



КАЗАНСКИЙ (ПРИВОЛЖСКИЙ) ФЕДЕРАЛЬНЫЙ УНИВЕРСИТЕТ

# Development of new tools for NMR well logging and core study

Kazan, December 2015



# New NMR logging tools

## Purpose :

The maximum of a investigation depth

Scanning of a fluid saturation of cores on the boring

Multiple and multi-dimensional logging

Logging of solid-state components of hydrocarbons

## Device:

“NML-1”

The NMR logging centric tool. Measurements after drilling.

“Core1-8”

The mobile NMR device for investigation of full-size cores

“CMRL” (the project finish)

The NMR logging centric tool. Measurements after drilling. Multi-frequencies NML logging tool joint with Wave Dielectric Logging tool

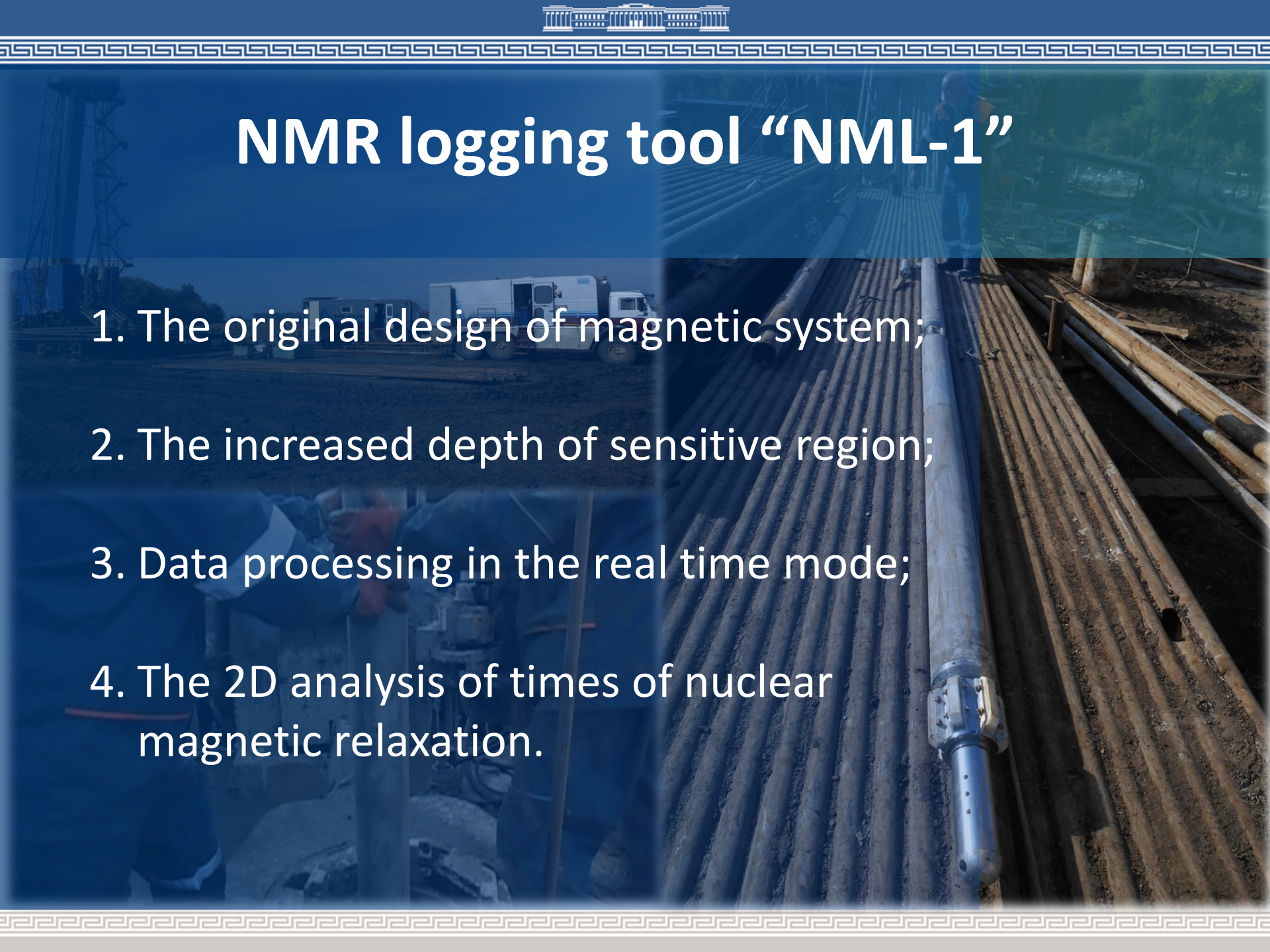
“WDHR” (in the project)

The NMR logging decentered tool



# NMR logging tool “NML-1”

1. The original design of magnetic system;
2. The increased depth of sensitive region;
3. Data processing in the real time mode;
4. The 2D analysis of times of nuclear magnetic relaxation.







# NMR logging tool “NML-1”

## **Purpose:**

Avoidance of effects of an infiltration of drilling mud on data of a nuclear magnetic logging..

