

Geological structure features of Menzelinsky, Timerovsky and Olginsky fields of the Republic of Tatarstan as a result of their genetic nature

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Abstract. The Menzelinsky, Timerovsky and Olginsky fields are located in the northeast of the Republic of Tatarstan and are associated with uplifts, sharply pronounced along the Tulsian surface of the Lower Carboniferous. With a small area of uplifts (1.5-2.2 km across), they are distinguished by a considerable (220-380 m) height and steep wings (up to 40°) of the carbonate rock array overlapped by the Radaevskian-Tulsian terrigenous strata. The carbonate array is represented by deposits of the Tournaisian-Famennian age on the arches of uplifts and by Famennian deposits on their wings. It is accepted to classify such carbonate structures as frameless reefs formed on local seabed areas with a combination of specific conditions for their continuous growth. In the opinion of the authors of the present article, characterized and similar uplifts were formed due to erosion-karst processes that took place on the Tournaisian continental land after the regression of the Tournaisian Sea in the east of the Russian Platform. Erosion and karst processed the limestone paleosurface of the continent during the entire Kosvinian time. As a result of the Late Radaevskian-Bobrikovian cycle of marine transgression, the entire Tournaisian-Famennian surface was covered by the terrigenous rock strata of Radaevskian-Tulsian on the wings of the uplifts and by Bobrikovian-Tulsian strata – on the arches.

Keywords: uplift, carbonate rocks, terrigenous strata, frameless reefs, erosion, karst, regression, transgression

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The Menzelinsky, Timerovsky and Olginsky fields are located in the northeast of the Republic of Tatarstan. Tectonically, the Menzelinsky and Timerovsky fields are confined to the Aktanysh-Chishminsky trough of the Kama-Kinel Troughs System (KKTS), the Olginsky field is confined to the southeastern slope of the North Tatar arch (Voitovich et al., 1998).

The fields were discovered in the last decade on the uplifts revealed by the seismic survey of CDP 2D and partly 3D on the reflecting Y horizon (the roof of the Tulsian horizon of the Lower Carboniferous). The uplifts have been drilled by exploratory and production wells. Oil production in the fields is carried out from the Tournaisian-Upper Devonian carbonate-bearing reservoir rocks. Oil deposits were also discovered in the Bobrikovian-Tulsian sandstone beds on the arched parts of the uplifts.

The uplifts, including the stratigraphic and lithologic-facies section of the sedimentary strata on them, and the oil deposits in the Tournaisian-Upper Devonian interval, have characteristic and general structural features that distinguish them from most of the uplifts known in Tatarstan with oil deposits in the Lower Carboniferous rock complex. These features are related to the genetic nature of the characterized uplifts, as well as their position in certain tectonic zones.

With a small area in the plan (1.5-2.2 km across) the uplifts are distinguished by a high altitude along the top of the carbonate rock array: 380 m – West-Yurtovsky (Menzelinsky field), 280 m – Timerovsky and 220 m – South-Izhevsky (Olginsky field).

The dip angles of the uplifts flanks along the Tulsian surface vary from 4°30' to 12°30', whereas on the roof of the underlying carbonate layer – from 17°40' to 40°30', that is, the uplifts are multiply steeper.

The cut of the sedimentary strata on all three uplifts is practically the same, and the degree of expression along the top of the Tulsian sediments is somewhat

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different. At the South-Izhevsky uplift (the Olginskoye field), the Tulsian surface is located according to well data for abs. mark from -832.0 to -911.0 m (exceeding 79 m), on the Menzelinsky – from -937.0 to -1043.0 m (exceeding 109 m), on Timerovsky – from -968.0 to -1092.0 m (exceeding 124 m). The Tulsian-Bobrikovian terrigenous strata on the Menzelinsky and Timerovsky fields have the same structure and the same thickness – 32 to 99 m at Timerovsky and 34 to 99 m on the Menzelinsky, which indirectly attests to the same conditions for its accumulation (Table 1). At the Olginsky field, the Tulsian-Bobrikovian deposits have a thickness of 24-77 m. The natural increase in the thickness of this rock complex toward the Nizhnekamsk trough is associated with the leveling of the “ancient” geomorphological depression enhanced by the erosion-karst processes in the post-Tournaisian time, the terrigenous strata formed as a result of the Radaevskian-Bobrikovian marine transgression. The thickness of the Radaevskian clay deposits in the Menzelinsky and Timerovsky fields is the same – 17-146 m and 14-148 m, respectively. On the Olginsky field it is less – 12-78 m. Radaevskian clayey stratum lies on characteristic formations according to logging data, representing frequent interbedding of carbonate rocks and clays. The thickness of the interlayers varies within 0.6-2.0 m. When comparing the sections of neighboring wells, individual interlayers do not correlate with each other, although the overall shape of these formations remains more or less constant, and the upper and lower boundaries are fairly distinct (Fig. 1-3).

