A SOFTWARE COMPLEX FOR CORE DATA PROCESSING WHEN ASSESSING HYDROCARBON RESERVES UNDER UNCERTAINTY

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Abstract: *to assess hydrocarbon reserves in the oil and gas industry, large volumes of diverse geological and geophysical information should be processed. There are high risks of wrong assessment of hydrocarbon reserves in case of inaccurate information or absence thereof.*

Hydrocarbon reserves are assessed at the initial stages of studying the field information; therefore, probabilistic fuzzy methods of reserves assessment are of interest since the deterministic assessment does not allow honoring errors. An adequate assessment of volumetrics in complex conditions, in case of unconventional and promising reserves of complex structure is necessary. The modern Digital Core technology is considered promising and high-potential. An integrated approach to the solution of problems with the use of all data available on complex oil and gas reservoirs is required.

The main work methods are probabilistic methods, fuzzy set theory and fuzzy logic, and recognition methods. The paper describes a complex of software which uses an integrated approach covering both the model of reserves estimation and determination of volumetrics and applying new modern intellectual computing technologies of information processing when assessing hydrocarbon reserves under uncertainty:

- *Probabilistic and fuzzy methods of reserves assessment and determination of volumetrics under different-type uncertainty and risks for gas, gas-condensate, and oil fields*
- *Comprehensive assessment of NTG and oil-saturated areas based on pictures of cores in day and ultra-violet light*
- *Fracture recognition, defining geometrical characteristics, fracture porosity and permeability based on micro-pictures of thin sections and core CT-scans.*

The software complex is intended for quality improvement when assessing hydrocarbon reserves and improving reliability of volumetrics determination under conditions of missing or insufficient data [8].

Keywords: *a software complex, pictures of core in day and ultra-violet light, criteria for evaluation of NTG and oil saturation, fracturing parameters, pictures of thin sections, CT-scans of cores, image recognition, assessment of oil reserves under uncertainty.*

КОМПЛЕКС ПРОГРАММ ДЛЯ ОБРАБОТКИ ИНФОРМАЦИИ ПО КЕРНУ ПРИ ОЦЕНКЕ ЗАПАСОВ УГЛЕВОДОРОДОВ В УСЛОВИЯХ НЕОПРЕДЕЛЕННОСТИ

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Аннотация: *для оценки запасов углеводородов в нефтегазовой отрасли необходимо обрабатывать большие объемы разнообразной геолого-геофизической информации. Существуют высокие риски неправильной оценки запасов углеводородов в случае недостоверной информации или ее отсутствия.*

Оценка запасов углеводородов производится на начальных этапах изучения информации о месторождении; следовательно, вероятностные нечеткие методы оценки запасов представляют интерес, поскольку детерминированная оценка не позволяет учитывать погрешность расчетов. Необходима адекватная оценка параметров в сложных условиях, при нетрадиционных и трудноизвлекаемых запасах. Перспективной считается современная технология «Цифровой керн». Необходим комплексный подход к решению проблем с использованием всех имеющихся данных о сложных нефтяных и газовых объектах.

Основными методами работы являются вероятностные методы, теория нечетких множеств и нечеткая логика, методы распознавания. Описан комплекс программного обеспечения, использующий комплексный подход, охватывающий как модель оценки запасов и определения объемов, так и применение новых современных интеллектуальных вычислительных технологий обработки информации при оценке запасов углеводородов в условиях неопределенности:

• Вероятностные и нечеткие методы оценки запасов и определения объемов при различных типах неопределенности и рисков для газовых, газоконденсатных и нефтяных месторождений.
• Комплексная оценка NTG и нефтенасыщенных участков по полноразмерным фотографиям керна в дневном и ультрафиолетовом свете
• Распознавание трещин, определение геометрических характеристик, пористости трещин и проницаемости по микроснимкам петрографических шлифов и томограммам керна.
Комплекс программного обеспечения предназначен для повышения качества при оценке запасов углеводородов и повышения надежности определения объема в условиях отсутствия или недостаточности данных [8].
Ключевые слова: *Программный комплекс, снимки керна в дневном и ультрафиолетовом свете, критерии оценки NTG и нефтенасыщенности, параметры трещиноватости, снимки шлифов, томограммы керна, распознавание изображений, оценка запасов нефти в условиях неопределенности.*

Relevance

In oil and gas industry, processing of large volumes of diverse geological and geophysical and commercial information is necessary for assessment of hydrocarbon reserves. There are high risks of wrong assessment of hydrocarbon reserves due to lack of or incorrect information.

