MODEL OF THE SOUTH-TEGYANSKY FIELD OF HEAVY OIL

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Abstract. The article considers the geological structure of the South-Tegyansky oil field, which until now remains underexplored. Geological and field characteristics, results of various estimates of geological and recoverable reserves and resources are given. Based on the seismic survey data and comparison of subhorizons XIa, XIb and XIc thicknesses in well sections, an upthrust model of the reservoir structure was proposed in the location of the only industrial well P-102. It is shown that the imposition of sub-horizon XIc with improved reservoir properties in the well section and increased fracturing of the upthrust area cannot increase the well productivity by almost an order of magnitude, so the assumption is made about deep feeding of the reservoir through disjunctive dislocations. Geochemical indicators of oil composition and distribution of molecules-biomarkers may indicate a mixed Devonian-Permian genesis of the oil in the South-Tegyansky field. A conclusion is drawn on the high potential of the subsalt Mid-Paleozoic deposit complex.

Keywords: Anabaro-Hatagskaya anticline, Upper Paleozoic, Mid-Paleozoic, oil field, halokinesis, uplift, oil-gas perspective

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Introduction

Currently, within the continental shelf of the Laptev Sea, large-scale seismic surveys are carried out by various subsoil users (PJSC Rosneft, JSC Gazprom and others). High prospects of oil and gas content in the Laptev Sea shelf are noted by many researchers. But it should be borne in mind that the Arctic shelf is the most inaccessible in terms of carrying out geological exploration both for climatic and transport-infrastructure conditions. At the same time, the coastal part of the Laptev Sea remains an extremely poorly explored area of the Siberian Platform. Here exploration for oil and gas was carried out in two main stages. At the first stage, in the 40-50's of the last century, the organization "Glavsevmorput" carried out prospecting for oil and gas in the Anabar-Khatanga interfluve to provide fuel for vessels plying along the Northern Sea Route. During these works, two small oil fields were discovered on the territory of the Republic of Sakha (Yakutia) – South-Tegyansky and Chaydakhsky. At the second stage, in the 80-90's of the last century, a network of CDP profiles with a total length of 6570 km was completed and several deep wells drilled. The results of these works did not lead to the discovery of an oil and gas field.

At the same time, taking into account industrial inflows and a certain volume of oil production from the South-Tegyansky field, we consider it expedient to clarify the model of the structure, complete additional exploration and make a calculation of the reserves.

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Formulation of the problem

The South-Tegyansky field is located within the Anabar-Khatanga saddle, which, in our opinion, is part of the Lena-Anabar trough. The field is confined to the brahinanthclinal fold of the sublatitudinal strike with the same name. Its dimensions along the Lower Cretaceous sediments are 19×6 km, the amplitude is 700 m. Fold axis forms two domes – east and west, separated by a saddle, while the eastern dome is above the western one for about 200 m. Penetrated by deep drilling section of the field is represented by the Upper-Lower Mesozoic terrigenous deposits. Quite thick clastic-carbonate of the Middle Paleozoic (up to 1 km), carbonate Lower Paleozoic (up to 1.3 km) and the Precambrian cover are expected to be developed in the unopened portion.

The industrial oil and gas potential of the South-Tegyansky field is associated with sediments (the horizon) of the roofing part of the Lower Kozhevnikovskian Formation of the Lower Permian. The productive horizon XI with a total thickness of 70-90 m lies in the depth interval 1580-1720 m. The maximum inflow of 15.3 m^3/day of oil was received in the well P-102, laid on the western dome. From the same well, an inflow of gas up to 1445 m^3/day was obtained. In other wells on the western dome, the flow rates vary from 0.1 to 2 m^3/day. On the eastern dome, oil inflows do not exceed 0.3 m^3/day. The density of oil is high from 0.930 to 0.970 g/cm^3, an average of 0.950 g/cm^3 (Kalinko, 1959).

