The Results of Stratification of Tournasian Deposits on Uplifts with Erosion-karst Surface on the Example of Zyuzeevsky Field

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Abstract. According to field logging of wells in Lower Carboniferous strata, the uplift is definitely marked with two stratigraphic boundaries – top of Zavolzhskian carbonate horizon of the Upper Devonian and top of Tulskian clastic complex of the Lower Carboniferous. The analysis of thickness between them shows that the Tulskian surface repeats Zavolzhskian surface, while modern surface of Tournaisian sediments has a complex differentiated nature due to erosion-karst processes. The reconstructed Tournasian surface repeats Zavolzhskian surface, i.e. we trace heredity of the Lower Carboniferous structural plan from the Upper Devonian.

Keywords: stratification, erosion-karst surface, uplift, incision, horizon, correlation, structural plan, heredity.
DOI: 10.18599/grs.18.1.1

For citation: Kharitonov R.R., Aref'ev Yu.M. The Results of Stratification of Tournasian Deposits on Uplifts with Erosion-karst Surface on the Example of Zyuzeevsky Field. *Georesursy* [Georesources]. 2016. Vol. 18. No. 1. Pp. 3-7. DOI: 10.18599/grs.18.1.1

Oil deposits on Zyuzeevsky field are confined to the Middle and Lower Carboniferous production intervals and controlled by homonymous brachyanticlinal uplift of the III order, pronounced in the structural plans of all marking Carboniferous horizons. The surface of Tournasian strata is an exception. It is characterized by the presence of relatively narrow (0.15-0.2 km), deep (up to 86 m) and countervailing 'incisions' that frame elevated areas of Tournasian relief.

Tournaisian surface that is difficult to differentiate is the result of erosion and karst processes in the dominant role of the latter (Kharitonov et al., 2015). Incisions are made of sand-clay rocks of Radayevskian-Bobrikovian to the upper edge of sides. Preserved from the karst and more or less evenly eroded areas of Tournasian uplift ('outliers') and incisions made of clastic rocks are overlapped by Bobrikovian-Tula clastic sand and clay formations.

Sandstone formations in the incisions and Tula-Bobrikovian strata, effective porous-permeable interlayers in Tournaisian limestones are oil-saturated and form a single oil-containing reservoir with a single water-oil contact (Fig. 1).

Tournasian body of this carbonate-clastic oil-containing object has no less complex structure than its surface. In its different sections Visean clastic rocks occur at stratigraphic heterochronous Tournaisian carbonate rocks. In sections of 15 wells, they lie on the karst surface of Zavolzhskian Upper Devonian horizon.

Relatively complete sections of Tournaisian strata, including Kizelovskian, Cherepetskian and Malevskian-Upinskian horizons are presented in 18 wells out of 115; in 39 wells Tournasian surface is composed of eroded and karst rocks of Cherepetskian horizon, in 58 wells – Malevskian-Upinskian.

In 47 wells Tournaisian deposits are not penetrated, and drilled bottom is in the Visean rocks.

It should be emphasized that the stratification of Tournasian sections exposed to erosion-karst processes, causes some difficulties. Even in normal (without clear signs of karst) sections the borders between horizons are often drawn conventionally. In the classic, i.e. the traditional sense, one stratotype is different from another by change of certain macro- and / or micro-faunal residues without any solid support on lithological change of some rocks by others at this boundary.

