Features of the Structure and Origin of Oil and Gas Generating Shale Strata in the Permian Deposits of the Urals

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Abstract. The composition and structure of oil and gas generating shale strata in the Permian deposits of the Urals are considered by the example of the geology of Mount Yangantau, which consists mainly of yangantauskian suite of bituminous minerals, containing components peculiar to domanicites (carbonates, clay material, sufficient amount of silica, organic matter content from 3 to 12 %). The geological structure of the object is caused by a combination of several natural factors: geomorphological, material-stratigraphic, hydrogeological and structural-tectonic. The latter is characterized by high values of tangential tectonic stress that results from the presence of olistostromes, which according to modern concepts is an indicator of such regime. The interaction of these factors provides a natural mechanism for the extraction of hydrocarbons from shale strata comparable with the known technological methods.

Keywords: oil and gas generating shale strata, Permian deposits, the Urals.
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The stated problem in the title of the article is considered on the example of mountain Yangantau, which is in the border zone of Karatau structure and Yuryuzano-Sylvinsky depression of the Ural foredeep (Fig. 1).

Yangantau Mountain is the container of healing hot vapor and gas used by the well-known mountain resort of the same name. They are confined mainly to yangantauskian suite, provided with bituminous minerals, containing components inherent to domanicites, and also have shale structure. The geological structure of the Yangantau object is determined by special natural factors: geomorphology, material, stratigraphic, hydrogeological and structural-tectonic. Their interaction creates the uniqueness of this natural phenomenon.

I. Geomorphological factor. Yangantau Mountain is a hill, extending from southwest to northeast along the right bank of the river Yuryuzan between villages Chulpan and Iltaevo of Salavat region in the Republic of Bashkortostan. Ravine system dismembered it into separate flat tops. The altitude of the top – 416 m, the bottom – 252 m above sea level. Side of the mountain that faces the river Yuryuzan – is steep, with scarp areas, down to the riverbed. The rocks are strongly fractured, because the slope is well purged.

II. Material-stratigraphic factor. Yangantau Mountain and its surroundings are composed primarily of Permian Artinskian deposits. On the surface, they are well studied by researchers from the Urals region: V.D. Nalivkin, N.M. Strakhov, G.A. Dmitriev, A.I. Osipov, N.G. Chochia, S.M. Domcharev, S.V. Maximova, K.A. and LA Milovidovy, G.V. Vakhrushev and many others. Within Yuryuzano-Sylvinsky depression, these deposits are subject to significant facial changes: more clayey and calcareous, common in the southwestern part of the region, replaced to the east and northeast by sandstones and conglomerates. The deposits are represented by two substages: the lower, the fauna of fusulinid relevant to Burtsevskian and Irginskian horizons, and the upper, which includes Sarginskian and Sarayninskian horizons.

Deposits of Burtsevskian and Irginskian horizons N.G. Chochia and S.M. Domrachev identified in balzyakskian formation of sandstones and conglomerates (Nalivkin, 1950). It is exposed at the foot of the mountain Yangantau, tracing along the band from the mouth of river Urdali in the northeast. In the southern part of the Mesyagutovsky anticline its structure is dominated by medium-grained sandstones with lenses of conglomerates that reach considerable thickness north of the village Chulpon. Among their clastic material quite large, deformed lumps of limestone occur, the dimensions of which reach 10 meters. When conducting combined with V.D. Nalivkin inspection we attributed them to olistoliths composed of chulpanskian olistrostrome (Fig. 2.3).