The XI horizon is divided into three sand subhorizon – XIa, XIb, XIc with a thickness of 10 to 49 m, with improved reservoir properties relatively separating them from mudstone layers with thicknesses up to 12 m. Sandstones are finely grained, in varying degrees, clayey and silty, weakly cemented by clay – micaceous-siliceous and carbonate cement. The subhorizon XIa was penetrated in the P-102 well in the interval of 1583-1605 m, XIb – 1617-1630 m, XIc – 1639-1670 m. The subhorizon XIb has the best reservoir quality. The open porosity of the sandstone in this horizon reaches 26%, an average of 11%, the permeability reaches 0.068 μm^2, with an average value of 0.004 μm^2. The reservoir pressure in the middle of the productive interval 1617-1630 m is 14.27 MPa, the reservoir temperature is 32.4 °C.

Total recorded cumulative production of the well was about 2085.15 tons of crude oil, of which, from 12.1948 to 08.1952 year – 1789 m^3 of oil (1789×0.95 = 1699.55 tons) and in the period from 06.1996 to 08.2002 year – 385.6 tons.

First a rough estimate of geological and recoverable reserves and resources of the Lower Permian reservoir in the Western dome of the South-Tegyansky field on C_2 category was performed by Trust "Krasnoyarsk-neftegazrazvedka" in 1976, in the volume of 3990/399 thousand tons of oil and 610/61 million m^3 of dissolved gas (recovery ratio was was assumed to be 0.1). Volumes of free gas contained in the gas cap of the deposit, because of the lack of parameters, were not counted. The following estimation of geological reserves of oil was carried out in 1996 (Safronov et al., 1996) in the volume of 6946 thousand tons on C_2 category, recoverable – 2083 thousand tons. And 1448 thousand tons and 434 thousand tons (the recovery ratio was taken equal to 0.3), respectively – on C_1 category (in the radius of drainage of the P-102 well).

Thus, the calculation of oil reserves of the South-Tegyansky field with approval in the State Balance of the Russian Federation has not been carried out to date. The objective reasons for this situation are insignificant inflows from wells (no more than 2 m^3/day), except for P-102, and insufficient knowledge of the oil reservoir model. A number of researchers have suggested that there is no active oil deposit, and oil enters the P-102 well through a fault from deep seams (deep source). The main argument in favor of this assumption is the anhydrous oil flowing of the P-102 well.

The aquiferous complex of the Upper Paleozoic-Mesozoic deposits of the geological region has been studied very poorly. The few data available indicate the low reservoir energy of the productive horizon XI.

Based on the available geological, geophysical and geochemical data, we will try to show the most approximate to the natural structure model of the South-Tegyansky oil field.

Experimental part

We have considered the thickness of subhorizons XIa, XIb, XIc at the field, given in the primary data (Puk, Kopylova, 1955). Table 1 shows the depths and thicknesses of subhorizons XIa, XIb, XIc. Figure 1 shows the change in the thicknesses of subhorizons XIa, XIb, XIc in wells drilled on the western dome of the South-Tegyansky field.

As can be seen from Table 1 and Figure 1, the thicknesses of subhorizons XIa, XIb and XIc differ significantly from the others in the well P-102. In all wells except P-102, horizon XIa has a small thickness, XIb – maximum and XIc – average; while in the well P-102 all three subhorizons have commensurable

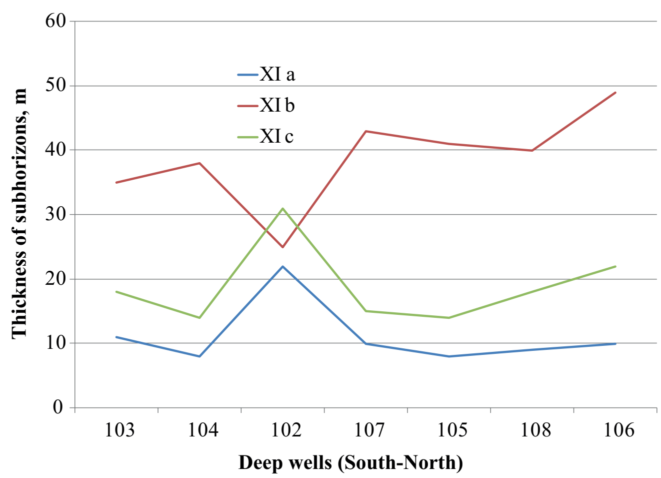

Fig. 1. Graph of the thickness variation of subhorizons XIa, XIb and XIc in the productive horizon XI. South-Tegyansky area

