STUDY OF THE UPPER PART OF THE SEDIMENTARY COVER AND SEARCH FOR HEAVY OIL DEPOSITS THAT OCCUR ON HIGHER LAYERS USING 2D CDP SEISMIC SURVEY ON THE TERRITORY OF TATARSTAN

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Abstract. The paper represents the results of experimental-methodical works of 2D CDP on the study of Permian- Upper Carboniferous interval of the section in order to develop techniques for the study of heavy oil deposits. As a result of 2D CDP seismic surveys the upper part of the sedimentary cover was studied in detail, including deposits of Tatarian, Kazanian, Ufimian tiers of the Upper Permian, Sakmarian, Asselian tiers of the Lower Permian and reflectors C3 and C3a in the Upper Carboniferous sediments, the depth of which does not exceed 500 m. The boundary of Neogene paleovalley is reconfirmed. Forecast is carried out for upper sand packs of Ufimian tier, which is associated with deposits of heavy oil.

Keywords: seismic survey, upper part of the section, heavy oil deposits, sand pack, well
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Introduction

Experimental and methodological works for the study of Permian – Upper Carboniferous deposits were held for the first time. To work out the methodology, the researches were carried out in the eastern part of Cheremshansky district of Tatarstan on sites Upper Karmalsky and Lower Karmalsky deposits of viscous oil (Dobrovolskaya, Morkovskaya, 2013).

For a detailed study of the Permian-Upper Carboniferous interval the seismic observations were carried out with 320-channel symmetrical arrangement with a pitch PP and PV 5 m, i.e. with the multiplicity of observations 160. During processing, calculation of datum static corrections was carried out by the first arrivals of refracted wave, and the magnitude of input statics corrections of the low-frequency component did not exceed 10 ms. This approach allowed us to consider the impact of topography and velocity anomalies in the upper part of the section.

Lithologic and stratigraphic binding of reflectors was made using data of seismic well logging and modeling of seismic wavelet based on the theoretical curves of acoustic logging, which allowed correlating reflectors along the profiles in the sediments of the Kazanian stage, from roofing surfaces of Tatarian, Ufimian, Sakmarian, Asselian and reflectors C_3 and C_3a in the sediments of the Upper Carboniferous. All of the above boundaries are characterized by different dynamic expression in a wave field and, as a result, quality of traceability (Figure 1).

Brief geological description of the target interval of the section

The studied area belongs to the Central bituminous area, "which corresponds to the large pole of bitumen accumulation located on the eastern edge of Melekess basin and the western slope of South Tatar arch" (Khisamov et al., 2006).

Upper Karmalsky and Lower Karmalsky deposits of heavy oil are located in the area of seismic operations, confined to the sand pack of Ufimian tier. The main reservoir for the accumulation of oil in the Upper Permian oil-bearing complex are Sheshminskian sandstones of Ufimian tier that occur in the upper pack of the horizon – sand pack $P_2u_2^2$, made of sand impregnated with viscous oil and thin interbedded sandstones and siltstones.

Virtually the entire Lower Karmalsky deposit from the roof to the formation bottom is water-flooded and washed in one degree or another. There is a certain similarity in the water-flooded nature of heavy oil reservoirs and reservoirs of massive type, operated a natural mode, for which it is difficult to build a current oil-water contact. Therefore, a lower limit of oil saturation is considered conventionally in the bottom of oil-saturated zone defined by quantitative and qualitative characteristics of laboratory core analysis and logging (Bazarevskaya, Tarasova, 2007; Yangurazova, 1997).

Upper Karmalsky heavy oil deposit is controlled by homonymous uplift complicated by a number of domes. The deposit was penetrated by 22 wells and is quite an extended lens, the size of 5.5 x 1.5 km of the northwest trending. Oil-saturated strata vary from 0.2 m (well 17 VK) to 15.5 m (well 418). The deposit is of structural and lithological type.

As it is known, the beginning of the Late Permian era was accompanied by a substantial restructuring of the structural plan of the territory. After a break in sedimentation, lagoon-marine and continental formations were formed. Early Ufimian time is associated with active lift of Paleo-Urals, where erosive processes were developed intensively. Streams of large masses of water, carrying detritus in the eastern regions of the platform, in Ufimian age covered a large part of Tatarstan. Thickness of deposited sediments gradually decreased in a westerly direction until all wedging out; their stratigraphic completeness and structural plans varied (Figure 2). In Early Sheshminskian time deposits of sand-clay packs were accumulated on hypsometrically lower areas of Sakmarian surface.

