



Neftegaztekhnologiya, LLC
Russian Federation

Blood Vessels™

Technology for the Creation of Radial Horizontal Small-Diameter Channels

info@n-gt.ru

www.n-gt.ru



1. Blood Vessels™ Technology (BV)

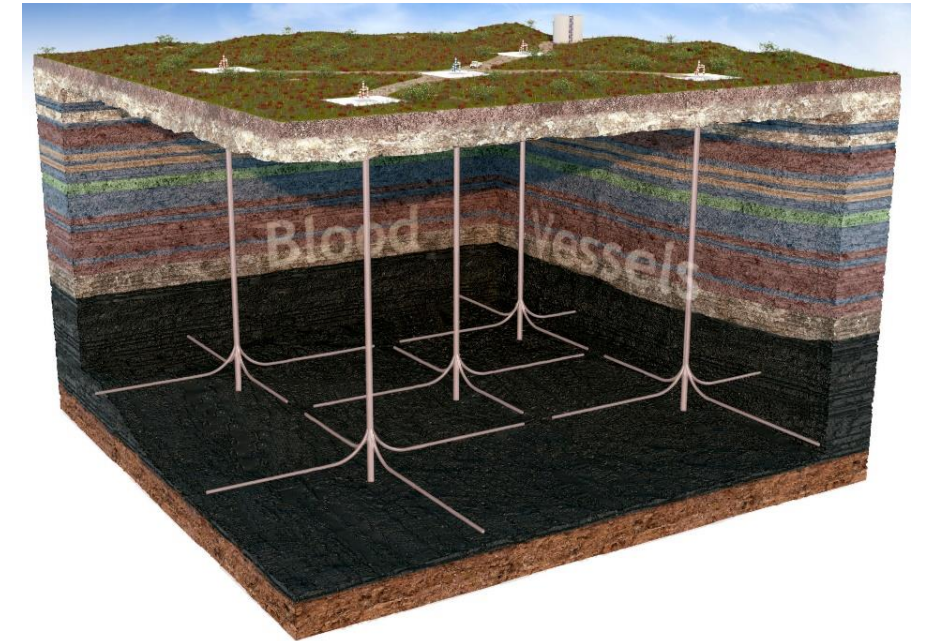
1.1. BV Technology is a tool for hydrocarbons inflow and oil recovery factor increasing by creation of network of radial channels in the formation

Versions:

- BV_01 - channels creation with autonomous deviation angle gauge
- BV_03 - channels creation with online control of deviation angle, azimuth angle and gamma-ray via cable channel inside Coiled Tubing

The channels for versions BV_01 and BV_03 are created from vertical or deviated cased holes and have the following parameters:

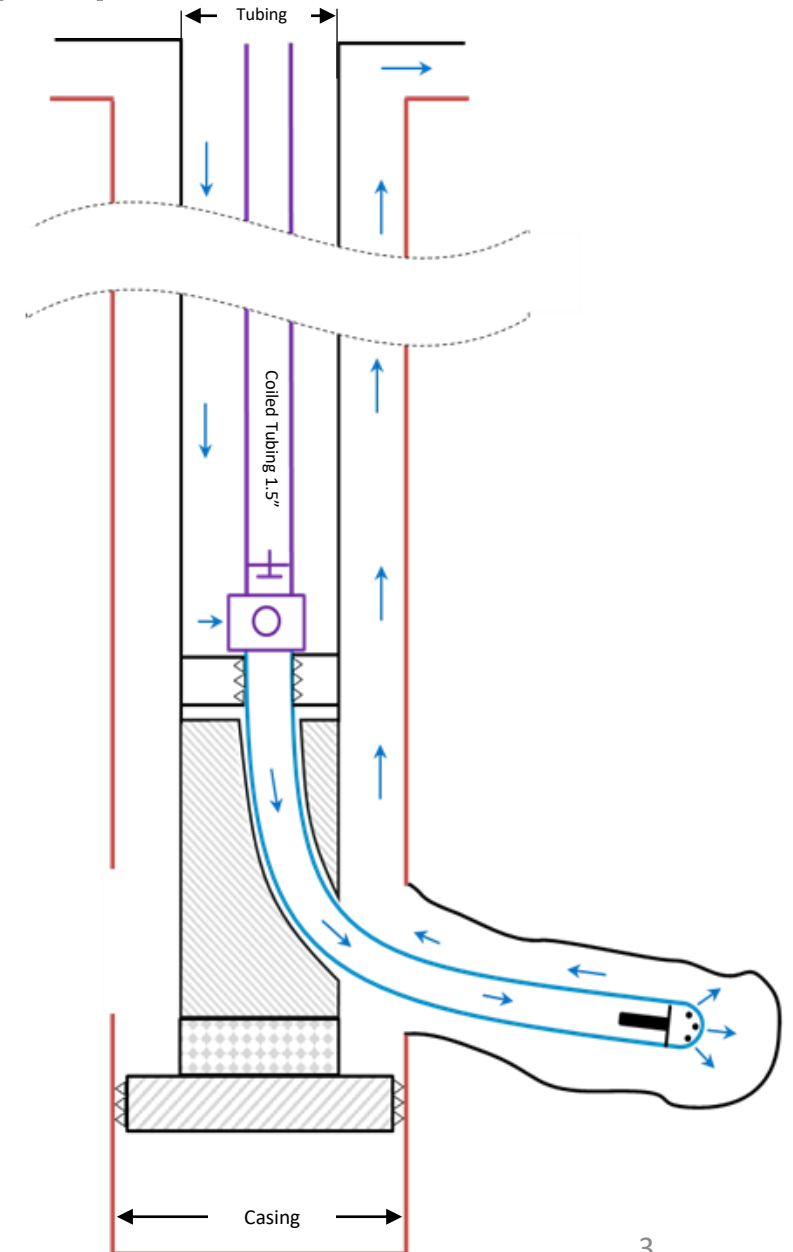
- number of radial channels – up to 4 at one level, number of levels is not limited
- channel diameter 60-80 mm
- channel length – up to 300 m
- build curve intensity up to 10 deg. / 1 m
- radius of formation penetration 9-12 m