The upper boundary, corresponding to a change in the clay-carbonate strata to clayey Radaevskian stratum, is practically unambiguous on logs. The lower boundary, corresponding to the change in the clay-carbonate stratum of interlayering on the Carbonate rocks of the Tournaisian-Famennian age in the arched wells and the Famennian ones – in the rest (and most of them), is not clear in all wells (Fig. 1-3). This stratum of interbedding, in our opinion, is a kind of weathering crust of the Tournaisian continent, which was eroded and karsted into the Kosvinskian (Elkhovskian) time, is a kind of foreslope. The thickness of the foreslope is not constant:

it is smaller in the arched wells (6-13 m) and increases up to 135 m in the Timerovskian uplift area in the well, which is hypsometrically lower than the rest on the roof of the Tulsian sediments.

On the profile through the Menzelinsky and Timerovsky fields (Fig. 4), the maximum thickness of the foreslope is confined to the deflection between the uplifts. In individual wells, there is no “foreslope”: at the Menzelinskoye field – in well No. 898-2, Timerovsky field – in wells Nos. 843, 2869; Olginsky field – in wells Nos. 2411, 2433.

The formation of the foreslope lies on different stratigraphic subdivisions of the carbonate sequence. In the arched wells – No. 895, 895D of Menzelinsky, No. 2802 of Timerovsky, No. 2411, 2418, 2419 of the Olginsky field – the trail covers the Tournaisian limestones, in the other wells – Zavolzhskian, and the lowest in the structures – the Dankovo-Lebedyanskian ones. The thickness of the Tournaisian deposits preserved from erosion varies from 10 m at the Olginsky field to 27 m at the Timerovsky field. In the well No. 2411 of Olginsky field, the Tournaisian interval has a thickness of 50 m and is represented by all horizons of the stage, whereas in the remaining wells that have opened the Tournaisian sediments, the latter are represented by the Malevskian-Upinskian strata (Fig. 5).

The roof of Zavolzhskian overhorizon, which is the supporting surface in the analysis of the Tournaisian-Famennian carbonate deposits, is recorded by the characteristic type of curves of the resistivity, spontaneous polarization, radioactivity logs. It is noteworthy that the thickness from the roof of Tulsian horizon to the roof of the Zavolzhskian overhorizon is 75 m at the Menzelinsky field, 78 m at the Timerovsky field and 80 m at the Olginsky field, i.e. is a value of the same order with thicknesses at other deposits of the Republic of Tatarstan (Zyuzeevsky, Tavel'sky, etc.). These facts largely support the thesis of the inheritance of the Tulsian surface from the Zavolzhskian (and from the Tournaisian paleosurface) on the entire eastern part of the Republic of Tatarstan and the erosion-karst nature of the modern Tournaisian (or Tournaisian-Famennian in the troughs of the KKTS) of the relief (Kharitonov et al., 2015).

Uplift (field)	Thickness, m				
	C1tl+C1bb	C1rd	C1t	From top C1tl to D3zv	Weathering crust (foreslope)
1	2	3	4	5	6
West-Yurtovsky (Menzelinsky)	34-99	17-146	12-14	75	7-67
Timerovsky	32-99	14-148	27	78	6-135
South-Izhevsky (Oginsky)	24-77	12-78	10-26	80	13-42