The total thickness of the horizon ranges from 100 to 200 m. In the area of the mouth of the river Urdali Balzyakskian formation is represented by shales with interbedded sandstone

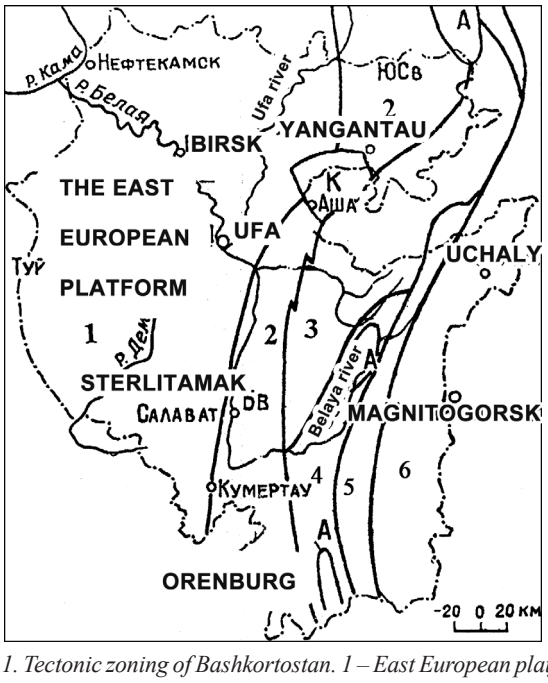

Fig. 1. Tectonic zoning of Bashkortostan. 1 – East European platform, 2 – Pre-Urals fore deep, 3 – Bashkir Anticlinorium, 4 – Zilair Synclinorium, 5 – Uraltau zone, 6 – Magnitogorsk Synclinorium; Bv – Belsky depression, YuSv – Yuryuzano-Sylvinsky depression, A – large allochthons in the western slope of the South Urals, K-Karatau allochthon.

Fig. 2. Deformed olistoliths of limestone in Balzyakskian formation. The right bank of the river Yuryuzan, below the village Chulpan.

Fig. 3. Deformed olistoliths of limestone in Balzyakskian formation. The right bank of the river Yuryuzan, below the village Chulpan.

Fig. 4. The lens of flint among shale of Yangantauskian formation on the eastern slope of Yangantau Mountain.

and marl. To the east of the river Yuryuzan as part of the formation, the role of conglomerates increases, the thickest layer of which appears in the formation base on the meridian of Turnali village. The upper part of Balzyakskian formation consists mainly of mudstone interbedded with marl and sandstone. Thickness along the river Yuryuzan is 100-180 m.

Strata of bituminous marl lying over Balzyakskian formation contains organic material in an amount of 3-5 %, in some areas up to 12%. N.G. Chochia and V.D. Nalivkin named it Yangantauskian formation. In addition to marl, it contains shales, limestones, dolomites, clastic rocks, and appreciable amount of silica. The most complete characterization of the formation composition is contained in the paper (Strakhov, Osipov, 1935), according to which the homogeneous marl stratum towards the east takes the shape of a typical flysch. This suite can be traced as a strip along the northern slope of the Karatau ridge, on the wings of Mesyagutovsky and Yukalikulevsky anticlines. Its best outcrops are known on the river Saldash, on mountains Kutkantau, Yangantau, Kantuntau, along the rivers Yuryuzan and Ai.

The rocks of Yangantauskian formation are characterized by foliation. One characteristic feature of Yangantauskian formation is a kind of layering, called 'lense-layering'. Its essence is that the rock consists of alternating stripes of different colors represented by the lenses of 1-2 mm in thickness and from 1-2 cm to several tens cm in length. Another variety of marl is characterized by thin bedding. The rock consists of close, extremely thin (share of millimeter), straight, black colored microlayers, which are located between the lighter layers. According to G.V. Vakhrushev in the western part of Yangantau Mountain outcrops also consist of two basic varieties of bituminous marl: thin-layered, foliated (layer with thickness from 1 mm to 1 cm) and massive (thickness of lens 10 cm to 5-10 m). Massive marl in some places are silicified and pyritized. Color for both thin and thick-bedded marl in most cases is dark gray.

Textural features of Yangantauskian formation are displayed on a photograph taken by us when performing material-structural studies of the late twentieth – early twenty-first century (Fig. 4), as well as sketches of the author (Fig. 5). In addition to the usual foliation, lenticular and wavy foliation is observed (Fig. 6).