well	XIa			XIb			XIc		
	roof	bottom	thickness	roof	bottom	thickness	roof	bottom	thickness
102	1583	1605	**22**	1611	1636	**25**	1639	1670	**31**
103	1599	1610	11	1613	1648	35	1660	1678	18
104	1643	1651	8	1660	1698	38	1704	1718	14
105	1607	1615	8	1616	1657	41	1666	1680	14
106	1642	1652	10	1655	1704	49	1709	1731+	22+
107	1661	1671	10	1680	1723	43	-	-	
108	1576	1585	9	1590	1630	40	1640	1658	18

Table 1. Depth and thickness of subhorizons XIa, XIb, XIc

thicknesses (22 m, 25 m, 31 m). The thickness of the subhorizon XIa was increased 2 times, the subhorizon XIb thickness was decreased noticeably relative to other wells, and the thickness of subhorizon XIc was increased 1.5 times.

In our opinion, these differences can be due to superposition of the section parts due to the upthurst dislocations. It seems unlikely to have a quite sharp change in the thickness of sand interlayers in a limited area of sedimentation (the first hundreds of meters), even in coastal-marine conditions. The presence of faults in the area of the well P-102, including the upthrusts, was reliably established by the latest seismic surveys in 2012 (Fig. 2, A). This disjunctive dislocation for the western dome has the form of a central or axial downthrow to the middle of the sediments, bounded by the reflecting horizons VII and VIb (the middle Carboniferous-Tuskakhstian formation of the Lower Permian). However, it is central only in the sediments of the Middle and Upper Paleozoic of the western dome, and in the layers of the Riphean and the Lower Paleozoic it is shifted to the southern periphery of the fold. The vertical displacements of the layers are 100-200 m. Fig. 2 (A and B) shows that from a depth

