Formation of Hydrocarbon Deposits in the Riphean-Lower-Paleozoic Sedimentary Basin in the Southern Siberian Platform

M R Marsanova¹, A G Berzin¹

¹M.K. Ammosov North-Eastern Federal University, 58, Belinsky str, Yakutsk, 677000

E-mail: marigotov@mail.ru, a_berzin@mail.ru

Abstract. In fluidodynamic theories activated deep faults with a key characteristic "activated" are an important and integral part of the oil and gas basins. The influence of fault tectonics on the processes of oil and gas formation is generally recognized and reflected in a variety of publications, but the mechanism of influence that is associated with the activation parameters: cyclicity of manifestation, generation redirection, time and the period of activation of fault systems, remains insufficiently studied [10, 11, 12, 13, 14].

Previously, in the marginal depressions of the east of the Siberian platform (Viluy Synclise), carried out by several sedimentary basins (OPB), periodic processes of different ages activation of previously laid deep fault systems with various directions and generations were established. It's argued that the formation of hydrocarbon deposits in the synchronous sediments of the same Riphean-lower Paleozoic OPB on-site of Nepa-Botuoba anteclise was due to subvertical fluid flows from underfoundation sources and processes of reformation of hydrocarbon deposits between productive layers under the influence of the periodic re-activation of fault systems with different spatial orientation. Deposits in productive formations of the terrigenous Vendian complex form under the influence of fault activation of early North-East, North of the North-East and submeridional generations. But in productive carbonate horizons of Wend-Cambrian and Lower Cambrian deposits form at the cost of reformation of deposits in the vendian deposits as affected by late north-west generation faults in the zones of overlaying on earlier generation. Oil exploration in the carbonates is recommended in the areas adjacent to the selected fault systems.

1. Introduction

"Overview of the productive horizons in the Cambrian and Precambrian section of the Siberian platform shows that the main oil and gas deposits are confined to the terrigenous part of the Precambrian sedimentary cover. At the same time, in a much more powerful Lower-Middle Cambrian halogen-carbonate complex, a few industrial accumulations of hydrocarbons have been discovered" [20]. This conclusion, made by a team of authoritative geologists of oil companies more than 3 decades ago, continues to remain unchanged by now and makes it urgent to identify the causes of this imbalance in the deposit development.

Section of the sedimentary cover of the Nepa-Botuoba anteclise (NBA) in the south of the Siberian platform, which contains the predominant part of the oil and gas reserves established here, mainly form the Vendian and Cambrian deposits. In their comlocation, a number of productive horizons of terrigenous and carbonate comlocation have been established and are forecasted [3].

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To date, at the attained degree of geological and geophysical knowledge of the said territory deep drilling, predominantly gas-saturated clastic horizons occurring in the lower sedimentary cover and allocated in part of early Vendian terrigene complex are dominated. The carbonate horizons, on the one hand, and the oil-saturated collectors of the Vendian-Cambrian and the Lower Cambrian, on the other, play a subordinate role against this background.

According to the existing concept, the carbonate horizons in the Siberian platform are associated with prospects of the largest reserve for increasing oil and gas deposits. In the sedimentary cover of NBA the productive formations are B3-4-5 in the Upper Danilov sub-horizon of subsalt carbonate complex (Vendian-Cambrian) and formations B1, B2 in the Lower Usolsk halogen-carbonate complex (Lower Cambrian). In the territory of Yakutia, these are the Yuryakh (Vendian-Cambrian) and Osynsk (Lower Cambrian) carbonate formation [21]. There is a need to assess the feasibility of these prospects based on the discussion of the nature and mechanism of deposits formation herein.

In this regard, we should note that the existing distribution of open hydrocarbon deposits, including those in the Vendian-Cambrian and Lower Cambrian carbonates, is not only in the NBA, but also in other adjacent areas of the Siberian platform: Baikit antecline, Katanga and Vilyuchansk saddle, the sedimentary cover of which is represented by one Riphean-Lower Paleozoic sedimentary and rocky basin (SRB) (Table 1).