On the mountains Saldash and Kutkantau only the upper part of the formation is exposed. Here layers of shale and sandstones are absent, but there are rare interlayers of marl and limestone with fauna. To the east, on the Yangantau Mountain, there are several thin layers of shale, and even further to the east, on the Kantuntau Mountain these shales compose a large part of the section. Probably these are the rocks that are currently under consideration as a source of shale gas -domanicites or oil-gas generation formations with hydrocarbon reserves difficult to recover (Kazantseva, 2013, 2014; Ismagilov, 2013).

On the Yangantau Mountain there are areas with rocks colored in red, which many researchers regard as a 'roasting' of bituminous marl and surrounding rocks. However, the red color of the rocks is well explained by the transition of limonite to hematite associated with zones of tectonic disturbances.

Formation thickness in the southern part of the Mesyagutovsky anticline reaches 200 m, on the Yangantau

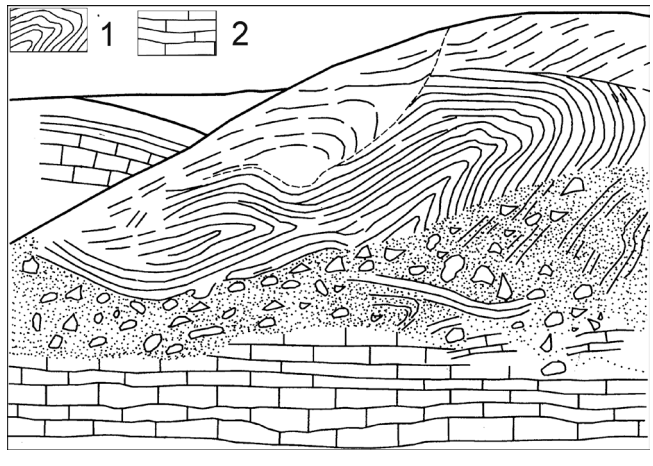

Fig. 5. The dislocation nature of shale layers in Yangantauskian formation. Sketch of exposure against the village Iltayevo. 1 – the dislocation nature of clay shale in Yangantauskian formation; 2 – limestone.

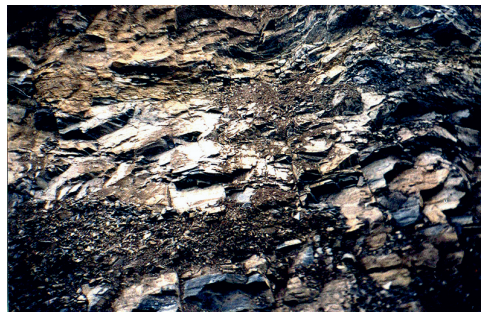

Fig. 6. Lens-layering nature of Yangantauskian formation northeast of Yangantau Mountain.

Mountain – 260 m, and on the Kantuntau Mountain (below the mouth of the river Urdali) – 340 m.

According to (Strakhov, Osipov, 1935) bituminous marl of mountains Kutkantau, Saldash, Yangantau represents a huge lens that tapers in both directions on the east and west. To the west it becomes organogenic-clastic limestone (partly bituminous), to the east – clastic rocks (sandstones and mudstones) of flysch type. Stretching of the actual marl part of the lens is measured about 40 km. Actually, the most important feature of the fore deeps is observed in this region, which consists in the regular sequence of formations laterally from the platform to the folded area: reef, carbonate, depression (shale), flysch (Kazantsev, 1984; Kamaletdinov et al., 1981).

Above bituminous marl of Yangantauskian formation I.G. Chochia and V.D. Nalivkin identified Tandakskian formation of sandstone and siliceous limestone. The formation can be traced from the village of Malaya Biyanki, along the northern slope of the Karatau ridge, on both wings of Mesyagutovsky anticline until Tandak River, northeast of Mesyagutovo and the northwest wing of Yukalikulevsky anticline.

