Natural reservoir as a geological body for storing helium reserves

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Abstract. In connection with the start of field operation of large oil-and-gas bearing deposits of helium in the south of the Siberian platform (SP) the problem of long-term helium storage arises. Some researchers propose to use reliable underground storages for this purpose. Natural reservoirs, geological bodies representing an association of rocks in which fluids can be contained and circulated, can serve as such a natural depository for the injection and preservation of helium reserves. Therefore, the permeability of caprocks in natural reservoir that can hold helium for a long time is of particular importance. The paper presents the results of lithologic composition, thickness and condition of the caprock formation as the regional impervious fluids in natural reservoir of the SP south. The Lower Cambrian deposits of the Usolie formation being a part of the Vendian-Cambrian oil and gas complex can serve as such a regional impervious fluid.

1. Introduction
Currently, the world's main resources and reserves of helium are concentrated in the United States, Algeria, Russia and Qatar. The degree of helium concentration in the fields of Eastern Siberia and the Republic of Sakha (Yakutia) gives Russia significant advantages over other countries on the world market for this valuable resource. However, to maintain long-term economic interests, technologies are needed to accumulate large amounts of helium in Eastern Siberia.

Underground storage technology first found a solution in the United States in the second half of the 20th century. Since 1973, the Cliffside gas-helium deposit has been used exclusively as an object for the storage and sale of helium concentrate [1]. In Russia, the same storage technology was applied in 1979 in the Orenburg region. Here, underground mine workings in rock salt formations were used to store helium concentrate [2].

Salt impervious fluids of the Usolie formation, unique in scale and conditions of localization, can solve the problem of the accumulation of helium concentrate in Eastern Siberia [3,4,5]. Analysis of the structural and lithological characteristics of the composition of natural reservoirs as geological bodies and the study of the paleofacial conditions of accumulation of salt-bearing impervious fluids allows considering them as objects of the helium concentrate storage.

2. Materials and methods
The paper presents the results of research work to determine the structural and lithological characteristics of the composition of natural reservoirs as the geological bodies of the Angara-Lena oil and gas province fields within the Baikit, Katanga and Nepa-Botuobia oil and gas regions. In order to determine the paleofacial conditions of accumulation of salt-bearing impervious fluids, archival and
published materials on drilling and geophysical studies of the Yurubchen-Tokhom oil-and-gas condensate, Kovykta gas condensate and Chayanda oil-and-gas condensate deposits and some other fields were used.

3. Findings and their analysis
Helium is an inert gas without color, taste and odor, one of the most common elements in the Universe, second only to hydrogen in this quality. Helium is widely used in high-tech industries: aviation, astronautics, medicine, metallurgy and in a number of other areas of industrial and scientific production [6].

Experts of the consulting company Ernst & Young, who conducted a study of the prospects for the extraction and production of helium in Russia in 2012, arrived at an unequivocal conclusion: the development of technologies will be accompanied by an increase in demand for this inert gas [7]. According to their estimates, by 2030, depending on a number of factors, it can reach 200–330 million cubic meters (Fig. 1).

East Siberian gas production regions, are located in the Krasnoyarsk Territory, the Irkutsk Region and the south-western part of the Sakha Republic (Yakutia). To date, 31 deposits have been discovered here, containing helium in various concentrations. Total assured resources of helium and its content in different fields are given in Table 1.

| Region of gas recovery, deposit, its type | Helium reserves billion m$^3$ | Basic chemical composition, % (vol) |
|-----------------------------------------|-------------------------------|-----------------------------------|
|                                         | $ABC_1$ | $C_2$ | He | CH$_4$ | T.U | N$_2$ |
| **Krasnoyarsk Territory**              |         |      |    |        |     |      |
| Sobinsk, OGC                           | 0,8     | 0,1  | 0,576 | 67,5 | 6,4  | 25,26 |
| Yurubchen-Tokhom, OGC                  | 0,3     | 0,5  | 0,183 | 83,0 | 8,4  | 7,80  |
| **Irkutsk region**                     |         |      |    |        |     |      |
| Dulisma, OGC                           | 0,18    | 0,04 | 0,260 | 84,1 | 6,8  | 6,8   |
| Kovykta, GC                             | 3,88    | 1,2  | 0,276 | 92,3 | 5,7  | 1,5   |
| **Sakha (Yakutia)**                    |         |      |    |        |     |      |
| Verkhnevilyuchan, OC                    | 0,18    | 0,1  | 0,13  | 84,5 | 7,5  | 7,46  |
| Srednebotuobia, OGC                    | 0,75    | 0,04 | 0,67  | 83,8 | 6,9  | 8,0   |
| Chayanda, OGC                           | 1,85    | 5,3  | 0,63  | 85,6 | 6,4  | 8,2   |

The data show that helium reserves of only one the Kovykta field many times higher than demand not only in the Russian, but also in the global market. There is an urgent need to develop storage
technologies. One method of storing excess gas is its injection underground in natural storages – natural reservoirs (NR).

The term "natural reservoir" (NR) means "a geological body or system of rock association, bounded by practically impermeable rocks, in which fluids may be contained and circulated." Impermeable rocks – impervious fluids ensure the safety of oil and gas deposits and natural state of bedded heterophase hydrocarbon system – formation pressure at the level of gas-oil, gas-water and water-oil contacts, pressure of the condensation beginning, etc. [8].