## **Scope of Application:**

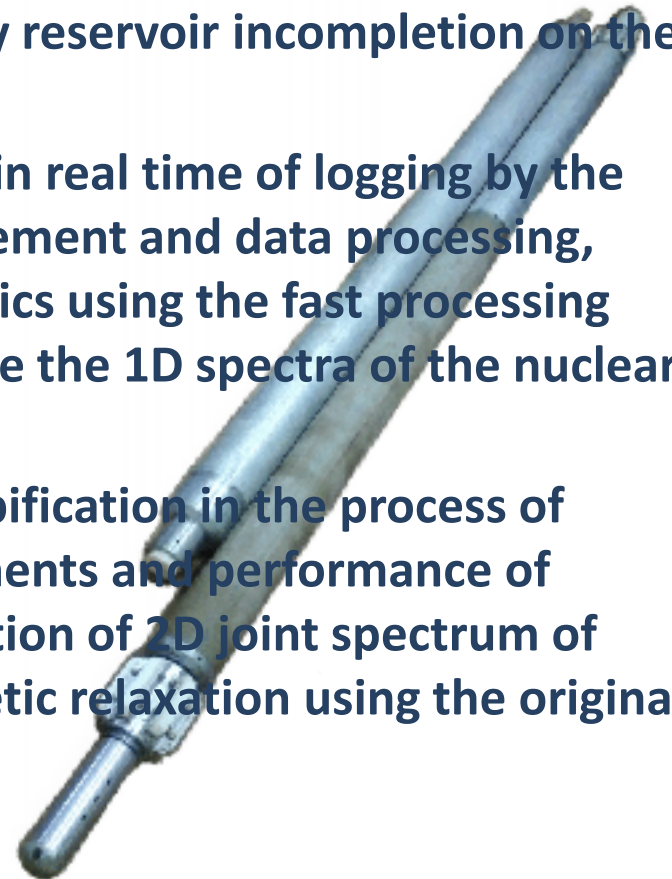
NMR logging and oil reservoir characterization in real time.





# Distinctive features of the tool

- increased depth of the investigation, which allows excluding the influence of the drilling fluid infiltration and integrity reservoir incompleteness on the logging as a result of drilling;
- evaluation of oil reservoir characteristics in real time of logging by the automated control system of data measurement and data processing, which allows quick calculation characteristics using the fast processing algorithms of NMR logging data to calculate the 1D spectra of the nuclear transverse relaxation times;
- the possibility of the oil reservoir fluids typification in the process of logging by suspending the basic measurements and performance of additional measurements with the calculation of 2D joint spectrum of transverse ( $T_2$ ) and longitudinal ( $T_1$ ) magnetic relaxation using the original fast algorithm.



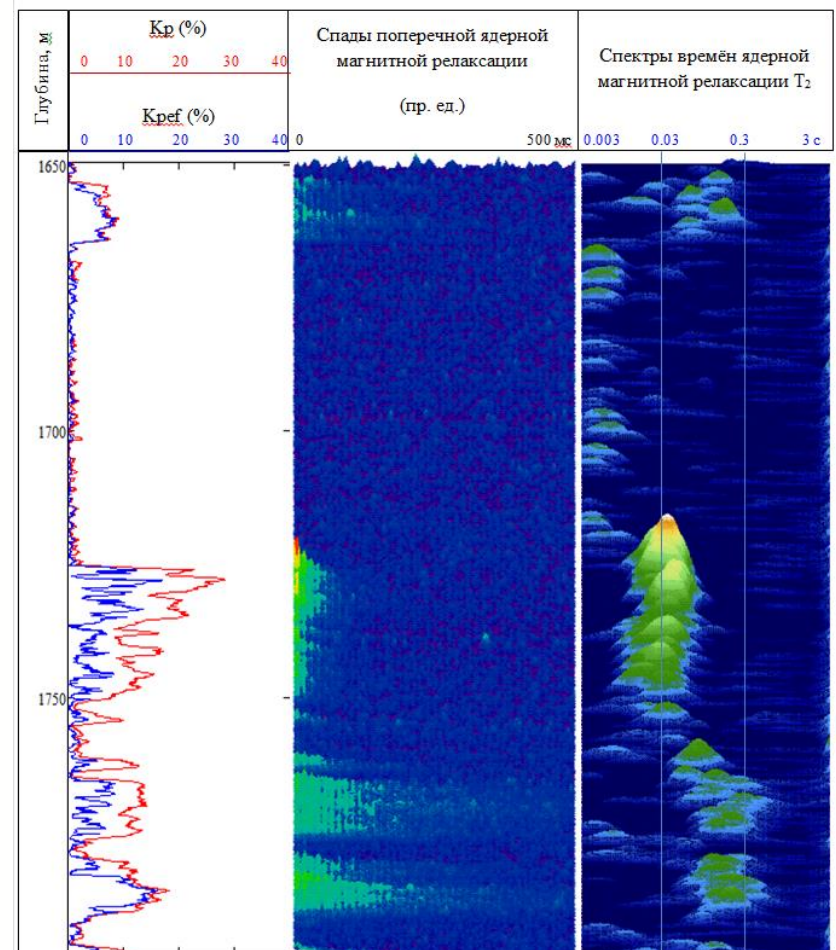
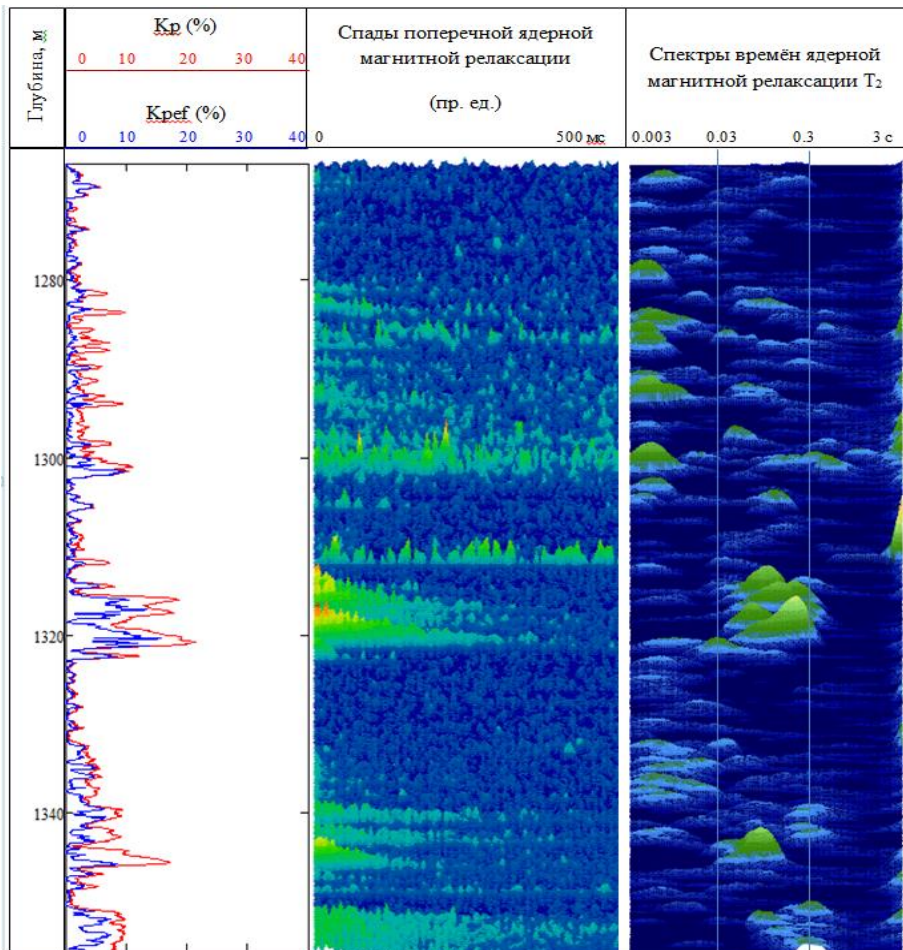
# Technical specifications of “NML-1”