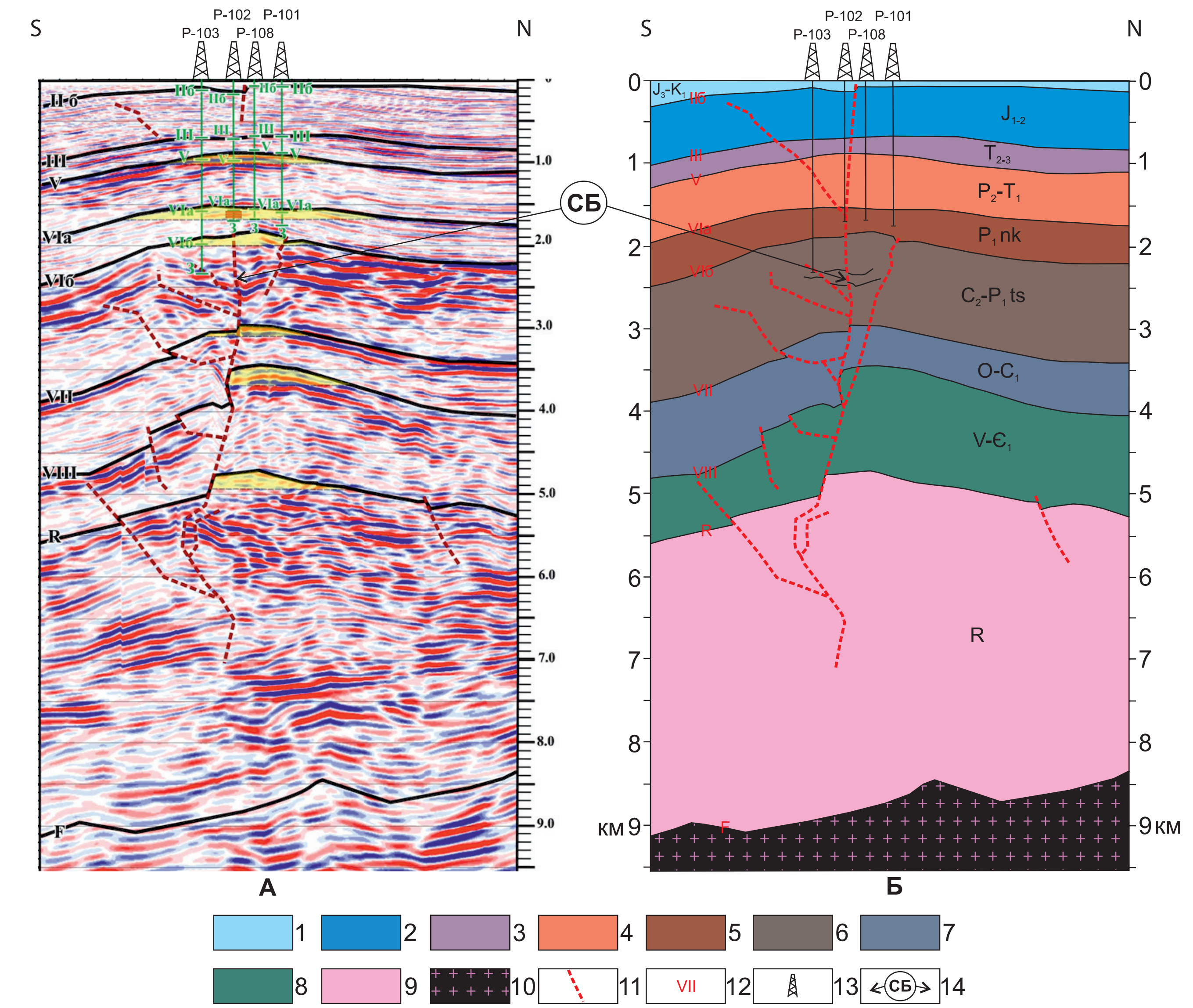

Fig. 2. Seismogeological section across the western dome of the South-Tegyasnky structure (profile section 050311 according to the materials of the State Research Center of the Federal State Unitary Enterprise "Yuzhmorgeologiya", 2012) with the additions of the authors. Legend: deposits: 1 – Upper Jurassic-Lower Cretaceous, 2 – Lower-Middle Jurassic, 3 – Middle-Upper Triassic, 4 – Upper Permian-Lower Triassic, 5 – Lower Kozhevnikovskian Formation of Lower Permian, 6 – Upper Carboniferous-Lower Permian (Tustakhskian Formation), 7 – Ordovician- Lower Carboniferous, 8 – Vendian-Lower Cambrian, 9 – Riphean; 10 – the basement; 11 – disjunctive dislocations; 12 – indices of reflecting horizons: IIb – roof of Lower-Middle Jurassic deposits; III – roof of Middle-Upper Triassic sediments; V – roof of Upper Permian-Lower Triassic deposits; VIa – roof of Lower Kozhevnikovskian Formation of the Lower Permian; VIb – roof of Middle Carboniferous – Tustahskian Formation of the Lower Permian; VII – the roof of the Ordovician-Lower Carboniferous, VIII – the roof of the Vendian-Cambrian deposits; R – the roof of Riphean deposits; F – the surface of the crystalline basement of the Archaean-Middle Proterozoic; 13 – deep wells; 14 – the transition zone of upthrust to downthrow

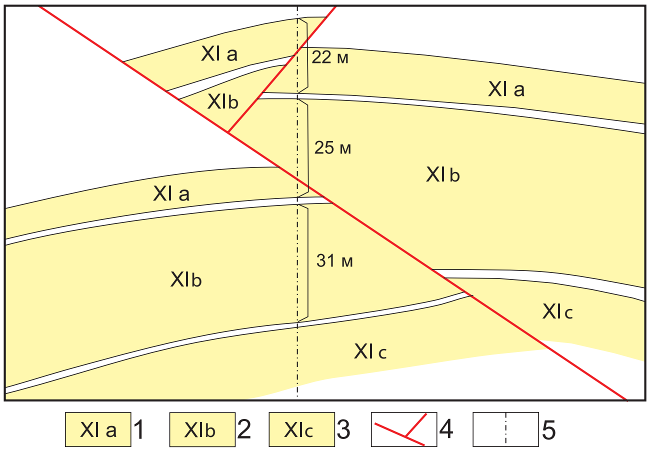

Fig. 3. Principal model of the deposit in the area of the P-102 well. Legend: 1 – subhorizon XIa, 2 – subhorizon XIb, 3 – subhorizon XIc, 4 – disjunctive dislocations, 5 – axis of the P-102 well

of 2.4 km the disjunctive dislocation takes the form of an upthrust. From the interval of productive horizon XI in the south direction, an additional disjunctive dislocation (upthrust) appears, where the fault plane is inclined to the south, the amplitude of the upthrust is small – 30-40 m. This disjunctive dislocation of the northwest strike does not complicate the eastern dome of the South-Tegyansky area.