Lithological boundaries, as we know, are clearly recorded

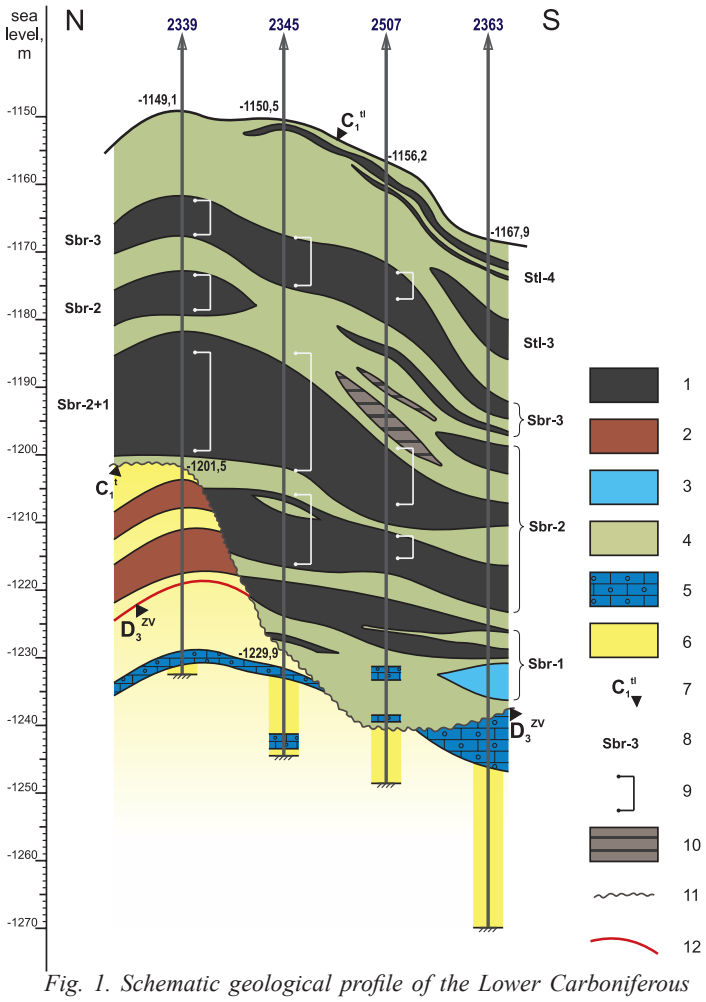


Fig. 1. Schematic geological profile of the Lower Carboniferous sediments. Horizontal scale 1:10,000, vertical 1:500, 1 – oil saturated sandstone; 2 – oil saturated limestone; 3 – water-bearing rocks; 4 – mudstone, argillaceous siltstone; 5 – water-saturated limestone; 6 – compacted limestone; 7 – stratigraphic index; 8 – index of the reservoir; 9 – perforated interval; 10 – carbonaceous-argillaceous rocks; 11 – surface of the breaking, 12 – surface of Zavolzhskian deposits.

by well logging. Since the core at sinking of production wells is not taken at all, or selected from specific intervals to study mainly reservoir properties of rocks, not the microfauna, the main and perhaps the only way to stratify Tournasian section is to perform well logging.

According to well logging it is not always possible to definitely draw horizon borders due to frequent interbedded porous-permeable (effective) and dense layers with markedly changing thickness, even for short distances. However, the problem is solved due to the presence of carbonate strata overlapped by Visean terrigenous rocks, reliable and obvious, according to a radioactive logging, marker surface, which is a top of Zavolzhskian horizon of Famennian stage of the Upper Devonian.

Lithologically this boundary reflects alternation of Zavolzhskian limestone with rare and relatively thin efficient interlayers allocated by well logging at different hypsometric levels, into Malevskian-Upinskian porous-permeable limestone interbedded with compacted differences (Fig. 2). With two reliable marker horizons – Zavolzhskian top and Tula top – we can trace Visean rocks in wells with the most complete, non-karst section of Tournaisian deposits. In these sections the horizon borders of Tournasian tier and their thickness will be determined with a high degree of reliability.

On the field, the total thickness of the Visean clastic rocks and Tournasian carbonate rocks, in whatever amount the latter may be represented, is 69-85 m. Maximum thickness – more than 80 m - is recorded in well sections in which Tournaisian deposits are completely denuded, and karst processes captured top of Zavolzhskian deposits at a depth of 10-12 m (wells No 945, 954, 2511 and others – total of 13). These wells trace the deepest post-Tournaisian incisions. On the remaining area of the uplift, complex of rocks from the top of Tula horizon to the Zavolzhskian top not exposed to karts ranges from 69 to 77 meters, averaging 73 meters.

It should be mentioned that this interval of thickness fluctuations are actually somewhat narrower (69-74 m), as in a number of wells in a volume of the Tula horizon stands STL-4 layer having lenticular nature of the occurrence. This means that in these wells, thickness 'countdown' is conducted from the top of STL-4, and in wells without the formation (most of them) – from the top of Tula clay crowning Visean terrigenous strata. In addition, the majority of wells drilled are directional inclined.

At almost similar thickness of rocks between the two marker horizons – tops of Zavolzhskian and Tula horizons – the structural plans coincide, differing only in details, without any fundamental importance. From this it follows that the Tula structure covers Zavolzhskian, i.e. it is inherited (Fig. 3 a, d).

