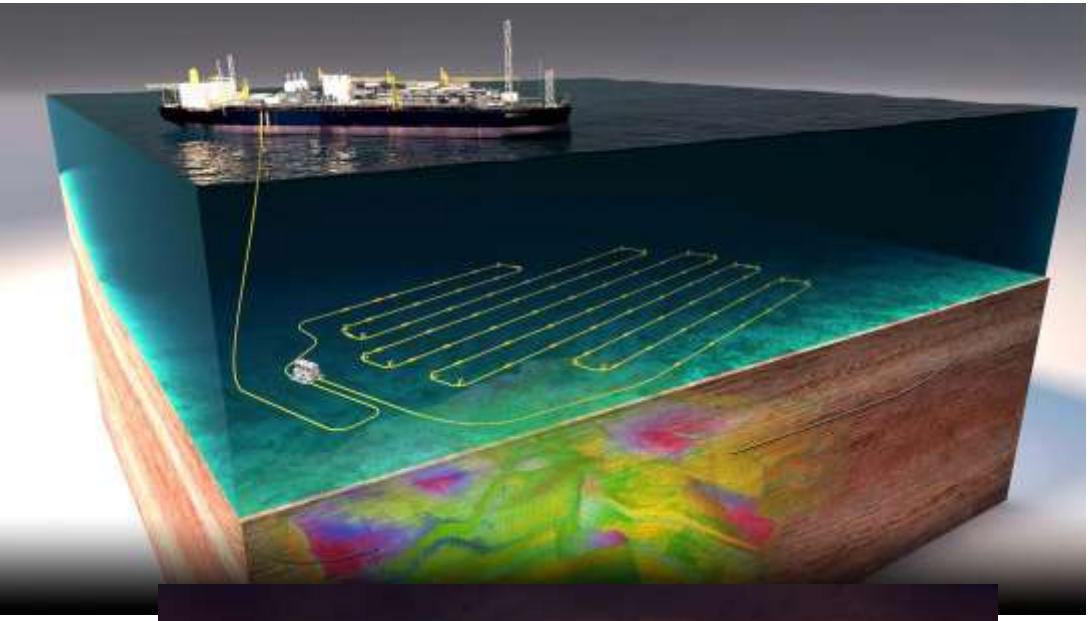
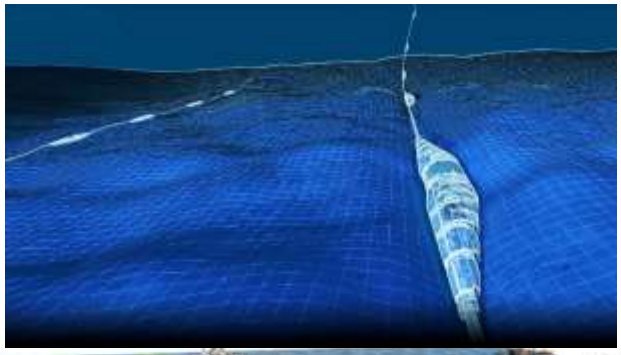
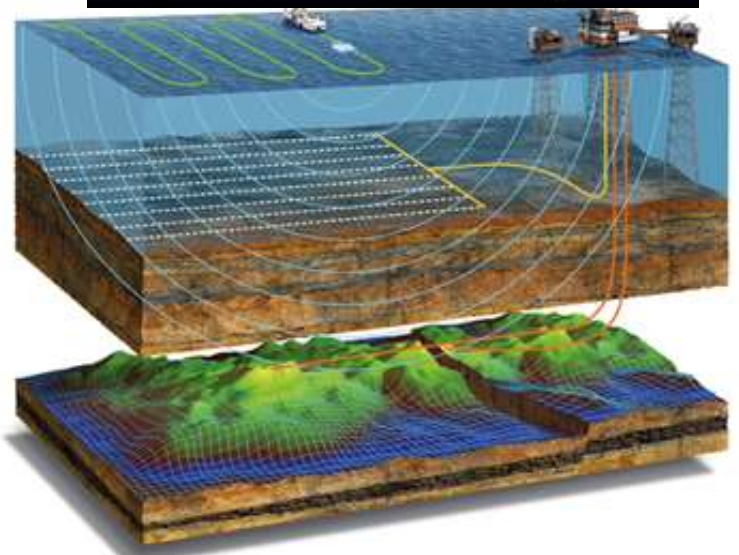
Permanent Reservoir Monitoring (PRM)