1. Blood Vessels™ Technology (BV)

1.2. Creation of radial channels is made by means of hydromonitor water jetting. The method has advantages over conventional rotary drilling

- High efficiency coefficient of water jetting due to straight usage of hydraulic power without its conversion into rotation and related losses of energy
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- Absence of torque effect allows faster and more accurate control over the channels trajectory



2. Advantages

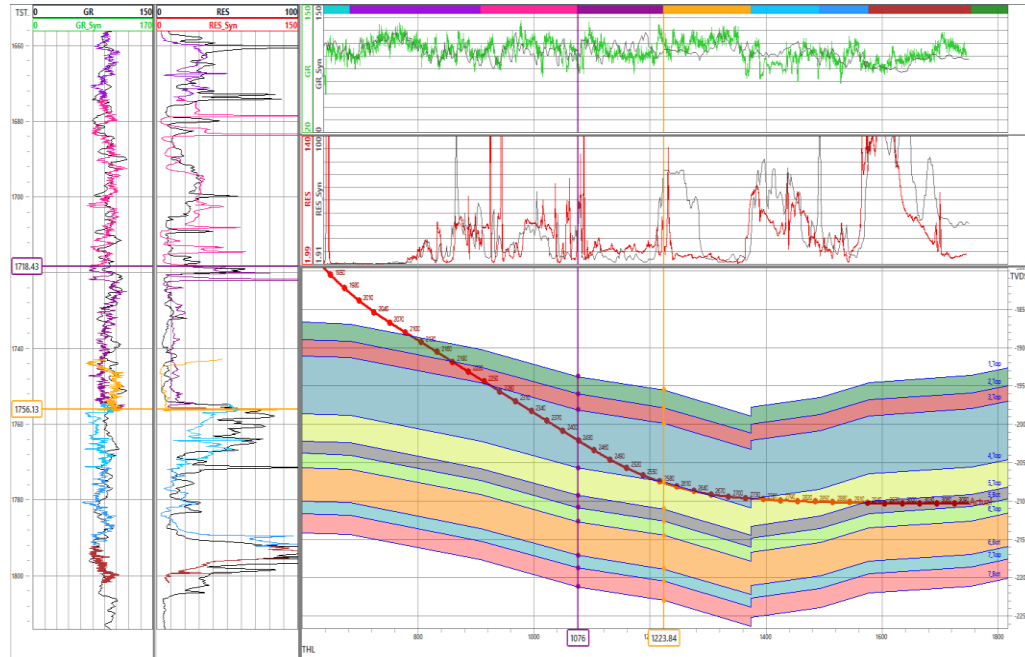
BV technology has advantages over other small-diameter radial channels creation technologies

- Oil production rate increase 2-3 times
- Low unit cost of operation on a basis of incremental ton of oil
- Channels trajectory monitoring by deviation angle during channels creation
- Channels trajectory control by usage of different bottomhole assemblies
- Underbalance operations with bottomhole pressure control
- Channels length 100-300 m
- Channels creation, matrix acidizing and nitrogen lift can be performed during one BV operation
- Ability to stimulate below the gas cap formations and water flowing formations as well as formations with ALRP and AHRP
- Environmentally friendly technology

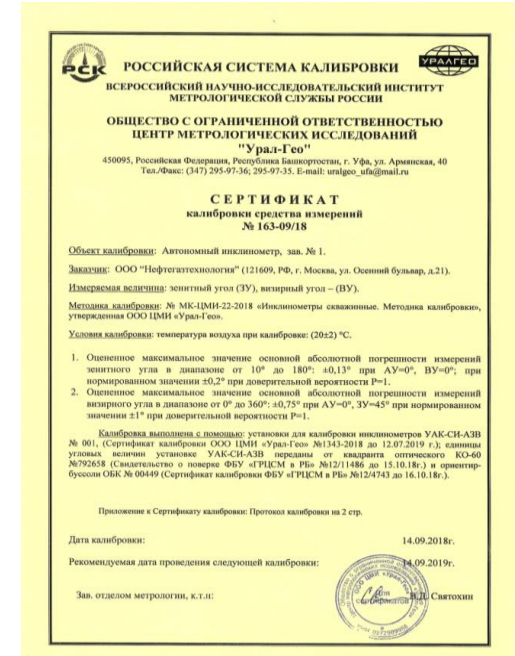


3. Channels Navigation

We confirm
actual channels
trajectory during
the job



Autonomous deviation angle gauge Characteristic:
OD 25 mm
Length 800 mm
Build curve intensity down to 12 deg./m
Tmax.100°C
Pmax. 700 atm.
Accuracy: +/- 0.5 deg.
Measured parameters:
Deviation, deg.
Deflector angle, deg.
Temperature, °C
Pressure inside coiled tubing, atm.
Pressure outside coiled tubing, atm.