On the so-called 'outliers' of Tournasian section – areas where Kizelovskian deposits are eroded for the same depth. Therefore, the amount of Tournasian deposits are most comprehensive, thickness of Tula-Bobrikovian rock complex is in its extreme values of 14-26 m, usually 19-23 m, and an

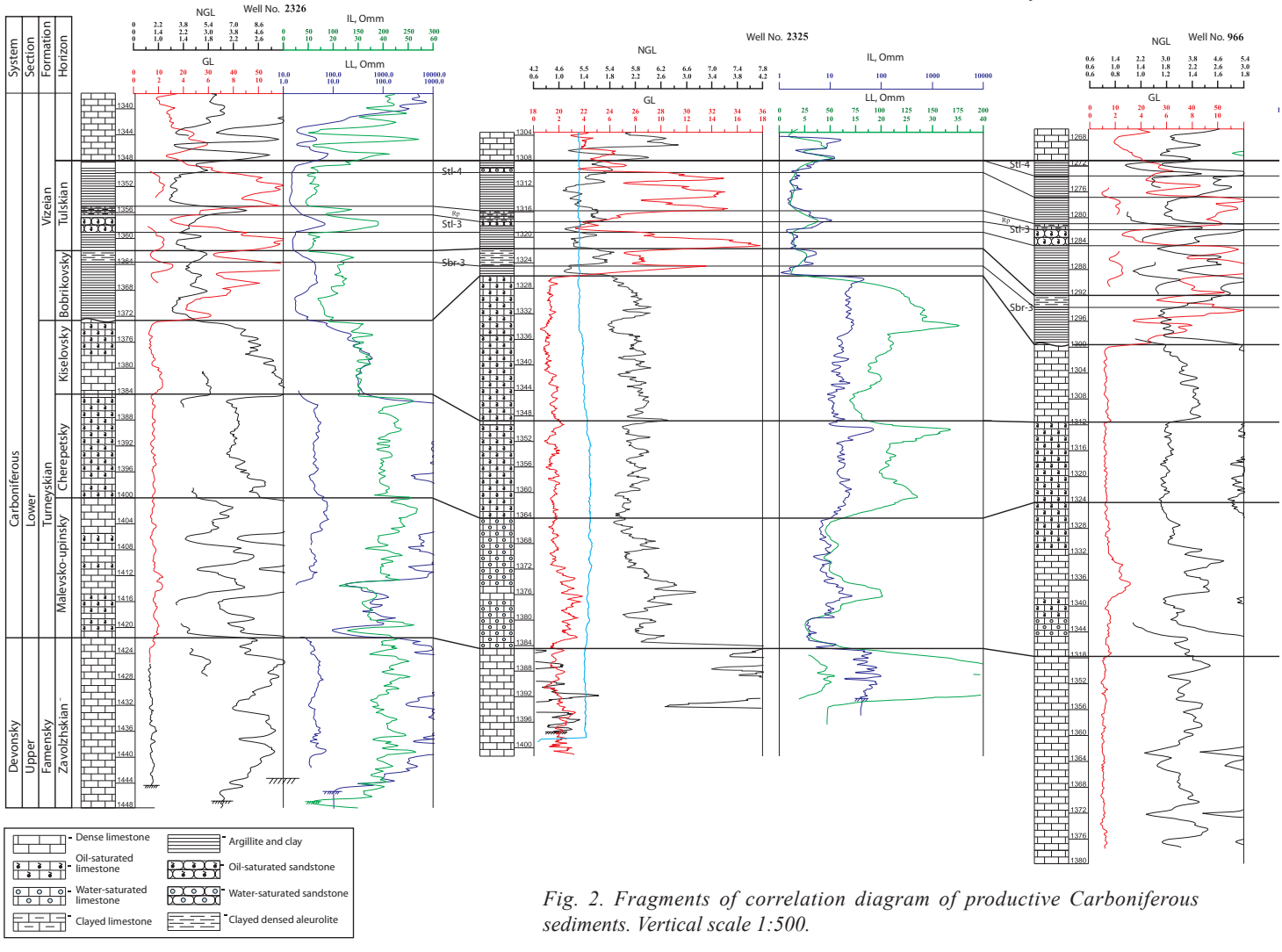


Fig. 2. Fragments of correlation diagram of productive Carboniferous sediments. Vertical scale 1:500.

average of 22 m. This means that Tournasian and Tula surfaces have the same structural appearance on the 'outliers': for example, 1180 m isohypse of Tula surface corresponds to the isohypse of 1202 m (+/- 3 meters) of Tournaisian surface, etc. Thus, paleorelief of Tournaisian surface repeated without sharp distortions of Zavolzhskian relief (Fig. 3a, b).