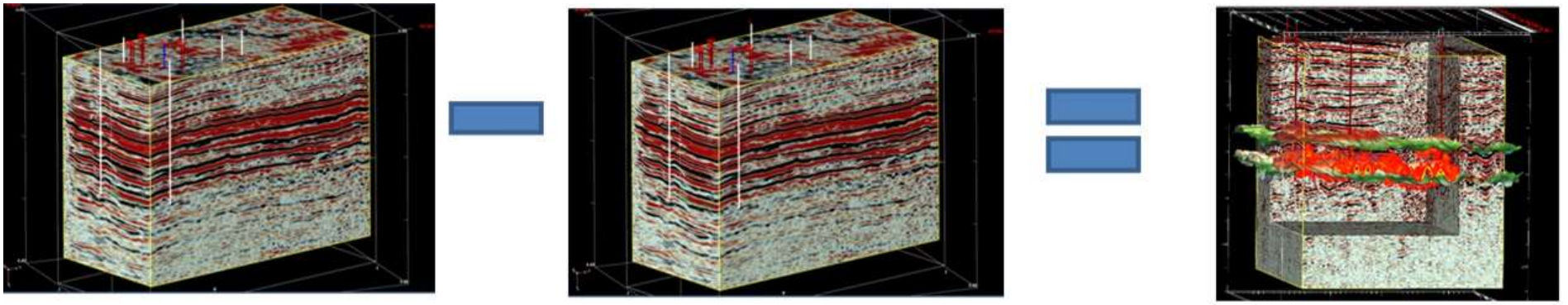


An example of total data acquisition systems

Permanent Reservoir Monitoring

Today paradigm of PRM is based on (in order of significance):

(i) 4D active seismic (subtraction of 3D reflector cubes)

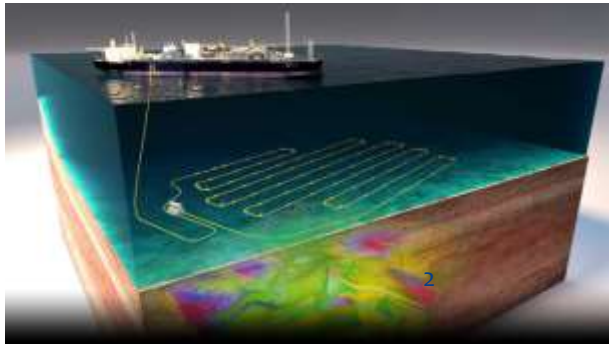


3D reflectors cube 1

3D reflectors cube 2

Subtraction of 3D reflectors cubes

(ii) Passive surface microseismic monitoring (plan to do)

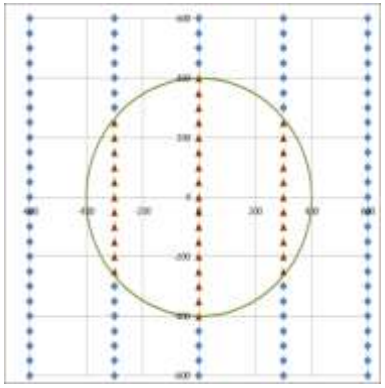


Data acquisition systems proposal (Seafloor&Land)

The layout of surface registrars:

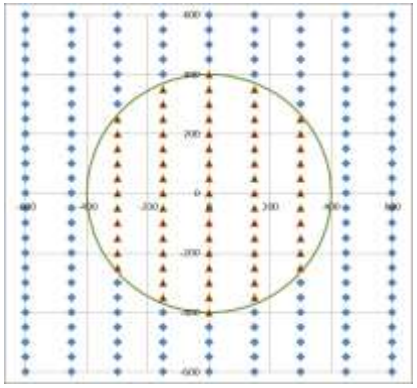
- Inline: 50 m
- Crossline: 100-150 m

Traditional scheme for 4D



Crossline: 300 m
Density of sensors: 77 sen./sq. km (39 per cycle)