In addition, in the descriptions of core material, numerous glide mirrors and crushing zones are established, which indicate about subhorizontal displacements (Kalinko, 1959). The schematic diagram of the section formation penetrated by P-102 well opened due to upthrusts is modeled and shown in Fig. 3.

The proposed reservoir model can cause a slight increase in the productivity of the P-102 well due to the imposition of the subhorizon XIb with improved reservoir properties and due to the zone of increased fracturing near the upthrust.

At the same time, since the specific drained volume of the well has practically not changed, the increase in productivity is almost one order of magnitude more likely due to another factor. It is highly probable that in the increased production rate of the P-102 well, the decisive role is played by deep feeding of the deposit through the established disjunctive dislocation from the subsalt Middle Paleozoic deposits. In any case, geochemical data does not contradict this assumption.

According to our data, the oil of the South-Tegyansky field refers to heavy (922-960 kg/m^3), sulphurous (2.16%), highly resin oil. The content of the gasoline fraction is 11%, in its composition 54.2% – of methane hydrocarbons, 29.4% – naphthenic and 16.5% – aromatic.

Saturated hydrocarbons are characterized by the alkanes predominance of normal structure (61%), and among them – relatively high-molecular homologues (Σn.k.-nC20/ΣnC21-k.k.=0.74), the presence of squalane, a significant content of 2- and 3- methylalanes (24%) and isoprenoids (15%), in their composition, phytan predominates over the pristane (pristane/phytan = 0.63).

In the topped oil fraction, hydrocarbons account for 51.5%, among them methane-naphthenic hydrocarbons are slightly higher than naphthenic-aromatic hydrocarbons (MH/HA = 1.16). Resins account for 29.2% with practically the same content of benzene and alcohol-benzene components (15.6% and 13.6%, respectively). Asphaltenes make up 8.4%.

Among the peculiarities of the polycyclic hydrocarbons of this oil, it is worth noting the significant content of tricycloalkanes (26.6%) and low – of moretanes, which is typical for the oils of the ancient deposits of the Nepa-Botuoba oil and gas basin generated by aquatic OM. The predominance of adiantane over hopane in the composition of pentacyclic hydrocarbons may indicate about the accumulation of petroleum-based OM in the conditions of carbonate or carbonate-evaporite facies (Connan et al., 1986; Peters et al., 2005). The presence of gamma-cerane in pentacyclanes is characteristic for conditions of increased salinity of the formation of the initial OM.

It should be noted that regrouped steranes (diasteranes) play an important role in the composition of the steranes of the South-Tegyansky oil, their ratio to regular steranes is 0.28-0.52. This distribution character of sterane hydrocarbons is usually considered as a sign of the terrigenous nature of the source deposits (Peters, Moldowan, 1993; Rubinstein, 1975).

Thus, a number of geochemical parameters, such as low values of pristane/phytane ratio, high concentrations of gamma-cerane and squalane, the predominance of adiantane over hopane indicate about the formation of source rocks in a sharply saline lagoon basin. Here, oil-source deposits of the Middle Paleozoic could be domanicoid by the type of the Lower Frasnian D_3 stratum, represented by massive black marine clay limestones with interlayers of limestones and calcareous mudstones.

At the same time, the ratio of diasteranes to regular steranes indicates about a predominantly terrigenous composition of the initial OM, which is characteristic of the lagoon-continental sedimentation with a wide development of the lake-marshy facies.

In general, the peculiarities of the composition and distribution of biomarker molecules, taking into account all the geochemical data, suggest that the source of the South-Tegyansky oil generation could be the OM of the mixed composition of the Devonian-Permian area of oil and gas generation (Kashirtsev, 2003; Kashirtsev et al., 2013). Like the other naphtides of the Anabar-Khatanga saddle, the Nordvkisky oil (T_2), oil shows of

Yuring-Tumus Peninsula (J_2) and the North-Suolemsky Well 2 (P_2), the South-Tegyansky oil "originates mainly from OM of the Devonian salt-bearing complex. The contribution of Upper Paleozoic oil-bearing rocks is less significant" (Kashirtsev et al., 2013).