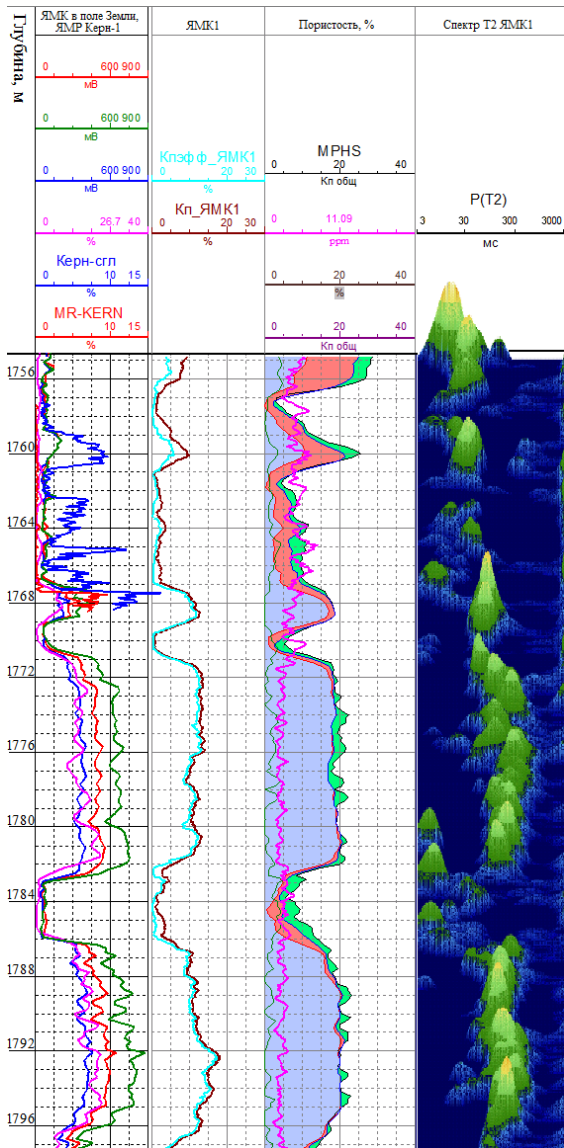
- Type of the logging tool - centric;
- Size of study field - toroid coaxial to the tool;
- **depth of investigation (radius to the resonance from the instrument axis) - 185 до 215 mm;**
- resonance field thickness - 30 mm;
- Resonance frequency on  $^1\text{H}$  nuclei - 362 kHz;
- Ranges of measured characteristics:
  - spin-spin relaxation times ( $T_2$ ) - 0.003 ÷ 3 sec;
  - spin-lattice relaxation times ( $T_1$ ) - 0.01 ÷ 10 sec;
- NMR porosity ( $\varphi$ ) - 1÷100%;
- Characteristics measurement mode - real time mode;
- **The vertical resolution - 30 mm.**