Research results

The obtained time sections display a distribution of Upper Carboniferous – Quaternary deposits, geometry of stratigraphic horizons and benchmarks, the nature of sedimentation, paleo-erosion and paleo-tectonics, and other features of the geological structure.

The first reflector at time sections is a boundary formed as the total impulse of the upper layers near the surface, characterized by a dynamically stable impulse with negative sign. According to the drilling, Quaternary deposits up to 20 m are developed ubiquitously at the surface; they are represented by diluvial and alluvial formations of sand, clay, gravel, loam, clay loams.

For the northeastern part of the studied area the feature is a partial washout of sand packs in the pre-Neogene time. Sediments of Neogene system, filling paleovalley of Sheshma River are mapped by the structural drilling. At the time section this site has the cross-section of paleovalley of irregular U-shape (steep, high sides, uneven bottom, transgressive occurrence on the eroded surface of various stratigraphic horizons (the deepest on the stratigraphy deposits, affected by pre-Neogene erosion, are rocks of Ufimian sand packs)) (Figure 3).

The thickness of Neogene sediments, composed of clay gray, brown, often greasy, plastic, calcareous, with fragments of shells pelecypods, gastropods, with interbedded sands of gray, fine-grained and medium-grained, polymictic in circuit area, reaches 105 m (well 397). Wave pattern: in the center – horizontal axis of in-phase, closer to the sides – chaotic form of recording, which is due to the fact that Neogene zone is narrow, deep and inhomogeneous, composed of rocks with different density, high-speed characteristics.

In areas of seismic profiles 05120301, 05120303 intervals are observed with weak seismic records that