A distinctive feature is the presence of packs and lenses of siliceous limestone among sand-shale deposits. Boundary of the formation is carried along the lower stratum of limestone. Directly on the Yangantau Mountain on the formation of bituminous marl, interbedded sandstones, siliceous and clay shale, marls occur. They are assigned to the bottom of the Tandakskian formation. In the border area there are lenses of siliceous limestone. They also contain an organic matter, but in an amount less than in Yangantauskian formation. Thickness of sandstone layers is from 20 to 50 cm, shale – 2-3 m. In many places a small folding is marked with discontinuity layers of sedimentation nature.

So, carbonates, clays dominate as part of the Yangantauskian formation (calcite and dolomite), in clastic material there are a lot of silica and organic matter, mostly 3-6 %, sometimes as much as 10% or more. Shale structure is characteristic. These features of the composition and structure of Yangantauskian formation allows classifying them as 'domanicites'. The origin of hydrocarbons in them should be seen as a result of special occurrences of geodynamic regime associated with the tectonic forces. Earlier continuous shale texture was accepted as a result of dynamic metamorphism in the traditional sense of the process from the fixation perspective.

The alternation of shale and non-shale structures in a single section, observed autonomic active dislocations of the first among the second, inconsistency of the bedding foliation elements and layering can be explained only by the regime of tectonic tangential compression, propagating from the active zone of fold region. Consequently, the observation of the foliation nature and its scale suggests the direction and type of tectonic stress, as well as fixation of the periodization. By changing the composition and structural-textural features of coeval formations across the strike of the whole folded area we can judge of the character of geodynamic regime in time and throughout the space.

But subhorizontal tectonic compression is responsible not only for the foliation of strata, but also for mechanical activation of rocks, most fully realized in the areas of thrusts, where crushing, mylonitization and foliation occur very active. This is confirmed by experimental studies of N.V. Chersky and others, who came to the conclusion that: "Mechanical fixed and variable loads accelerate the transformation processes of fossil organic matter ten times, even at low temperatures (20-40 °C), and go with high intensity»(Chersky et al., 1982, p. 21). In this regard, earlier data of N.B. Vassoevich, Yu.I. Korchagin, N.V. Lopatin and V.V. Chernyshev are indicative (Vassoevich et al., 1969).

Even in 1969 they gave an example of experimentation with mudstone that did not dive below a depth of 700 m. Under the pressure of 150 kg/cm^2 bitumen was extracted from it 2 times more than under the pressure of 5 kg/cm^2. At that, the composition of the chloroform bitumen significantly changed. If before applying pressure of 150 kg/cm^2 asphaltenes predominated over hydrocarbons in chloroform bitumen, after – hydrocarbon content increased by 3.5 times and their quantity became 5 times greater than asphaltenes. This is consistent with the concept of oil and gas generation in argillaceous rocks, however, as many of ore minerals, resulting from directional tectonic pressure.

III. Hydrogeological factor. At the level of river Yuryuzan in the bottom part of the Yangantau Mountain, a single water-bearing zone is located with an active circulation in the upper parts. This zone is divided into separate aquifer intervals. There are numerous outputs of groundwater at the river Yuryuzan at the bottom of Yangantau Mountain, between the village Chulpan and a sharp bend of the river upstream of its flow. They represent the major reservoir bodies, or individual sources. It is believed that water outputs do not rise above 1-2 m from the low-water level of the river and flooded during spring floods. Water is mineralized, hydro-sulphate-calcium and magnesium-calcium, sometimes weakly radioactive, with a value of radiation up to 17 units of Mach.

Mineralization of water increases with the depth. Intake areas of the described aquifier are outputs of Yangantauskian formation to the north of the mountain. Here, at high elevations completely waterless areas are located with numerous and deep ravines. The water absorbed by these highly fractured array, moving eastwards and filling in Yuryuzano-Aiskian basin, are discharged in excess part on the bank of Yuryuzan River, under the mountain Yangantau. Well 3-K, laid on top of the mountain, at the level of 414.66 m, entered the water-bearing zone at a depth of 156.5 m and deepened in it by 24.5 m, at the absolute elevation of 258.16 m. Well 2-K lies at the level of 332.8 m in the eastern ravine bordering the mountain. The total depth is 127.5 m. At a depth of 73.23 meters it went into the water-bearing zone and revealed it at 53.27 m. Consequently, approximately 20 m in depth refers to the aquifer horizon. The chemical composition of the water, with the deepening in the water-bearing zone has changed in the direction of increasing salinity. At a depth of 124.5 m, this well went into slow circulation area.