Table 1. Thickness of stratigraphic complexes of the Lower Carboniferous

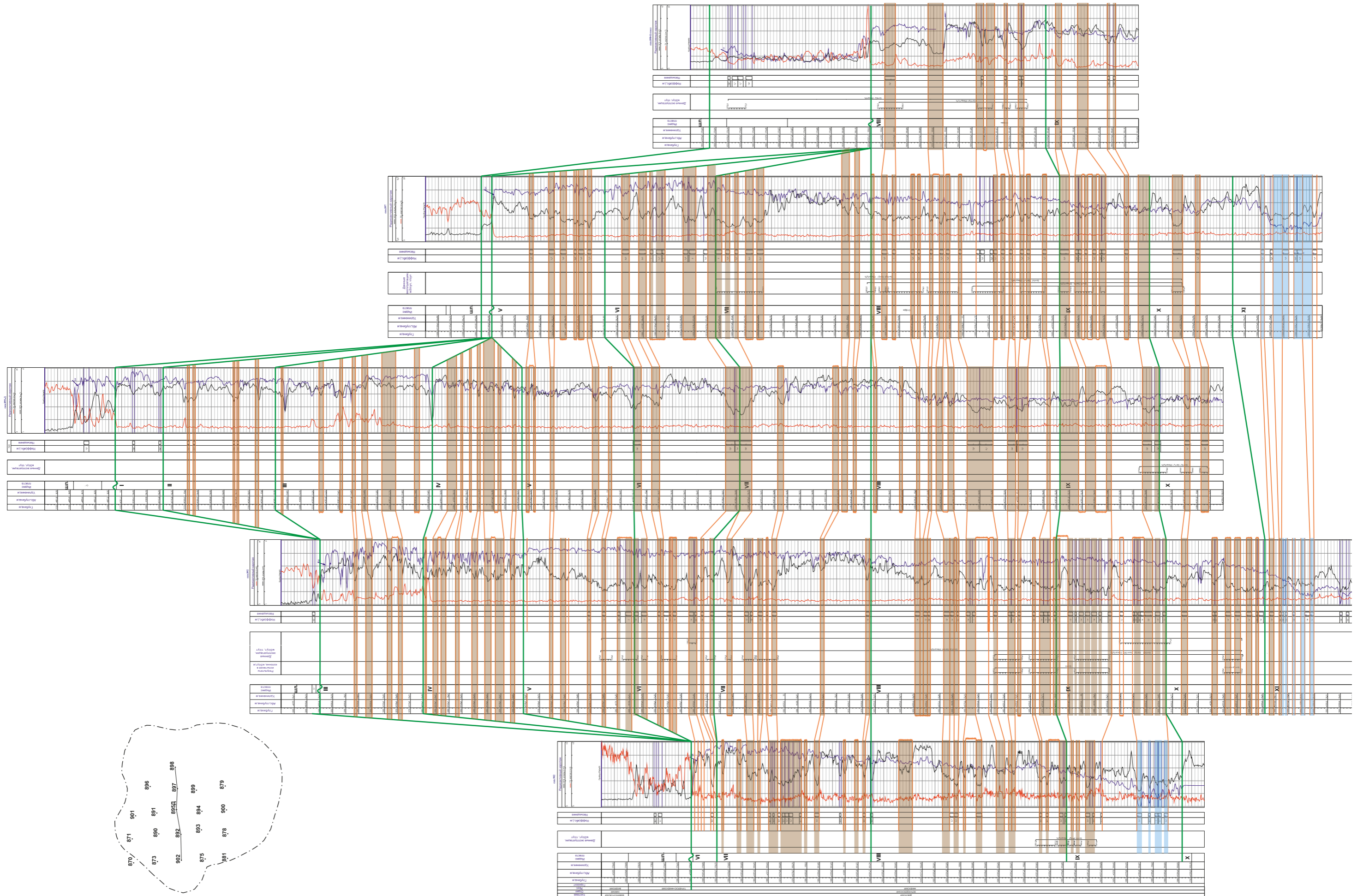


Fig. 1. Correlation scheme of the Lower Carboniferous-Upper Devonian sediments for the wells of the Menzelinsky field of the Republic of Tatarstan