Purpose

The software complex is intended for core information processing for assessment of HC reserves under uncertainty [10].

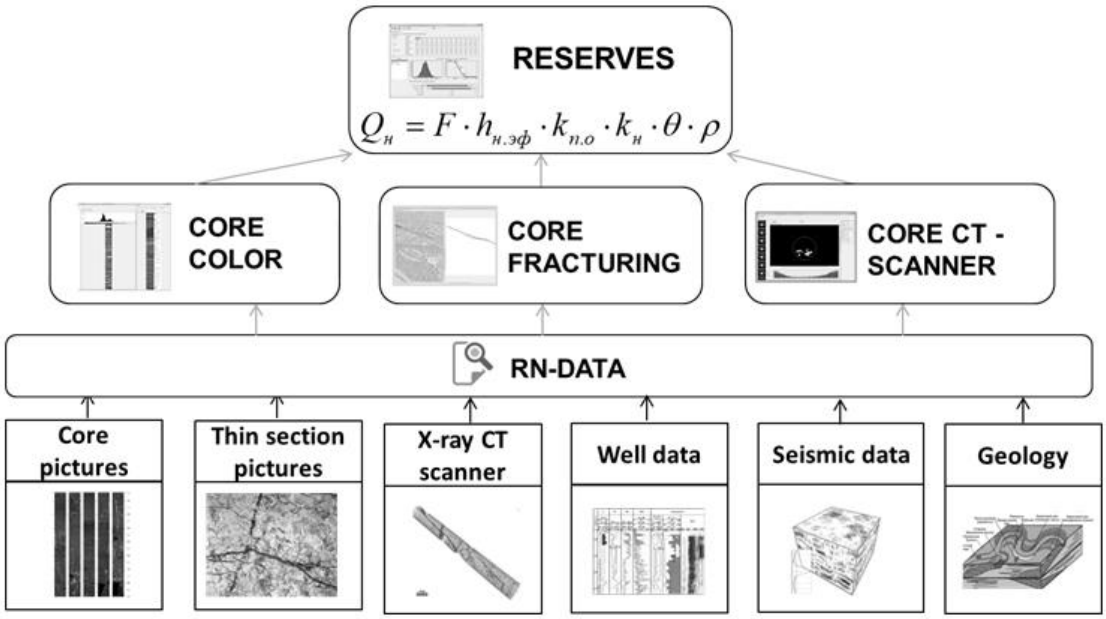

Fig. 1. A diagram of the software complex functions

Scope

The software complex is applied to data processing at any stage of building a geological model of an oilfield under conditions of insufficient and lack of data and complex geology (thin-layered reservoirs).

Research Methods

Methods of mathematical modeling, probabilistic methods, fuzzy sets theory, image recognition, and analytical and numerical algorithms.

Technological Process of Receiving Input Data

The Tyumen Petroleum Research Center is an institute specializing in the studies of cores and formation fluids by applying modern technologies. The technological process is ensured by high-precision equipment which allows to receive input information for the SW complex operation.