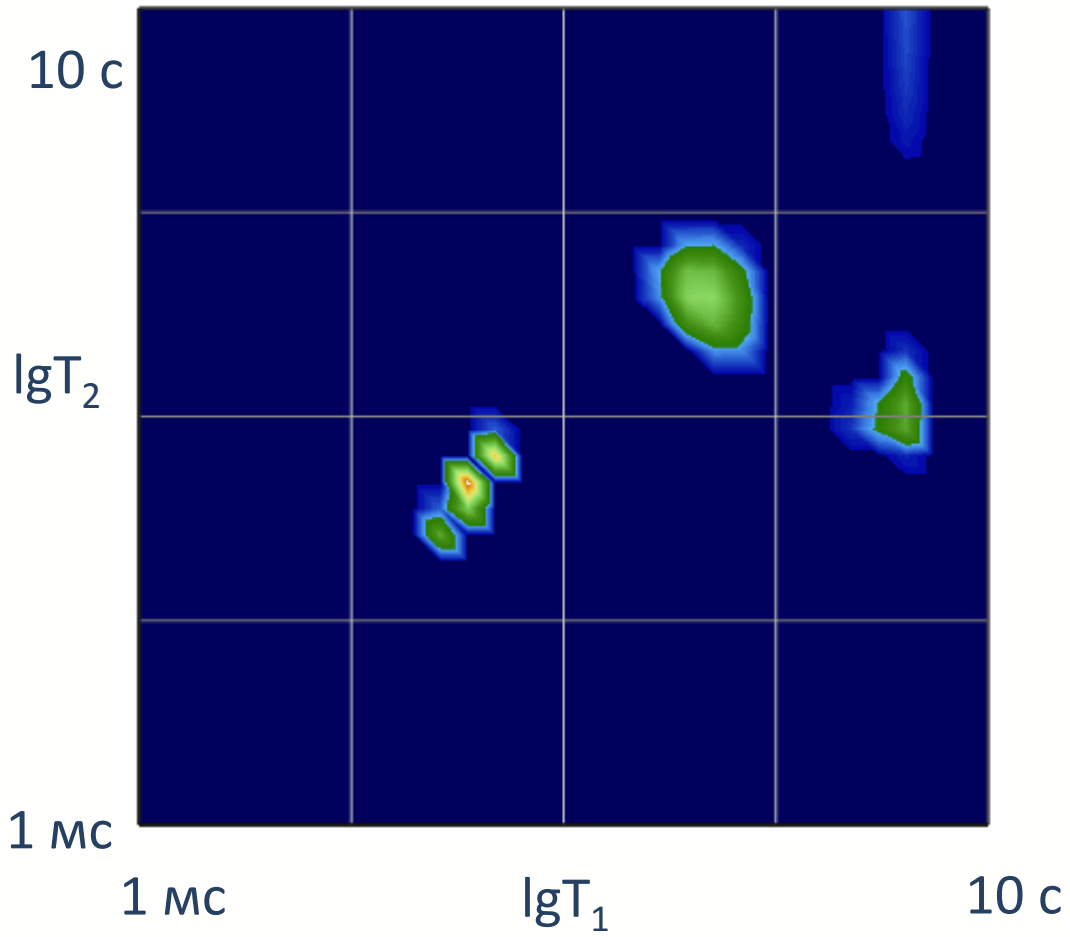
# Primary logging data







# 2D-plot T2-T1

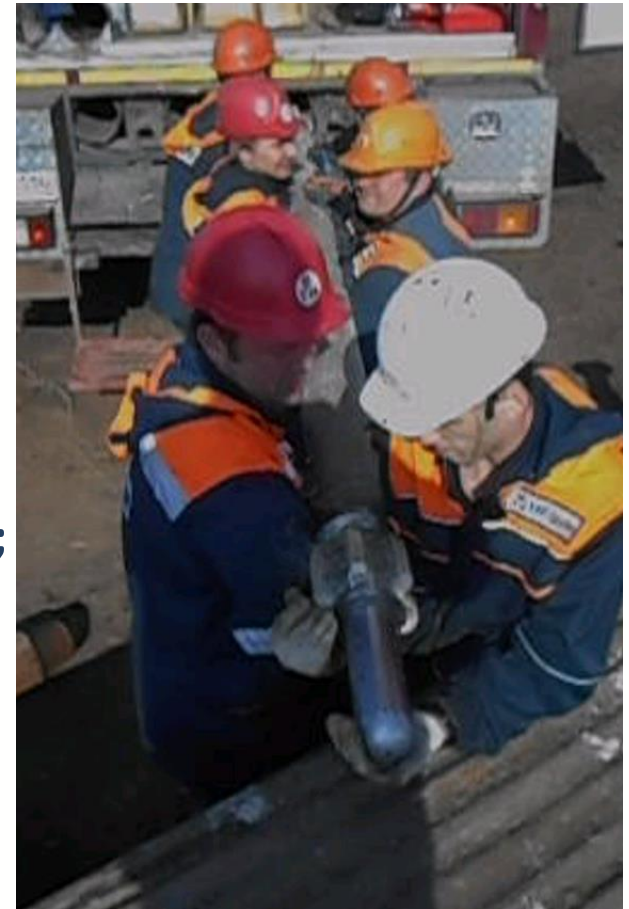






# Operational features

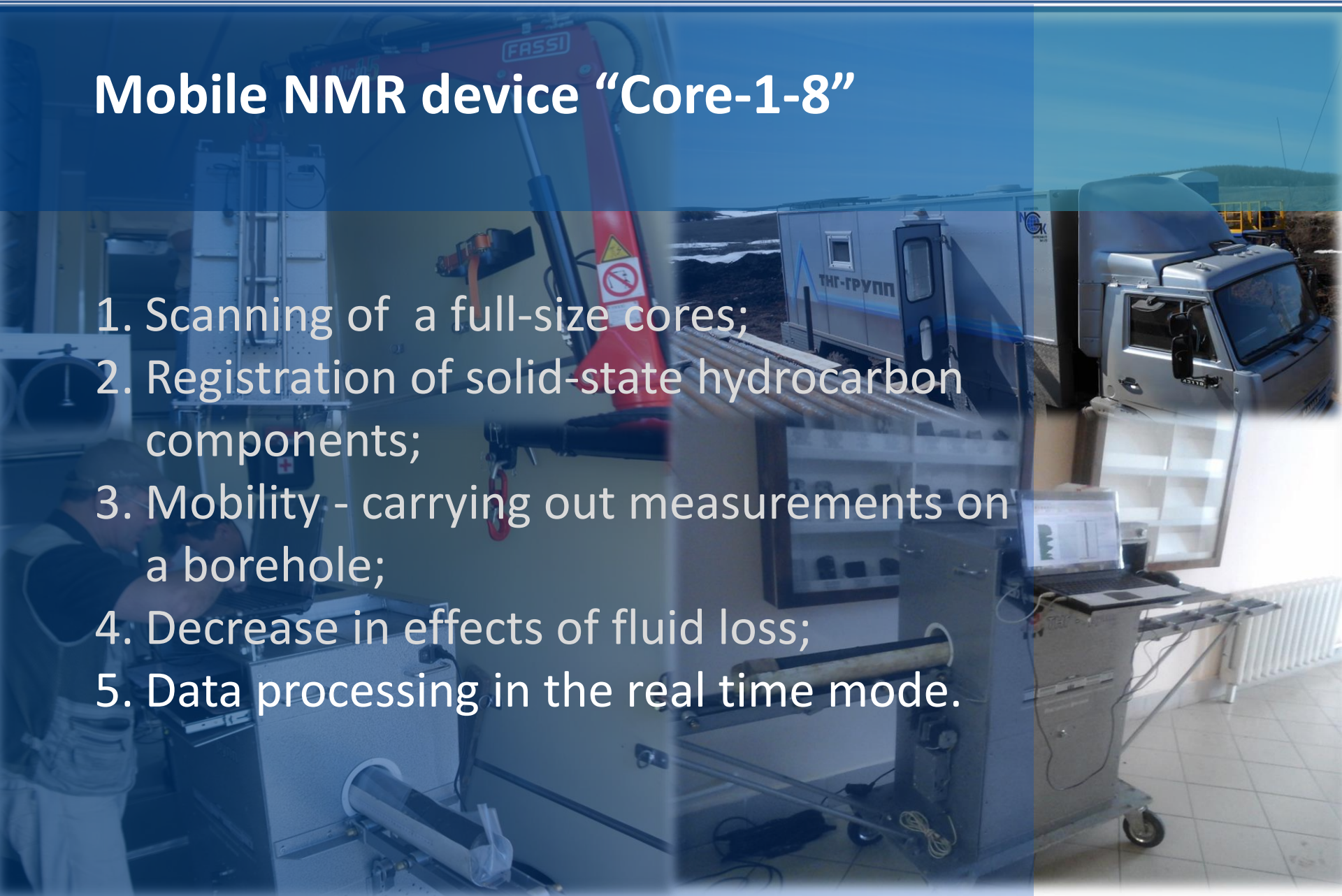
- Logging rate at lifting - 50÷200 m/h;
- Preparing time for the tool use - 40 min;
- Dimensions in use:
  - diameter of the tool body - 155 mm;
  - diameter of centralizer - 176 mm;
  - **length of the tool - 7.1 m;**
  - **weight - 250 kg;**
- Dimensions in transportation:
  - length of separable modules - 3.1 and 4.0 m;
  - weight of modules - 100 and 150 kg;
- Permissible borehole diameter - 190÷295 mm;
- Permissible drift of the borehole - to 30°;
- **Maximum operating pressure - 800 atm;**