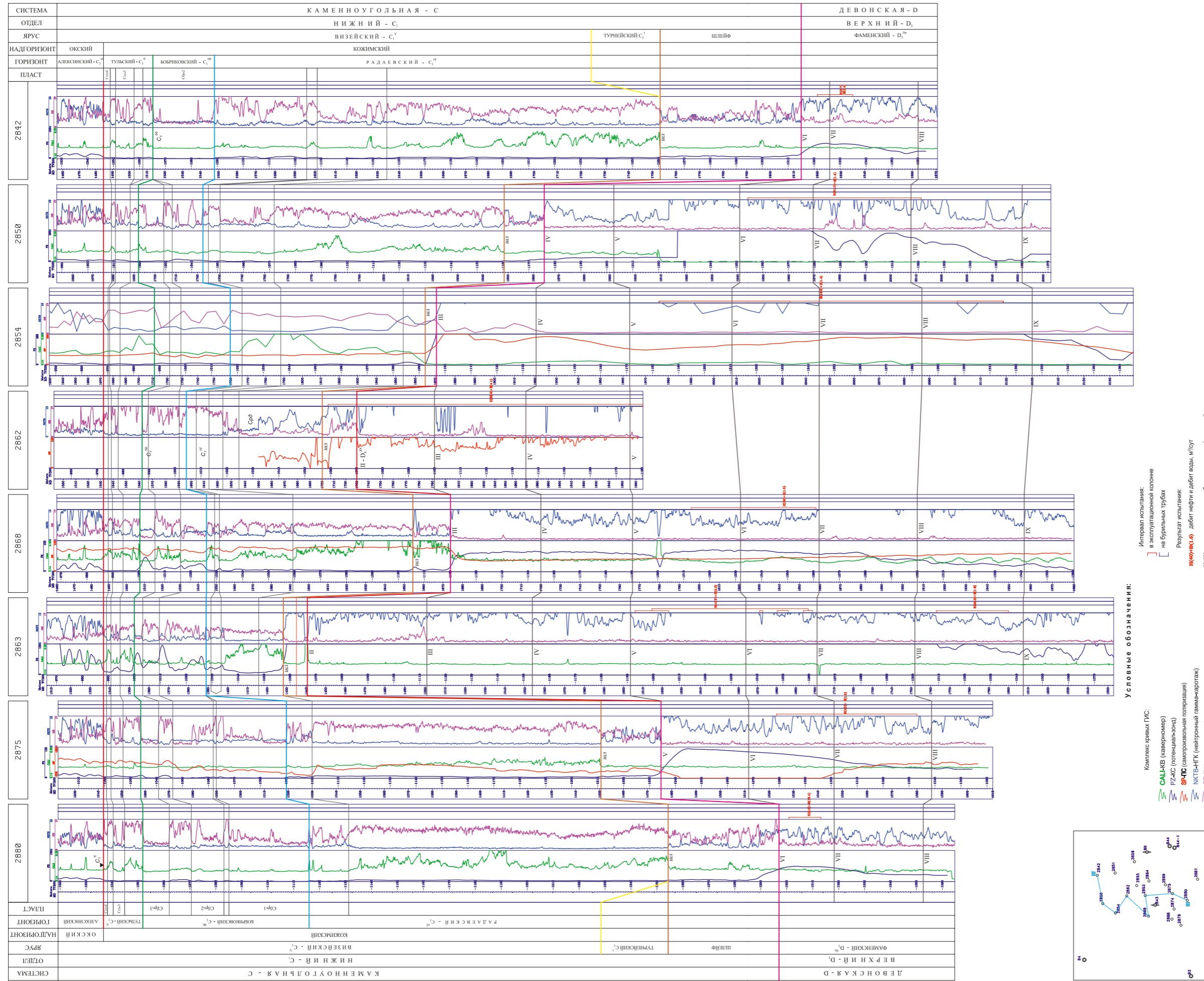


Fig. 2. Correlation scheme of the Lower Carboniferous-Upper Devonian sediments for the wells of the Timmerovsky field of the Republic of Tatarstan

