Features of the natural bitumen distribution in the Kazan deposits on the territory of the Melekess depression in Tatarstan

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Abstract. This article presents the distribution of natural bitumen in the sediments of the Kazan tier of the middle Permian. Natural bitumens, concentrated in the Permian sediments of the Republic of Tatarstan, occur at shallow depths and are heavy, highly viscous, hypergenically converted oils. In the tectonic relation, the area of maximum Kazan bitumen occurrence is confined to the Melekess depression and the adjacent slope of the South Tatar arch.

1. Introduction
The study of the Permian deposits occupies a special place in the history of the development of oil fields of the Republic of Tatarstan. The discovery of industrial deposits of oil and gas was preceded by a nearly two hundred year study of the surface manifestations of bitumen.

In assessing the actual conditions of occurrence of bitumen and their resources, due to the ambiguity of the factual material interpretation, two diametrically opposite approaches have emerged.

Supporters of the first approach (I.M. Akishev and a group of TatNIPIneft employees) were based on ideas about the continuous development of bituminous in Kazan and other Perm complexes. The second approach to the study of bituminous (V.T. Troepolsky and others) developed earlier ideas about the presence of local accumulations of bitumen in Permian sediments and was based on the analysis of new data on the structure and spatial relationships of bitumen-containing complexes.

Analysis of the structural drilling carried out in the 70s of the last century showed that the bituminous territories are heterogeneous. There are distributed areas of a large number of small deposits, surrounded by a dense background of various intensity bitumen occurrences. At a number of sites, in the presence of favorable prerequisites (reservoir, tires, positive structural forms, etc.), bitumen is localized into larger deposits and their associations. [2]

2. Methodology
Kazan deposits are a thick stratum (more than 100 meters) of carbonate and terrigenous rocks with interlayers and inclusions of sulphates (Figure 1).
There is a rhythm of various types of rocks alternation, which is reflected by a periodically repeated transgression and regression of the basin, a change of shallow-water sediments more deeply. [3]

The deposits of bitumen in deposits of the Kazan usually represent a combination of deposits confined to terrigenous and carbonate reservoirs located at different stratigraphic levels.

![Figure 1. Lithological and stratigraphic section of the Kazan deposits of the Republic of Tatarstan (Ellern, 1984). Symbols of rocks that compose Kazan deposits: 1 - sulphate, 2 - carbonate 3 - sandy, 4 - clayey-silty, 5 - clayey ("lingular clay "), 6 - low-permeable, 7 - the boundary between the lower and upper substages, accepted by geologists of the" TN "(Bogov, Petrov).](image)

The study of the natural bitumen occurrence conditions in the Kazan sediments of the Melekess depression showed that their bulk is concentrated in the lower part, which belongs to the Lower Kazan terrigenous-bitumen complex. The upper boundary of the complex is the sole of a sulphate pack, sufficiently aged along the strike, which is regarded as an analogue of the “slaughter” series of the Prikazansky district. The lower boundary of the complex is held along the roof of the “lingule” clays or in the zone of their absence along the base of the younger Kazan deposits, which overlap directly onto the eroded surface of the lower Permian sediments.

This complex is ambiguous in its lithological composition. Within the eastern part of the Melekess depression, two lithological sequences are distinguished: the lower one is predominantly carbonate and the upper one is mostly terrigenous, containing small interlayers or inclusions of carbonates.

The thickness of the carbonate stratum is variable (from 0 in the northern part to 85 m in the south-west), which is connected both with the conditions of sedimentation and with two erosion: Neogene
and Kazan. These changes are manifested in different ways on the territory. Ellern S.S. and Vinohodova G.V. identified three types of cuts.

The western type of the section is geographically distributed in the southwestern part of the eastern side of the Melekess Depression, and covers Akanskaya, Yukhmachinsky, Kondurchinsky, Maximskaya and other areas. This type of section is characterized by the complete absence of terrigenous rocks. The carbonate stratum is stratigraphically represented by deposits of the Baitugan, Kamyshlinsky, and Barbashinsky horizons. Thickness varies from 50 to 70 m.