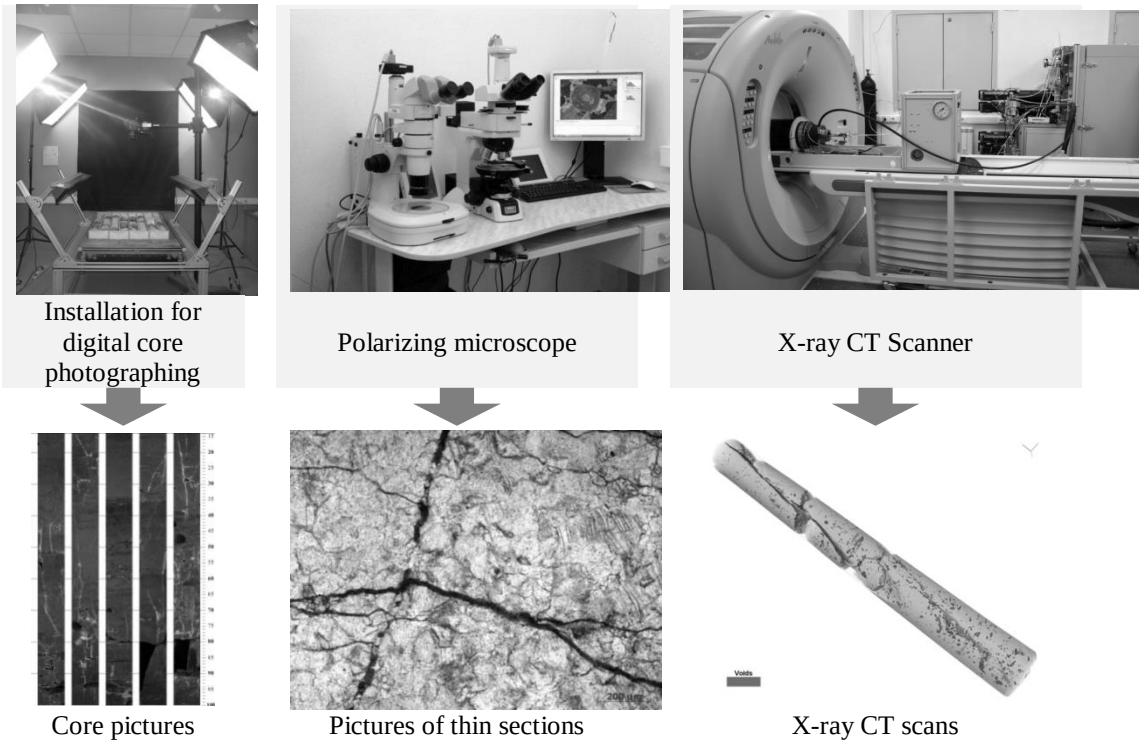

Fig. 2. Receiving high-quality core information

Evaluation of calculated parameters from alternative sources - the CORE COLOR Module

A reliable assessment of reserves requires an accurate determination of petrophysical parameters: area, thickness, porosity, and oil saturation. Of particular difficulty are situations with lack of/insufficient data, complex geological conditions (such as thin-layered reservoirs), and insufficient resolution of well logging data. The software package implements techniques that are alternative to the standard options for determining the volumetrics from high-precision digital data. Alternative sources of information are digital core pictures.

Core Photo is a bitmap image of array pixels. Digital processing of core pictures in day and ultraviolet light is performed for preliminary estimate of petrophysical parameters (Fig. 3).

- The algorithm is based on a color-vision model (Fig. 4).
- A comprehensive assessment of NTG and oil-saturated areas.
- Building pseudo-logging curves for assessment of petrophysical parameters.