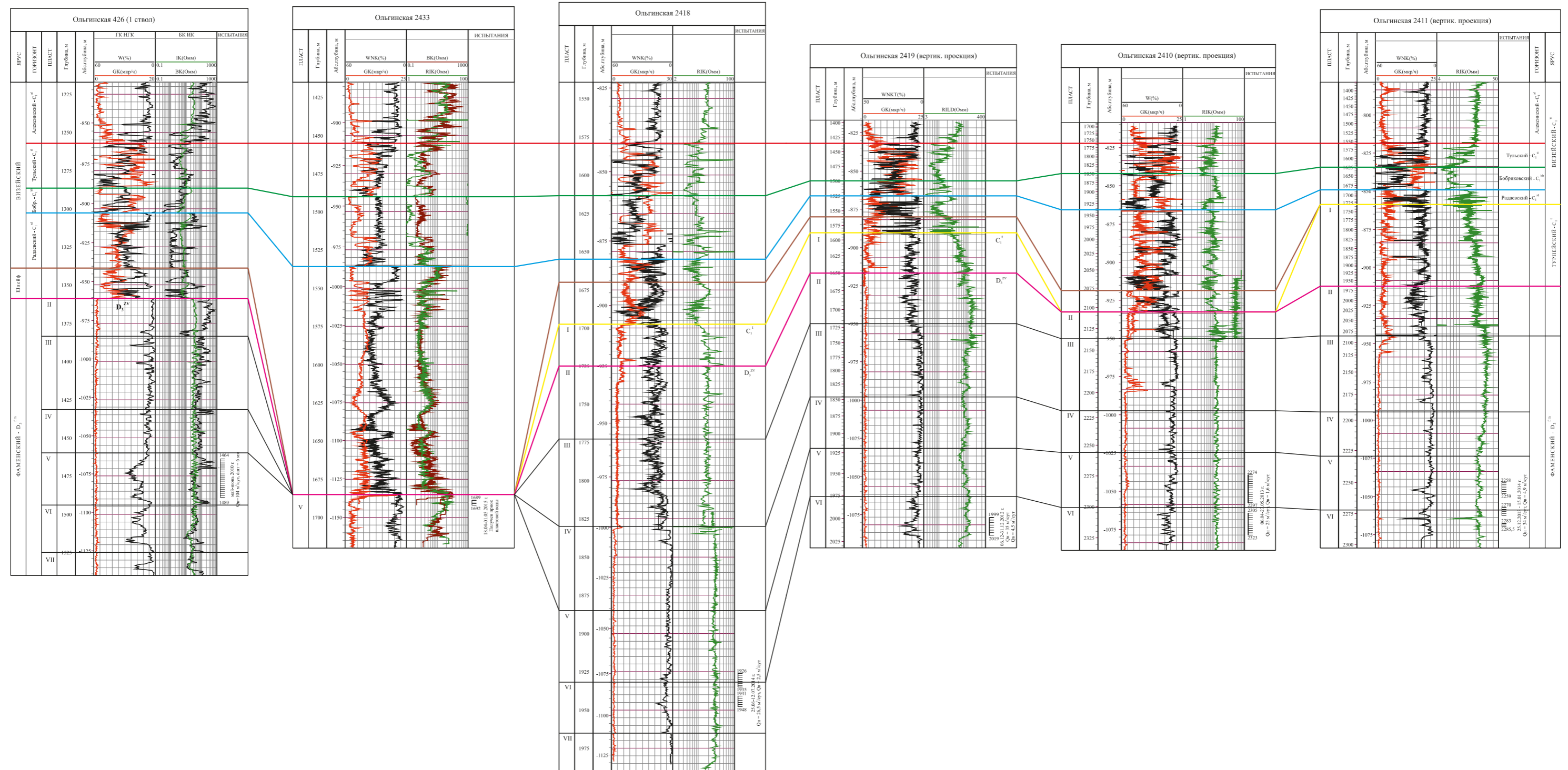


Fig. 3. Correlation scheme of the Lower Carboniferous-Upper Devonian sediments for the wells of the Olginsky field of the Republic of Tatarstan

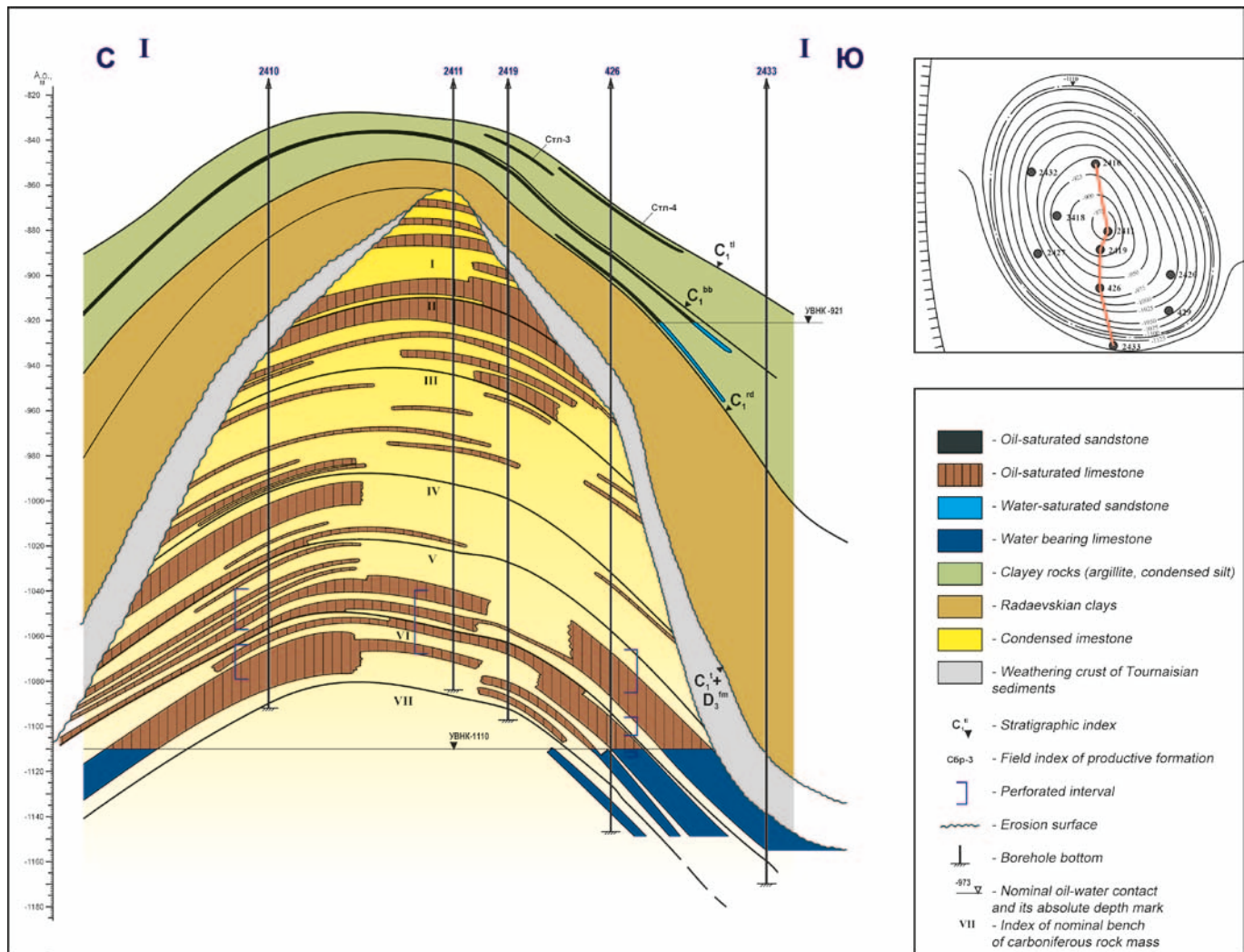


Fig. 5. Schematic geological scheme of the Lower Carboniferous-Upper Devonian sediments for the wells of the Olginsky field