- **Maximum operating temperature - to 150 °C.**





# Mobile NMR device “Core-1-8”

1. Scanning of a full-size cores;
2. Registration of solid-state hydrocarbon components;
3. Mobility - carrying out measurements on a borehole;
4. Decrease in effects of fluid loss;
5. Data processing in the real time mode.





# Mobile NMR tool «Core-1-8»

## Purpose:

nondestructive prompt logging (rapid method for analysis of the core samples) using nuclear magnetic resonance (NMR) data.

## Scope of Application:

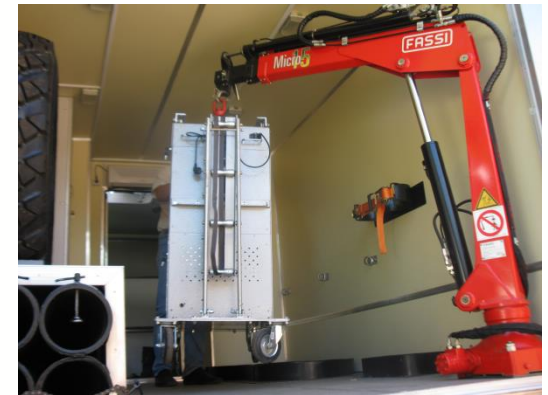
- rapid analysis of the core samples taken from prospecting, exploration and producing wells;
- perform of the laboratory petrophysical investigations.



