breaks

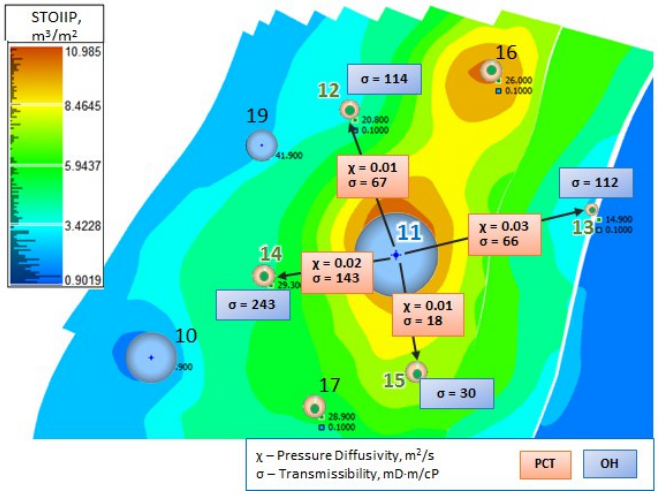
The **PCT** analysis around injector **11** is showing that transmissibility in all directions is around 50% of the OH log prediction.

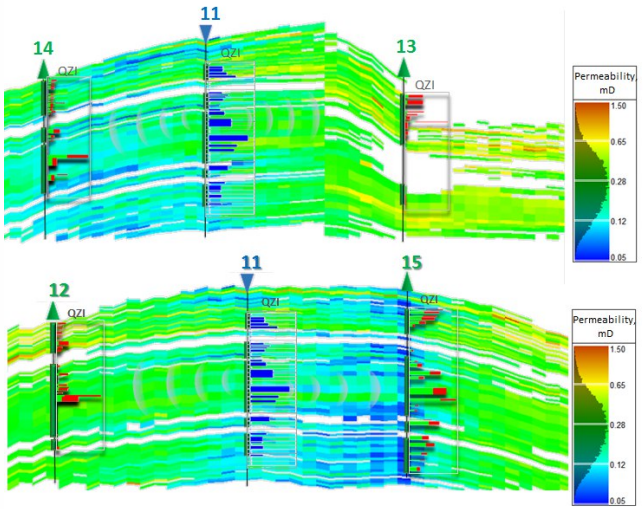
The **PLT** in injector **11** is showing a predominant injection in the middle part of the reservoir which is separated by thin tight beddings from above and below as suggested by OH logs interpretation.

The OH logs in the offset producers have the same pattern of the tights.

The **PCT** findings suggest that these beddings are all fair shale breaks with areal extension.

PCT analysis also indicates that upper and lower formation units are not flooded efficiently.



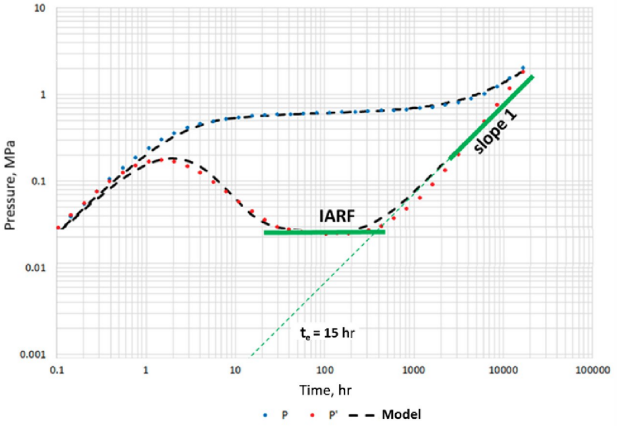


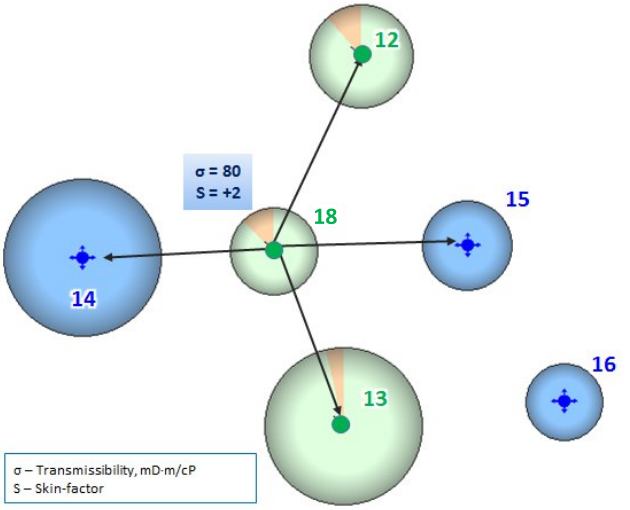
APPLICATIONS –

#9 Quantify reservoir properties in the cross-well interval

The history of producer **18** does not contain long-term transients which could have helped reservoir characterization and formation pressure assessment. The single-well deconvolution is dramatically influenced by sever communication with offset production and can't be used for transmissibility estimation.

