МЕТОДИКА ГЕОЛОГОРАЗВЕДОЧНЫХ РАБОТ

UDC:551.242:004.4

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EXTRACTION OF SYSTEMS AND FRACTURE ZONES IN COMPLEXLY STRUCTURED RESERVOIRS IN GEOTERIC SOFTWARE USING LOGGING DATA AND LABORATORY ANALYZES OF CORE SAMPLES

ЭКСТРАГИРОВАНИЕ СИСТЕМ И ЗОН ТРЕЩИНОВАТОСТИ В СЛОЖНО-ПОСТРОЕННЫХ КОЛЛЕКТОРАХ В ПРОГРАММНОМ ОБЕСПЕЧЕНИИ GEOTERIC С ПРИВЛЕЧЕНИЕМ ДАННЫХ КАРОТАЖА И ЛАБОРАТОРНЫХ АНАЛИЗОВ ОБРАЗЦОВ КЕРНА

KGEOTERIC БАҒДАРЛАМАЛЫҚ ҚАМТАМАСЫЗДЫҚТАҒЫ КҮРДЕЛІ ҚҰРЫЛЫСТЫ КОЛЛЕКТОРЛАРДА КАРОТАЖ МӘЛІМЕТТЕРІН ЖӘНЕ КЕРН ҮЛГІЛЕРІНІҢ ЗЕРТХАНАЛЫҚ ТАЛДАУЛАРЫН ПАЙДАЛАНА ОТЫРЫП ЖАРЫҚШАҚТАНУ ЖҮЙЕЛЕРІН ЖӘНЕ БЕЛДЕМДЕРІН БӨЛУ

Possibilities of up-to-date software for identifying and tracing of tectonic disturbances were experimentally studied from the sediments of the Tournaisian stage of one oil and gas field in the Caspian depression.

Faults, fractured systems and zones were extracted from the colour summation cubes and spectral decomposition in GeoTeric software using seismic data from CDMP-3D in the automatic mode.

There is a high degree of correlation between the fracture porosity parameters determined using various methods of well and laboratory analysis (acoustic logging, laboratory core studies, interpretation of FMI data) with the lateral distribution of the values of the fracture corridor density cube using CDMP-3D seismic data.

Keywords: field, seismic, faults, dynamic analysis.

По отложениям турнейского яруса одного месторождения углеводородов в Прикаспийской впадине в экспериментальном порядке изучены возможности современного программного обеспечения по выделению и трассированию тектонических нарушений.

В программном обеспечении GeoTeric по данным сейсморазведки МОГТ-3D в автоматическом режиме из кубов цветового суммирования и спектральной декомпозиции экстрагированы разломы, системы и зоны трещиноватости.

Наблюдается высокая степень корреляции параметров трещинной пористости, определенных с использованием различных методов скважинного и лабораторного анализа (акустический каротаж, лабораторные исследования керна, интерпретация данных FMI), с латеральным распределением значений куба плотности трещинных коридоров по данным сейсморазведки МОГТ-3D.

Ключевые слова: сейсморазведка, отражающий горизонт, тектонические нарушения, динамический анализ.

Каспий маңы ойпатындағы бір көмірсутегі кен орнының турней ярусының шөгінділерінде тектоникалық бұзылыстарды бөлу және трассалау бойынша қазіргі заманғы бағдарламалық қамтамасыз етудің мүмкіндіктері эксперименттік түрде зерттелді.

ОТНӘ-3D сейсмикалық барлау деректері бойынша GeoTeric бағдарламасында түстерді қосудың кубтарынан және спектрлік декомпозициядан автоматты режимде жарылымдар, жарықшақтылық жүйелері мен аймақтары экстрагирленген.

ОТНӘ-3D сейсмикалық барлау деректері бойынша жарықшақты дәліздер тығыздығының куб мәндерін латеральды бөлумен ұңғымалық және зертханалық талдаудың (акустикалық каротажға, керннің зертханалық зерттеулеріне, FMI деректерін интерпретациялауға) әртүрлі әдістерін пайдалана отырып анықталған жарықшақты кеуектілік параметрлерінің корреляциясының жоғары дәрежесі байқалады.