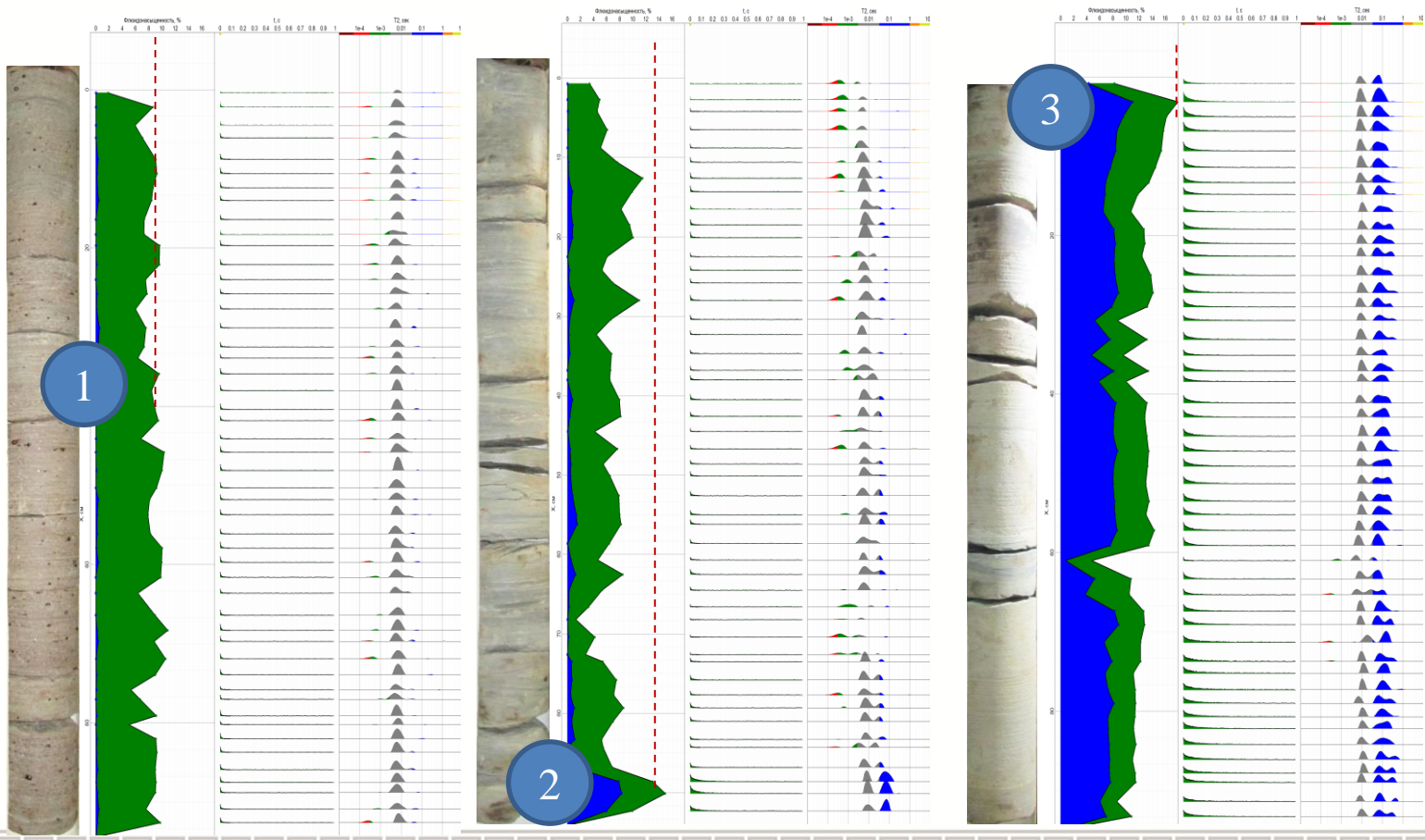
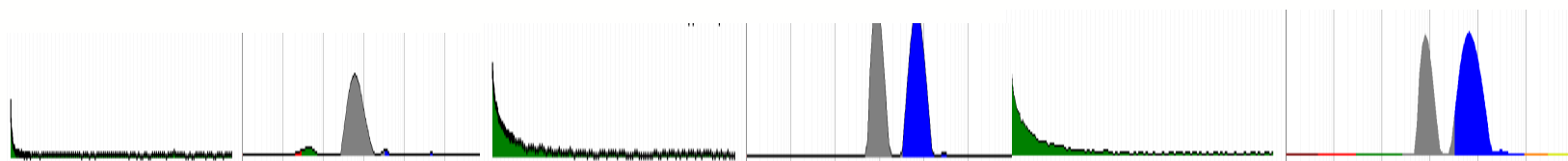


# Distinctive features of the device

- **high sensitivity of the tool** due to application of a magnetic system with the strong and highly homogeneous field;
- wide range of measured values of transverse nuclear magnetic relaxation times and self-diffusion coefficients;
- **registration of solid-state hydrocarbon components;**
- **automatic positioning of a core sample** while scanning;
- **automated measurement and data processing system**, which allows real-time calculation of the spin-spin relaxation times spectra while scanning.



