ISSN: 0975-766X
CODEN: IJPTFI
Research Article

Available Online through
www.ijptonline.com

TRANSFORMATION OF SANDBODY GEOMETRY AS THE RESULT OF ENCLOSING CLAY ROCK COMPACTION

S. E. Valeeva, B. V. Uspensky
Kazan (Volga region) federal university, Kazan, Kremlevskaya str., 18

Received on 04-03-2016 *Accepted on 29-03-2016*

Abstract

During paleogeographic studies the identification of channel, deltaic and avandeltaic environments of sedimentation is obstructed. Experience shows that their definition according to the granulometric composition of constituent deposits is not a sufficient basis for the reference to the category of continental facies. To do this, we should attract some indirect evidence, for example, the drawing of paleo drain network, the geometry of sandbodies and the configuration of basal and lateral contacts, etc. The performed studies demonstrated the transformation of sandbodies due to the nonuniform compressibility of clay and sand rocks, causing to the formation of various pseudo-structural elements in the form of bends and folds. Therefore, during the identification of formation conditions for clastic natural reservoirs the adjustment of trap forms is needed for the processes of enclosing clay rock compaction.

Keywords: sedimentation terms, sandstone pack, alluvial-deltaic formations, hydrocarbon traps

1. Introduction

The study of stratigraphic and lithologic traps of hydrocarbons shows that most of them are confined to terrigenous formations, folded mainly by sandy-silty rocks.

The analysis of lithologic and stratigraphic deposits discovery, in particular the deposits, associated with alluvial-deltaic formations indicates that the success of their detection depends mainly on the knowledge of sandy body condition formation, a correct reconstruction of paleogeographic and paleogeological environments of their formation. This is explained by the fact that the formation of numerous hydrocarbon traps is controlled mainly by the conditions of sedimentation accumulation and largely by secondary processes.

The revealing among the buried strata of sedimentary alluvial-deltaic deposits is significantly contributed by the fact that modern analogues thereof because were more studied due to their greater availability than the subaqueous marine sediments. However, as G. Bush specifies fairly [1], many of the world oil and gas basins have ancient alluvial-deltaic formations which remain unknown, described as sea current sediments or as the rocks of unknown origin. The materials and the experience of domestic and foreign, mainly North American researchers, clearly show that the study of only one lithologic composition is not sufficient for a qualified and unambiguous revealing of alluvial-deltaic genesis among thick sedimentary sections [1-4].

In this regard, the identification of fluvial, deltaic and avandeltaic environments of sandstone pack deposit sedimentation on the eastern side of the Melekess Basin and the south-eastern slope of the South Tatar crest requires the use of indirect attributes. These attributes include: the drawing of a paleodrain system, the nature of the facial paragenesis, the structure and the sorting of sandy-silty rocks, sand bodies geometry and the configuration of basal and lateral contacts, the mineralogical characteristics of clastic rock clay fraction, etc.

2. Tracing of Paleodrain System Drawing

In order to trace the sediments of a sandstone pack performing paleovalleys the method of isopachyte maps development for sand and silty rocks was applied. The analysis of performed structures shows (Figure 1) the traps associated with these deposits, form linear systems, which are located in general according channel flows, the flows within delta and form separate strips of uplifts, which are usually referred to as ridges in geomorphology.

The ridges are separated from each other by depressions, within which a reservoir rock, composing them, is characterized by a sharply reduced power (less than 10 m) or is absent completely.

The figure of paleodrain system is expressed by an intense repeated branching of the main channel, which is more typical of avandeltaic deposits. In terms of a platform the avandeltaic accumulations, as opposed to the alluvial ones, are presented by sandy and silty rocks and do not contain some scattered or "concentrated" (layers, lenses) gravel-pebble material. In the basal part of avandeltaic sandy lenses the amplitude of underlying sediment erosion is usually minimal one and the sole of heavy oils in a sandstone pack is flat or slightly concave partly because of this fact.