Түйінді сөздер: сейсмикалық барлау, шағылыстырушы горизонт, тектоникалық бұзылыстар, динамикалық талдау.

Development of complexly structured oil and gas reservoirs with the developed fault systems and intensive fracturing is a priority task of the up-to-date exploration process. The key role in solving this issue is given to the construction of a bulk geological model using CDMP-3D seismic data.

The actual bulk geological modelling consists of two stages. The first is aimed to construct the structural framework of oil and gas (O&G) fields with elements of tectonic disturbances. The second one is to study the reservoir properties and lithofacies that fill this framework of rock units.

The construction of the structural framework of O&G fields and oil-and-gas-promising areas includes identifying the separating boundaries based on changes in the values of the acoustic stiffness of the geological environment and identifying the fault planes that determine the modelling objects fragmentation.

The construction of boundaries in the framework model in up-to-date software implies no particular obstacles, especially with the drilling data at hand, and acoustic impedance has consistently high values along reflecting boundaries.

The situation is complicated at fault zones and the development of fracturing systems that are critical at all stages of the exploration process, ranging from geological modelling and predictive O&G production calculations to planning the design well paths.

In order to solve this problem, automatic (semi-automatic) methods for tracing horizons, faults and fracture zones have been developed, introduced and are widely used; these methods are based on using the surface and bulk seismic attributes, coherence cubes and spectral decomposition according to CDMP-3D seismic data [1-4].

They are applied to estimate coherence and discontinuity of seismic wave packets of reflected waves that characterize the presence of faults, fractured

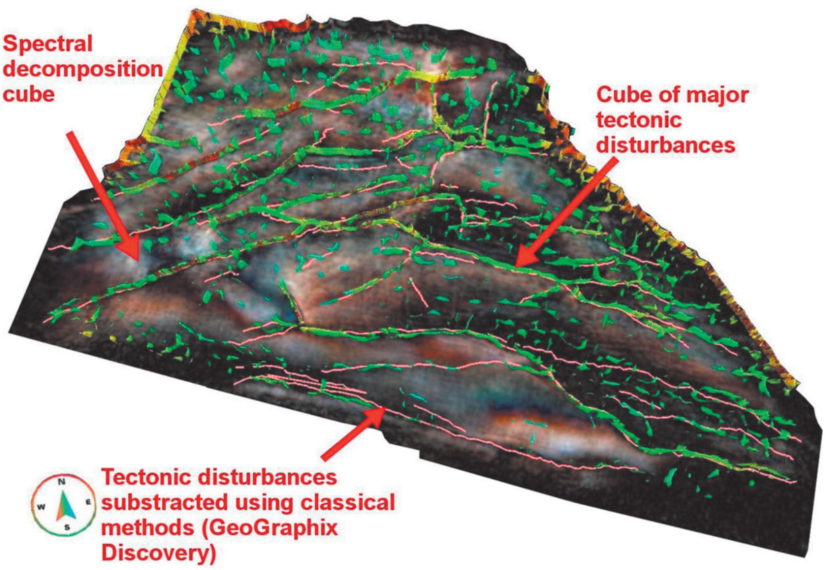

Figure 1 – Tectonic disturbances substracted manually (pink colour) and by the spectral decomposition cube (green colour), C_1t horizon (15Hz, 17Hz, 20Hz)