The **PCT** analysis around producer **18** has deconvolved the unit-rate self-response which were interpreted as conventional pressure transient analysis. The skin-factor was assessed as +2 and transmissibility turned to be 80 md · m/cp which is in good correlation with predictions from OH data logs based on the current formation saturation.





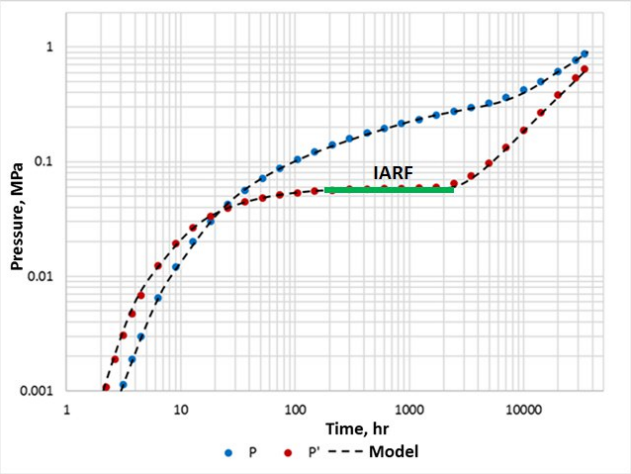
Reservoir Study

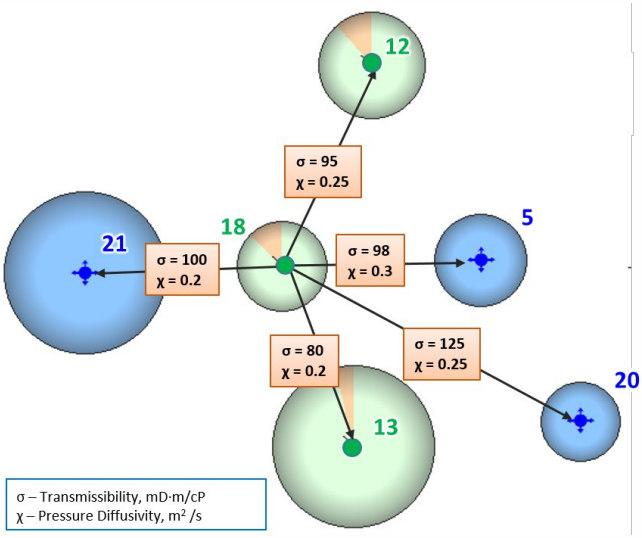
#10 Quantify reservoir properties in near-well area

The **PCT** analysis around producer **18** has deconvolved the unit-rate cross-well responses which were interpreted with conventional PTA interpretation workflow in **PolyGon** software.

The transmissibilities in intervals **18** → **13**, **18** → **21**, **18** → **5** and **18** → **12** turned to be similar to predictions from OH logs.

The high transmissibility in interval **18** → **20** and high-pressure response from **20** is most probably a result of spontaneous hydraulic fracturing in **20**.