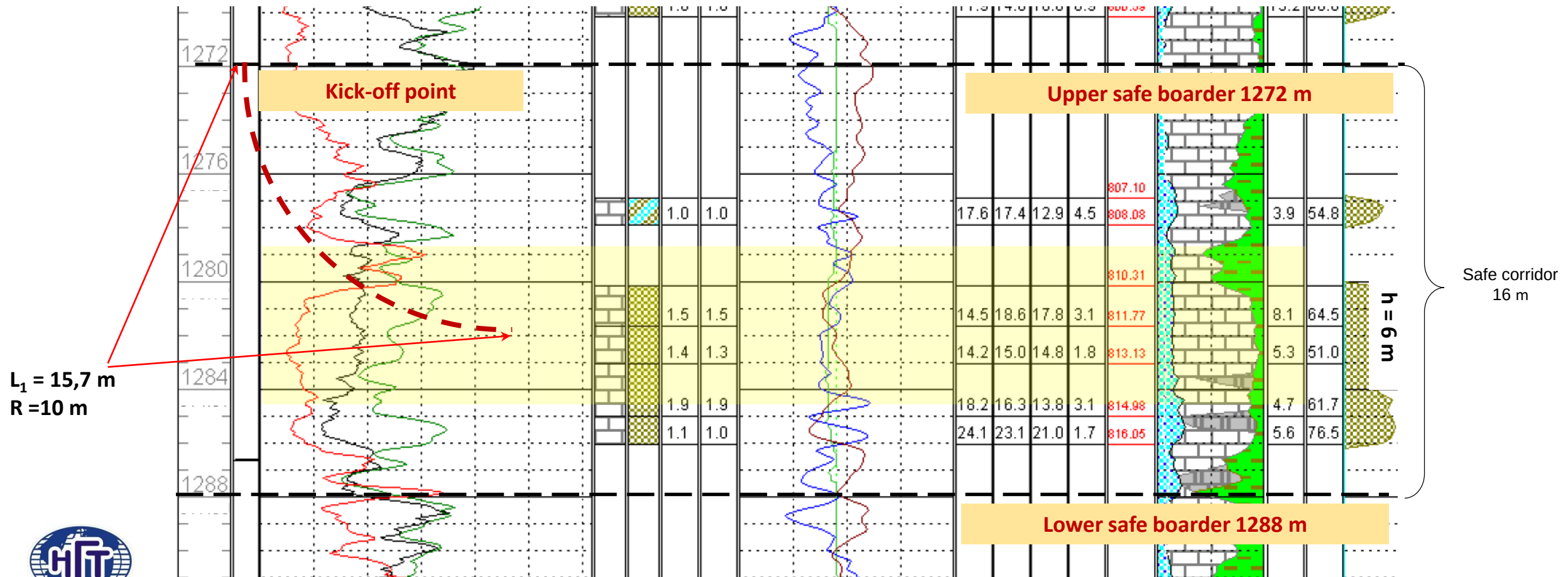


We can make radial
channels in >10m height
formation corridor at
3500m well depth



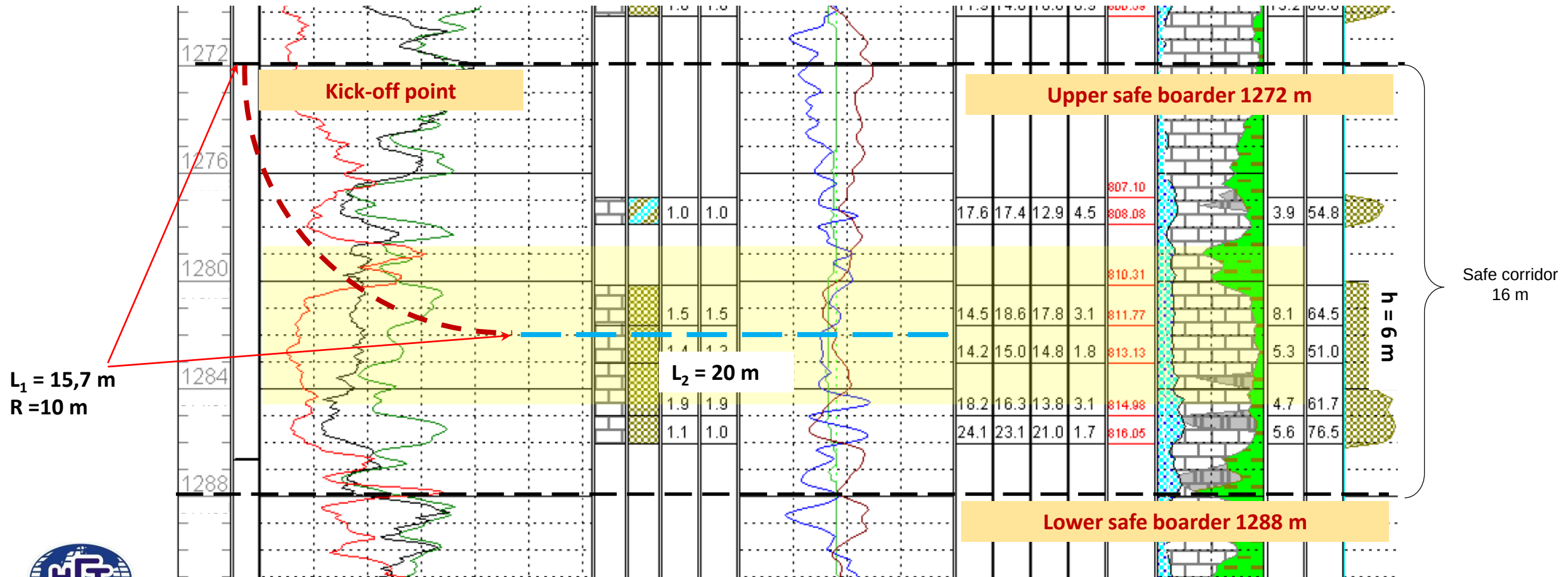
4. Channels from Cased Holes – BV_01 Technology

1st STEP – slide down, going to horizontal. Identification of safe corridor borders. Kick-off point positioned 10m above planned horizontal section of the channel. The horizontal section is planned to be located in producing layer of the formation. The section between kick-off point and horizontal section should consists of dense rocks without porous anomalies. The horizontal section of the channel should be 5m above OWC or another undesirable object. The length of the first “drilling” is less than the safe corridor height – it is a guarantee of positioning of the channels inside the safe corridor borders. Than the bottomhole assembly is pulled up the well, the “drilled” channel trajectory is obtained, the assembly is corrected as needed.