Analysis of well logs and their comparison by the longitudinal and transverse well profiles allows a more or less reliable borders of Cherepetskian and Malevskian-Upinskian horizons, relying on revealed constancy of thickness from the top of Tula horizon to the top of Zavolzhskian and heredity of Tournasian structural plan before it is exposed to exogenous processes from Zavolzhskian.

Lower, indivisible into horizons, Malevskian-Upinskian stratum stands at a relatively high values of gamma-ray logs, but lower than for Zavolzhskian interval according to radio log and recession of gamma-ray curve on the border with Cherepetskian horizon (Fig. 2). Thickness of Malevskian-Upinskian interval in its entirety is 19 to 23 m. Its top part is exposed to karst and eroded at different depths; in Zavolzhskian strata with karst surface Tournaisian deposits are completely absent.

Cherepetskian deposits stand out on well logs in comparison with overlying and underlying strata with relatively low values of gamma-ray logs. Horizon thickness is 15-16 m on 'outliers'; it decreases on the rest of the uplift up to complete absence.

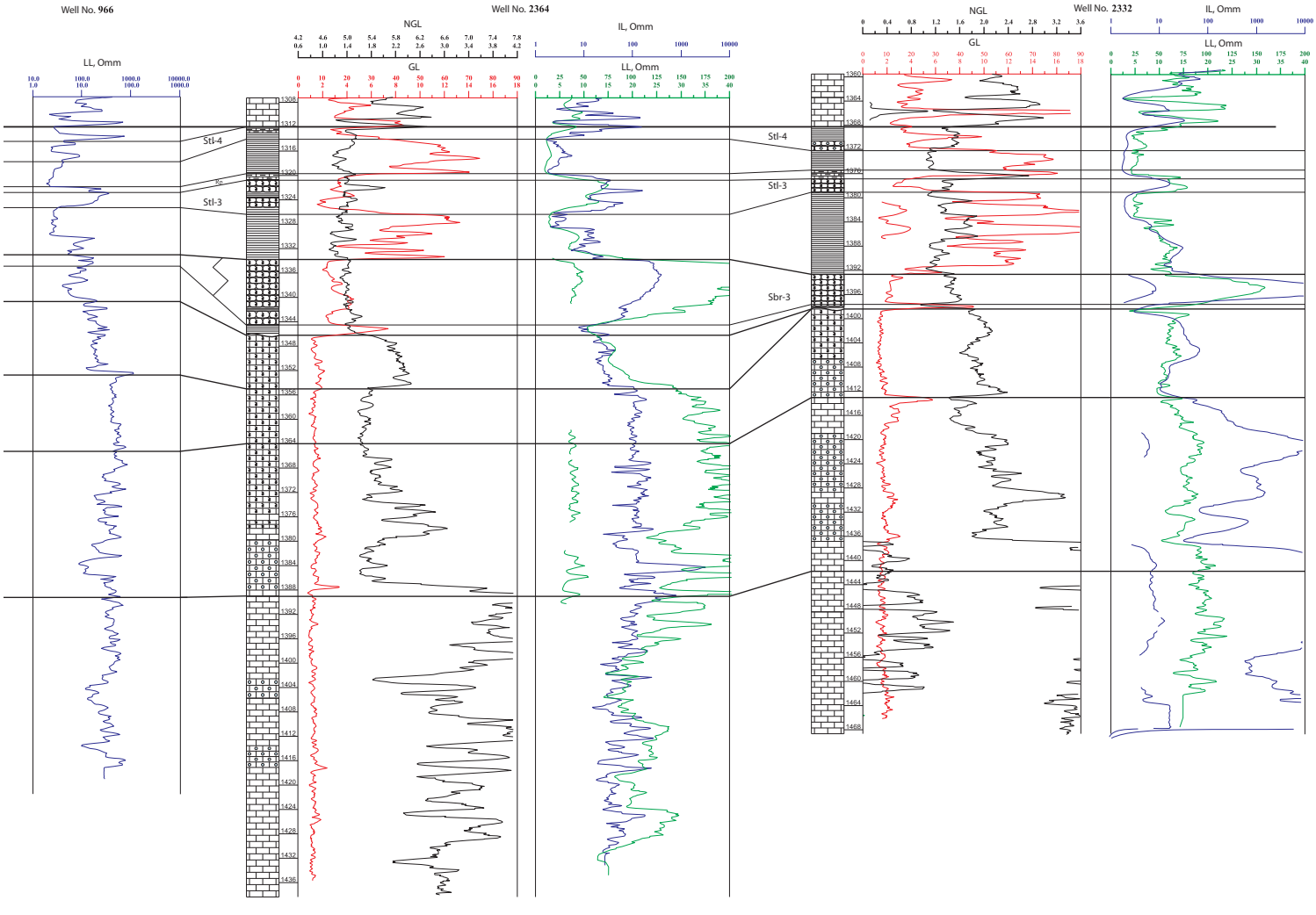
Kizelovskian deposits suffered the greatest erosion and karst, being on the daylight surface after regression of Devonian-Tournasian sea basin. Accordingly, their thickness ranges from zero to a maximum of 29 m in the well No. 2385 on outlier. In the same well the lowest value of Visean terrigenous sediments is marked – only 12 m with the absence of them in the section of productive strata Stl-3 and Sbr-3 present in all neighboring wells. Kizelovskian stratum stands out on logs with higher values of gamma ray compared to underlying cherepetskian sediments.