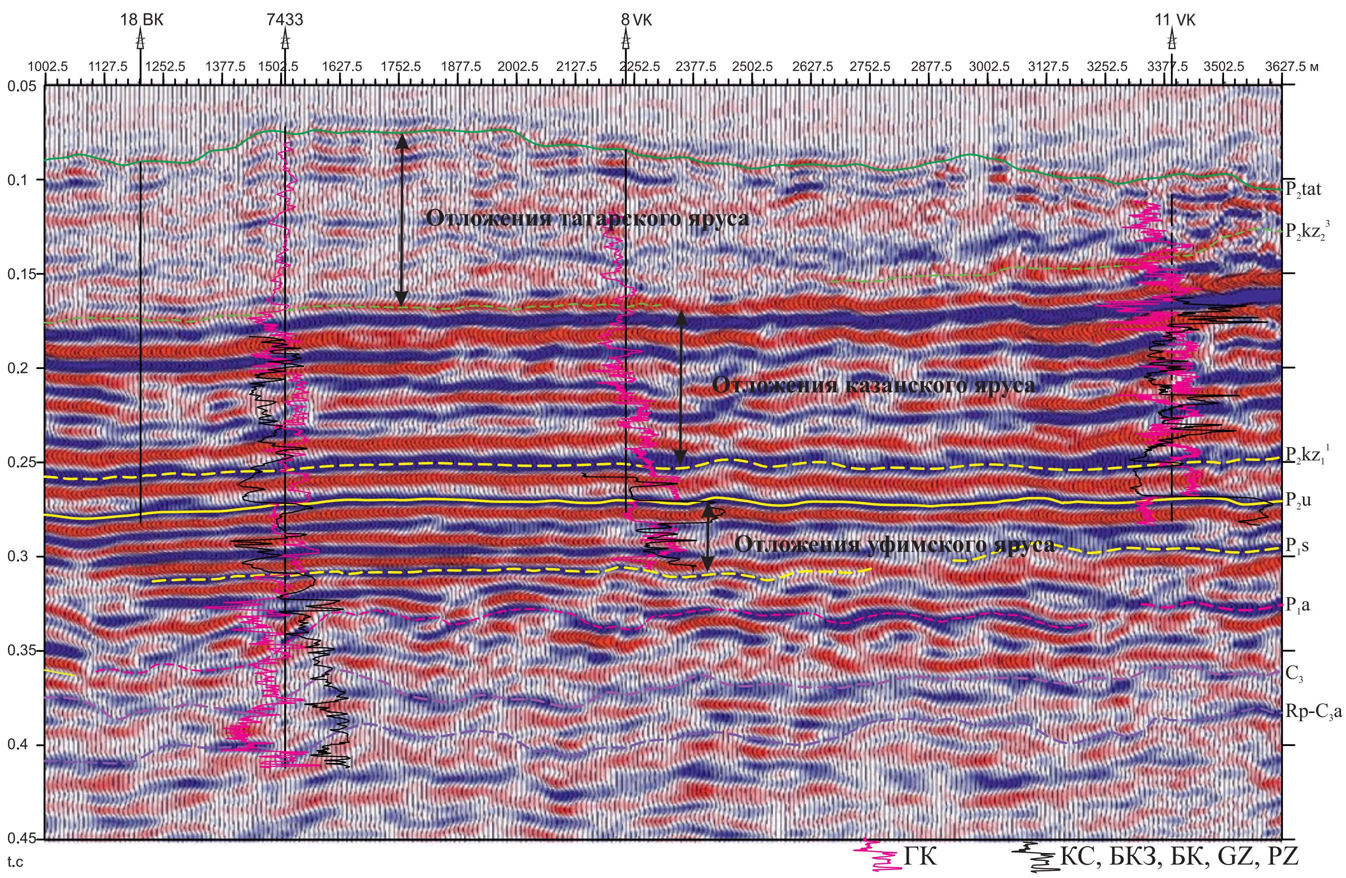

Figure 1. The nature of wave pattern in the range of Permian-Upper Carboniferous deposits.

match the stratigraphic binding according to the deposits of Tatarian stage. As the result of existed pre-Neogene and modern erosion they preserved not everywhere and not in full. Lithologically they are filled with multi-colored clays, siltstones, marl interbedded with sandstones, dolomite, limestone, gypsum, the total thickness of which reaches 50 m. Maximum thickness of deposits is observed in the range of pk 2.5-3502.5 of profile 05120301.

In the Upper Kazanian time there were four cycles of sedimentation, each of which was characterized by specific conditions and duration. However, sediments accumulated in these cycles are the alternation of small and medium-grained sandstone, siltstone, clay, marl, small cavernous dolomite, limestone, with inclusions of gypsum with different density and acoustic properties. In the wave field this interval is characterized, for the most part, by the horizontal stratification of reflectors with different configuration, traceability, dynamic expression.

On the border of the Tatarian and Kazanian deposits, as a result of sharp change of lithology, quite a contrast reflection in its dynamic characteristics is formed in the wave field. Thickness change of the Upper Kazanian substage from 58 to 204 m is controlled by the time interval change between the reflectors $P_2kz_1^1$-$P_2kz_2^3$.

The following reflection in the wave field is formed from the roof of Ufimian tier and is presented with a positive sign of the impulse. Reflection is dynamically expressed, correlated without difficulty.