Table 1. Distribution of fields with deposits in the terrigenous complex of Riphean and Early Vendian and carbonate formations of the Vendian-Cambrian and Lower Cambrian [16].

| Superorder structures | Baikit antecline | Katanga saddle | Nepal-Butuobin antecline | Vilyuchansk saddle | Total |
|-----------------------|------------------|----------------|--------------------------|--------------------|-------|
| Republic of Sakha (Yakutia) | 5 | 2 | 17 | 8 | 3 | 35 |
| Irkutsk Region | 0 | 0 | 2 (1)* | 5 | 3 | 10 (9)* |
| Total Deposits | 3 | 2 | 17 | 7 | 3 | 32 |
| With deposits in the carbonates of Vendian-Cambrian and Lower Cambrian | | | | |
| With deposits in the Vendian | 3 | 2 | 17 | 7 | 3 | 32 |
| With deposits in the Riphean | 2 | 0 | 0 | 0 | 0 | 2 |

*In the territory of Yakutia, the author refers only Talakan deposit to deposits with deposits in carbonates of the Osynsk horizon. The central block of the Mid-Botuoba field, where the oil and gas manifestations in the Osynsk horizon were noted in 3 wells, the HC reserves were not counted due to their insignificance.

Due to revealed giant scales of deep degassing of the Earth, including hydrocarbon degassing (CH4, CO2, N2, H2, etc.), the fluid dynamic schemes of oil and gas accumulation processes are being developed in addition to the classical biogenic, also due to degassing processes both direct and with an intermediate accumulation of bacterial mass and its processing into oil [2, 6, 8, 15, 19, 20]. The theory of convergence in the formation of HC deposits among the latter, in our opinion, is the most acceptable for explaining the nature of NBA deposits. The correctness of this theory application presupposes the existence of a sub-fundamental source, a sub-vertical filtration of HC fluids, and a powerful sedimentary stratum. Thus, in particular, the geological and geophysical studies and modeling carried out in recent years have made it possible to confirm such conditions in the territory of the Nepa-Peleduy arch within the Nepal-Butuoba antecline [9].
2. Research methods
Methods of the study: correlation and cross-correlation analyzes of maps of geological reference points and seismic reflecting horizons, as well as maps of hydrodynamic performance according to the well test data, the results of which were correlated with the results of linear analysis based on data from space surveys and potential fields.

3. Research results
Earlier in the marginal depressions of the east of the Siberian platform (Vilyui syncline), executed by several sedimentary-rocky basins (SRB), the lower one of which is the Riphean-Lower Paleozoic basin, the periodic processes of different ages activation for the previously laid deep faults of different directions and generations. We call such a fault system as a pool-forming system. It is shown that those consedimentation active systems have a significant effect on the sedimentation, formation and stages of the SRB development [4]. It is suggested that they reflect the relation between the evolution of sedimentary basins and fault formation in the tectonosphere and, in particular, with the phenomenon of the main divisibility of the earth's crust, its blocky structure, and certain primary faults [1]. The turn seems to be caused by the gradual activation of already existing, previously embedded fault systems of various directions and generations [5], and is also caused both by a planetary mechanism [7] and the processes occurring in the Proterozoic-Phanerozoic in the areas of Siberian continent articulation with other continental blocks.

If one maintains the viewpoint of the dynamic nature of deposits formation (deformation) during the geological time, the formation of deposits in carbonate reservoirs belonging to the upper productive part of SRB section was decisively affected by fault systems of the last activation (during the post-Cretaceous period and to the present), having a north-west strike. The activation of such fault systems and its nature are identified in the territory of the Vilyui syncline, according to the results of processing various scale lineaments of the earth's surface relief from the data of space images and is confirmed by data of special processing of gravitational and magnetic fields [4] (Fig. 1).

It is assumed that under the influence of faults of the north-west generation the simultaneously forming processes of reservoir-filtering properties in the reservoir carbonate rock and reorientation local structural plans of traps that fall in their zone of influence took place. The processes took place, obviously, as a result of a directed change in the physical properties of carbonate matrix skeleton (primarily porosity - fractured vuggy) under the influence of aggressive fluid solutions (or magmatic masses and post-magmatic solutions) that enter the faults during their activation. This leads to a change in the compression characteristics of the formation (Young's modulus and Poisson's ratio) and its transition to a new stress-strain state, which inherent the strike of the activated fault system.