The central type of the carbonate stratum seam occupies most of the eastern side of the Melekess depression. This type of cut, as well as the West, has a strike from northwest to southeast. The carbonate stratum of this type has a two-layer structure. Its upper part, corresponding to the XI-XIа formations, is absent, which is probably due to erosion; this erosion significantly affected its middle part (XIII-XIIIa layers). The lower part of the stratum (XY-XYII layers) also falls out of the section. The thickness varies in the range of 45-50 m, with the result there are numerous zones of thickness difference. They form carbonate bodies of various configurations along closed isolines of 15, 20, 25, 30 m. Among them, dome-shaped and oval forms of predominantly north-western strike, sometimes almost isometric (1-3x1-7 km) with minimum thickness up to 10 m. In the area of the North-Katerginskoye field, the lowest carbonate thickness was recorded. In some cases, the thickness of the carbonate stratum reaches 45-50 m. Such an increase in its power is observed in the marginal parts of the central zone. North of the latitude of Bilyarsk, the central zone of reduced capacities expands in a northeast direction to the settlement area of Starosheshminsk. Here there are numerous areas of the absence of carbonate stratum or its small thickness of the order of 20–30 m, which is explained by the erosion of its surface in the pre-Akchagyl time. From the analysis of the materials, it follows that the carbonate stratum of the central type of the section corresponds, apparently, only to the Kamyshla horizon. The lithologic carbonate stratum of the central type of the section differs from the western one by the predominant development of organogenic-detrital dolomites, but other species are also found.

The eastern type of the section, which is characterized by the predominance of terrigenous rocks, mainly clays with sandstones and siltstones, is developed in the eastern part of the study area. This type of section is carbonate – terrigenous. The total thickness of the sediments increases to 70-80 m. The heterogeneity of the carbonate stratum of terrigenous rocks has created a kind of cyclical structure of the latter: at the base of each cycle is a stratum of carbonate rock overlapping with terrigenous sediments, with each overlying layer of carbonate sediments lying on the underlying terrigenous unconformity. Towards the central type of the section, the terrigenous deposits pinch out.

The terrigenous stratum of the considered territory of the Kazan deposits, as well as the carbonate stratum, is distinguished by a non-uniform structure. This concerns its lithological composition and sediment thickness. Here intermittency of strata is observed, reflecting its peculiar cyclical structure associated with the transgressive-regressive development of the basin. The thickness of the terrigenous strata is even more variable than the carbonate one. [1]

As a result, the section of the terrigenous sequence was dissected into a series of packs, which are combined into separate elementary cycles. At the base of such a cycle, the most clayey rocks are located, which are replaced upwards along the section by sandy-silt rocks. Four cycles were
distinguished by Vinogradova G.V. It should be noted that the cyclical nature of the terrigenous stratum in the direction of both the eastern and western boundaries of its distribution becomes less distinct, which is associated with the formation of the marginal parts of this stratum in various facies. In this case, as a rule, the upper parts of the cycles, represented by sandy-silt rocks, are compacted and pinned out. In this regard, in this area, as well as for carbonate strata, there are three types of terrigenous strata: western, central and eastern.

The most consistently characterized sand-silty "layers" Y and YII. The majority of fixed bitumen occurrences on core are confined to them. The Y and YII strata are most clearly seen in the central type of the section, absent in places in the areas of development of Neogene incisions and local pinch zones. The strip of sandy-silty rocks of each layer in this type of section extends from northwest to southeast. The length of the lanes is 80 - 100 km, the width reaches 40 - 50 km. In each of the layers, the development to the same extent of siltstones and sandy rocks with thin interlayers of clays and dolomites is characteristic; sandstones and siltstones are usually calcareous and often plastered. The thickness of the layers Y and YII unevenly distributed. Thickness fluctuations reach 20 m. Also, there is a coincidence of areas of increased thickness of the terrigenous sequence with the areas of distribution of sandstones or coarse-grained siltstones. Such examples have been established at the Katerginskoye, Pionerskoye, Uzeyevskoye and other fields. It is these areas and forms a kind of local "body". In terms of their configuration, these sand "bodies" have a characteristic shape: a flat base and a convex upper surface. In the western (I) and eastern (III) types of section, the sand-siltstones rocks of these layers are represented by thin layers, as if wedged into predominantly clayey rocks. It is characteristic that the western type of the section directly adjoins the facies zone, alternating with carbonate rocks to the west, and the eastern one borders on the area of the development of red sediments.

A typical representative of the central type of the mine is the Uzeevskoe field. It consists of deposits of the Kamysdlia and Barbashin horizons and the series “yadrenyi kamen” and “sloisty kamen”. Other conditions for the extraction of deposits include: the contour of deposits, the presence of unambiguous ideas about the nature of the distribution of bituminous reservoirs, data on well productivity, a set of laboratory core analyzes to substantiate the categories of reserves (C1 + C2), at least half of the reserves to the area of deposits, limited by 5m isolines (optional feature), etc.

Pioneer field. Due to the proximity to the Uzeevskoye field, the sections of the deposits are identical. The most intensive bitumen maintenance is confined to the undifferentiated thicker sediments of the series “yadrenyi kamen” and “sloisty kamen” of the Upper Kazan and Barbashin horizons of the Lower Kazan.