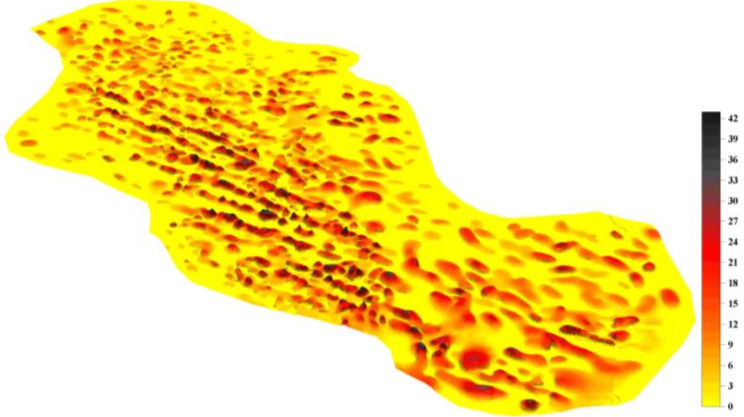

Fig. (1). - Sand body traps of sedimentary genesis Bugulminsky horizon on RT territory (the scale of sandstone

pack thickness in meters).

The facial replacement of sand and silty rocks alleged earlier [5, 6] by the authors in the top of a pack into the deposits of "lingula clays" makes now doubt among the majority of researchers nowadays. According to the latest chart (MSC) a sandstone pack previously allocated as the part of sheshminsky horizon of Ufa tier refers to the basal deposits of Kazan one (Bugulminsky horizon). One proof of the stated fact is the intermittency of sand and silty rocks with clearly marine shelf deposits, which is more typical for avandeltaic accumulations. This is also shown by the composition of a sandstone pack clay fraction where metastable mixed-layer minerals are present in a considerable amount, the formation of which is associated with allogenic biotite degradation, brought into the sea transgressing basin by river waters.

3. Sand Body Geometry and the Nature of Their Basal and Lateral Contacts

In order to study the geometry of sandy bodies and the nature of their basal and lateral contacts let's consider a the number of paleogeologic and paleogeomorhological structures (profiles) performed at Ashalchinsky, Mordovo-Karmalsky, Sugushlinsky and other heavy oil deposits.

When profiles are designed the rock compaction factor is taken into account, because in diagenesis stage many of precipitation change their textural appearance, and the rock which passed this stage, often lose the traits that it had, being in the form of precipitation. The accumulated precipitates during diagenesis lose the water contained therein, decrease in volume, but the degree of reduction is different among the precipitation of various lithological composition: it is the largest one among clay and siliceous rocks and the smallest one among carbonate and sand rocks. At that the clays of mainly kaolinite composition are compacted substantially less than montmorillonite ones.

For example, according to M.B. Pronicheva data during the compaction of rocks at the diagenesis stage, the sediment power is reduced as follows: clays - 80%, argillaceous siltstone - 35%, sand, limestones and dolomites are not compacted virtually [7].

According to V.A. Babadagly et al. [2] clays may be compacted clay up to 45-55% of the initial capacity.

I.N. Nesterov, studying the processes of compaction for different depths, took the starting absolute porosity as the porosity of silts, which are on the transition boundary from a liquid into a plastic state, which corresponds to the values of porosity ratio in the range of 35-40% [8].

Knowing the specific values of an absolute porosity ratio of clay rocks for the studied Lower Kazan and Ufa sediments, we may calculate correction factors.

It is known that the rocks of the Kazan and Ufa tiers of lithologically heterogeneous ones. Therefore, the construction of paleogeological profiles of Mordovian-Karmalsky, Sugushlinsky and other fields was carried out taking into account the factor of sediment uneven compaction.