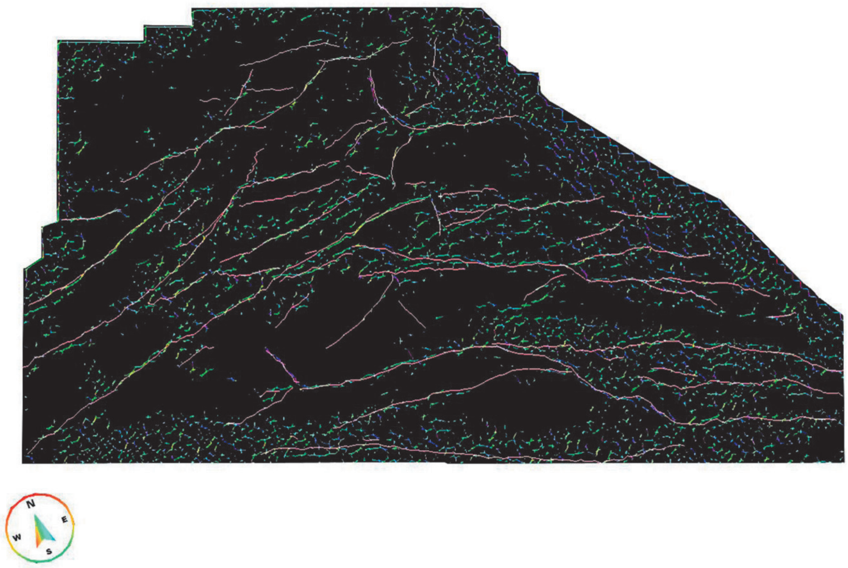

Figure 2 – Visualization of fracture corridors with superimposed tectonic disturbances substracted manually (pink colour) for C_1t horizon

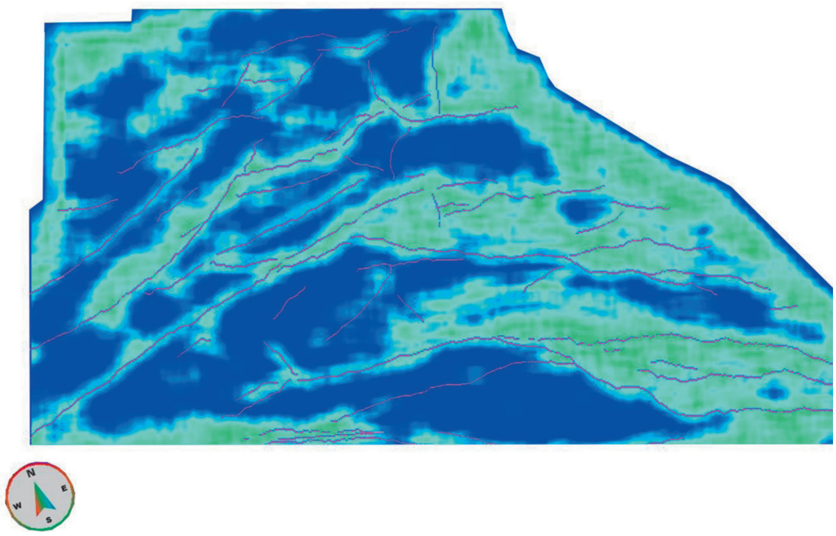

Figure 3 – Visualization of the fracture corridor density with superimposed tectonic disturbances substracted manually (pink colour) for C_1t horizon

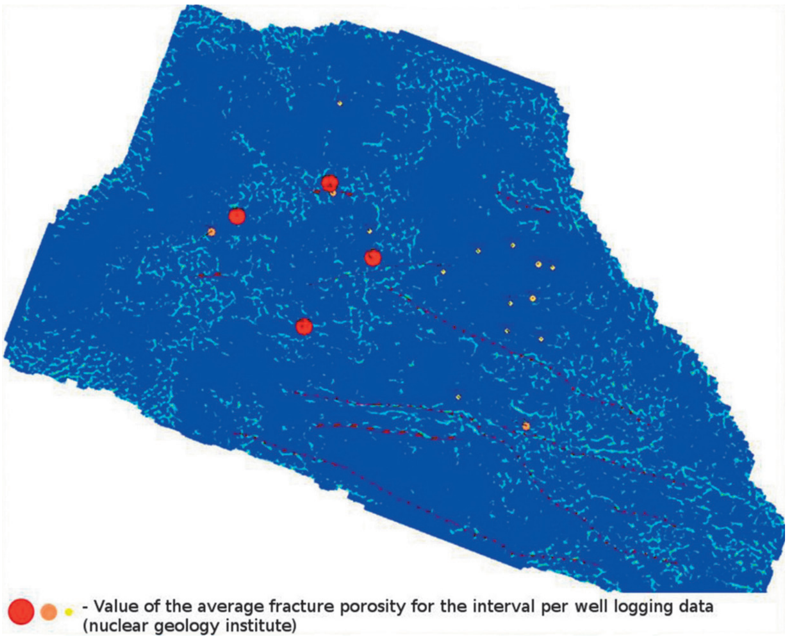

Figure 4 – Distribution of average values of fracture corridors in the interval of 10ms from the roof of the C_1t horizon with superimposed wells, in which the fracture porosity was calculated according to the method of the nuclear geology institute