Their modern conical shape and relatively steep slopes are due to the processes of erosion and karst, which continued throughout the Kosvinian time, and not to local layering of organic remains on a limited area. The cores of the reef-building structures are confined, apparently, to the thickness of the over-Rechitskian age. The roof of the Middle Fammenian is not lithologically expressed, therefore, it is impossible to carry it out with sufficient confidence in the curves of the apparent resistivity, radioactivity and other logs. Since there was no break in the sedimentation at the boundary of the Late-Middle-Famenian times, the Dankovian-Lebedyanskian deposits conformably envelope to the Slovetskian-Yeletskian, and the surface of the Zavolzhsikian sequence repeats the Dankovian-Lebedian sequence.

Structural forms, similar to the three above described, are traditionally considered to be biohermic structures – reef-building structures successively formed by different-aged cores – Retchitskian-Dankovian-Lebedyanskian, Cherepetskian and Kizelovskian, which have their own structural features (Volkov, 2008; Gubaidullin et al. 1973, Shakirov, 2003; Larochkina, 2013). Carbonate

strata of a later age envelop the earlier ones, increasing in thickness on the arch of the structure and decreasing on its wings to minimum values. For theoretical substantiation of the formation of such structures, they were classified, according to V.G. Kuznetsov, as non-framed reefs (Volkov, 2008). The remains of marine organisms – foraminifera, crinoids, bryozoans, solitary corals, various algae – concentrated on a small section of the bottom, overlapping each other and thereby ensuring vertical growth of the reef. Favorable conditions for local prosperity of organic life were created due to the fact that the Menzelinsky, Timerovsky, and Olginsky reefs, for example, were located in the junction zone of the regional Prikamsky and Bakhchsarai faults, mobile tectonically and provided the inflow of heat necessary for the prosperity of organic life from the earth’s interior into the sea basin.

Thus, for the appearance of a frameless reef and its continuous growth until the end of the Kizelovskian time, an indispensable combination of several conditions was required, the main ones the lowering of the lower boundary of the photic layer to the level of the bottom

surface due to fluctuations in the sea basin level and the high density of disjunctive dislocations per unit of that area, where the remains of marine organisms accumulated (Volkov, 2008). It should be noted that the distance between the Menzelinsky and Timerovsky reefs is only 2.6 km, although the first of them is confined to the axial zone of the Nizhnekamsk trough, which is part of the CKSP system, and the second – to its internal side zone. These zones according to (Larochkina, 2013; Muslimov et al., 1999) differed by differentiated subvertical movements due to the rise and immersion of the corresponding territories. However, the causes and results of multidirectional motions of the earth's crust at the "junction" of the axial and side parts of the deflection and at such a short distance are not given.

Apparently, the whole strata of rocks, including the crystalline basement, were involved in differentiated and various-amplitude subvertical movements. And since the amplitude of such movements reached several tens of meters, in the sedimentary stratum (the Lower Carboniferous-Devonian), disjunctive dislocations with a displacement of the blocks on either side of these dislocations would inevitably arise. However, traces of similar displacements of the same-aged strata of the Tournaisian-Devonian section in the traversed wells were not recorded either within the troughs of KKTS or outside it.

Even if we suppose the growth of the top of the reef in such a limited space – first cone-shaped, and then more and more steep, then the question arises: how did the hydrodynamic regime of the sea basin and, in a broad sense, the weather and climate conditions of that time affect such underwater structures? The sea currents, the depth of the wave impact zone, including the powerful storms, inevitably had to affect the top of the frameless reef, washing off part of the accumulated non-precipitated rainfall and redepositing them beyond the base of the reef.

The structure of the modern relief of the Tournaisian surface, in our opinion, is determined by two main genetic factors that have manifested themselves in different periods of geological history. The first in time is sedimentary, rock-forming; the second – erosion-karst, rock-destroying and at the same time rock-transforming.

The sedimentation factor created a mass of Tournaisian limestones deposited on the surface of the Zavolzhskian formations under the conditions of the continuity of the Tournaisian sea basin from the Upper Devonian. There were no geological "shocks" and "transformations" at the turn of geological epochs – late Devonian and early Carboniferous – in the vast sea basin that occupied the whole northeast and eastern parts of the Russian platform. In this large space, there was a stable marine regime with a changed hydrochemical situation, which manifested itself in the replacement of compacted

dolomitized and gypsum-bearing mainly crystalline and pelitomorphic limestones of the Volga region on structurally and texturally diverse organogenic-detrital and crystalline limestones interbedded with densely compacted dolomitic limestones of Tournaisian age.