In the studied area the Ufa deposits occur on calcareous foundation of Sakmarian rocks that are resistant to compaction in relation to the overlying ones, mainly clastic strata. As the tectonic activity of the study area during the late Permian period and the subsequent periods was a negligible one, then during the construction of profiles a modern structural plan of Lower Permian deposit surface was taken as the basis, putting up the thickness of the overlying deposits of sand and clay and sandstone packs, "lingulian clays" and "median sperifiral limestone" of Ufa and Kazan tiers taking into account the decompression coefficients.

Summing the thickness of clay, silt, sand and carbonate layers in the studied well sections separately for Lower Kazan substage and Ufa tiers and taking into account decompression coefficients for these rocks, we got their power by the time of their accumulation.

The geological profiles of Mordovian-Karmalsky and Sugushlinsky deposits demonstrate that the lower boundary of the sandstone pack is almost horizontal and resembles the sole bar deposits (Figures 2a, 3a, 4a), while paleogeological profiles performed with the deconsolidation of sandy-clay pack rocks, showed, that the sole of "tar sands" is a concave one: the accumulation of a sandstone pack happened with its crashing into the underlying layers (figures 2b, 3b, 4b). This is also evidenced, obviously, by the presence of carbonate rock fragments from the soles of sheshminsky horizon sand and clay pack found in "tar sands".

The genesis of "tar sands" in avandelta conditions is evidenced by their slightly arched surface at the moment. Since the flow energies were not enough for the erosion of underlying sediments, then accumulative bodies were developed, towering above the bottom of the sedimentation basin.

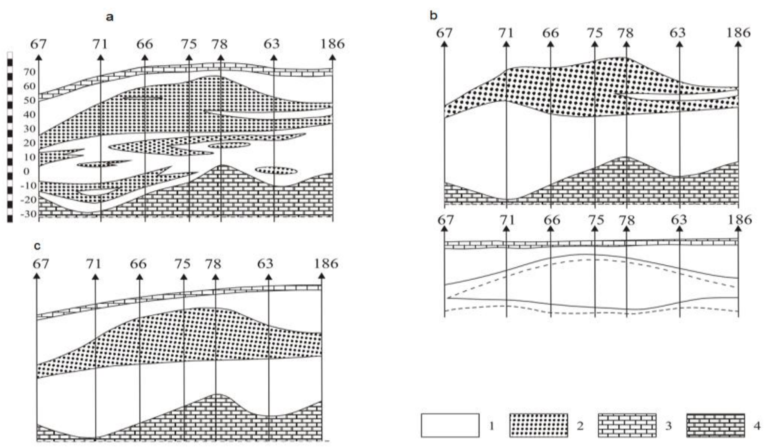

Fig. (2). - Mordovian-Karmalsky bitumen deposit.

a) Geological profile along the line of wells №№ 67, 71, 66, 75, 78, 63, 168. Paleogeomorphological profiles: b) taking into account the rock decompression ratio of a sand and clay pack; c) considering the decompression factor of "lingulian clays"; g) by the method of reference surfaces (dotted line specifies the powers of sediments taking into account the decompression factor of "lingulian clay" rocks; 1 - argillaceous rocks 2 - sandstones, 3 - limestones, 4 - dolomites.

Subsequently, the structural plan a sandstone pack roof changed since during the compaction of the underlying clay rocks of a sand and clay pack the sandstones appeared to be in a raised position (Figures 2b, 3b, 4b).