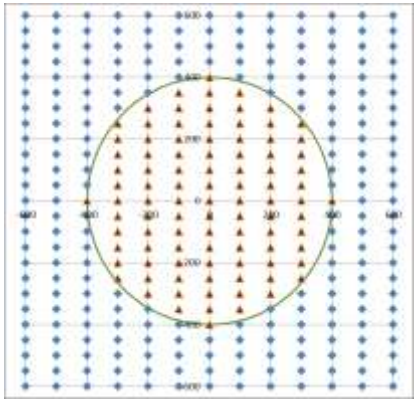
New scheme for 4D, 150m



Crossline: 150 m
Density of sensors: 137 sen./sq. km (69 per cycle)

or

New scheme for 4D, 100m

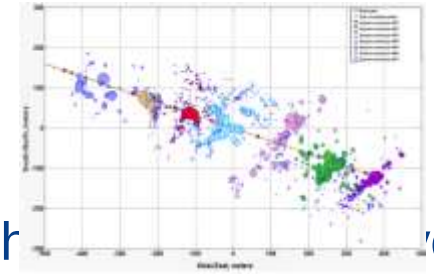


Crossline: 100 m
Density of sensors: 193 sen./sq. km (97 per cycle)

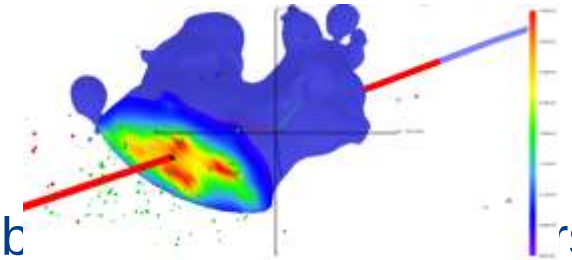
New 4DPRM Approach

New paradigm **4DPRM Approach** is based on (in order of significance):

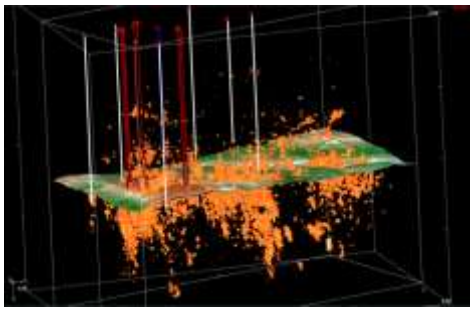
(i) The surface passive **4D MicroSeismicPRM** monitoring



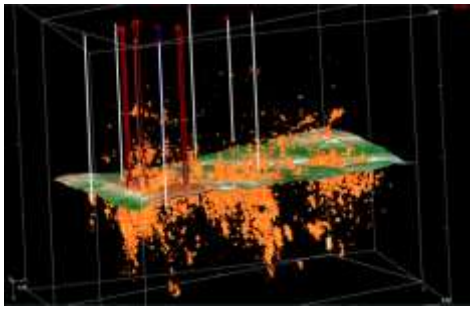
(ii) Th ve seismic (sub



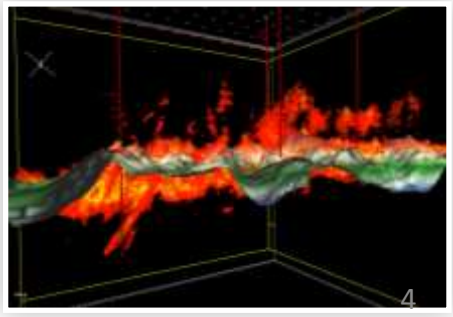
rs cubes)



3D CSPD- diffractors cube 1



3D CSPD-diffractors cube 2



Subtraction of 3D CSPD-diffractors cubes

4DPRM Approach Structure

* High-Density Data Acquisition Systems
* Smart 4DPRM Technologies
* Supercomputing Processing
* Simultaneous Joint Inversion

Pilot Smart Oil Field Project (4DPRM Approach)