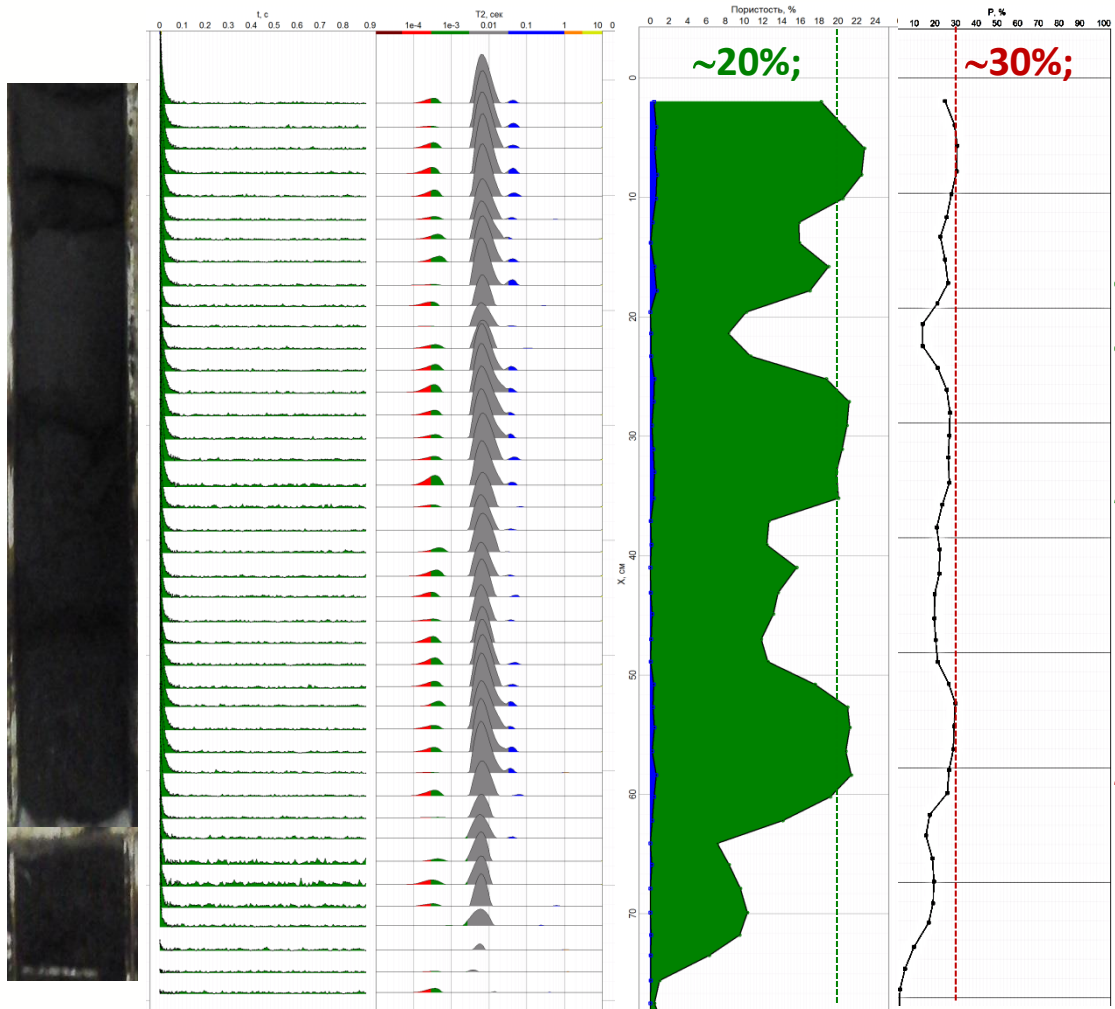
# Scanning plots of cores



**cracks  
breaks**



# NMR-porosity and content of hydrogen



Total NMR-porosity

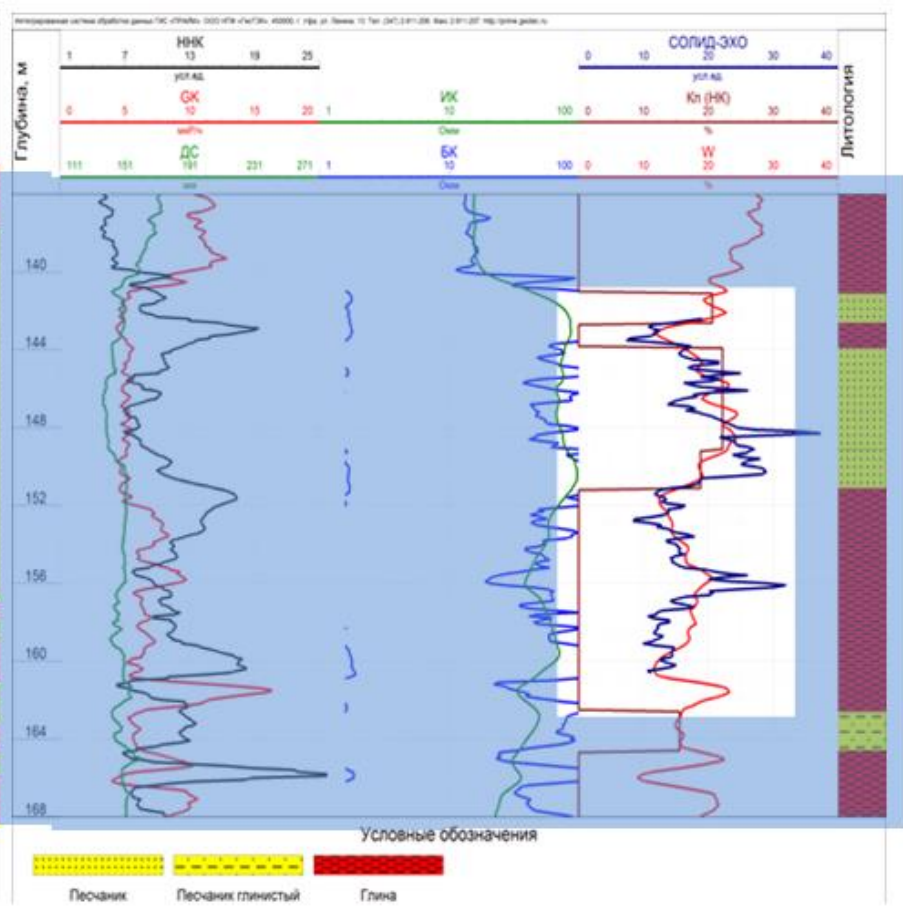
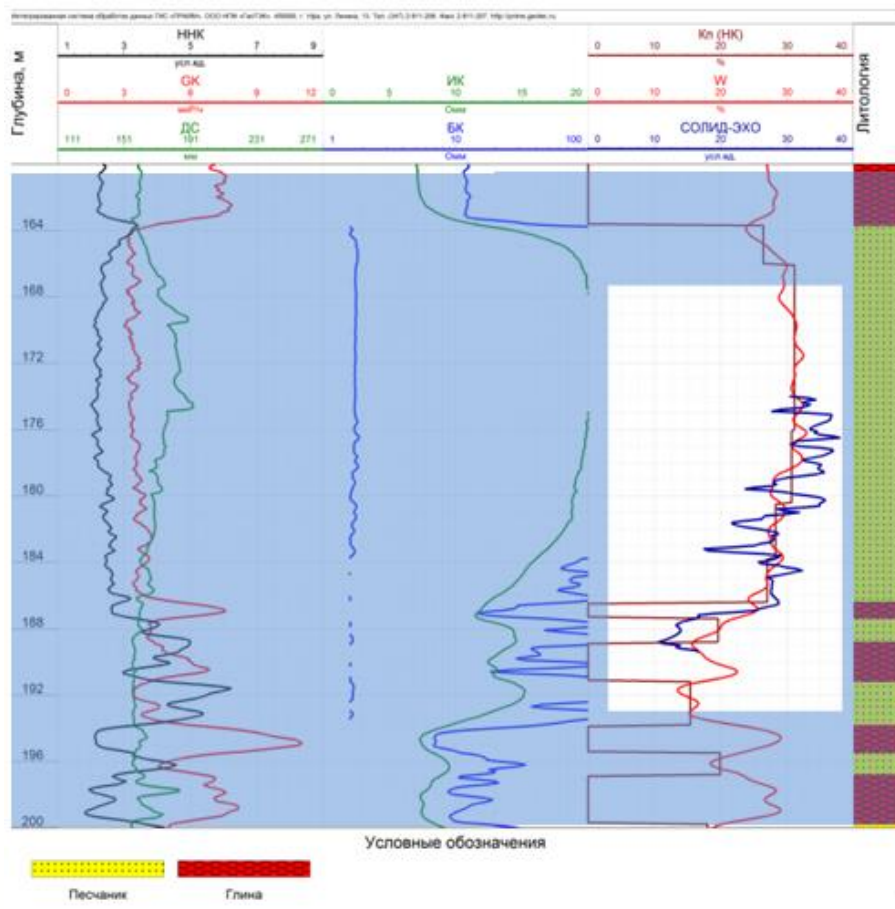
Content of hydrogen

- Registration by standard activation  $T_2$ :
  - shift of a range of times of  $T_2$  in area less than  $500 \mu s$ .
  - total NMR-porosity  $\sim 20\%$ ;
- Registration by sequence "solid-echo"
  - Content of hydrogen  $\sim 30\%$ .





# Comparison with neutron logging



1 - neutron logging

2 - "solid echo" NMR



# Technical characteristics

- Diameter of the core sample - not more than 116 mm;
- The maximum length of the core sample - 1500 mm;
- Resonance frequency (on 1H nuclei) - 8,21 MHz;
- Maximum pulsed magnetic field gradient - 1 T/m;
- Weight of the mobile tool - 350 kg;
- Dimensions (height/width/depth):
  - in transportation - 1450 / 950/ 620 mm
  - in use - 1450 / 3050 / 620 mm;



**Analogs of the tool are absent.**

# Operational characteristics

- Core sample positioning accuracy - 1 mm;