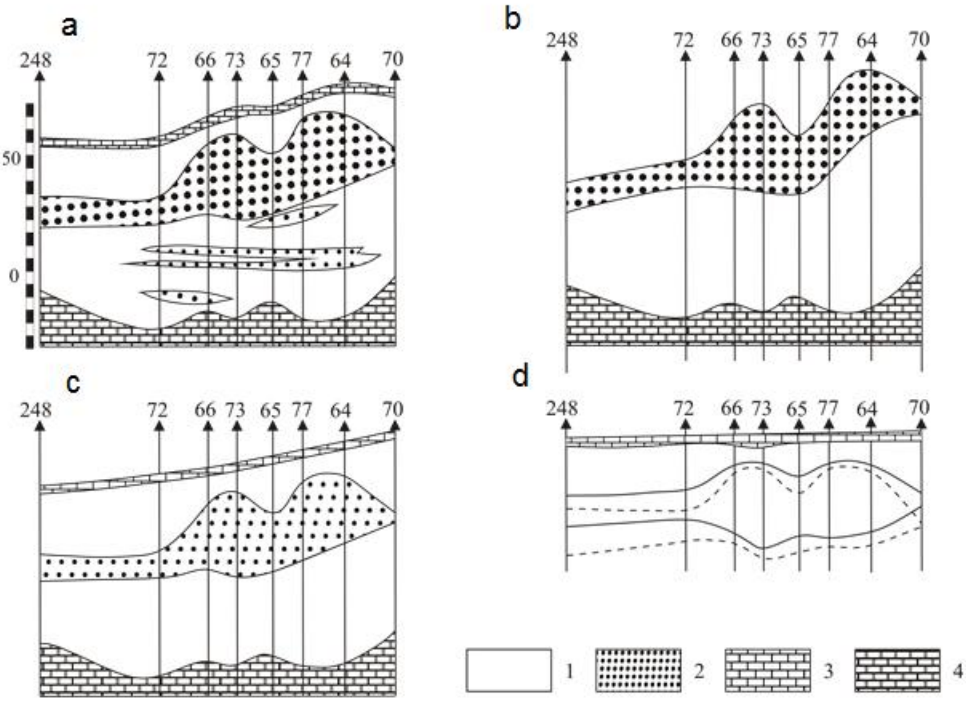

Fig. (3). - Mordovian-Karmalsky bitumen deposit.

a) Geological profile along the line of wells №№ 248, 72, 66, 73, 65, 77, 64, 70. Paleogeomorphological profiles: б) taking into account the rock decompression ratio of a sand and clay pack; c) considering the decompression factor of "lingulian clays"; g) by the method of reference surfaces (dotted line specifies the powers of sediments taking into account the decompression factor of "lingulian clay" rocks; 1 - argillaceous rocks 2 - sandstones, 3 - limestones, 4 - dolomites.

The sequential decompression of sand-clay rocks underlying "tar sands", and then "lingulian clays" overlapping them, which allows us to trace the paleorelief of a sole surface, a sandstone pack roof and "an average spiriferal" limestone.

By the end of "lingulian clay" pack formation period the leveling of sedimentation basin bottom occurs and the formation of "an average spiriferal limestone" was on the flat surface of "lingulian" sea bottom. This is evidenced by the consistency of a limestone interlayer within the power of 0.4-0.6 m and its regional distribution (Figures 2в, 3в, 4в).

Subsequent compaction processes of "lingulian clays" caused the subsidence of overlying limestones, i.e. the modern structural plan for the roof of baytugan layers formed (Figures 2a, 3a, 4a) due to the shaping of sand bodies by them.