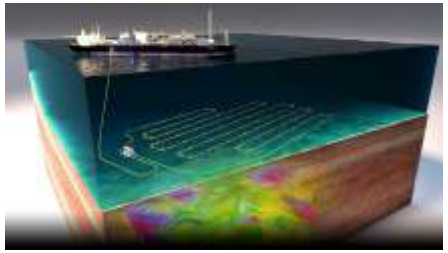
Scope of the Project:

1. Process instrumentation of the new generation of geophysical field registration
2. Application software for collection and supercomputing processing of the registered data
3. Geological and geophysical databases and knowledge bases for the development objects
4. Smart 4DPRM technologies of continuous information support of the field development
5. High-precision technologies influencing the field development process for efficient reserve recovery

List of the Main Process Components

1. Process instrumentation of the new generation of geophysical field registration

1.1. Fiber-optic system of seismic and microseismic waves registration using Bragg grating



1.2. Fiber-optic well measurement systems

1.3. Field supercomputing special-purpose matcher

1.4. Multifunctional multiprocessor PetaFlops supercomputing package

List of the Main Process Components

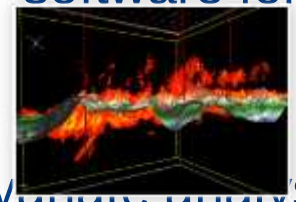
2. Application software for collection and supercomputing processing of the registered data

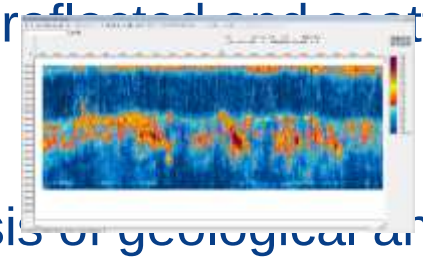
2.1. Software for collection and primary field on-line processing of microseismic monitoring data

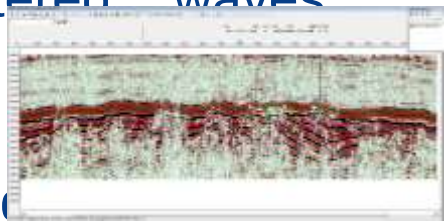
2.2. Software technologies of data-flow supercomputing processing of very large microseismic data

2.3. 4D seismic survey software for reflected and scattered waves

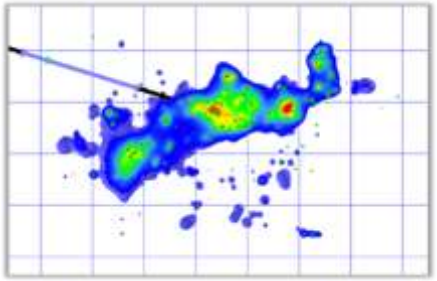
- ***CSPD 2D/3D***
- ***VPRTM 2D/3D***
- ***SVARTM 2D/3D***







2.4. Software for multivariate analysis of geological and geophysical results of permanent monitoring of the development process and 4D visualization



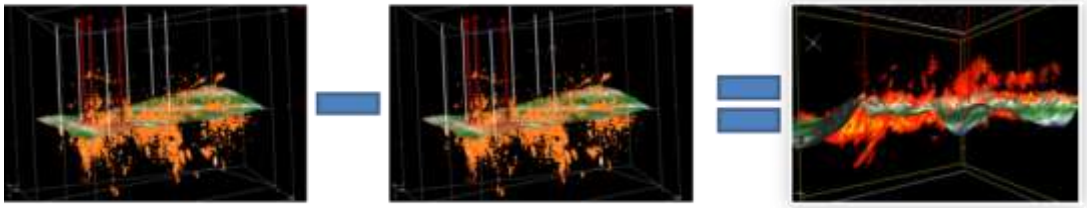
List of the Main Process Components

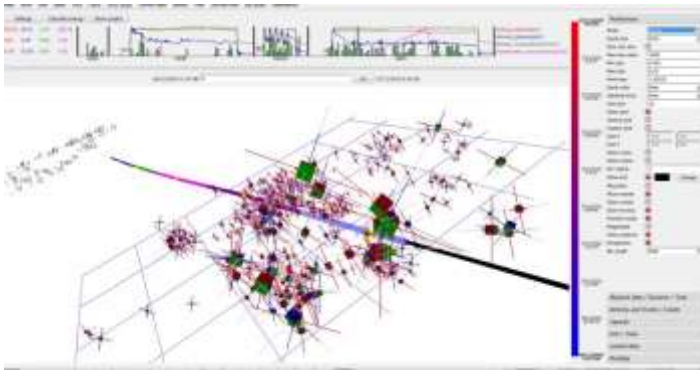
3. Geological and geophysical databases and knowledge bases for the development objects