Thus, in the bottom part of Yangantau Mountain there is a single water-bearing zone with an active circulation in the upper parts.

According to sources No. 3, 8 and wells 2-K and 3-K V.V. Shtilmark composed hydrogeological scheme of the aquifer, where hydroisohypses are displayed with the condensed nature of the distribution in the upper part. It follows that the movement of an underground stream is carried out towards the river Yuryuzan. Unloading here is significant, which is consistent with the features of contour thickening (Fig. 7).

Fresh sources are usually located approximately at the level of the spring waters of Yuryuzan River. As a consequence, during the spring flood water-bearing zone may be partially fed by its waters. During this period, the dip of hydroisohypses should be the opposite, i.e., inside the mountain. This stream can be diluted with groundwater, lowering mineralization and simultaneously cooling them. Sulfur sources are frequently encountered, which are usually placed at low-water level of standing water in the river. Among these sources sulphide water is marked, concentrated near the mouth of the eastern mountain ravine and upstream the river Yuryuzan. They have a low flow rate (less than 0.1 l/s), fluctuating temperature and hydrogen sulfide content of not more than 3-4 mg/l. G.V. Vahrushev indicates that some sources of Yangantau, except hydrogen sulphide, have also smell of oil. It is known that fresh water springs flowing from the mountain Yangantau contains radium emanation 0.37, and the water from the river Yuryuzan – 0.08 units of Mach.

Besides warm radioactive source Kurgazak, near Yangantau and 20 km downstream the river Yuryuzan, at the foot of the mountain Kutkan and at the lower end of the village Kuselyarovo there is a number of hydrogen sulphide springs with water temperature of 16°-19° Celsius. Some of these sources have very high capacity – about 20-30 l/s each. According to observations of G.V. Vakhrushev, under the mountain Yangantau sulfur springs are warmed up to 19°. Fresh water flowing 0.5-1 m hypsometrically above, are warmed up only to 6°-7°. Similar sulfur springs are found on the left bank of Yuryuzan River, under the mountain Kutkantau. Judging by the white fly of amorphous sulfur on the rocks, there are the outputs of sulfur sources at the bottom of river Yuryuzan.

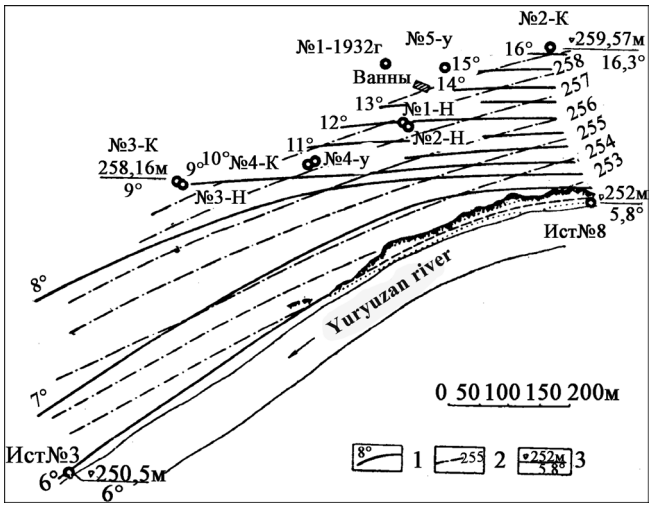

Fig. 7. Scheme of hydroisohypses and geoisotherms in the aquifer zone of Yangantau Mountain (by Shtilmark, 1960). 1 – geoisotherms; 2 – hydroisohypses; 3 – absolute elevation of water level and water temperature.