- Space resolution along the core sample - 10 mm;
- Ranges of measured parameters:
  - spin-spin relaxation rate ( $T_2$ ) - 0,00005÷5 sec;
  - spin-lattice relaxation time ( $T_1$ ) - 0,01÷10 sec;
  - NMR-porosity ( $\varphi$ ) - 0,2÷100%;
  - self diffusion coefficients ( $D_s$ ) - 10<sup>-8</sup>÷10<sup>-12</sup> m<sup>2</sup>/sec;
  - hydrogen <sup>1</sup>H content (in compare with H<sub>2</sub>O) - 1÷100%;
- Scanning time of the 1.0 m core sample with 1 cm scanning step
  - while only NMR-porosity is measured (with 1 acquisition) - 3 min;
  - while spin-lattice relaxation time ( $T_1$ ) or self-diffusion coefficients ( $D_s$ ) is measured (with 1 acquisition) - 41 min.







**Thank you  
for your attention!**





КАЗАНСКИЙ (ПРИВОЛЖСКИЙ) ФЕДЕРАЛЬНЫЙ УНИВЕРСИТЕТ

ИНСТИТУТ ФИЗИКИ  
ИНСТИТУТ ГЕОЛОГИИ И  
НЕФТЕГАЗОВЫХ ТЕХНОЛОГИЙ

Научно-образовательный центр  
«ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ И  
ГЕОФИЗИЧЕСКИХ ИЗЫСКАНИЙ»

**ЯМР каротаж**  
**NMR logging**

Октябрь 2014 г.