3.1. Instrumentation of databases and knowledge bases
3.2. Knowledge engineering software

4. Smart 4DPRM technologies of continuous information support of the field development

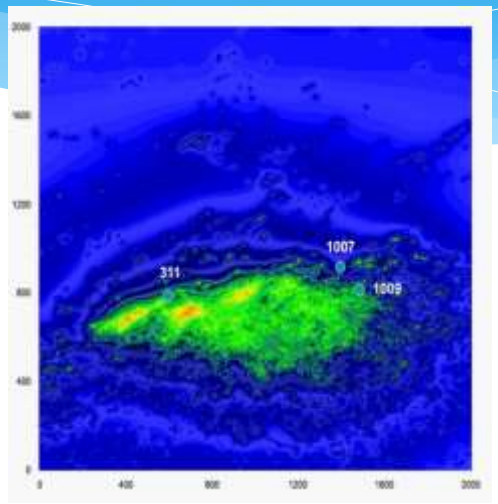
4.1. Supercomputing technologies of active seismic 4D monitoring and passive 4D microseismic monitoring:



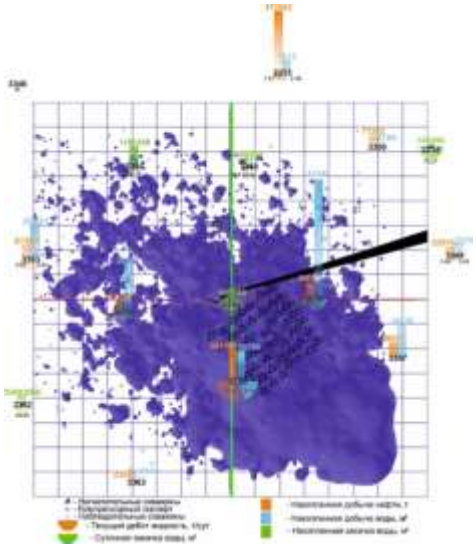


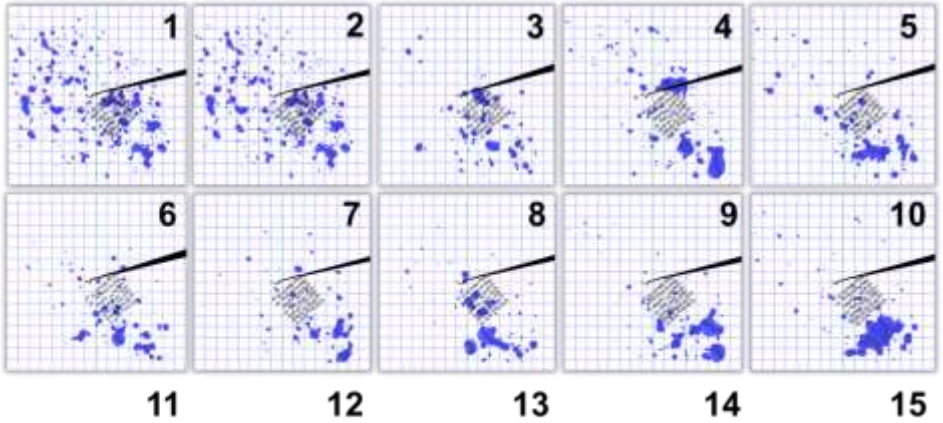
Smart 4DPRM technologies

* 4DPRM microseismic technologies to detect feed zones of production wells under depletion (the first development stage)