Kizelovskian, Cherepetskian, to lesser extent Malevskian-Upinskian horizons are oil-saturated in relatively complete sections of Tournasian tier.

In Zavolzhskian horizon, especially in its top part, effective interlayers are not allocated by well logging. In some wells, they are 6-10 meters below the top and are water-saturated. In the few wells thin oil saturated interlayers are allocated in the top.

Correlation of well sections drilled on the field and the analysis of terrigenous and carbonate parts of the Lower Carboniferous sediments allow reconstructing paleostructural Tournaisian plan (Fig. 3b), confirming its heredity from Zavolzhskian plan and heredity of Tula structural plan from paleo-tournaisian; erosion and karst were compensated by Bobrikovian-Radaevskian deposits.

For the reconstruction of Tournaisian surface the average value of Visean deposits on the 'outliers' was taken for basis, which was equal to 22 m and counted from the mark of the Tula horizon by log diagram in the remaining wells. Since



deviation from the average thickness in either direction does not exceed 3 m, we can state that the reconstructed surface is sufficiently reliable. Characteristically, it almost coincides with the surface of the productive Bobrikovian formation Sbr-2, rising to 2-3 m above the latter in wells with a small (1.0-1.5 m) effective thickness of the formation (Fig. 1).

In wells stopped in Visean terrigenous rocks, absolute elevation of the Zavolzhskian horizon surface was determined by recalculation: 73 m was added to the absolute elevation of the Tula horizon top (taking into account the values of the average thickness of the Visean-Tournaisian strata).

Conclusions

1. Tournaisian paleostructural plan corresponds to Zavolzhskian, which is quite natural, since Tournaisian sediments blocked Zavolzhskian in the same sea basin, which did not experience any geological 'shocks' at that time.

2. The difference of the lithologic appearance between the Tournaisian and Zavolzhskian section is connected, firstly, with widespread changes in the hydrochemical regime of the sea basin at the end of Zavolzhskian time, and secondly, with the processing of Tournaisian paleosurface by erosion and karst processes that created a modern Tournaisian relief.