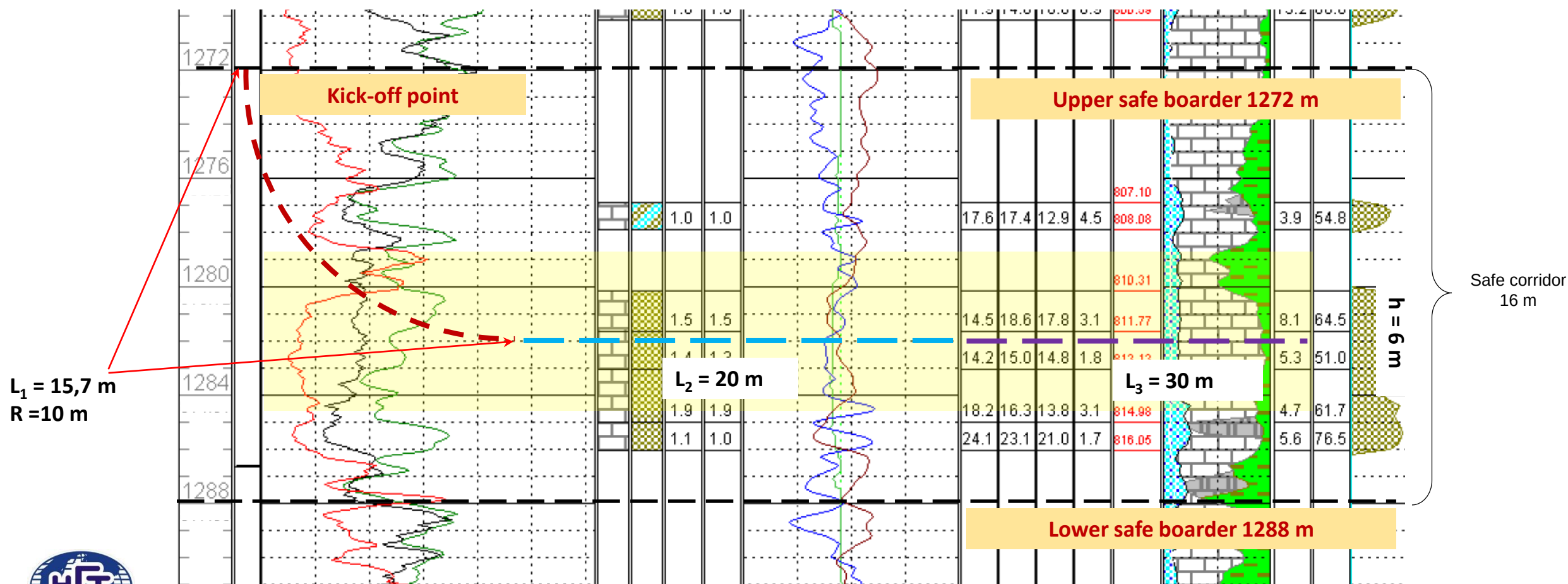
4. Channels from Cased Holes – BV_01 Technology

2nd STEP – stabilization of deviation angle, channel elongation. Running in hole a bottomhole assembly for stabilization of deviation angle. The length of 2nd “drilling” is identified taking into account cone of uncertainty inside safe corridor borders. Pulling the bottomhole assembly out of hole, confirmation of planned trajectory trend, calculation of length of 3rd section.



4. Channels from Cased Holes – BV_01 Technology

3rd STEP – finish of “drilling”. Drilling of 3rd section, pulling out of the hole the bottomhole assembly. Run in hole for Acidizing. Acidizing with repeated running into the radial channels and acid pumping in hydromonitor jetting regime from the every channel toe to hill. Nitrogen lift, downhole pressure decreasing and reaction products recovery from the channels.



5. Factors of Generation of Additional Oil Recovery due to BV Introduction at Oil Producing Wells

4 radial 100 m BV channels
increase formation surface
contact area at 100 m²

1. Targeted “drilling” through the low permeability formations sandwiched
2. Inclusion of producing layers in vertical and horizontal directions
3. Full cleaning of radial channels, confirmed by cuttings cleanout to surface
4. Downhole pressure control eliminate/control fluid losses into formation during circulation
5. Acidizing with repeated running into channels lowers skin factor
6. Nitrogen lift right after Acidizing lowers skin factor
7. Ability to perform underbalance operation in case of ALPR
8. Penetration of radial channels into formation zones with better reservoir properties

BV technology effect:

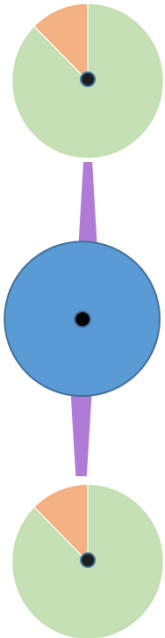
Oil production rate increase 2,5-3 times
Gas production rate increase 3-5 times
Oil recovery ratio increase at 20-40%
Skin factor lower -0,5



6. Factors of Generation of Additional Oil Recovery due to BV Introduction at **Injector Wells**

Without intensification

Water injection causes fast water breakthrough into oil producing wells along the less resistant way. Causes are natural anisotropy of the formation, unfavorable azimuth of Fracturing.