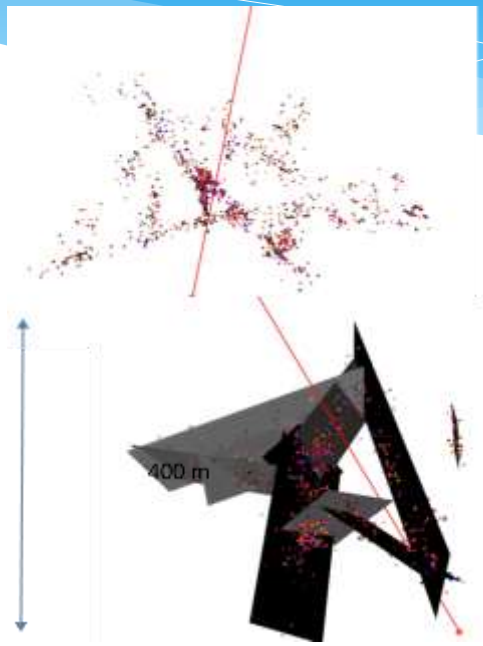
* 4DPRM microseismic technologies to control the displacement front upon injection of the active agent into the rock (the second development stage)

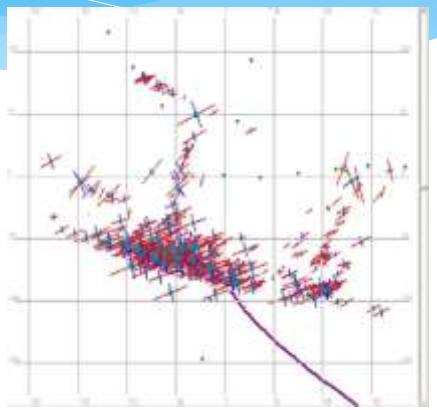




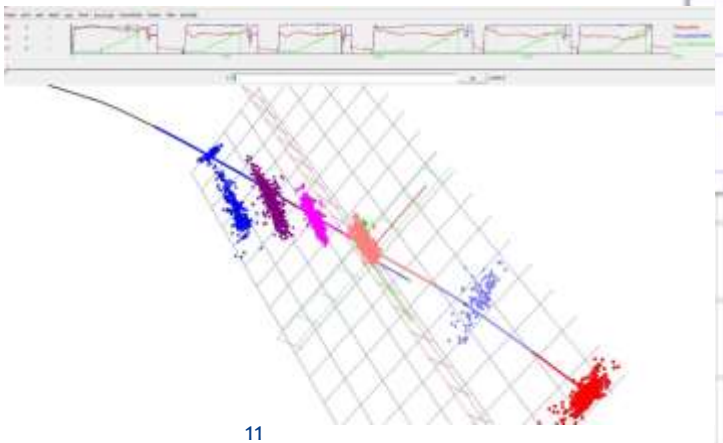
Smart 4DPRM technologies

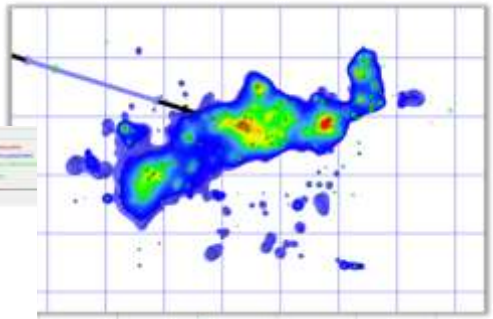
* 4DPRM microseismic technologies to plot the fault block structure near the borehole bottom (the second and the third development stages)

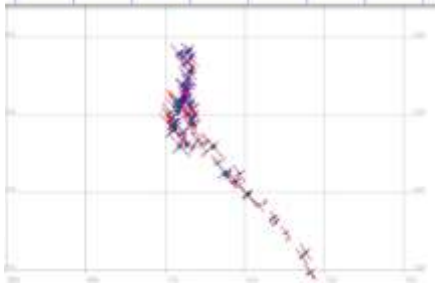




* 4DPRM microseismic technologies to control the geotechnical measures to increase oil recovery rate of reservoir intervals (drilling of inclined, horizontal, and multi-branch wells using multistage hydraulic fracturing, etc.) (the second and the third development stages)