IV. Structurally-tectonic factor is sufficiently covered in the papers of R.I. Nigmatulin, T.T. Kazantseva, M.A. Kamaletdinov, Yu.V. Kazantsev, A.S. Bobokhov (1998); Kazantseva (2007); S.G. Fattakhutdinov, A.I. Konyukhov, I.A. Khairetdinov (1976), and others. They argued that the structural features and modern geodynamics of Yangantau are determined by its location in the complex node of tectonic interaction of contrasting compositions and structures. On the one hand it is Karatau allochthon, on the other – a set of relatively small-amplitude scales in the southern end of Yuryuzano-Sylvinsky depression of the Ural foredeep. The most characteristic features of these structures were brought. They are as follows. Karatau structure in its present form has the shape of tapered prism with a thickness of 1 to 5 km. It is formed by the surface of the Karatau thrust, Ashinsky and Yuryuzansky strike-slip.

Yuryuzansky strike-slip is reflected by a broad zone of depressions in modern relief that is associated with an extremely high degree of fragmentation and folding of strata, especially at the nodes of its intersection with the front plate parts of Yuryuzano-Sylvinsky depression. One of these areas – Akhunovsky dislocations – is shown in Fig. 8.

The northwest corner of Karatau 'prism' falls on the part of Mesyagutovsky plate, whete Yangantau Mountain is located. Yangantausky dislocations produced Karatau allochthone in the opposite direction to general Urals movements. In the geological past the territory had typical occurrences of high heat values, as coincident with modern thermal anomalies and widespread much wider. Ancient thermal anomalies are consistent with the elements of modern structures (Fig. 9).

All known thermal sources in this area are confined to Yuryuzansky strike-slip influence zone.

Modern geodynamic activity of the mountain is displayed on seismotectonic scheme of Yu. V. Kazantsev, where there is a local section of the annular arrangement of the seismic values from 3 to 8 units. At the same time the highest rates are found in the periphery, dramatically decreasing towards the center (Fig. 10). This researcher has interpreted this feature as discharge of seismic compression in the Yangantau Mountain that is consistent with the geodynamic model of the heat source of this phenomenon. Data of A.S. Bobokhov of connection of modern thermal anomalies and paleotemperatures values with faults (Fig. 9) also confirms their tectonic origin.

Fig. 8. Outcrops of folding zone at the eastern edge of the village Akhunovo.

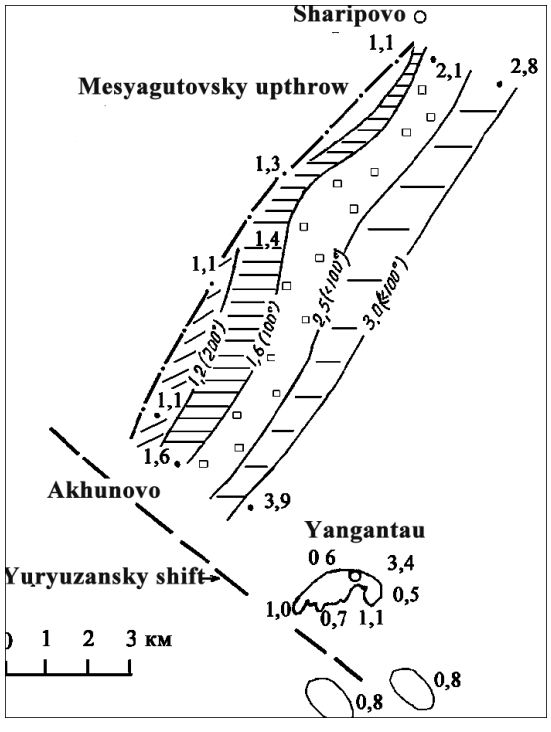

Fig. 9. Paleotemperature regime of the region (by A.S. Bobokhov). Legend: point – sampling; figures from 0,5 to 3,4 – thermal degasifying intensity values; figures in brackets – paleotemperatures in degrees, decreasing from the front of Mesyagutovsky thrust to its rear; thin lines – boundaries of thermal zones.