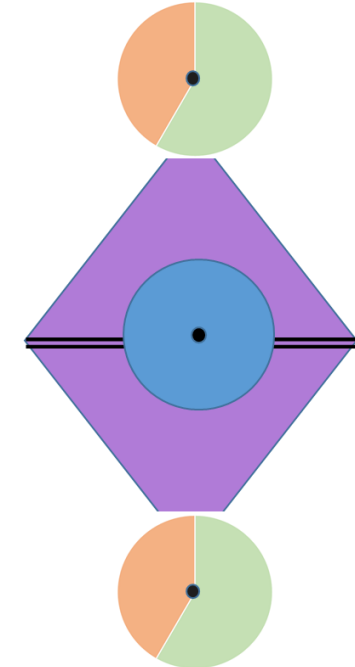
With intensification

Injection of cement or viscous fluids into formation causes plugging of high-conductive zones and expansion of displacement front. The effect is lowering or stabilization of water-cut at oil producing wells.



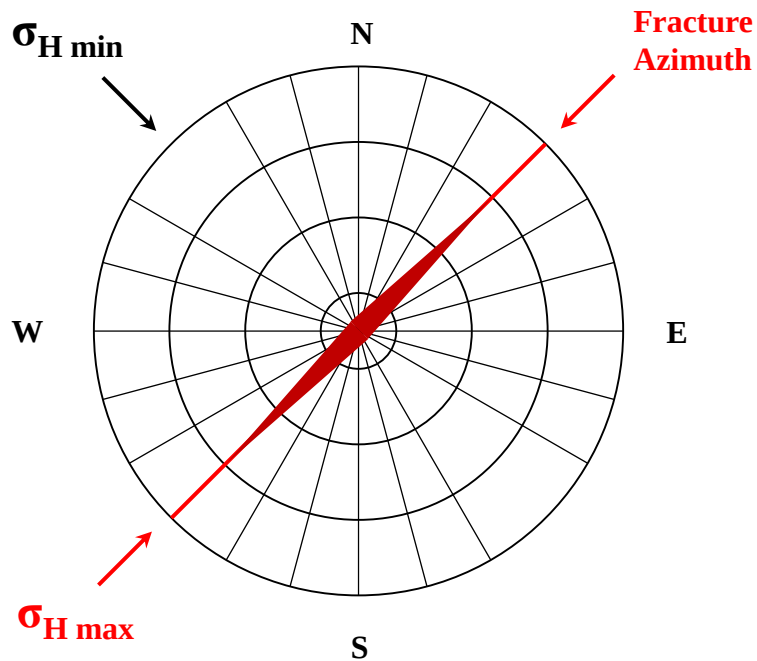
With BV + intensification

Creation of radial channels a predetermined azimuth with subsequent pumping of viscous fluids. It will widen displacement front, decrease water-cut and increase oil recovery factor.