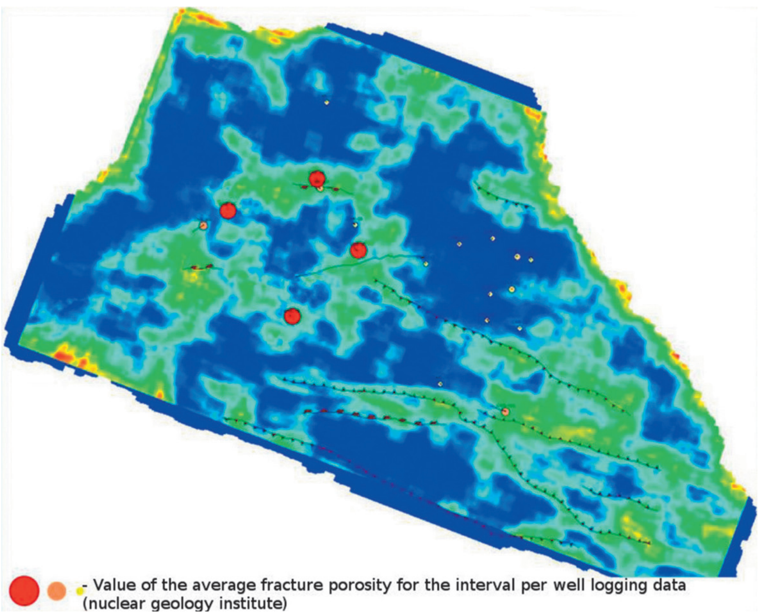

Figure 5 – Distribution of average values of the density of fracture corridors in the interval of 10ms from the roof of the C_1t horizon with superimposed wells, in which the fracture porosity was calculated by the method of the nuclear geology institute