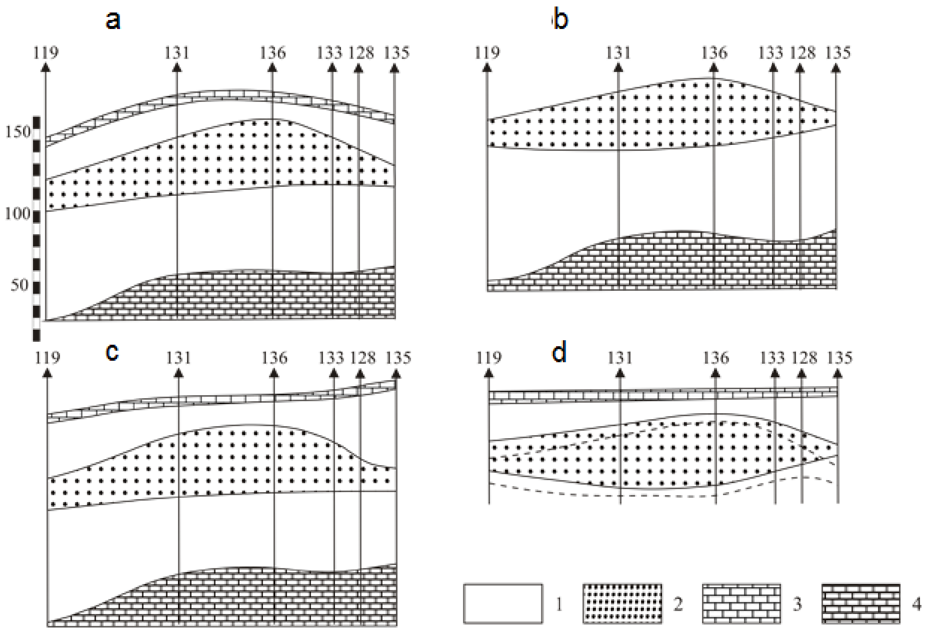

Figure 4 - Sugushlinsky bitumen deposit.

a) Geological profile along the line of wells №№ 119, 131, 136, 133, 128, 135. Paleogeomorphological profiles: б) taking into account the rock decompression ratio of a sand and clay pack; c) considering the decompression factor of "lingulian clays"; g) by the method of reference surfaces (dotted line specifies the powers of sediments taking into account the decompression factor of "lingulian clay" rocks; 1 - argillaceous rocks 2 - sandstones, 3 - limestones, 4 - dolomites.

The validity of the abovestated facts is evidenced by palaeogeomorphological profiles compiled by authors and built by the method of reference surfaces [3, 10]. An "average spiriferal" limestone was chosen for construction as a reference horizon as this layer meets the conditions of its use as a marker horizon, namely: it has a regional distribution; it has the resistance of lithological characteristics, indicating similar conditions of sedimentation at the accumulation of sediments for this layer; it is sufficiently substantiated stratigraphically; it is bounced good at electric logs, which allows to identify it easily in the sections of boreholes. Besides, the deposits an "average spiriferal limestone" lie close to the reconstructed surface of "tar sands" sole and are not separated from it by disagreement. This is shown in Figures 2г, 3г, 4г. The surface of "tar sands" sole is a concave one, which confirms our assumptions that the formation of these deposits took place with the cut in underlying layers, and the sandstone morphology change is the result of an irregular packing for lithologically inhomogeneous rocks.

Consequently, the unevenness in the compressibility of sandy and clay rocks leads to the formation of various pseudostructural elements like bends and folds. Plication is not extended to the underlying layers, but the lower levels of overlying layers due to the formation of compaction fold formation may bend forming shaping structures.

The possibility of an erroneous determination of lithofacie sand and silty genesis due to the underestimation of clay and sand material differential compaction is indicated by other authors [1, 2, 9, 10]. So, G. Bush [1] writes that "... in the process of clastic sediment compaction, including the lenses of sandstones, the roof geometry of the last ones is transformed and attain a pseudo bar appearance". G.T. Yudin [10] in Stavropol region noted that the inclusion in the pack of sandy sediment clays resulted in the appearance of compaction folds, which led to the structural mismatch of plans along the roof of Khadum horizon, in the silt pack roof of Upper Maikop. P.A. Safronitsky and G.A. Fattahutdinov [9], conducting the research in Bashkortostan, concluded that in the formation of "... local positive and negative structures ... the main role was played by non-uniform compaction".

4. Conclusion

Thus, the performed studies demonstrate the transformation of sandbodies resulting in a nonuniform compressibility of clay and sand rocks, causing the formation of such various pseudostructural elements as bends and folds. It was noted above that the folding is not extended to the underlying layers, but the lower levels of overlying layers due to the formation of compaction folds may bend forming the structures of shaping.

Therefore, at the identification of clastic natural reservoir formation conditions the adjustment of trap forms for the compaction processes of enclosing clay rocks.