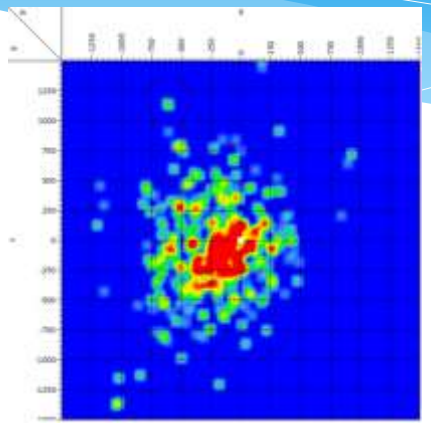


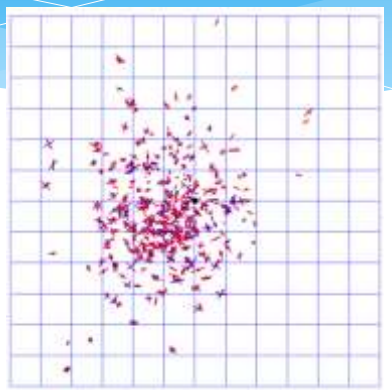


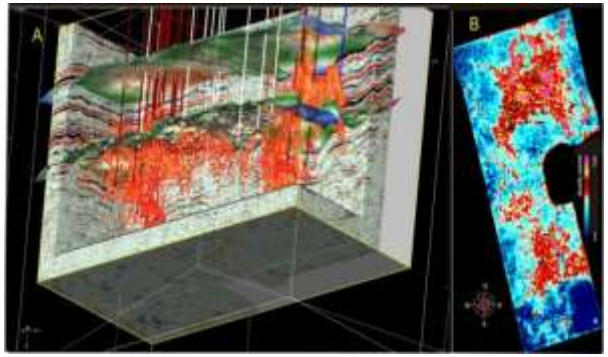


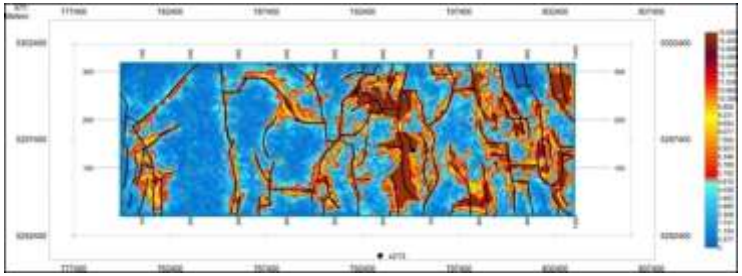
Smart 4DPRM technologies

* 4DPRM microseismic technologies to control the physical and chemical methods of enhanced oil recovery (the third development stage)
* 4DPRM microseismic technologies to control the plasma impulse stimulation (the second and the third development stage)
* 4DPRM scattered wave seismic survey for additional exploration of the hydrocarbon fields to detect new deposits with fractured reservoir rock (all development stages)