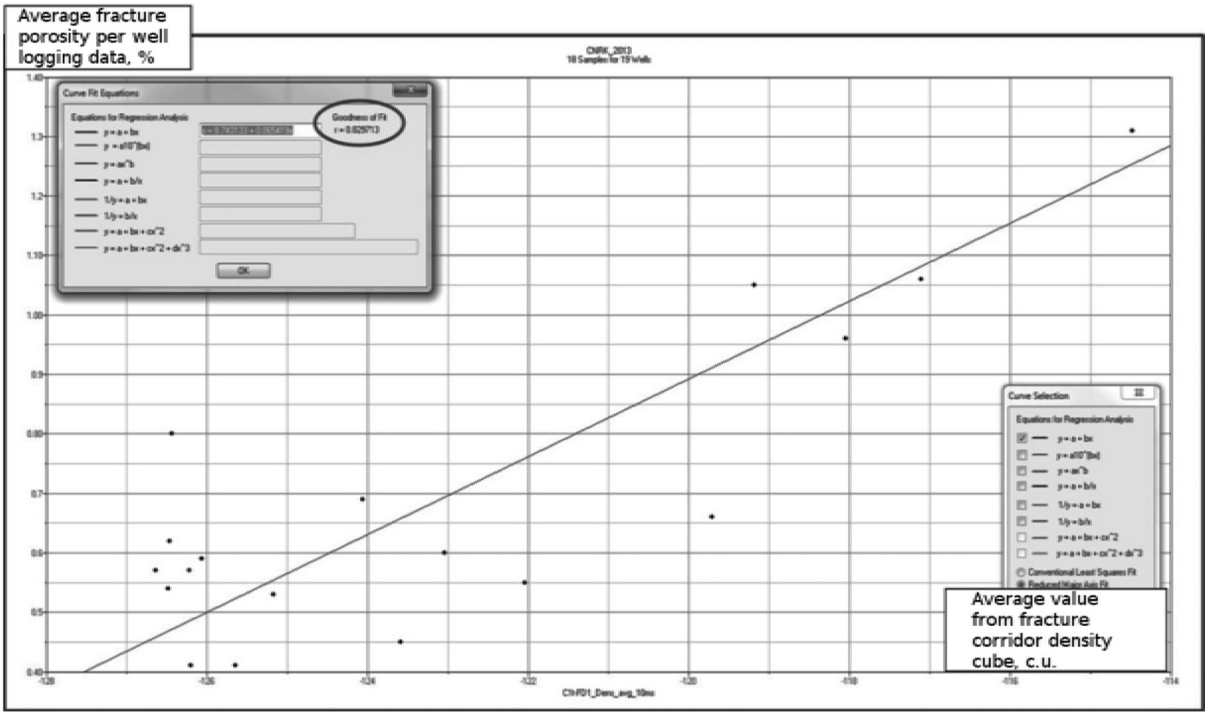

Figure 6 – Comparison of average values of the fracture corridor density in the interval of 10ms from the roof of the C_1t horizon and the average values of fracture porosity for a given interval according to well logging data calculated by the method of the well logging institute

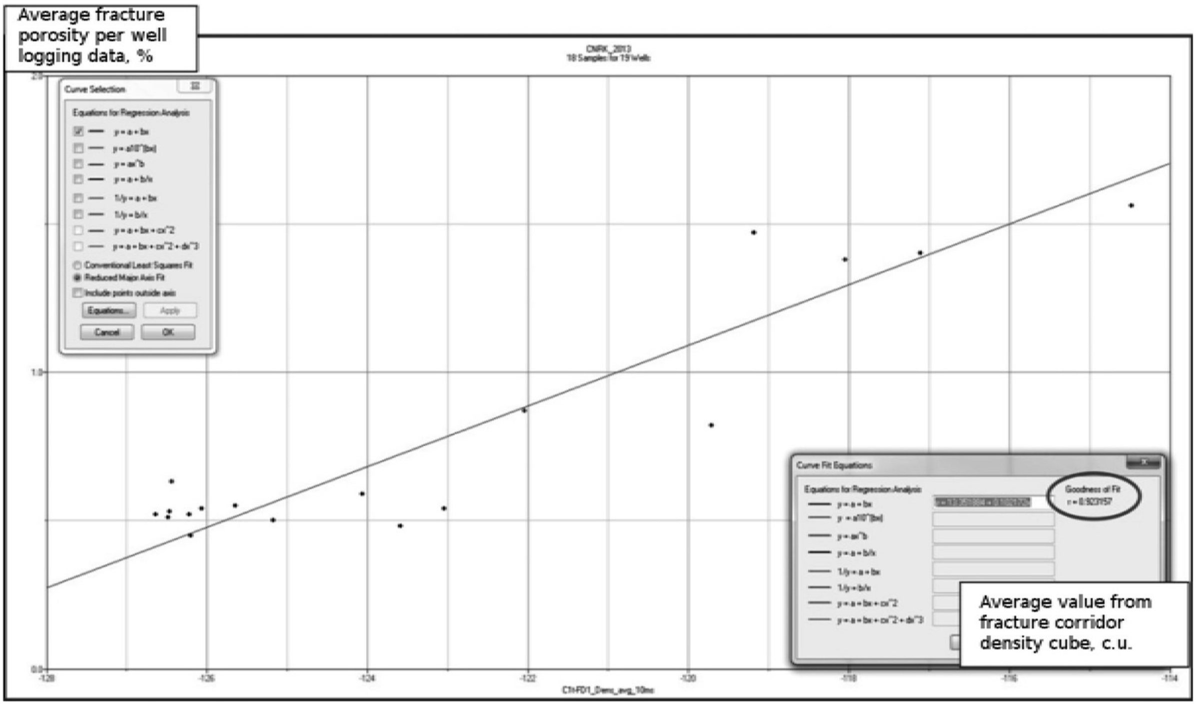

Figure 7 – Comparison of average values of the fracture corridor density in the interval of 10ms from the roof of the C_1t horizon and the average values of fracture porosity for a given interval according to well logging data calculated by the method of the nuclear geology institute

systems and zones. At the same time, the most reliable interpretation results suggest the availability of rich azimuth field seismic survey data with the registration of longitudinal and transverse waves (3C) [1-4].