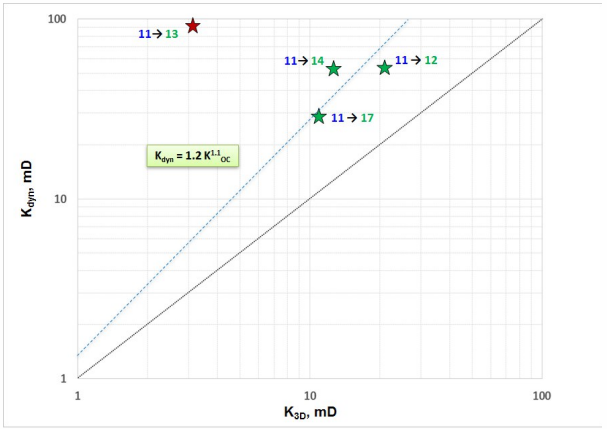
APPLICATIONS –

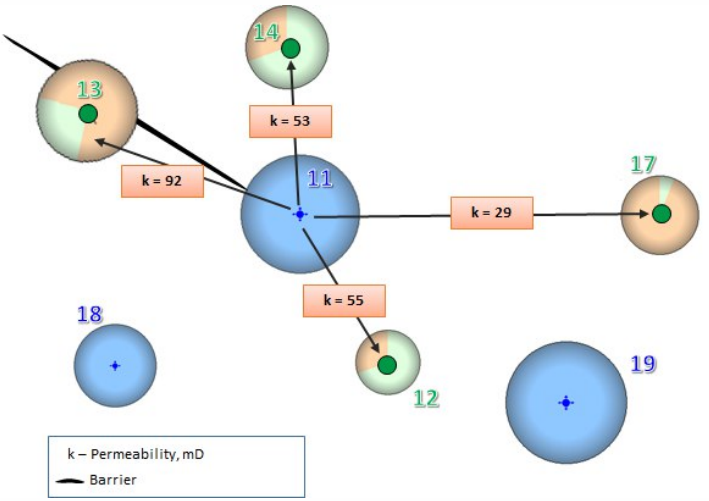
#11 Assess formation permeability

The intervals between generator **11** and receiver **12, 13, 14** and **17**, represented on permeability cross-plot (K_{OH} vs K_{PCT}), give estimates of matrix permeability in PCT intervals and the presence fracture conductivity in PCT interval **11** → **13**.

On this cross-plot, two clusters of points can be defined that correspond to two different petrotypes (A1 and A2). The upper layer A1 is drained by the wells **12**, **14** and **17**, and the lower layer A2 is drained by the wells **18** and **19**).

It is recommended to recalibrated permeability properties in 3D model and introduce a fault in the direction of well **13**.



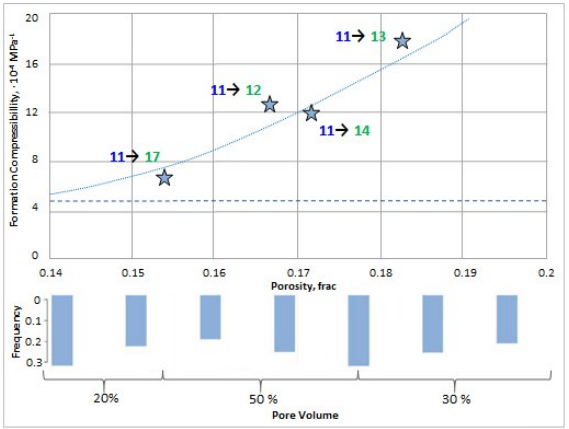


Reservoir Study

#12 Assessing formation compressibility

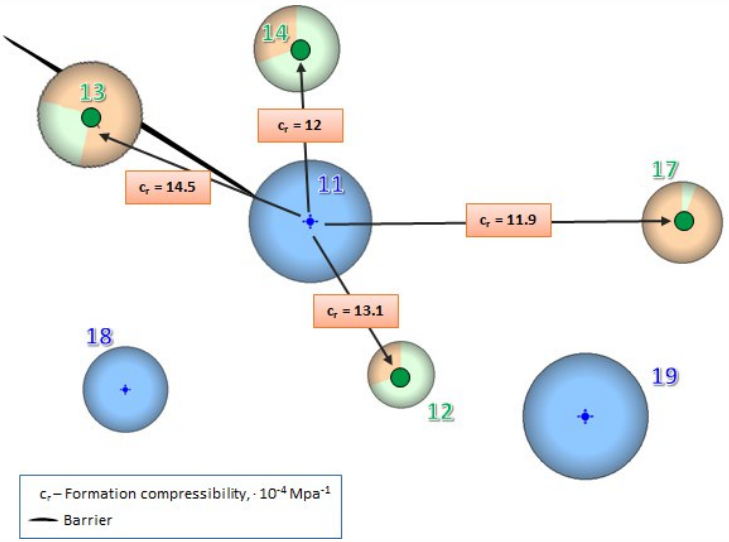
The intervals between generator **11** and receiver **12**, **13**, **14**, and **17**, represented on compressibility plot (Porosity vs cf PCT), give estimates of matrix compressibility in PCT intervals.

It is recommended recalibrated formation compressibility properties in 3D model.