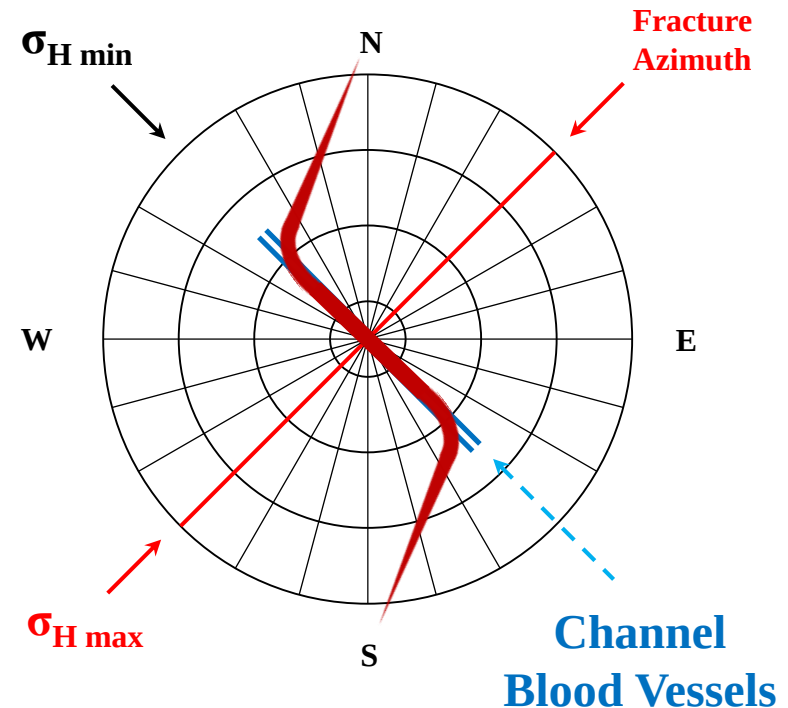


7.1 Fracture Azimuth Control

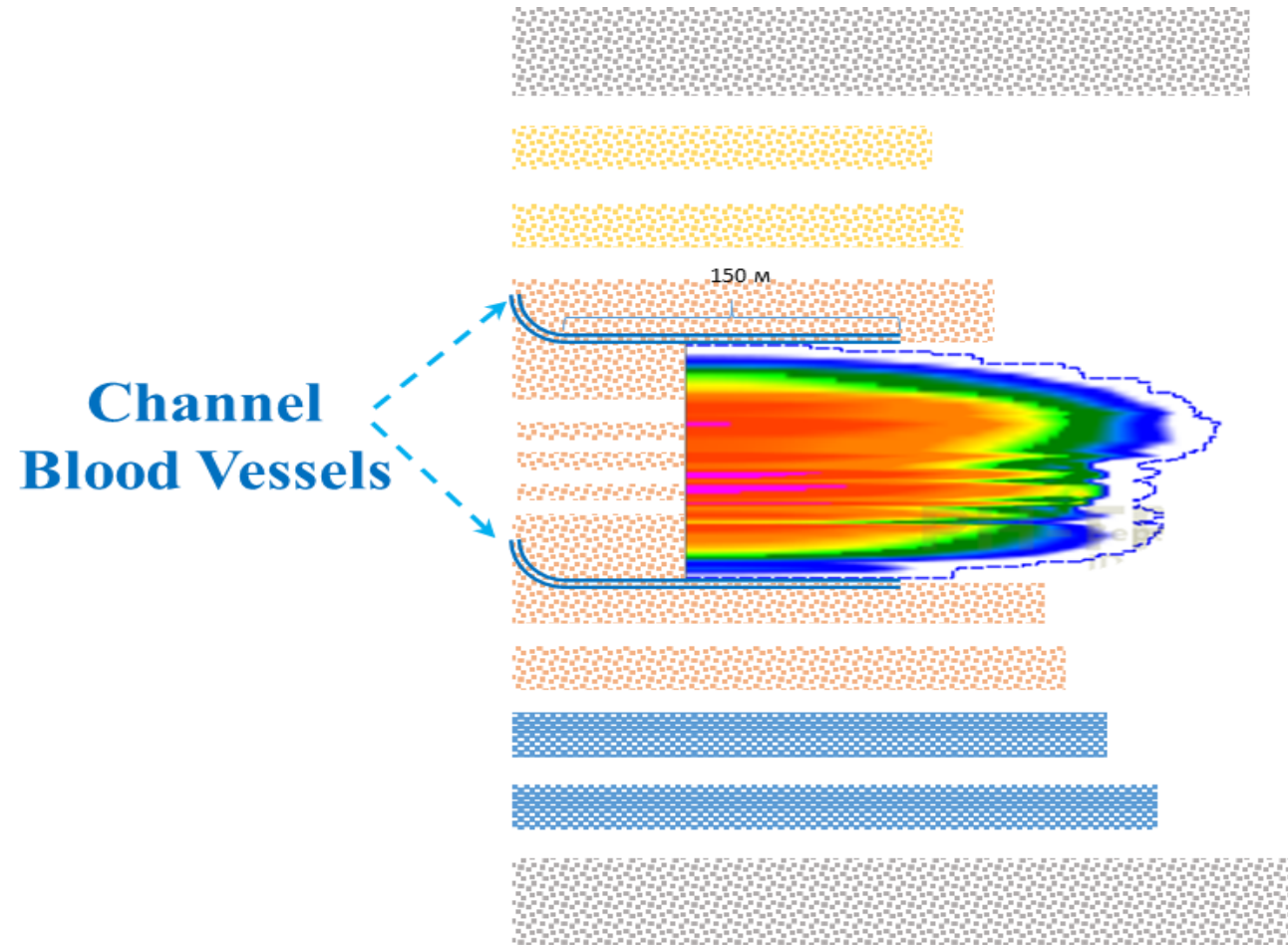
The conventional propagation pattern of a hydraulic fracture follows the path of maximum horizontal stress.



Blood Vessels perpendicular to the prevailing maximum horizontal stress establishes the physical prerequisites to modify the azimuthal direction of hydraulic fracture propagation.



7.2 Hydraulic Fracture Height Control

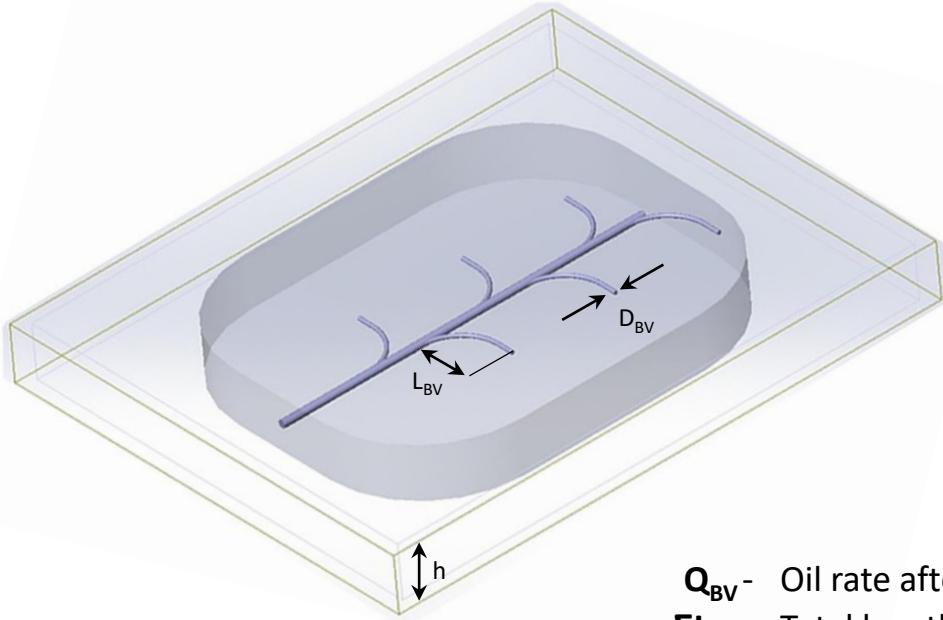


The deployment of **Blood Vessels** radial channels along a unified azimuth at the top and bottom of the formation enables the limitation of fracture growth in height under conditions where there are no geological barriers to prevent the fracture from spreading beyond the boundaries of the productive layer



8. Additional Oil Recovery Calculation

DR. S. D. JOSHI



$$Q_{BV} = \frac{0,00708 * k_h * h * (P_{res} - P_{bh}) / (\frac{\mu_0}{B_0})}{\left[\ln * \left(\frac{a + \sqrt{a^2 - (\sum L_{BV} / 2)^2}}{\sum L_{BV} / 2} \right) + \left(\frac{\beta * h}{\sum L_{BV}} \right) * \ln \left(\frac{\beta * h}{D_{BV}} \right) + S \right]}$$