Of great importance here is well data that provides for macro-descriptions of core and laboratory analyzes of core samples with the determination of fracture orientation which can be used to calibrate the geometric, frequency and amplitude characteristics of the seismic cube so as to predict the lateral distribution of fractured zones and fracture corridors. Fracture zones are understood to be linearly elongated areas with an intense pattern of disturbed coherence of the reflected waves generated by deformed geological environments.

The results obtained are compared with the results of assessing the discrete fractures and fractured zones using the well data. As part of the latter, it is desirable to include methods for dipole acoustic logging, acoustic and electric formation multiscanners.

Currently, global leading service companies have made obvious progress in developing programs for automatic and semi-automatic extraction of faults, fractured systems and zones.

So, for example, GeoTeric can be correctly attributed to the efficient software that calculates a series of colour summation and spectral decomposition cubes to track tectonic disturbances. This software is developed by Foster Findlay Associates providing software solutions for seismic studies of CDMP-3D analysis in the oil and gas industry around the world.

GeoTeric effectively combines objective data analysis and interpretation based on the experience and knowledge of the interpreter.

As a demonstration of the capabilities of this software, a spectral decomposition cube along subsalt deposits at one of the fields in the Caspian depression was combined with the resulting cube of major tectonic disturbances traced manually using the Geographix Discovery software package.

The results of the comparative analysis show that all the major tectonic disturbances traced for the spectral decomposition cubes and substracted manually are spatially combined (Figure 1).

In addition to the major tectonic disturbance cube, GeoTeric makes it possible to calculate the propagation cube for fracture zones and systems (fracture corridors) by reducing the number of cleaning iterations and reducing the filter length when identifying fracture zones by CMY (Cyan Magenta Yellow) – colour sum cube (Figure 2).

The section of the fractured corridor cube with superimposed tectonic disturbances substracted manually using the Geographix Discovery software package contrastively shows the variability of distribution of these corridors over the area in the development zone of the main (root) faults. However, there are no fractured zones in some areas of the main faults (Figure 2).

The existing discrepancy between the development of fracture corridors and independently substracted faults (Figure 3) can be considered as direct evidence of the objectivity of the distribution density of fracture systems at a given depth slice.

Otherwise, with complete coincidence of areas of increased density of fracture corridors with the position of all faults substracted manually, one would assume that they reflect only a visually visible picture of their development, excluding the spread of faults with amplitude beyond the CDMP-3D seismic resolution.

In order to assess the reliability of the obtained interpretation results for seismic data in the investigated depth interval (C_1t horizon), the results of laboratory analysis of core samples, well logging data (geophysical surveys of wells) and drilling (drilling fluid absorption, increase in drilling speed, etc.) were used.

It should be noted that the study of core samples, in addition to lithologic-petrographic, biostratigraphic characteristics, and reservoir properties, also included the study of the possible presence of fractures.

The collected core samples in the roof of the C_1t deposits are represented by limestones and dense, slightly porous and porous dolomites with rare styllolitic and fractured caverns. The section demonstrates thin layers of clayey rocks.

The pores are mainly interfragmentary, less frequently intrafragmentary and leached. Fractures are sub-horizontal and sub-vertical up to 3.0mm wide.

As a result of laboratory studies of core samples, the following parameters were determined:

- size of the fracture opening;
- fracture density;
- fracture porosity coefficient;
- orientation and shape of fractures (sub-vertical, sub-horizontal);
- gas permeability.

Qualitative and quantitative confirmation of calculated cubes of fracture corridor propagation (at a qualitative level) and density of fracture corridors (at a quantitative level) was obtained by comparing them with the results of determining fracture porosity using well data.

The following results were used as the initial parameters:

- calculation of fracture porosity, determining the number and direction of fractures according to the dipole acoustic logging (methods of well logging and nuclear geology research institutes); acoustic and electrical formation multiscanners;
- direct determination of fracture porosity on core samples under the laboratory conditions;
- fracture detection in core macro-description.