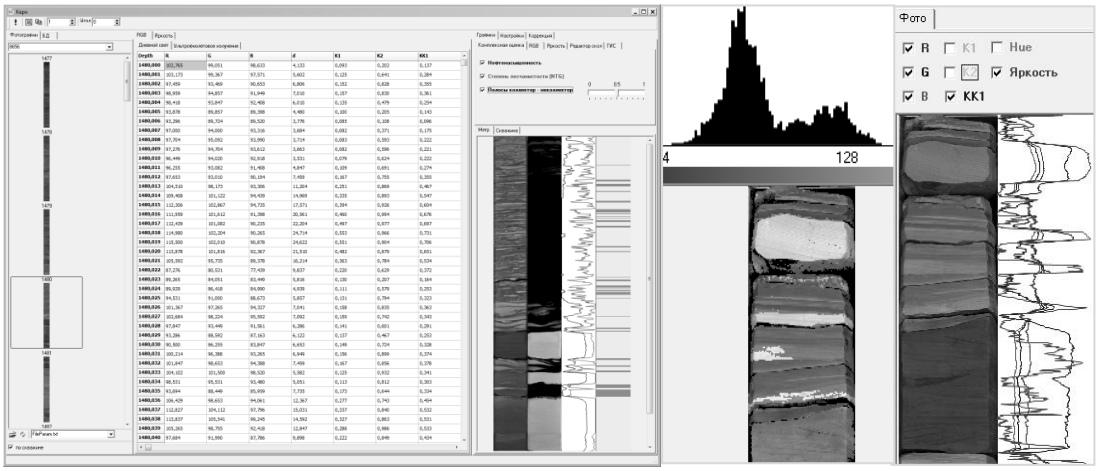

Fig. 3. An example of parameters calculation in the CoreColor Module

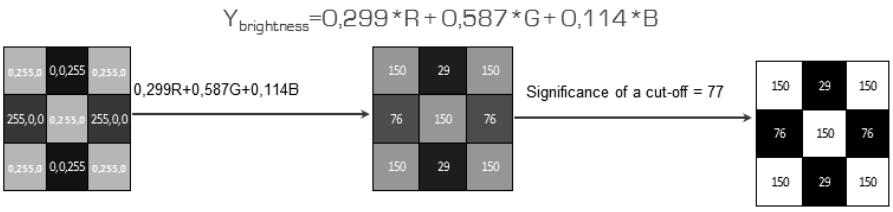

Fig. 4. A color-vision model

The recommended cut-offs and sand layers are automatically calculated using 0.5 value on a histogram of accumulated frequencies (Fig. 5).

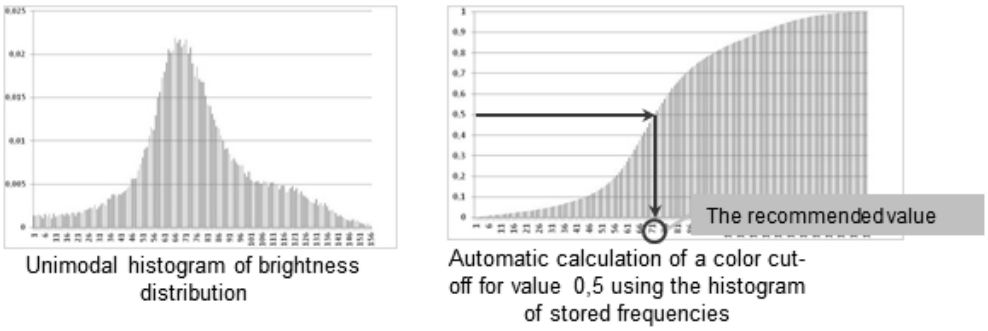

Fig. 5. Calculation of the recommended cut-off

We obtain a contrasting picture of light (sandy) and dark (clayey) areas [3]. The estimated fraction of impermeable layers and inclusions is the ratio of the number of dark pixels to the total number of pixels:

$$\mathcal{X} = \frac{\sum dark\ color}{\sum dark\ color + \sum light\ color} \qquad (1)$$

The result (Fig.6) is a continuous Net-to-gross curve: $NTG = 1 - \mathcal{X}$.

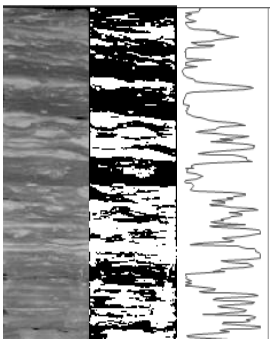

Fig. 6. Layer-by-layer processing of pixels

Calculation of oil-saturated core areas in such a way is complicated. The brightness of oil-saturated pixels must be artificially overestimated to bring them into the light component area. The NTG of oil-saturated areas is defined by artificial increase of the brightness of the red regions (Fig. 7).

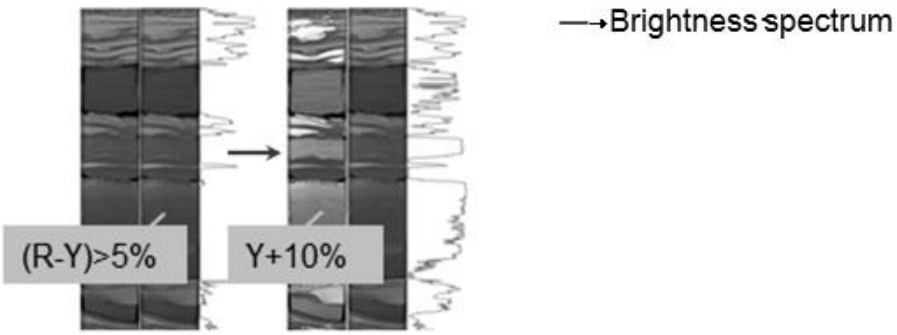

Fig. 7. Brightness of red regions

An analysis of core pictures in daylight shows the divergence of color spectrums in oil-saturated areas (Fig.8). This can be additionally confirmed by rather high brightness values [7].