Taking into account the processes described by authors it was established that the rocks of a sandstone pack formed in the delta ducts, and the uppermost layers were formed in avandeltaic parts of paleorivers.

5. Summary

After the mapping of paleoriver system, the study of sand body geometry and the nature of their basal and lateral contacts, facial transitions, the granulometric composition and the sorting of sand and silty rocks, the mineralogical characteristics of the clastic rock clay fraction, etc., the nature of heavy oil and bitumen trap was cleared. In the specific case it was the sedimentation (atectonic one). The coincidence of the surface structural plans for "average spiriferal limestone" and the "tar sand" roof is not related to tectonic processes, but it is the result of a non-uniform compaction processes of lithologically inhomogeneous rocks. The deposit of a sandstone pack clastic material happened in the mobile hydrodynamic environment with the cutting into the bedrocks in the riverbed, deltaic, underwater deltaic parts of paleorivers. The traps related to the deposits of a sandstone pack, form linear bodies, which are located in accordance with the channel flows, the flows within a delta and form separate strips of uplifts separated from each other by depressions, within which a reservoir rock, which constituents them is characterized by a drastically reduced thickness (less than 10 meters) or is completely absent. The extension of these bodies can be seen in the south-eastern direction outside Tatarstan in Samara and Orenburg regions. The transportation of terrigenous material took place from this location. In these areas, the thickness of sand bodies is increased, more coarse-grained types of rocks appear, indicating that paleoriver beds (Bokaevskaya, Glazovskaya, Ishteryakskaya and other areas) are formed by sand deposits here.

Conflict of Interest

The author confirms that the presented data do not contain any conflict of interest.

Acknowledgement

This work was supported by the Russian Fund for basic research and with the support of ANO "Kazan Open Talent University 2.0" on the results of the "Talent Cooperation" contest.

References

1. Bush, D.A. Stratigraphic traps in sandstones [Text] / D.A. Bush. - Moscow: Publishing House MIR, 1977. - 215 p.
2. Babadagly, V.A. Alluvial-deltaic systems of Paleozoic Lower Volga region [Text] / V.A. Babadagly, S.V. Yatskevich, M.G. Shebaldina. - Saratov: Sarat. University publishing house, 1982. - 154 p.
3. Konibir, I. Paleogeomorphology of petroleum sandbodies [text] / I. Konibir. - Moscow: Nedra, 1979. - 256 p.
4. Levorsen, A.I. The geology of oil and gas [text] / A.I. Levorsen. - Moscow: Publishing House MIR, 1970. - 639 p.
5. Uspensky, B.V. Geological and geochemical bases of bitumen deposit development in the Middle Volga region [text] / B.V. Uspensky, A.Z. Badamshin, G.A. Ilyina, N.P. Lebedev. - Kazan: The publishing house of Kazan University, 1988. - 148 p.
6. Uspensky, B.V., Valeeva I.F. The geology of natural bitumen deposits in the Republic of Tatarstan [text] / Uspensky, B.V., Valeeva I.F. - Kazan: the Publishing House LLC "Hart", 2008. - 347 p.

7. Pronicheva, M.V. Paleogeomorphology in petroleum geology: Application method and experience [text] / M.V. Pronicheva. - Moscow: Nauka, 1973. - 175 p.
8. Nesterov, I.N. The compaction of argillaceous rocks [text] / I.N. Nesterov // Soviet Geology. - 1965. - № 12. - pp. 69-80.
9. Sofronitsky, P.A. About some compaction structures of platform Bashkiria [text] / P.A. Sofronitsky, G.A. Fattahutdinov // Geology and petrography of the Western Urals. - Perm, 1967. - pp. 91-98.
10. Yudin, G.T. About the reasons of Miocene deposit structural plan non-compliance in Tahtinsky-Bezopasninsky region of Stavropol [text] / G.T. Yudin // Gas industry, 1958. - № 11. - pp. 8-12.