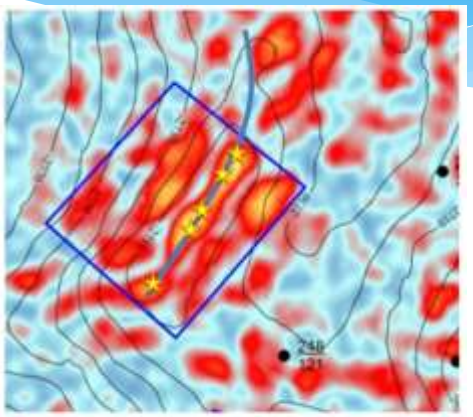


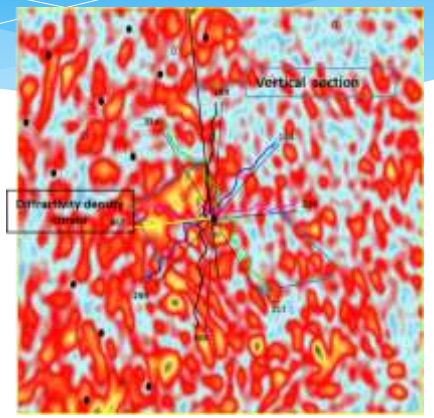


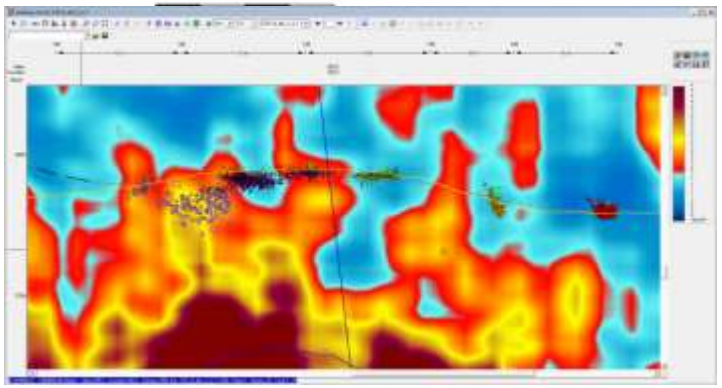


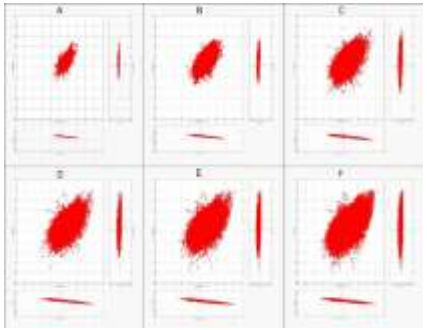
Smart 4DPRM technologies

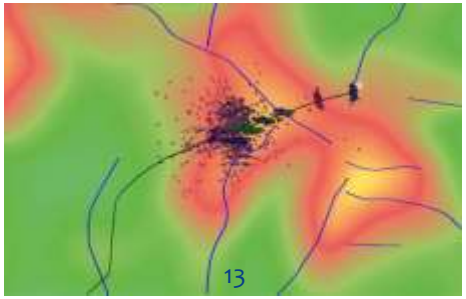
* 4DPRM scattered wave seismic survey together with 4D microseismic technologies to optimize the route of the horizontal part of the well to increase the drainage volume and ensure safe drilling (the second and the third development stages)
* 4DPRM microseismic technologies to control the flame front upon thermal gas treatment (the third development stage)

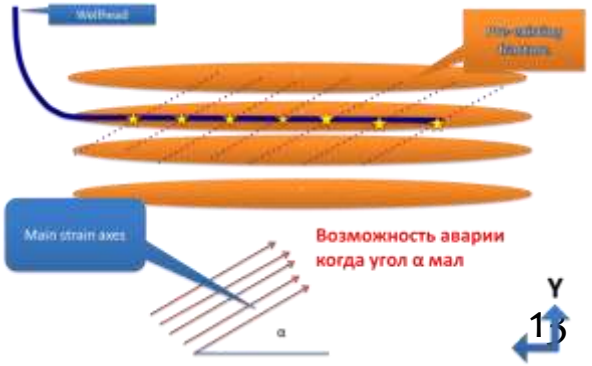












List of the Main Process Components

4.2. 2D well monitoring technologies based on fiber-optic sensors

4.3. 4D surface monitoring technologies for high-precision gravity and magnetic survey as well as electrometric

5. High-precision technologies influencing the field development process for efficient reserve recovery

5.1. Methods to intensify oil production and enhance oil recovery rate:

- drilling of horizontal bore holes with multistage hydraulic fracturing (MHF)
- drilling of inclined, horizontal, and multi-branch wells
- hydraulic fracturing upon drilling or bottom-hole deepening

List of the Main Process Components

- sidetracking with vertical or horizontal termination points
  transfer of wells to the overlying or underlying bed
  physical and chemical methods (water flooding with application of surface active agents, polymer flooding, etc.)
- gas methods (injection of hydrocarbon gases, solvent liquids, carbon dioxide, nitrogen, flue gas)
- thermal recovery methods (displacement of oil using heat transfer agents, impact by means of intraformational, heat-generating oxidative reactions - thermal gas)
- microbiological methods (injection of bacterial agents into the rock

5.2. Wave methods to influence the rock

- vibration technologies to influence the rock upon injection of fluids to intensify oil production and increase the intake capacity
- depression seismic stimulation of oil production