Interval of the time section, concluded between

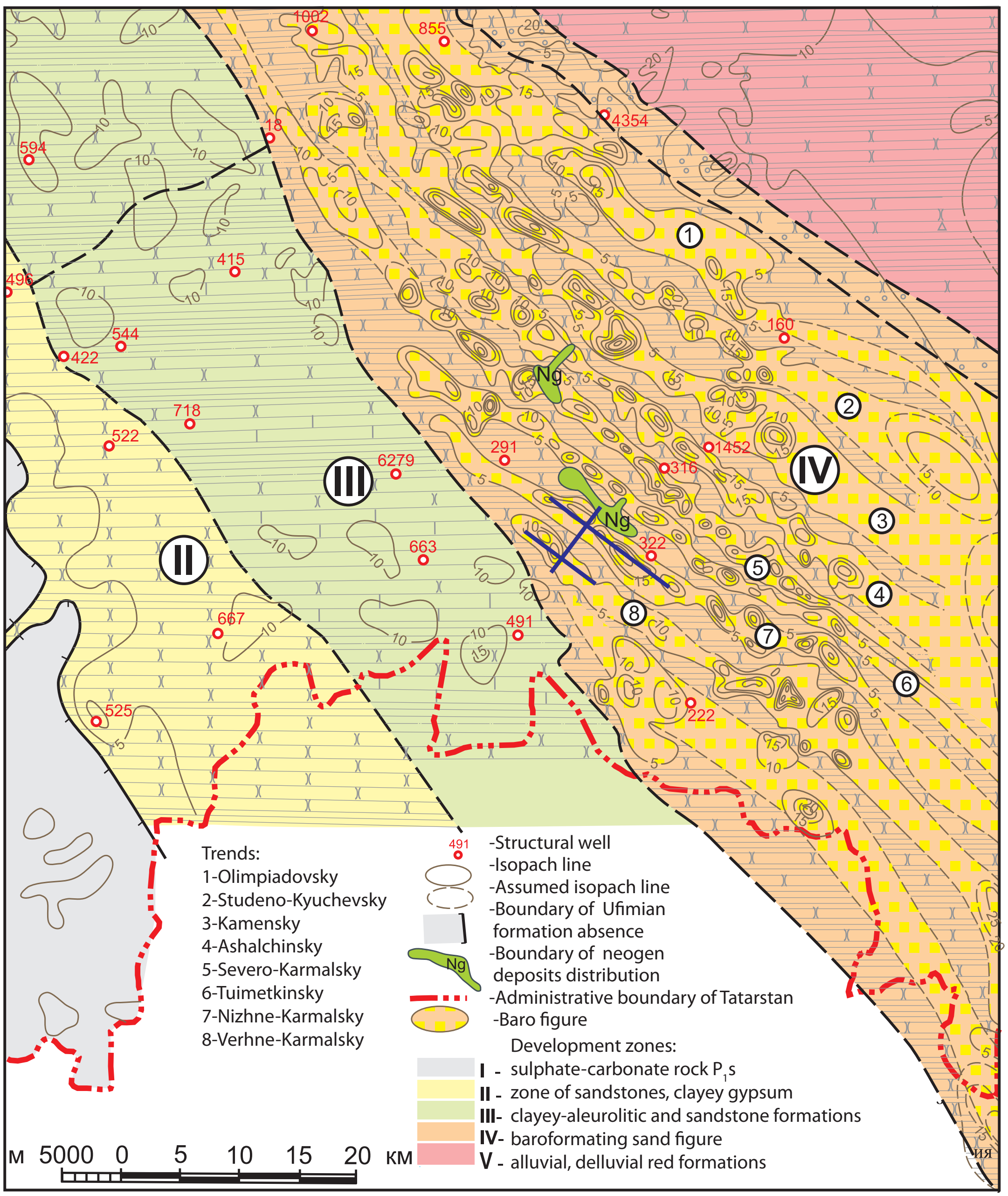

Figure 2. Lithofacies map of the Ufimian sand pack. South-Tatar arch. Note: the copy of Figure 2.1 to the report on 5/85 "Analysis of the geological prospecting and exploration results of bitumen deposits in the Tatar Autonomous Soviet Socialist Republic, the development of recommendations for their further maintenance and improvement of methods", TatNIPIneft 1987

the reflectors and P_2u and P_1s, displays the structure of Ufimian sediments, which within the territory are represented by Seshminskian horizon, 37.2-100 m thick in the area of the Lower Karmalsky deposit, and 33.1-79.0 m – in the Upper Karmalsky deposit. The tier consists of two packs: the upper – sand and lower – sand and clay.