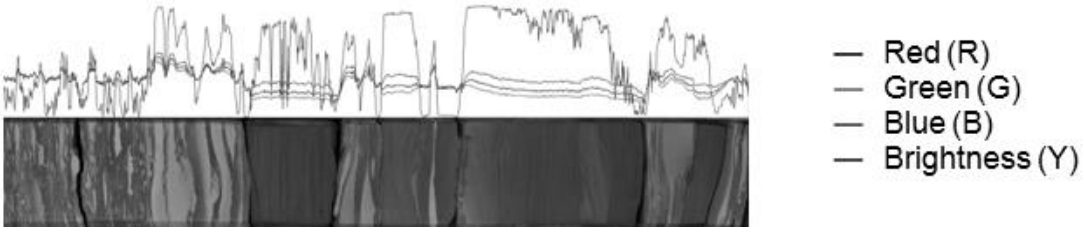

Fig. 8. Color spectrum for core pictures in daylight

It is common to oil-saturated areas in the core pictures in UV light that in case of great general color divergence two colors almost go together (Fig. 9). Black color means non-reservoir (clay). Yellow color means productive oil-saturated layer. Blue color can correspond to: 1- light oil, 2 - residual oil.

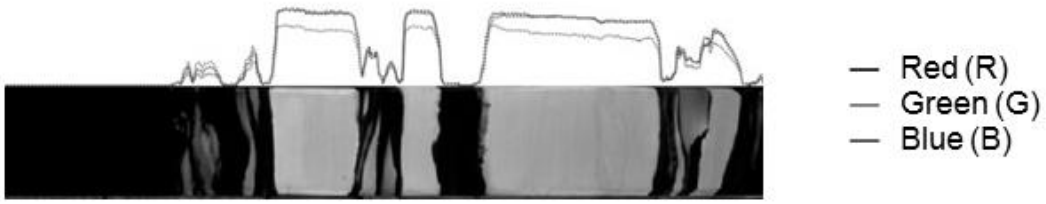

Fig. 9. Color spectrum for core pictures in UV light

The formal criteria are developed based on the color range divergence [9] (Fig. 10)

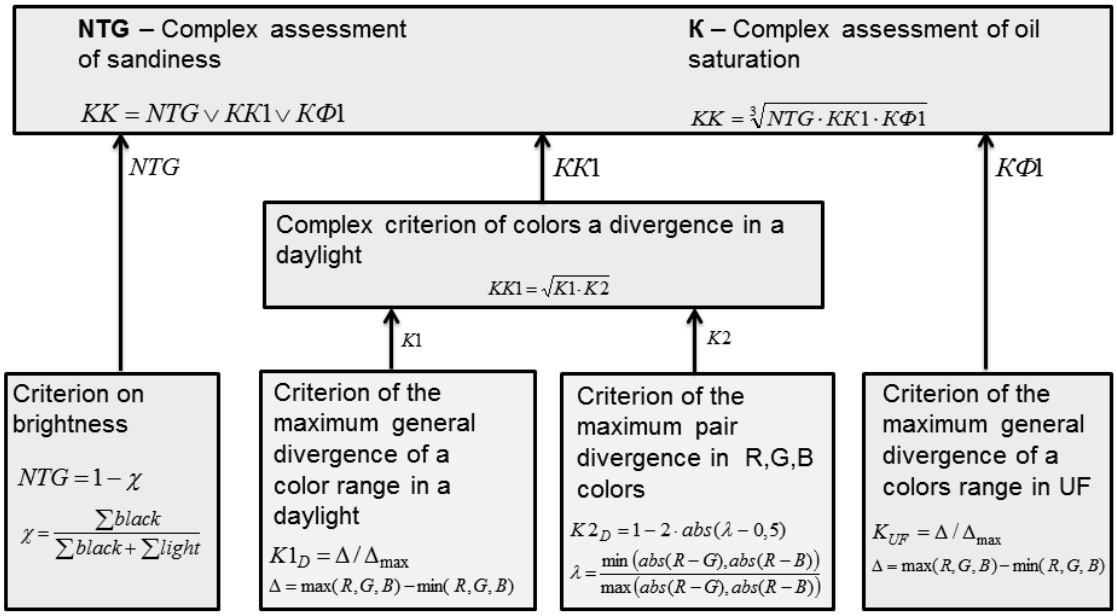

Fig. 10. Complex assessment of NTG

The CORE FRACTURING Module is a system for fracture recognition.

When assessing hydrocarbon reserves, an important task is the correct estimation of the void space volume. Currently, the problem should be solved by modern approaches to data processing using a computer, and not manually.