A diverse organic life flourished in the Tournaisian sea basin – plankton and bottom (foraminifera, ostracods, pelecypods) organisms, various fish species, attached forms (solitary corals, crinoids, spiriery, etc.) and various plant forms – blue-green, scarlet, tubular algae (phytoplankton) (Antropov, 1972). Sedimented carbonate silt had both chemogenic and organogenic-clastic nature. Their distribution according to the area of the sea bottom was determined by many factors: the unevenness of the bottom relief, the change in the direction and strength of the sea currents, the depth of the waves, the frequency and intensity of the storms and sea currents that led to the tsunami. These factors violated the ideal sequence of sedimentation and often obscured it. Therefore, it is extremely difficult to identify any specific cycles of sedimentation in a lithologically monotonous Tournaisian-Famennian sequence. Significant role was played also by the processes of transformation of originally deposited silt-like sediments – processes of lithogenesis (diagenesis, epigenesis and hypergenesis). They determined partly the variety of structural and textural features of the carbonate section and its stratification (Khisamov et al., 2010).

The second factor – erosion-karst, which included two processes that occurred simultaneously, but with varying intensity. This factor manifested itself after the regression of the Tournaisian sea basin, caused by a large-scale transformation of the Earth's surface on the Russian platform (Igolkina et al., 1977). The consequence of regression was the formation of a vast continental land area, folded from the surface by carbonate muds, to a varying extent, lithotified. Processes of erosion and karst had determined the forms of the relief of the modern Tournaisian surface.

The period of the interruption in sedimentation that began at the end of the turn of the century continued throughout the Elkhovian period and part of the early times. In this segment of geological history, the continental surface began to undergo simultaneously both erosion and karsting. All the basic conditions for karsting were formed (Gvozdetskii, 1954): the presence of a soluble rock – limestone; their permeability, which was determined by the texture-structural features of carbonate silt and resulting fracturing due to dehydration during removal from sea level; active movement of surface waters due to frequent and intense storm currents in hot and humid climates; the aggressiveness of atmospheric water due to the high content of carbon dioxide in the Earth's atmosphere. On the exposed bottom of the Tournaisian Sea, the West-Yurtovsky,

Timerovsky and South-Izhevsky uplifts were allocated in the form of hills, arched parts of which were larger in area than their modern swells.

The intensity of the karst processes that created the modern sculptural appearance of the West-Yurtovsky and Timerovsky uplifts was determined by the position of the latter in the Nizhnekamsk trough of the ancient deposition, which divided the Northern and Southern Tatar arches in the Archaean period of their consolidation. This deflection existed for a very long geological time and was only lightened at the end of the Visean century as a result of the Radaevskian-Tulskian marine transgression. In the geological literature, however, the opinion prevails that the Nizhnekamsk trough, like the whole of the KKTS, is an intraformational deflection located above the monoclinical slope along the top of the terrigenous Devonian and formed as a result of prolonged differentiated and multidirectional movements of its parts – sides and axial region (Larochkina, 2013; Muslimov et al., 1999).

According to our ideas about the time and conditions for the formation of the Nizhnekamsk trough, its severity in the relief of the Tournaisian seabed, which became part of the continental land in the Kosvinian period, contributed to the widespread development of erosion and karst processes on its surface. Frequent and strong rain streams processed slopes of uplifts; temporary river streams, changing their direction and channel and flowing into the deflection, unevenly blurred its sides, dissolving the slightly lithified carbonate rocks and transferring their insoluble residue to the most lowered areas of the relief. They also moved and mixed fragments that accumulated in the slopes of the slopes and formed partly due to the collapse of the cornices of denser and organogenic-detrital limestones on the slopes of the uplifts. The deflections dividing the uplifts went deeper; residual – from dissolution and collapse – the formation of redeposited, changing the places of their accumulations. Naturally, the transferred fragments, the size of which, apparently, could reach several meters, are well recorded on logs of wells. The fragments contained faunal remains, and their structure could be very different. As a result of the Radaevskian transgression, the fragments were mixed with clay material deposited in the basin. If you agree with the opinion of E.B. Grunis (Grunis, 2010) about the instantaneous geological character of the Late Radaevskian transgression, it should be assumed that its force also contributed to the change in the relief forms and the redistribution of carbonate debris along the area and along the vertical.

The erosion-karst processes that occurred on the post-Tournaisian continent created a modern relief of the Tournaisian-Famennian surface, and, secondly, played a decisive role in the formation of the void space of the part of carbonate section that was affected by

them. The current thickness of the carbonate deposits of the Tournaisian and Famennian ages is described as a sequence of interbedding of various types of complexly constructed reservoir rocks and dense differences of the same rocks with mutual crossings along the lateral and along the horizontal. Thicknesses and the number of effective and dense interlayers within one local uplift vary from well to well without apparent pattern, although in general the distribution of rock packs containing dense and porous-permeable interlayers is quite confident.