The upper sand pack with thickness from 5.5 to 40 m,

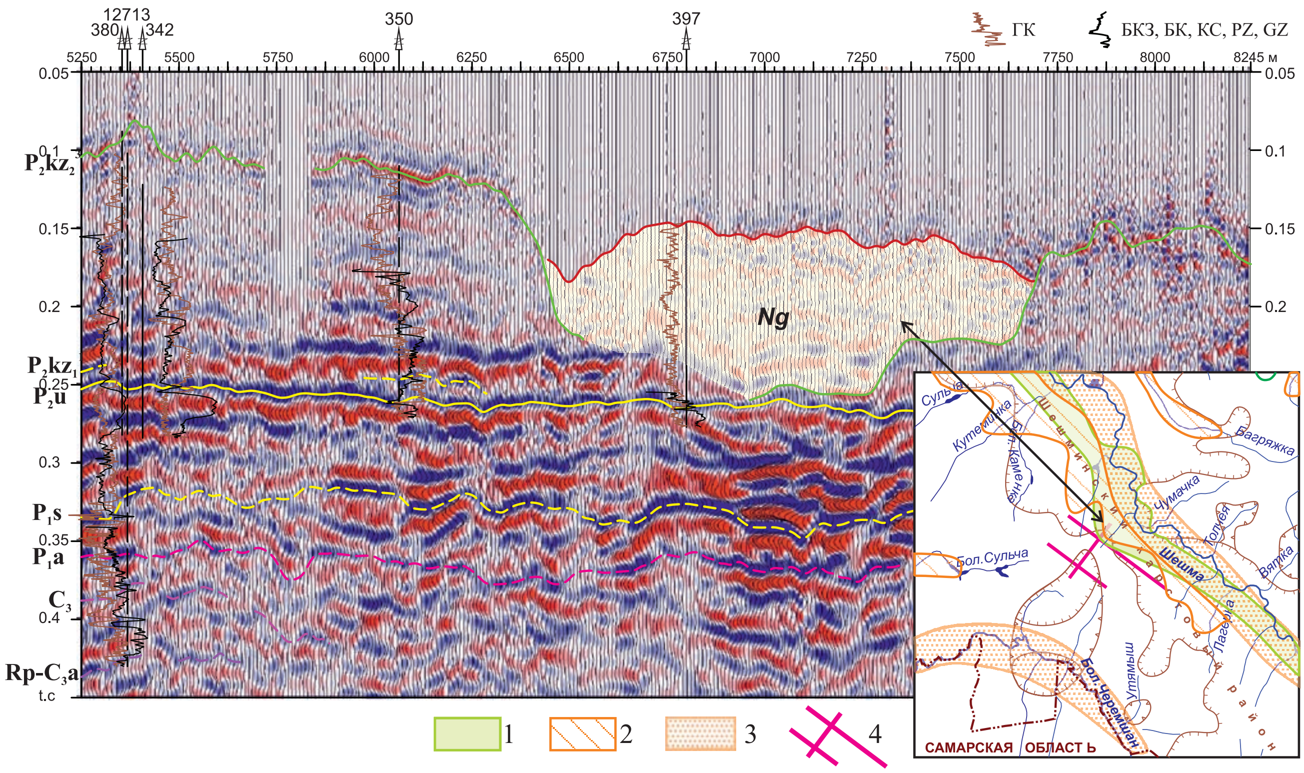

Figure 3. Display in the wave field of paleovalley of Sheshma River. Scheme of interrelations of pre-Pleiocene, Quaternary river valleys and karst in the Lower Permian deposits. 1 – pre-Pleiocene river valleys (according to N.V. Kirsanov, A.I. Bashlev, 1962); Quaternary river valleys: 2 – erosion, 3 – accumulative; 4 – profiles s.p. 5/12-3.