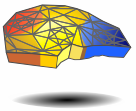


Compressibility Model

$C_r = 0.2 \cdot e^{(23.6 \cdot \Phi)}$ [10^{-4} MPa^{-1}]

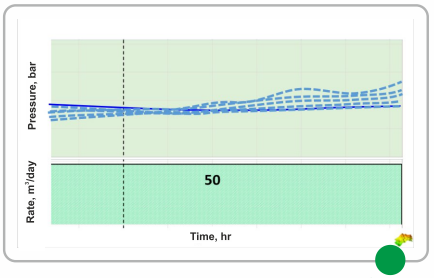


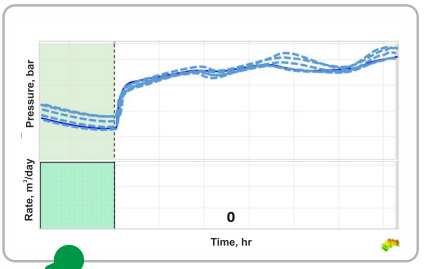
PCT Technologies

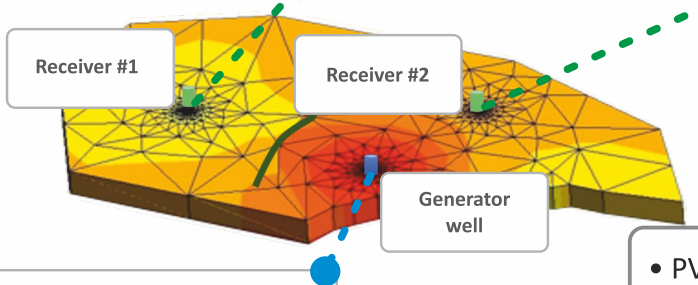


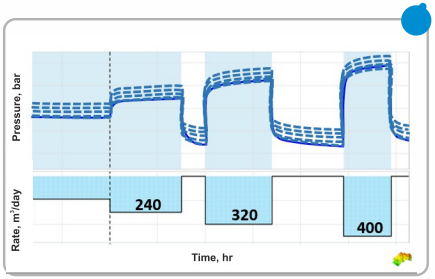
PolyGon

PolyGon Software









- PVT Modelling
- SCAL Modeling
- Numerical 2D modeling
- Pressure Transient Analysis
- Production Analysis
- Multiwell Deconvolution
- Pressure-Pulse Code Testing

zPas-20M

Quartz Downhole Pressure Gauge

ZSCAN LLC

Parameters	SPECIFICATIONS
Pressure Rating	0.1 – 60 MPa (1 – 592 bar)
Temperature Rating	0 - 150 °C
Temperature Accuracy	± 0.1 °C
Temperature Resolution	0.001 °C
Pressure Accuracy	± 0.1 %
Pressure Resolution	20 Pa (0.0002 bar)
Sampling Rate	1 - 3600 sec
H_2S	30 %
Diameter	28 mm
Weight	0.5 kg
Material	Titan

Pressure Resolution of 20 Pa is one of the highest in the world

PCT Geography

Khanty-Mansiysk

- Identifying auto-fractures properties
- Identifying effective formation thickness
- Identifying effective from waterflooding
- Forming recommendations on horizontal well drilling

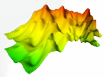
Ural-Volga region

- Identifying effective formation thickness
- Identifying current oil saturation between wells
- Forming recommendation on horizontal well hydraulic fracturing

- Identifying dy
- Identifying w
- Forming recor

SPE Papers

- SPE-181555-MS, Application of Multi-Well Pressure Pulse-Code Testing for 3D Model Calibration – 2016
- SPE-187927-MS, Verifying Reserves Opportunities with Multi-Well Pressure Pulse-Code Testing – 2017
- SPE-189258-MS , Carbonate reservoir waterflood efficiency monitoring with cross well pulse-code pressure testing – 2017
- SPE-196338-MS, Localization of the Remaining Reserves of R Oilfield With Pulse Code Pressure Testing – 2019
- SPE-206493-MS, Comparative Analysis of Tracers Against Pressure Pulse Code Interference Testing based on the Numerical Simulations of the Synthetic Oilfields with Complicated Geology – 2021



Western Siberia

- Identifying waterflooding effectiveness
- Identifying reservoir connectivity
- Verifying dynamic permeability and effective thickness

Kazakhstan

- Identifying dynamic permeability
- Identifying effective formation thickness
- Locating early water breakthrough
- Forming recommendations for inflow intensification
- Forming recommendations for horizontal well drilling