Comparison of a slice in the interval of 10ms (about 30 m) from the roof of the C_1t horizon on the cube of the average values of fracture corridors with the results of the assessment of the average fracture porosity

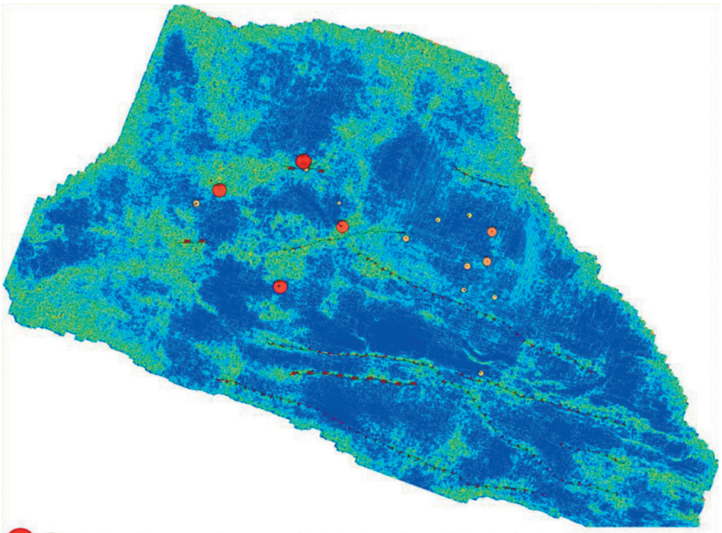

Figure 8 – Distribution of seismic attribute of minimum curvature for the C_1t horizon

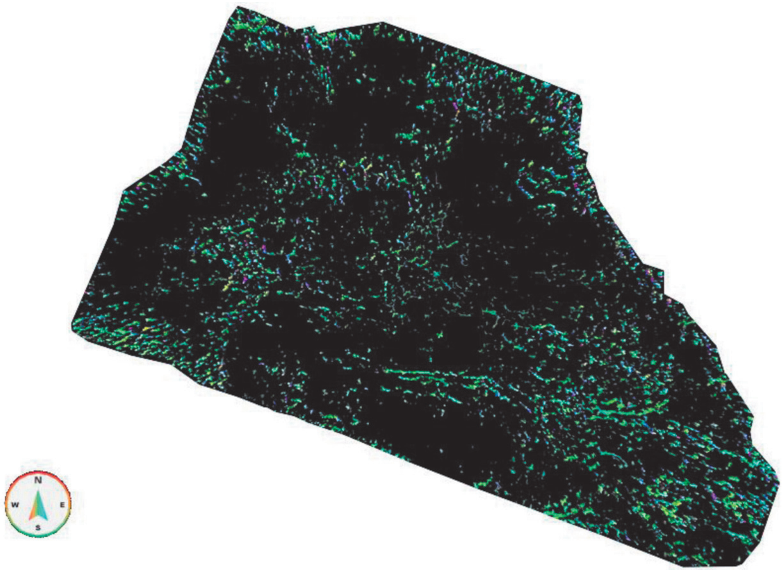

Figure 9 – Slice of the cube of fracture corridor direction trends in the interval of 40ms from the roof of the C_1t horizon (colour codes the direction)

for the Tournaisian deposits based on well logging materials (according to method of the nuclear geology institute) showed a clear correlation dependence of the location of wells with increased average values fracture porosity in areas with impaired coherence of the seismic reflecting waves.

And, on the contrary, wells with low fracture porosity in the analyzed interval of the section are isolated in areas with regular wave pattern (Figure 4).

The correlation of areas with increased or decreased fracturing over the investigated depth interval, identified by seismic and well logging data, acquires more contrasting forms when using the cube of density of fracture corridors. At the same time, the correlation coefficient exceeds the value of 0.8 (Figure 5-6).

Comparison of the cube of fracture corridor density with the results of fracture porosity assessment using well logging, estimated using a different technique (nuclear geology institute), shows a similar trend with high values of correlation coefficients (Figure 7).