- Q_{BV} - Oil rate after BV, m3/day
- $\sum L_{BV}$ - Total length of BV channels, m
- k_h - Horizontal permeability, mD
- k_v - Vertical permeability, mD
- D_{BV} - BV channel diameter, mm
- h - Reservoir effective height, m
- S - Skin-factor
- P_{res} - Reservoir pressure, atm
- P_{bh} - Bottomhole flowing pressure, atm
- M_o - In-situ oil viscosity, CP
- B_o - Formation volume factor
- a - Half of major axis of drainage ellipse, m
- β - Anisotropic factor

$$a = (\sum L_{BV} / 2) * \left[0,5 + \left[0,25 + \left(2 * \frac{r_{eh}}{\sum L_{BV}} \right)^4 \right]^{0,5} \right]^{0,5}$$

$$\beta = \left(\frac{k_h}{k_v} \right)^{0,5}$$



9.1. BV Technology Trial Job

well #718, Bukharskoe oilfield, Tatneft, Tatarstan, Russia



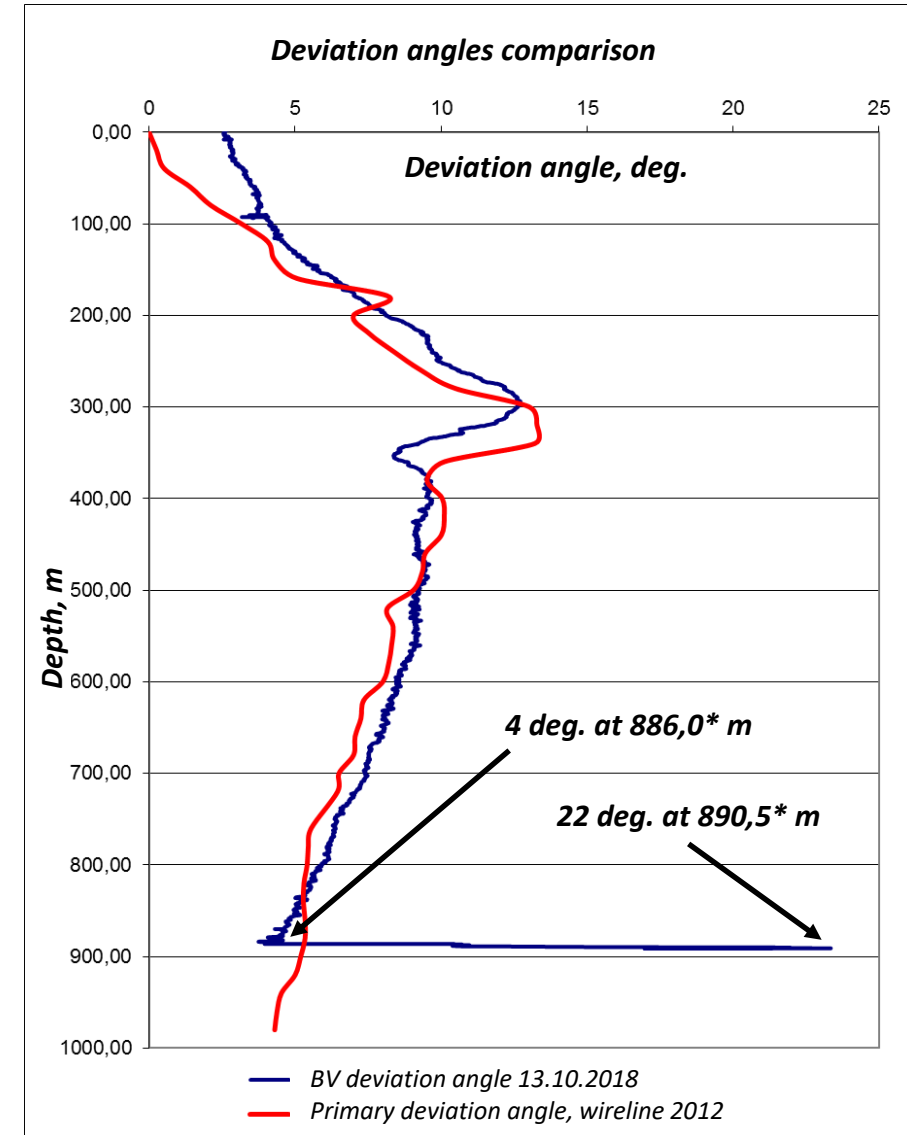
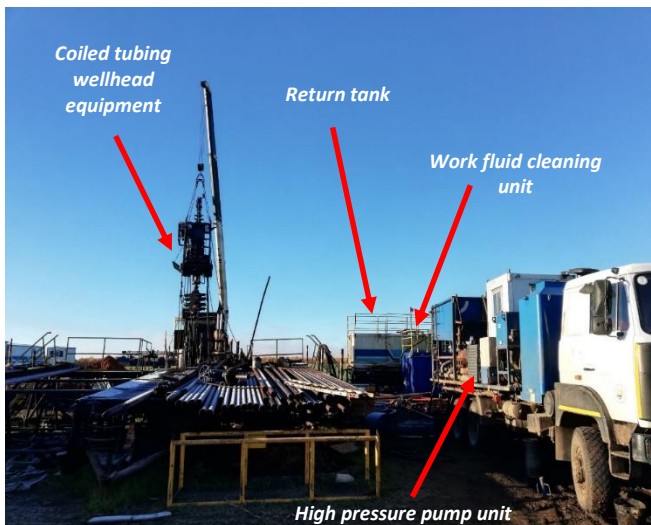
1. 4 windows were milled in casing 5 3/4" at depth 890 m during one workover run

2. 3 lateral channels were created in the formation. The channels lengths up to 35m. Drilling speed is up to 100 m/h

3. Autonomous deviation angle gauge :
- pressure testing at 600 atm.
- deviation angle building up to 22 deg.
- measurements from autonomous inclinometer are correlated with primary well inclinometry