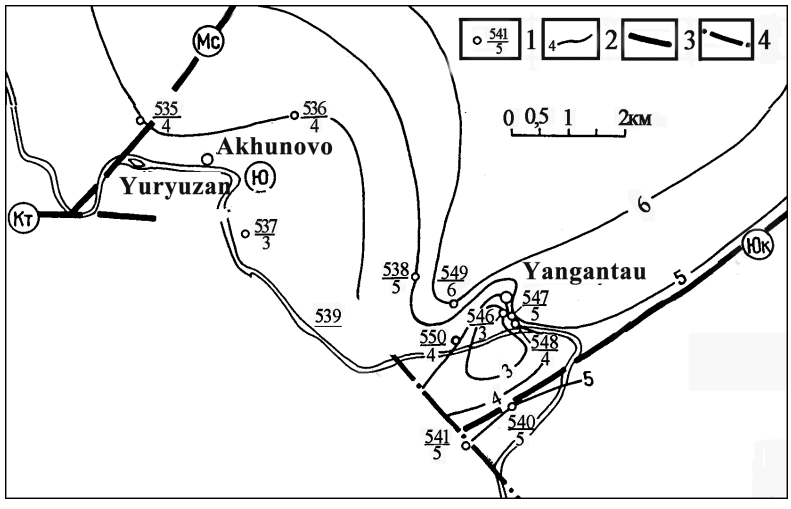

Fig. 10. The isolines nature of seismic noise in the area of Yangantau Mountain. According to Yu.V. Kazantsev. 1 – points of setting seismic devices: number in the numerator, values of seismic noise in the denominator in nanometers, 2 – isolines of seismic noise; 3 – thrusts (Kt – Karatau, Ms – Mesyagutovsky, Yuk – Yukalikulevsky); 4 – strike-slips (Yuryuzansky).

Thus, we identified geological factors involved in "Yangantau phenomenon": geomorphological, material-stratigraphic, hydrogeological and structural-tectonic. We determined the value of each of them. Auspiciousness of geomorphological factors is in presence of steep eastern slope of the mountain, high fracturing of composing rocks creates an opportunity for good purging by slope winds. Development of bituminous stratum of shale structure in the area – Yangantauskian formation of Permian Artinskian tier – can be considered as oil and gas generating. The presence at the base of the Yangantau Mountain of olistostromes, which according to modern concepts, are indicators of high stress of tangential compression, creating a very active geodynamic regime. Presence of aquifer discharged into the river Yuryuzan provides a fairly powerful stream of water, which is the source of steam. A variety of components that are present in water and rocks (clays, silicates, sulfates, sulfides, radioactive substances, impurities of manganese, vanadium, etc.) supplies water with medicinal properties, and also can serve as catalysts for gas emission. Finding a natural energy source is due to tectonic stresses of horizontal compression of the periodic discharge. We do not accidentally consider shale of Yangantauskian formation as possibly oil and gas generating. There is much talk and write about shale gas, which is produced by using special technology.

It includes: horizontal drilling, hydraulic fracturing using a powerful water flow (under significant pressure and temperature), possibly hydrocracking (with different kinds of catalysts), and the seismic modeling. It is obvious that all of the components of gas production from shale require large energy inputs. This explains the cost of shale gas (technological), which is considerably higher than for the natural gas. It seems to us that in accordance with the above views on geological factors, recorded in the area of this mountain, such conditions can be provided by natural features. In this case, we can assume that the phenomenon of Yangantau Mountain is based on a natural mechanism comparable to technology of producing shale gas.

References

Vassoevich N.B., Korchagina Yu.I., Lopatin N.V., Chernyshev V.V. Glavnaya faza neftegazoobrazovaniya [The main phase of oil and gas formation]. *Vestnik MGU. Ser. 4. Geologiya* [Bulletin of the MGU. Ser. 4. Geology]. 1969. No. 6. Pp. 3-27.