3. Results and Discussions
Two bituminous complexes are confined to the deposits of the Kazan tier: the Lower Kazan terrigenous-bituminous complex and the Upper Kazanian complex.

The Lower Kazan terrigenous-bituminous complex. The facial environment of sedimentation predetermined the differentiated nature of the distribution of bitumen in the Lower Kazan sediments. In the Kamysdlia horizon, favorable reservoir beds are associated with organofragmatic and detrital and oolitic carbonate rocks. The areas of their distribution are confined to the submerged part of the
eastern side of the Melekess depression. The boundaries of these lithofacies include the Arbuzovsko-Merezenskaya zone, which is distinguished by a high concentration of bitumen.

Within the zone, the dependence between the intensity of bitumen manifestations and the positive structural plan is clearly manifested. Areas with well-saturated layers (2 or more meters thick) are associated with local uplifts complicating shafts and structural terraces (Gorskoe, Merezenskoe, Aksubaevskoe, Arbuzovskoe, Uzeevskoe, Adelyakovskoe, etc.). Other lithofacies are characterized by the absence of aged collectors and insignificant bituminous.

In the Barbashin horizon, bitumen are much more widespread than in the underlying sediments. However, the uneven development of reservoir rocks left a definite imprint on the distribution of bituminous. According to the scale of concentration of bitumen in this horizon, the territory of the Melekess depression is unequal. In the direction from east to west, three main zones of bitumen concentration can be distinguished: the eastern or Arbuzovsko-Merezen, central and western. The intensity of bitumen decreases in a westerly direction. The majority of bitumen deposits are associated with sandy reservoirs of the eastern zone. Many deposits are small in size due to the complex structure of the host rocks. Lithofacies of carbonate rocks is developed within the central zone. The most intense bitumen are concentrated in the area of Akan uplift. No significant concentrations of bitumen were found in the rest of the territory. Within the western zone, quite numerous, but generally small-scale, concentrations of bitumen are established, which is explained by the heterogeneity and local development of carbonate reservoirs, partial erosion of sediments and unfavorable genetic prerequisites.

The Upper-Kazan complex is an extremely complex, facially changeable multilayer reservoir, divided by a screening sulfate pack of the “podboi” series into two parts: the lower (lower bituminous horizon) and upper (middle and upper bituminous horizons). The lithological composition of rocks is characterized by impermanence and naturally changes in the latitudinal direction. The spatial distribution of bitumen is controlled by types of lithofacies. The confinement of the most intense bitumen concentrations to the central lithofacial zone, represented by marine terrigenous-carbonate and carbonate-terrigenous sediments, has been established.

4. Conclusions
An increased concentration of bitumen is noted on the eastern side of the Melekess depression. It is caused by the presence of small lithofacies with a well-defined distribution of reservoir and tire layers and their favorable ratio with positive structural forms of various bituminous horizons. The combined areas of their distribution in terms of coincide with the fragments of the previously allocated Arbuzov-Merezen zone in the Lower Kazan complex. The most significant in the concentration of bitumen is the lithofation of sandy rocks of the “yadrenyi kamen” series. Bitumen occurrences in cavernous and fractured dolomites, sandstones and siltstones of the “sloisty kamen” series are widely developed. In the middle and upper bituminous horizons, the intensity of bitumen is markedly reduced. This is due to the deterioration of the composition of host rocks due to the uneven distribution of reservoirs, the lack of sufficiently pronounced tires, etc. [2,3,4]

A variety of studies cited in past years did not lead to a complete disclosure of the patterns of bitumen placement and agreed conclusions about the size of their resources. For a long period, prospecting and exploration were carried out without a clear understanding of the actual conditions of occurrence of
natural bitumen, which entailed unfounded estimates of the prospects for bituminous. The authors propose to reconstruct the paleogeographic and paleotectonic situation in Kazan time for a more complete study of the conditions of formation of deposits of natural bitumen.

References
[1] Vinokhodova G V et al 1985 On the structure of the lower part of the Kazan tier of the east of the Melekess depression and features of the distribution of bitumen (Kazan: Kazan State University) pp 8-24
[2] Voitovich E D 1997 Perm bitumens (Kazan: Report of the TEO OJSC Tatneft) p 198
[3] Troepolsky V I et al 1997 Productive bituminous strata of the Permian sediments of the Melekeess depression and the Tatar arch (Kazan: Kazan State University) p 104
[4] Fakhrutdinov E I et al 2018 Features of the particle size distribution of the Ufimian-Lower Kazanian sediments of the section of Karkali (Academic science - problems and achievements XVII.: Proceedings of the Conference. North Charleston, USA) pp 5-9