4. 20 micron fine cleanliness fluid cleaning system was developed and introduced

5. All the developed and introduced equipment confirmed working efficiency and safety



9.2. BV Technology Trial Job

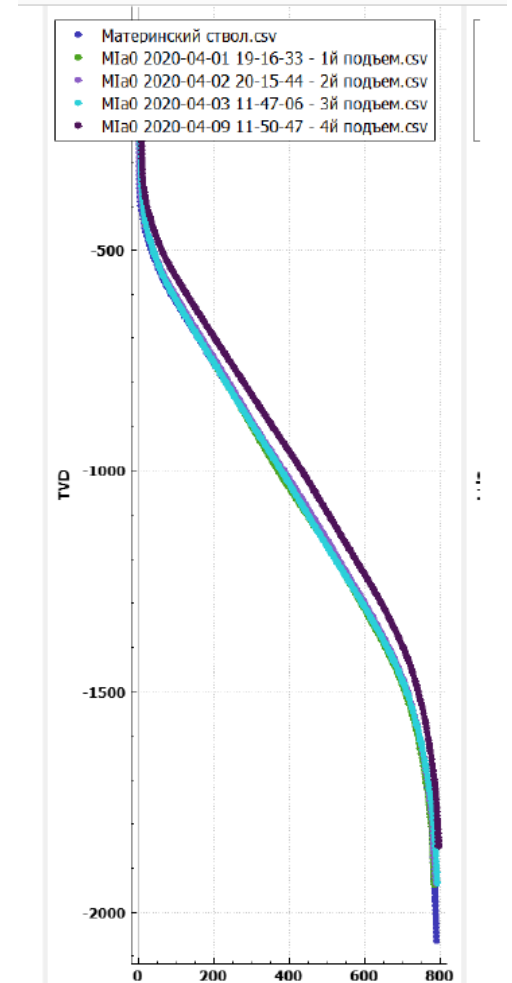
well #10, Osvanyurskoe oilfield, LUKOIL, Usinsk, Russia



Trial job performed at 2020:

1. 4 windows were milled in casing 6 5/8" grade C90 at depth 2165 m
2. System of coiled tubing whipstock orientation was introduced. The system do not require workover operations
3. Upgraded version of autonomous inclinometer with 25 mm OD was introduced. Measurements of the tool well correlate with initial inclinometry of the main bore.
4. All the special BV equipment, either for running in hole at tubing or coiled tubing, performed as planned and proved their operational lives.

Important information for further technology development was received during the well operation.



9.3 Bench tests

based on the results of pilot work at well No. 10 of the Osvanyurskoye field



In August 2020, bench tests were conducted to create seed channels before wiring the side barrels using modified hydraulic monitoring nozzles.

Conclusions.

1. It is necessary to create seed channels in strong carbonate rocks before wiring the main side shafts.
2. The possibility of creating a sequential seed and main lateral channel in solid carbonate rocks has been confirmed.
3. The technological modes of side barrel wiring used at the OPR provide sufficient power to create side barrels.



As a result of the bench tests, a result was obtained that confirms the readiness of further implementation of the technology in strong carbonate rocks using special cutting hydraulic monitor attachments.



10. Screening Criteria of BV_01 and BV_03 Technologies

1. Vertical or deviated wells 0-40 deg. (41-60* deg. optionally)
Casing OD 5.5 - 7"
2. Reservoir thickness >10 m with 10-12 m of dense rock above
3. Well depth to 3500m
4. Potential to work at idled well:
 - ALPR
 - behind-the-casing water flow
 - loss of production due to remedial cementing
 - loss of perforated interval (obstacle at 10-20m above)
 - lithologically screened deposits
6. Low permeability deposits including low permeability formations sandwiched



11. BV technology in lightly cemented sandstones with trunks attached with a propane packing.

The solution to the problem today is the installation of anti-dust filters in the window interval after the BV trunks. The effectiveness of lateral shafts in loose sandstones is confirmed by the practice of operating horizontal branched shafts of large diameter with the descent of one casing string into one trunk in comparison with the operation of horizontal wells with one cased trunk without branching.

In addition, it is possible to create a version of the BV technology with mechanical packing of the side trunks with gravel packing in combination with the descent of anti-dust filters.



12. Directions of technology development

Current

1. BV technology for cased shafts of vertical and directional wells.

It is recommended for testing at depths up to 2500m, preferably in carbonate reservoirs, with a productive reservoir capacity of 10 m.

2. BV technology in open barrels.

It is recommended for testing at depths up to 2500m, with a productive reservoir capacity of 10 m.

Development perspective

3. BV technology for cased horizontal trunks.

4. BV technology in weakly cemented sandstones with the attachment of trunks with a propane packing.

5. BV+hydraulic fracturing technology. With the wiring of the unloading side channels BV, it becomes possible to direct the development of the crack wings in the direction optimal for development.

6. BV technology in new vertical, directional and horizontal wells prior to casing descent.

7. BV technology in new vertical, directional and horizontal wells after casing descent. This direction has more obvious theoretical foundations to become a driver of horizontal drilling, provided that the completion arrangements with BV ports are developed.

8. BV technology + methods of increasing oil recovery. BV trunks in injection wells will allow you to control the hydrodynamic situation in the deposit and increase the efficiency of oil production.

9. BV technology in shales. There is a potential of BV technology in the development of unconventional hydrocarbon deposits.

10. BV technology on the shelf. The use of BV technology is particularly relevant in offshore projects and the Arctic, when environmental properties, safety, low material consumption and the cost of BV technology are of particular importance.

11. BV technology with the option of casing the side trunks with shanks.

12. BV technology for elongation of horizontal cased and open trunks in carbonate reservoirs.



*To see something new,
you need to make something new.*

1780 George Lichtenberg



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