The carbonate layer deposited in the marine basin was characterized by a variety of textural-structural types of rocks and was characterized by primary porosity and permeability, macro- and micro-lamination (Kozina et al., 1973). After the regression of the marine basin, the carbonate, unlithified silt exposed onto the day surface was dehydrated, turned into a “crust” of rocks, which cracked with the formation of numerous and predominantly subvertical cracks. It is believed, however, that for reefgenic structures like the Menzelinsky, Timerovsky and neighboring reefs, the fracture is associated with tectonic processes occurring in the body of the crystalline basement and in the sedimentary layer overlapping the basement (Volkov, 2008; Shakirov, 2003).

The exposed bottom of the regressed Tournaisian Sea was distinguished by a dismembered relief – the presence of different in area and height and relatively shallow uplifts, separated by deflections and depressed portions.

On its surface there were open karst processes, in the thickness of rocks – a closed karst. These processes included both the dissolution of the primary rock and the mechanical action by rain storms. Storm streams removed an insoluble residue from the surface, and high temperatures promoted the warming of rocks from the surface and increased solubility of limestones. The open karst thus denuded the upper part of Kizelian sediments in different depths, depending on the nature of the relief and “purity” of the limestone, as a result of which there are no complete sections of the Tournaisian stage in Tatarstan.

The more contrasted the Tournaisian relief, the more processing it was subjected to from the surface. Greater solubility was possessed by fine-grained and pure limestones of lesser extent – limestone organogenic-detrital and clay (Kozina et al., 1973). As a consequence, protrusions, cornices, steps, niches formed on the slopes of the uplifts. Over time, protrusions and cornices collapsed under the influence of continued dissolution and gravity, and their fragments were transported to the lowered parts of the relief, forming a kind of weathering crust and breccia interlayers, which were taken for the erosion of those deposits on which the breccia interlayers lie.

Those parts of the Tournaisian uplifts had undergone particularly strong processing, that adjoined the slopes,

as rain streams flowed over them, and the surface of the slopes warmed up well. A large role in the underground karst was played by the sedimentary layering of carbonate rocks and the thickness of their various structural differences. This should be taken into account when evaluating the effective thicknesses of wells drilled at one local elevation, since the effective thicknesses in the two adjacent wells can not differ by an order of magnitude if they are due to their appearance to the same process. In the development of Tournaisian (and Tournaisian-Famennian) sediments, the highest oil rates are often observed in wells located on the slope parts of the uplifts, in which the reservoir properties indicators of the productive formation are usually higher (Muslimov et al., 1999).

In the modern tropical countries, positive karst forms of relief are widespread: high and steep remnants in the form of pillars, towers, cones and dome-shaped forms.

Local elevations of the Menzelinsky, Timerovsky and neighboring reef-like structures have a characteristic dome-shaped form. This form seems to be typical for all Tournaisian-Famennian uplifts in the axial zone of the Nizhnekamsk trough and is less common outside its borders. Most of the Tournaisian uplifts have smoother shapes.

In our opinion, the shape and size of modern uplifts in the Nizhnekamsk trough are determined primarily by erosion and karst processes. The significant height of the void-porous reservoir on the uplifts is entirely due to its formation by an underground karst.

Main conclusions

1. The surface of the Tulsian horizon, taken for the reflecting horizon U under seismic constructions, corresponds to the Tournaisian paleosurface, inherited in turn from the Famennian-Zavolzhsian, since there was no break in the sedimentation on the border of the Famennian and Tournaisian centuries.

2. The thickness of rocks enclosed between the roof of the Tulsian horizon of the Visian Stage of the Lower Carboniferous and the roof of the Zavolzhsian overhorizon of the Famennian Stage of the Upper Devonian remains relatively constant (70-80). This means that the thicknesses of the Tournaisian horizon preserved from erosion and karst also vary within a narrow range.

3. The modern surface of the Tournaisian deposits is formed by erosion-karst processes that dominated the Tournaisian continent, formed after the regression of the Tournaisian sea basin in the entire east of the Russian platform.

4. The wide development of karst was facilitated by the combination of the conditions necessary for its manifestation: geological – the presence of a thick layer of permeable and fractured limestones, the duration of the continental break; geomorphological – a dissected surface, inherited from the Famennian, with its positive

and negative forms of relief; climatic – humid and warm climate, a large amount of sediments in the form of showers with the formation of temporary water flows and a high content of carbon dioxide in the atmosphere.

5. Surface karst in combination with wind and river erosion created a variety of modern structural forms of the Tournaisian-Famennian surface; The deep (underground) karst formed a hollow-fractured volume of oil and water-containing reservoirs in the Tournaisian and Tournaisian-Famennian strata.

6. The Tournaisian-Famennian relief in most of the territory of the Republic of Tatarstan is blocked by Radaevskian clays containing a spore-pollen complex of Elkhovian appearance.

7. The transgression of the marine basin took place in two stages: in the Late Radaevskian and Radaevskian-Bobrikov time. The established marine regime in the territory of the Republic of Tatarstan is at the beginning of the Tulsian time.

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