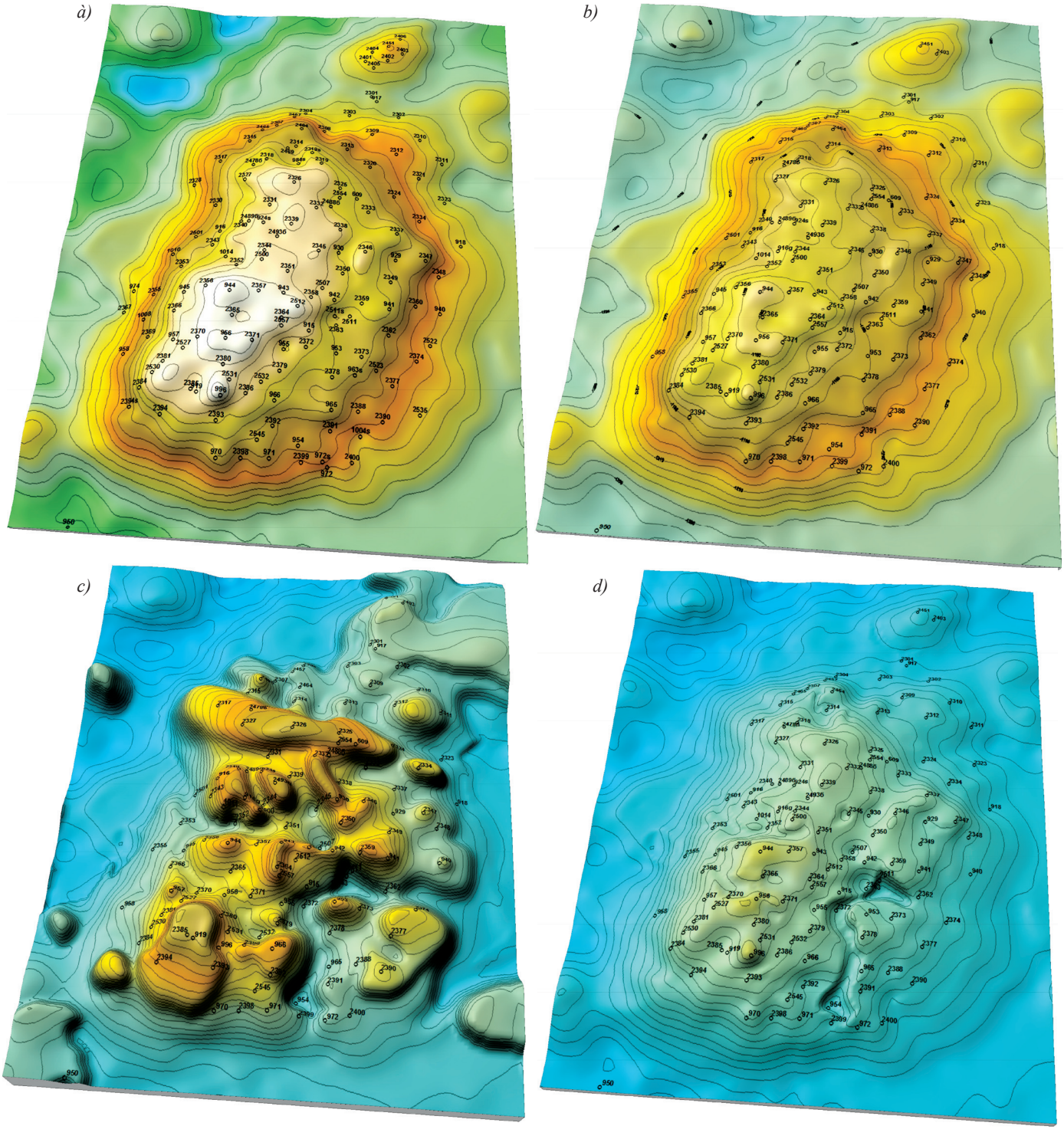


Fig. 3. a) Structural map of the Tula surface of the Visean Lower Carboniferous, b) Paleostructural map of the Tournaisian surface of the Lower Carboniferous sediments. Scale 1: 10,000. c) Structural and erosional map of the Tournasian surface of the Lower Carboniferous sediments. Scale 1: 10,000 d) Structural map of the Zavolzhskian surface of the Famennian Upper Devonian. Scale 1: 10,000.

3. Erosion-karst processes have played a major role in creating a void space of Tournaisian strata preserved from denudation. They practically have not affected, except for a small area on the uplift, Zavolzhskian deposits, retained the original appearance.

4. Paleosurfaces of stratigraphic horizons of Tournasian tier lie parallel to each other and the Zavolzhskian surface, inherited from the latter.

5. All horizons of Tournaisian tier, to a lesser extent - Malevskian-Upinskian strata containing a large amount of dense layers are oil-saturated. Zavolzhskian deposits on the field are comprised of thick limestones and dolomites and serve as a bridge consistent vertically and horizontally bridge between oil-saturated Visean-Tournaisian strata and water-saturated Zavolzhskian intervals.

References

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Received January 31, 2016