The automated fracture recognition system for preliminary analysis of core material [6]:

- Measures geometrical parameters of fractures based on pictures of thin sections: opening, intensity, extent (Fig.11).
- Determines fracture parameters.

Fig. 11. Fractures on thin sections

The system includes thinning or skeletonization of a fracture image using a Zhang-Suen algorithm [4], as well as express assessment of fracture geometry. The result was tested for divergence with manual measurements (~3%). Below is the determination of fracturing parameter by VNIGRI method [2] (Fig. 12).

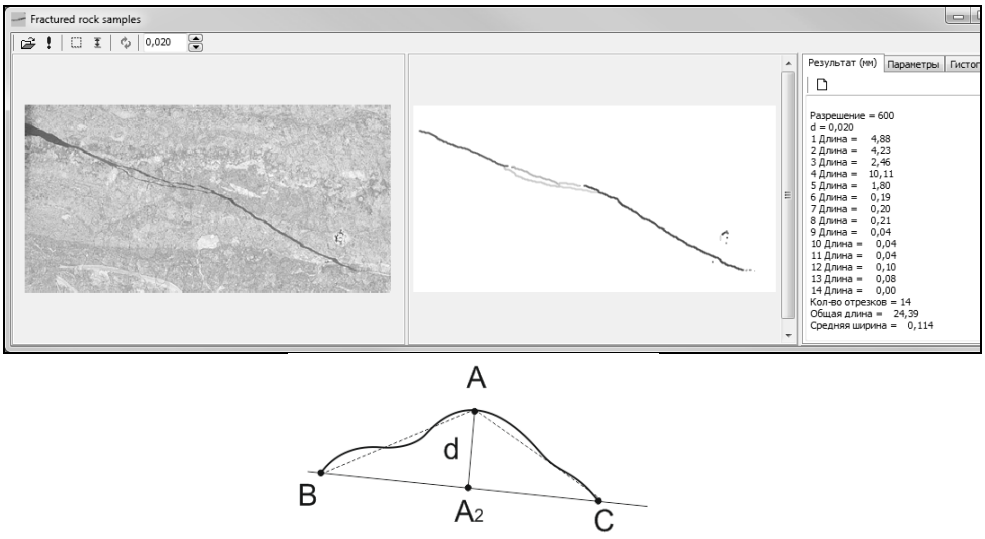

Fig. 12. Measurement of a fracture length

Automated processing of X-ray CT scans of single core plugs in the CORE CT SCANNER Module

The X-ray CT scans of core plugs are processed at the stage of core plug quality evaluation for screening and rejection before SCAL.

- Quality control as the basis for SCAL.
- Processing of x-ray density values in the DICOM format.
- Building brightness histograms.
- Applying band-pass filter for densities on Haunsfild scale.

Calculation of the core area and the area of solid inclusions for the entire set of slices is shown in Fig. 13.

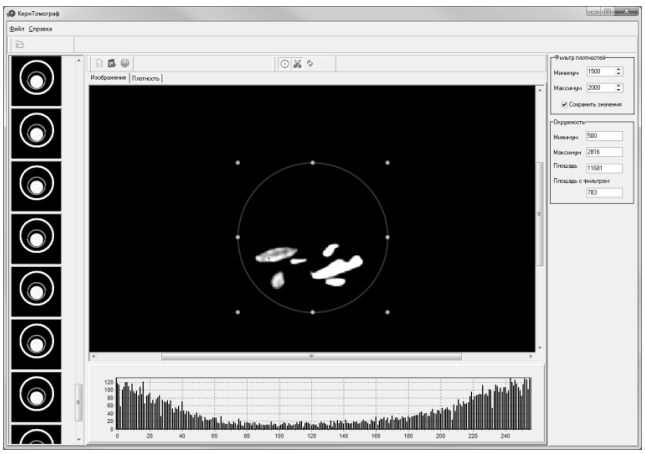

Fig. 13. Processing of x-ray CT scans

Probabilistic assessment of oil and gas reserves in the RESERVES Module

The Module serves for the estimation of oil and gas reserves by a volumetric method based on inaccurate geological field data using a probabilistic model [5] (Fig.14)

- The algorithm is based on the Monte Carlo method (Fig.15).
- A known equation is used which allows for fuzzy parameters.
- Parameters are set by different types of distributions.
- The method of condensation of probabilistic distributions is applied that significantly reduces time for obtaining stable result (a Latin hypercube method) [1].
- Applied in risk factor estimates.
- Building diagrams of parameters influence on reserves assessment (Tornado charts).