The results of laboratory analyzes of core fracture porosity are also well correlated with the values of the cube of the fracture corridor density (substracted per seismic data) both in qualitative and quantitative comparison.

In addition to the use of volumetric attributes, the analysis of the curvature of the reflecting horizon surface is often used to assess fracturing /5/.

Comparison of the average values of fracture porosity using well logging with the results of the distribution of the seismic attribute of the surface curvature of C_1t horizon shows almost identical values of the fracture corridor distribution, which confirms the previously identified patterns (Figure 8).

To assess the prevailing directions of fracture corridors, a cube of trends of their directions was

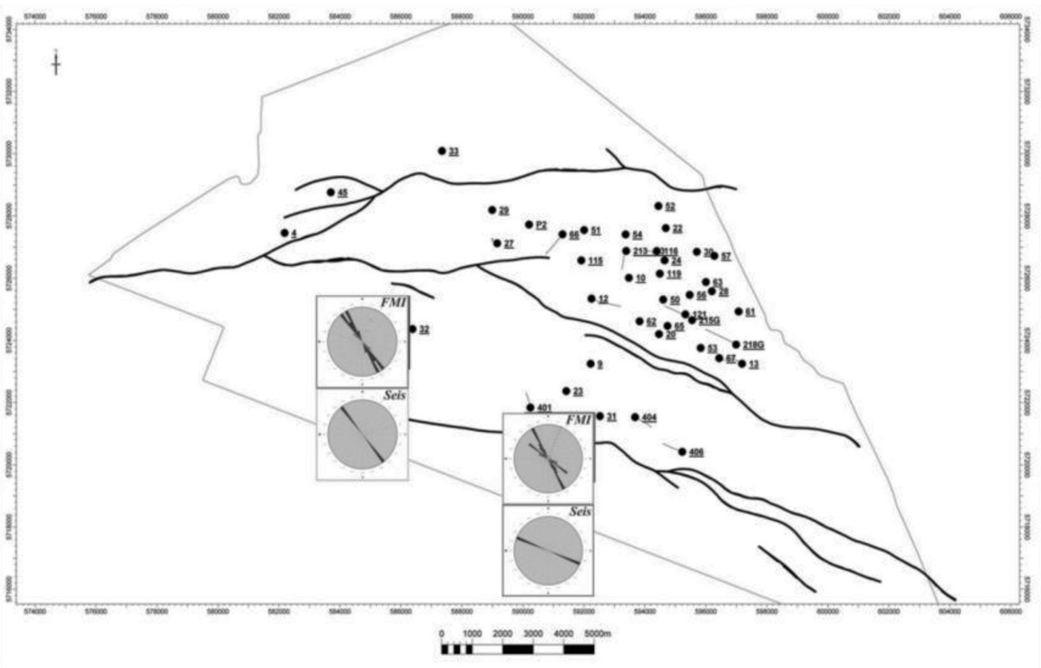

Figure 10 – Orientation of the directions of average values of fracture corridors in the interval of 40ms from the roof of the C_1t horizon and measurements of the fracture azimuth according to the interpretation of FMI logs in wells in the same interval

calculated, in which the direction of extended sections with impaired correlation of the seismic wave field is coded in colour (Figure 9).

The numerical value of the colour gradient of the 8-bit colour palette 0-255 in this cube was recalculated into the numerical value of the direction degrees of the fracture corridors 0-360^0. For each well within a radius of 100 meters, the average prevailing direction was calculated, which is largely correlated with the prevailing azimuth according to the FMI interpretation data (Figure 10).

Despite the non-identical values of fracture porosity per well logging, when evaluated using various methods (well logging and nuclear geology institutes), the regularities of the spatial distribution of this porosity in various wells discovered by the Tournaisian deposits are maintained regardless of the assessment methodology.

By the way, the lateral distribution of the fracture corridor density complies with the direction of movement of the formation waters during the service of the Tournaisian reservoir.

Thus, the results of the studies show that for the Tournaisian deposits there is a high degree of correlation of fracture porosity parameters determined using various methods of well and laboratory analysis (acoustic logging, laboratory core studies, interpretation of FMI data) with lateral distribution of fracture corridor cube values using CDMP-3D seismic data.

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