For the practical application of the established effect of the age-dependent fault systems activation on the HC deposits formation in solving the oil and gas field search problems, it is particularly important to identify the pool-forming fault tectonics, which was activated in anthropogenous times, and the traces of its manifestation in past eras.
**Figure 1.** Manifestation of the deep faults activation (north of the north-west direction)

I—generalization of different-scale lineaments based on space survey data (SSD) for the territory of Vilyui synclise: a) assembly of lineaments with various directions; lineaments for directions: b) east of the north-east; c) north-east; d) north of the north-west; e) rose-diagram of lineaments; II—lineaments of magnetic (a) and gravitational (b) fields at the Atyakha square in the Kempendyai basin. The arrow points to the lineaments reflecting the fault system for the north-west strike of the last activation, which "cross" lineaments of other directions.

The isolation of such tectonics, especially in the first case, presents certain difficulties. The period of activation of the basin-forming faults is equal to the time of existence of the SRB (tens and hundreds of millions of years), in the first half of which the basin and fault are subjected to various-period deformations, but the mode of expansion of the crust dominates, and the second is the compression regime. For example, detection methods and fracture activity indices have been developed with a period of activation (hundreds or less years) that trigger the trigger mechanism of earthquake processes [17, 18], but the issue of the identity of activated faults and the faults of basin-forming systems identified by them has not been studied. There are supposed indirect indications of the active faults detection, to which, in our opinion, the transregional nature of the distribution and the linear-zonal nature of the deposits location formed under their influence can be attributed.

In the territory of the NBA and Vilyuchansk saddle in the borders of the Republic of Sakha (Yakutia), there are no problems in identifying the formerly activated fault systems of the north-eastern and sub-medial directions. On the maps of fault tectonics of various authorial collectives, these directions are predominant. The spatial location of fields developed here with deposits in the Vendian (20 of 32 in Table 1) inherits the dominant northeasterly strike and confirms the unequivocal connection between the nature of these deposits formation and fault systems of such directions (Fig. 2-I).

Finally, on the maps of fault tectonics, the structural-tectonic zone of the north-western strike, through the territory of Vilyuchansk saddle (location of the conditional center line "B-B", Fig.2-I), whose existence could explain the local spatial location of fields discovered here with deposits in Vendian-Cambrian carbonaceous rocks in the framework of the presented concept (Iktekh, Verne-Vilyuchansk and Vilyuisk-Jerbinsk deposits) cannot be seen at all.
Maps with an overlay of local and superorder structures within the Republic of Sakha (Yakutia): I. fault tectonics of All-Russian Geological Research and Development Oil Institute [5]); II. Map of the magnetic field \( \Delta T \).

1 – field contours; 2 – contours of the structures: a) – in training funds, b) – inherit the strike of the fault system; 3 – administrative border of Yakutia; 4 – boundaries of superorder structures (names of structures are in Fig.2); 5 – location of the conditionally axial lines for fault systems of the north-west strike; 6 – contours of the Nepa-Peleduy arch (NPA) and Myrninsky protrusion (MP) of the NBA; 7 – deposits that are referenced in the text: 1 – Talakan, 2 – Upper Chon, 3 – Vakunai, 4 – Upper Vilyuchan, 5 – Vilyuisk-Djerba.

4. Conclusions

1. Fields formation in the HC traps of synchronous deposits of a single Riphean-Lower Paleozoic SRB within the NBA probably occurred due to subvertical fluid flows from sub-fundamental sources and the HC deposits reformation between productive Vendian strata under the influence of periodic activation of fault systems of different spatial orientation.

2. HC deposits in productive strata of the terrigenous Vendian complex were formed under the influence of active faults of early north-eastern and / or subsequent north-eastern and sub-meridional generations, and HC deposits in the Vendian-Cambrian and Lower Cambrian carbonate horizons - under the influence of active faults of late north-west generation with the inheritance of local structural plans for the strike horizons of these faults. This leads to a discordant correlation of the local structural plan of deposit in the carbonate strata with respect to the regional plan or formation plan in the Vendian deposits at the multi-layer fields.

3. A stage is established in the deposits formation in the SW traps upwards along the section. At the first stage, under the action of fault systems of the early north-eastern and subsequent generations, the north-east and sub-meridional north form and then reform deposits in the productive Vendian strata. Deposits in the productive Vendian-Cambrian and Lower Cambrian carbonate horizons are formed at the second stage under the influence of faults of late north-western generation in the zones of their overlapping to faults of earlier generation due to reformation (de-formation) of deposits in terrigenous Precambrian reservoirs.

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