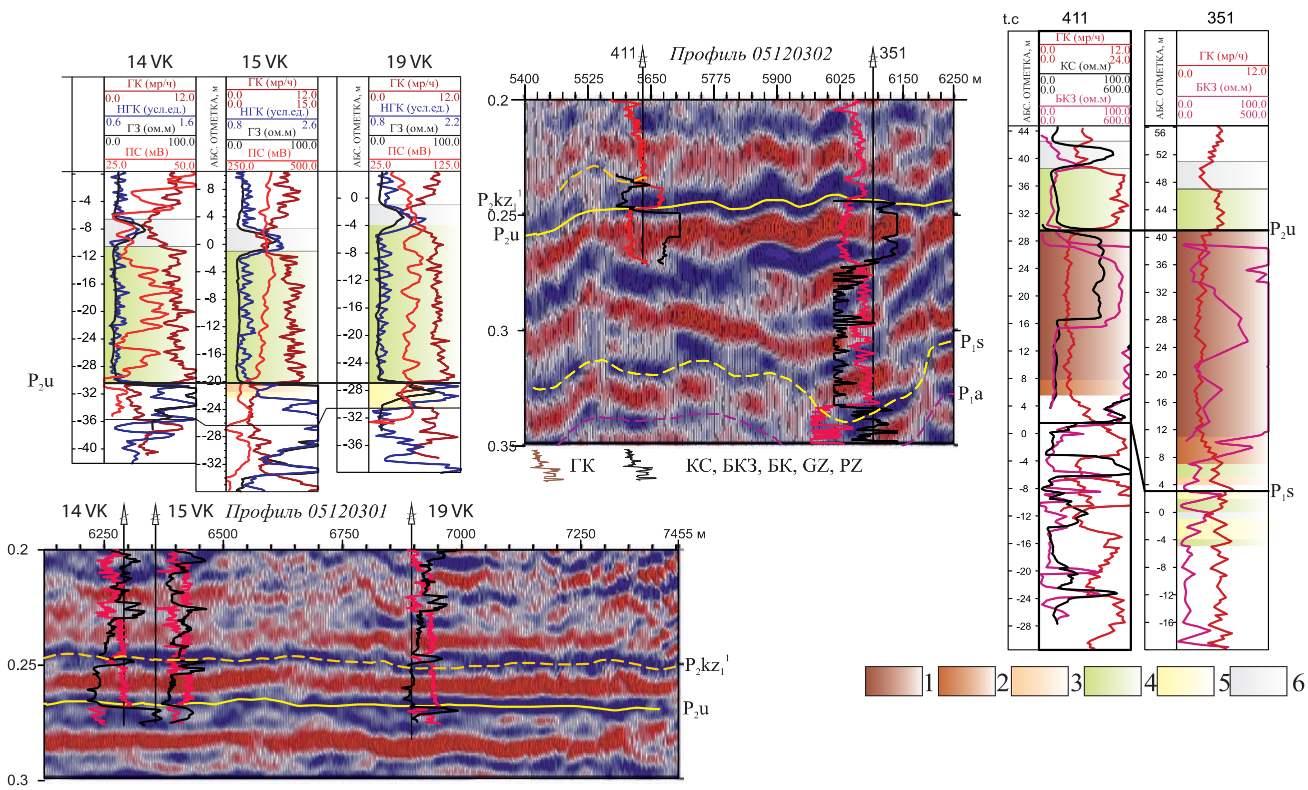

Figure 4. Changes in the wave pattern in the bedding of Ufimian sand pack. 1 – intensively bituminous sandstone; 2 – medium bituminous sandstone; 3 – weakly bituminous sandstone; 4 – argillaceous rocks; 5 – sandstone; 6 – limestone.