Ismagilov R.A. O yangantauskoy svite kak o neftegazogeneriruyuschem ob'ekte [About Yangantau suite as oil and gas generation object]. *Izvestiya Otdeleniya nauk o Zemle i prirodnykh resursov. Geologiya = News of the Department of Earth Sciences and Natural Resources. Geology*. Ufa. 2013. No. 19. Pp. 106-108.

Kazantsev Yu.V. Strukturnaya geologiya Predural'skogo progiba [Pre-Ural trough structural geology]. Moscow: Nauka Publ. 1984. 185 p.

Kazantseva T.T. O genezise termal'nykh istochnikov g. Yangantau na Yuzhnom Urale [On genesis of Yangantau thermal springs in the southern Urals]. *Yuzhno-Rossiyskiy vestnik geologii, geografii i global'noy energii = South Russian Bulletin on geology, geography and global energy*. Astrakhan. 2007. No. 1(25). Pp. 68-70.

Kazantseva T.T. K probleme padeniya temperatur, debitov goryachikh parov i sukhikh gazov v nedrakh kurorta Yangantau [The problem of temperature, hot vapor flow rates and dry gas drop in the depths of the resort Yangantau]. *Izvestiya Otdeleniya nauk o Zemle i prirodnykh resursov Geologiya = News of the Department of Earth Sciences and Natural Resources. Geology*. Ufa. 2013. No. 19. Pp. 68-78.

Kazantseva T.T. O proiskhozhdenii i sokhranenii fenomena gory Yangantau [The origin and preservation of the mountain Yangantau phenomenon]. *Vestnik akademii nauk RB = Bulletin of the Academy of Sciences of RB*. 2014. V. 19. No. 3. Pp. 16-28.

Kamaletdinov M.A., Kazantseva T.T., Kazantsev Yu.V. Osobennosti stroeniya shar'yazhey Ufimskogo amfiteatra [Features of the Ufa amphitheater overthrusts structure]. *Byulleten Moskovskogo obschestva ispytateley prirody. Otdel geologicheskiy = Bulletin of Moscow Society of Naturalists. Department of Geology*. 1981. V. 56. No. 3. Pp. 34-44.

Nalivkin V.D. Fatsii i geologicheskaya istoriya Yuryuzano-Sylvinskoy depressii [Facies and geological history of the Yuryuzano-Sylvinsky depression]. Moscow: Gostoptekhizdat. 1950. 180 p.

Nigmatulin R.I., Kazantseva T.T., Kamaletdinov M.A., Kazantsev Yu.V., Bobokhov A.S. Geologiya i genezis teplovykh anomaliy gory Yangantau [Geology and genesis of thermal anomalies of the Yangantau mountain]. Ufa: AN RB. 1998. 71 p.

Strakhov N.I., Osipov A.I. Bituminoznye porody r. Yuryuzani [Bituminous rocks of the river Yuryuzan]. *Byull. MOIP = Bulletin of the Moscow Society of Naturalists*. 1935. V. XIII(1). Pp. 3-39

Fattakhutdinov S.G., Konyukhov A.I., Khayretdinov I.A et al. K genezisu sovremennykh term Yangan-Tau (Bashkiriya) [The genesis of the Yangan Tau current term (Bashkiria)]. *V Vses. sovesch. po termobarokhimii* [Proc. V All-Union Conf. on termobarochemistry]. Ufa: BFAN USSR. 1976. Pp. 149-150.

Shtil'mark V.V. Ekzogennaya termal'naya anomaliya gory Yangan-Tau v zapadnom Priural'e [Exogenous thermal anomaly of the Yangan-Tau mountain in the Western Urals area]. *Dokl. k sobr. Mezhdunar. assotsiatsii Gidrogeologov* [Proc. Int. Association of hydrogeologists]. 1960. Pp. 310-314.

Cherskiy N.V., Tsarev V.P., Soroko T.I. Vliyanie seysmogeologicheskikh protsessov na preobrazovanie iskopaemogo organicheskogo veschestva [Influence of seismic and geological processes on reformation of fossil organic matter]. Yakutsk. 1982. 56 p.

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