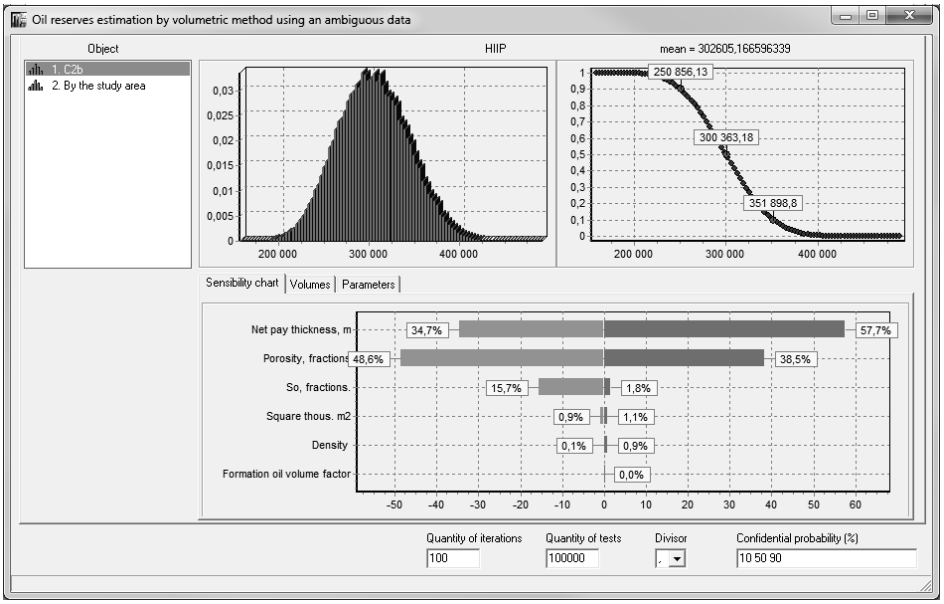

Fig. 14. Example of calculation in the Reserves Module

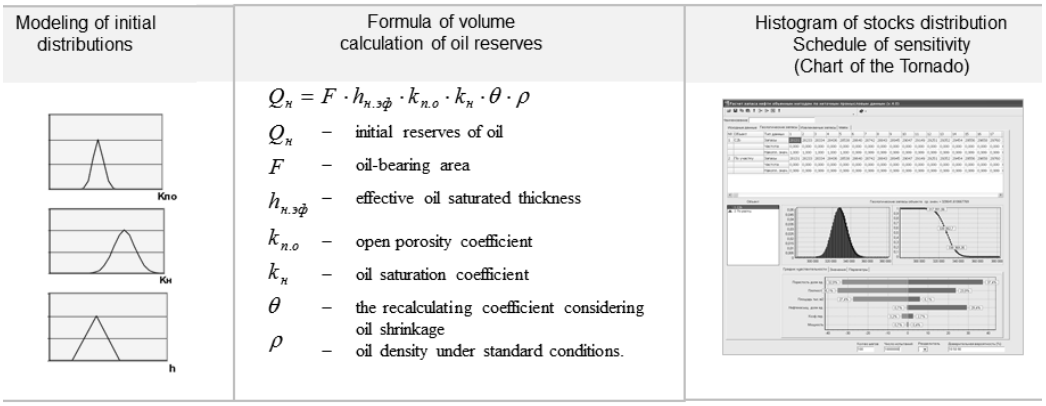

Fig. 15. Probabilistic estimation of oil and gas reserves

The RN-DATA module ensures single-point access to information from different sources (Fig.16). It allows for information search in all connected data sources, to learn about the knowledge level on any territory, and quickly get the data you need.

Fig. 16. Single data-access window

Result

A software complex has been created for processing core-based information when assessing HC reserves under uncertainty. The uniqueness of this product is in that it implements an integrated approach to estimation of oil and gas reserves using new and efficient methods.

The work results were presented and reviewed by innovative projects of Rosneft. The software complex is currently applied by the Tyumen Petroleum Research Center. The assessments are being made for existing

reservoirs and fields of West Siberia. 14 scientific papers have been published. 5 copyright certificates have been issued.

The prospects for the development of the software complex include solutions to large-scale problems, such as processing 3D CT-scanner data.

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