The discussion of the results

The formation of oil reservoirs at the level of the Lower Kozhenikovskian Formation in the studied geological region apparently began with the formation of anticlinal traps due to tectonic activation in the Lower Triassic period, with the imposition of halokinesis processes of Devonian salt deposits. After the Late Permian-Early Triassic tectonic activation was completed, the described area was lowered and the formation of the deposits continued until the late Cretaceous mainly due to lateral migration. Subsequent renewal of differentiated tectonic movements that continued in the Cenozoic resulted in partial destruction of the traps both at the level of the Lower Kozhevnikovskian Formation and at the level of the subsalt sediments of the Middle Paleozoic, as evidenced by numerous epigenetic naphthyde spots over the fractures that occur in the Mesozoic deposits from a depth of 70 m (Kalinko, 1959).

In our opinion, at the present time the destroyed reservoir at the lower level of the Kozhevnikovskian level, fueled by hydrocarbons from the lower parts of the section, can be productive only in certain near-fault zones. At the regional level, significant accumulations of oil and gas in the Middle Paleozoic potential oil and gas bearing complex can be confined to the crypto-diapir structures formed due to halokinesis of salt deposits without the formation of significant disjunctive dislocations.

Conclusion

To clarify the prospects of the oil and gas potential in the lower part of the section of the studied geological region (from the Riphean to the Middle Paleozoic) and to establish the model of the South-Tegyansky field, it is proposed to drill a well with a depth of up to 5 km. Before drilling a well, it is expedient to clarify the structural plans of the subsalt deposits.

Drilling a well may also allow the calculation of oil and gas reserves in the field and put it on the State Balance of the Russian Federation.

According to the geological area in question, the main prospects for oil and gas potential are likely to be associated with the subsalt Middle Paleozoic complex of sediments.

References

Connan J., Bouroullec J., Dessort D., Albrecht P. The microbial input in carbonate-anhgidrite facies of a sabkha paleoenvironmant from Guatemala: A molecular approach. *Organic Geochemistry*. 1986. V. 10. Pp. 29-50.

Kalinko M.K. Hystory of geological development and prospects of oil and gas potential of Khatanga depression. Leningrad: Gostoptekhizdat. 1959. 353 p.

Kashirtsev V.A. Organic geochemistry of nafthides of the East Siberian platform. Yakutsk: YaF SO RAN Publ. 2003. 160 p. (In Russ.)

Kashirtsev V.A., Kim N.S., Fursenko E.A., Dzyuba O.S., Fomin A.N., Chalaya O.N. Genesis of oils and oil shows of the Anabar-Khatanga saddle (Arctic sector of the Siberian platform). *Geology and mineral resources of Siberia*. 2013. No. 1(13). Pp. 54-63. (In Russ.)

Peters K.E., Moldowan J.M. The biomarker guide. Prentice Hall, Englewood Cliffs, New Jersey. 1993. 363 p.

Peters K.E., Walters C.C., Moldowan J.M. The biomarker guide. 2nd ed. N.Y. Camburidge Univ. Press. 2005. 1155 p.

Puk P.S., Kopylova T.N. Basic data on the geological structure and oil content of the Anabar-Khatanga interfluve. Report, Book 5. Leningrad. 1955. (In Russ.)

Rubinstein I., Sieskind O. and Albrecht P. Rearranged sterenes in a shale: Occurrence and simulated formation. *Journal of the Chemical Society*. Perkin Transaction 1. 1975. Pp. 1833-1836.

Safronov A.F., Kungurov V.M., Stepanov R.T. Yuzhno-Tigyansky oil field. *Sb. trudov I Mezhd. konf.: «Znanie – na sluzhbu nuzhdam Severa»* [I Int. Conf. "Knowledge – to the needs of the North": Collected papers]. Yakutsk: Severoved. 1996. Pp. 167-169. (In Russ.)

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