GCC

amic permeability
erflood effectiveness
mendations for sidetrack drilling

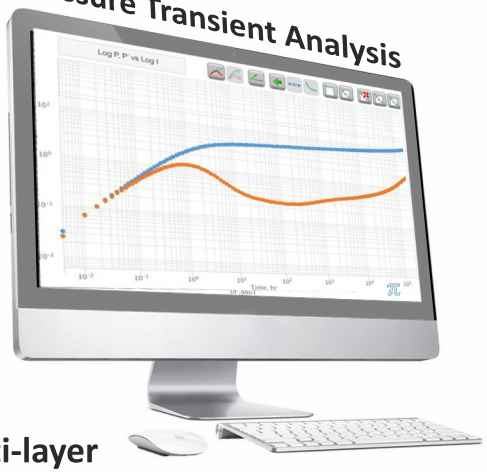
Southeast Asia

- Identifying barrier presence
- Client drilled a well and achieved

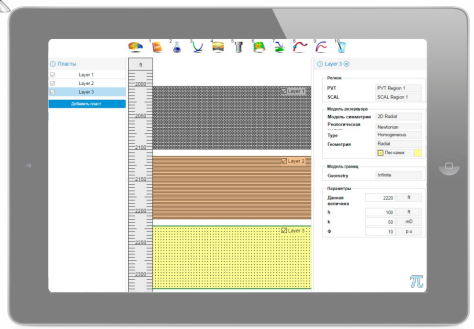
POLYGON

Multi-well Deconvolution

Pressure Transient Analysis

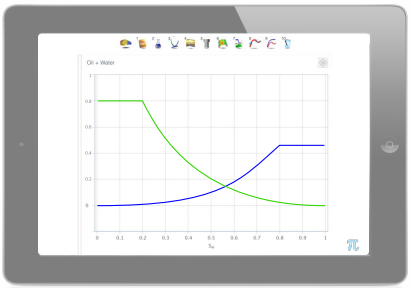


Multi-layer



PVT Modelling

SCAL Modelling

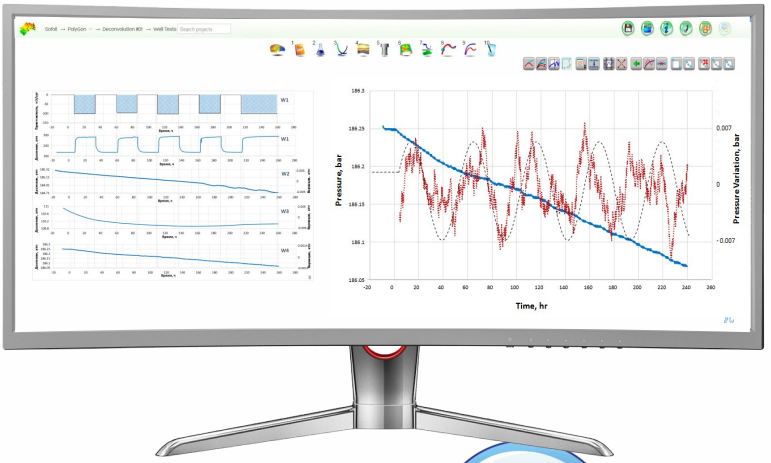


- Analytical models
- Wizard-type Web Interface
- Built-in video tutor

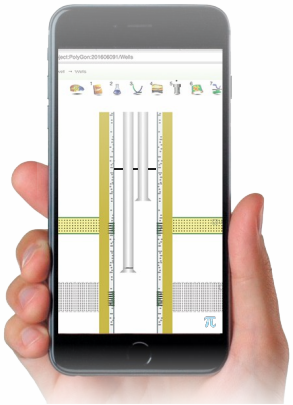
PRESSURE & RATE MODELLING FACILITY

Rate Transient Analysis

Pulse Code Decomposition

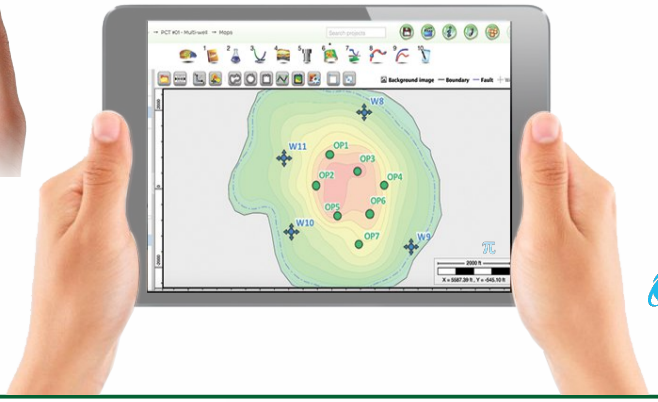


Well Sketch



Multi-core cloud computing

Numerical 2D model



polykod.com