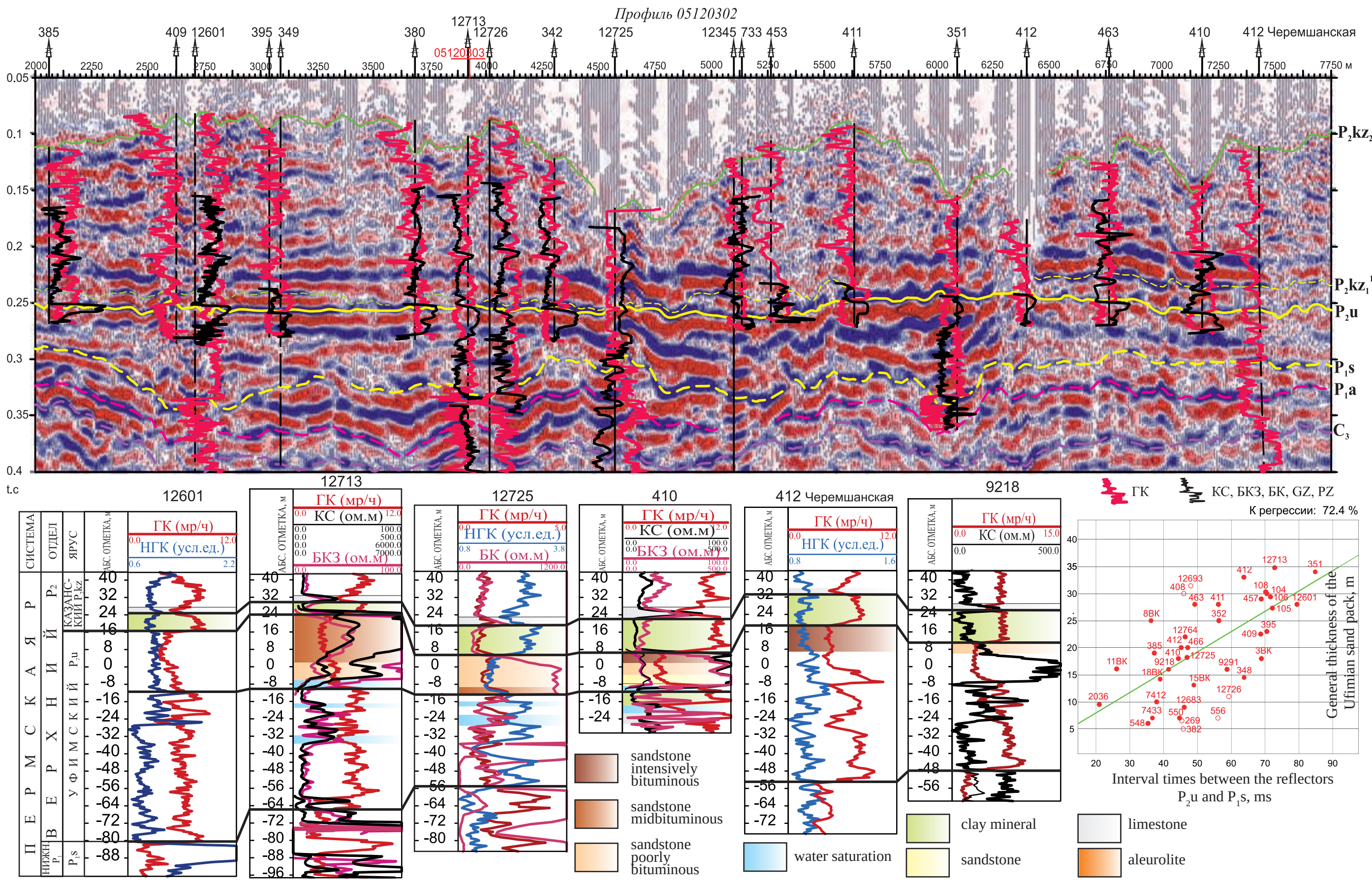

Figure 5. Prediction of correlations between changes in the interval times between the reflectors P_2u and P_1s and the general thickness of the Ufimian sand pack.

which is associated with the main deposits of heavy oil, is filled by loose, fine- and medium-grained unconsolidated sands and sandstones with thin interlayers of siltstone and clay –at the top, and thick, sturdy, calcareous, polymictic, thin sandstones – at the bottom. The thickness of the upper pack varies from 0.4 m to 35 m (well 80 Ashalchinsky). The biggest thickness of sand packs is associated with near-arch parts of uplifts.

In the wave field upper sand pack does not generate its own reflection, which is due to the absence at the bottom of benchmark with contrasting petrophysical properties. However, visually there is a relationship between the thickness of the pack, its saturation and dynamic characteristics of the reflector, registered under the roof of the Ufimian tier (Figure 4). When the thickness of the sand packs reaches 15-20 m in the wave field, there is a stable single-phase reflection with the negative sign.

With further increase of the sand packs the reflector thickens with decreasing amplitude, and, as a result, there is an interference of reflected waves with formation of two dynamically expressed reflectors of different polarity (area of well 12713). In areas of sand packs thinning in the area of wells 14VK, 15VK, 19VK the reflected wave is 'split' in the upper weakly expressed border (up to complete disappearance) and lower border with brightly expressed amplitude.

In the process of work, the attempt was made to find a correlation between changes in the interval time of the reflection with negative sign recorded under the roof of Ufimian tier and the thickness of the upper sand packs of Ufimian tier. But due to the above reasons, as well as the location of only a small number of wells on seismic profile line, correlation coefficient was not significant.

At the same time there is a relationship between changes in the interval times between the reflectors P_2u and P_1s and the total thickness of the Ufimian upper sand packs that gives grounds to assume a close relationship of paleorelief of underlying horizons and overlying compensating sediments. The regression coefficient was 72.4% (Figure 5). Thus, there is a probability in the forecast of productive sand pack of the Ufimian tier according to seismic data, provided that the testing of 2D seismic profiles will be performed on a uniform grid over the maximum number of wells.

Conclusion

We have obtained clear geological results: morphology of uplifts is adjusted, the interrelation is established between changes in the dynamic characteristics of reflection, recorded in the upper part of the Ufimian tier with thicknesses of productive sand packs of Sheshminskian horizon.

Thus, the study of the Upper Permian section interval, containing deposits of viscous oil, by means of seismic survey is advisable to perform at a dense and regular grid of profiles.

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