Nature of the natural reservoirs genetic types characterized by a specific set of lithogeodynamic rock complexes is extremely important In the process of ontogenesis and preservation of HC. In the volume of the Riphean-Vendian-Cambrian sedimentary basin of the Siberian platform south O.V. Postnikova identified several levels of development of natural reservoirs, the lateral and vertical distribution of which, genetic type, and also structural features are determined by belonging to certain geodynamic and paleogeographic zones of the paleobasins [9].

The Vendian-Cambrian reservoir with a regional impervious fluid – the Usolie formation is of particular interest for our studies, emphasizing structural and lithological characters. It is known that the main productive horizons at hydrocarbon fields of the Siberian Platform (SP) are confined to the Riphean-Vendian and Vendian-Cambrian oil and gas complexes [10, 11]. The composition of the Usolie formation (analogue is the Yuregin one), the presence of powerful salt mass in it, determines its screening properties and allows it to serve as the most reliable impervious fluid that ensures the safety of helium reserves. Rock salt is characterized by low porosity, plasticity, high density, low hydraulic conductivity, and as well as by low helium diffusivity [12]. The peculiarities of composition and thickness of deposit are reproduced in schematized sections of the Usolie (Yuregin) formation, which is part of the salt (halogen-carbonate) complex of the sedimentary cover of the SP on individual hydrocarbon fields (Figure 2).

![Figure 2](image-url) - Schematized sections of the Usolie (Yuregin) formation of the Lower Cambrian within oil and gas fields of the Siberian platform south. Legend: 1-salts; 2-limestones; 3 - dolomites; 4 - clayey dolomites; 5 - dolomites anhydrite; 6 - dolerites; 7 - dolomites with stylolitic sutures.

The Usolie formation and its analogs are common almost throughout the entire territory of the SP. Its field capacity varies from 1000 to 160 m, which is explained by salt tectonics and plasticity of salts capable of forming salt caprocks.

Rock salt, detrital dolomites and thin-layer rocks of mixed aleurite-anhydrite-clay-dolomite composition are common among the Usolie formation lithotypes. The minor lithotypes include fine crystalline limestones and dolomites with no signs of detrital structure (evaporite carbonate rocks), intraclastic cracking breccias, lenticular clumps of broken shells, fine-crystalline and fine-grained anhydrites, stromatolite limestones and dolomites, rare silicates. Typical inter-salt sediments are fine- and fine-detrital dolomites and limestones approaching the salts by abundance in total volume [13, 14].
The uniform composition and large amplitude of the thickness change are fully explained by the position of the SP in the Upper Proterozoic–Early Paleozoic. It is necessary to note the presence of rare genetic types of sediments, which are extremely important for restoring sedimentation patterns — intraclast, cracking breccias, weakly compacted muddied silts, thin layers of stromatolite limestone and dolomites. Such composition and sediment features indicate a relatively shallow water and domination of storm sedimentation in sedimentary basin with a predominance of sulphate-carbonate evaporitic sedimentation. Similar deposits are usually referred to turbidites generated by storms, corresponding to littoral and supralittoral facies [15].

These data are confirmed by the paleogeographic position of the SP in the Late Proterozoic time. Features of structure and lithological composition of oil and gas structures sections find quite logical explanations, if we take into account the paleogeographic position of the SP established using data of paleomagnetic studies of V.E. Pavlova [16]. In the first periods of its existence, the SP was almost entirely located in the zone of low latitudes, and only its northern (in modern coordinates) edge was opened to the south of the equator, that is, at the beginning of its drift, the platform was deployed almost 180° relative to its present position and maintained orientation (with small clockwise and counterclockwise rotations) up to the middle of the second half of the Mesoproterozoic. Model of the Magnetic Pole Curve (MPC) of V.E. Pavlov allowed determining the latitudinal position of the Siberian Platform and its orientation relative to the meridian for almost two billion years - i.e. from the time of its formation - about 1.9 billion years ago - until the Late Cenozoic. “For almost all this time, it has been located in tropical and subequatorial latitudes, periodically shifting either to the southern or to the northern hemisphere. Toward the end of the Mesoproterozoic ~ 1100 Ma, the platform experienced a significant movement to the north, and its southernmost (in modern coordinates) edge was in the region of temperate latitudes ~ 50-55° of the Northern Hemisphere” [17]. The established data on the position of the SP are confirmed by the algal-archeoic bioherms (stromatolites) patterns in marine salt basins in the low latitude zone which is marked by their wide presence in the sections of oil and gas structures in the south of the SP in the Riphean and Vendian-Cambrian sediments [17]. The paleotemperatures in the sedimentary basins reached 25–56°C, which is typical of the areas of modern evaporite formations — basins with high salinity, located in areas with a hot climate. This is confirmed by the deposits of the Early Cambrian evaporites, composed of thick layers of salts, gypsiums and dolomites, and so many salts that they are used for industrial purposes (Usolie, Tyret’, Troitsk and Kanaraysk fields).

4. Discussion

The East Siberian Vendian-Cambrian basin contains 1.5–2.5 mln m³ of salts and is one of the four largest salt-bearing super giant basins [18]. The largest temporary maximum of the quantitative distribution of salts is В – С2, which is reflected in the areal distribution of this basin and the total thickness of the rock salt layers of the Usolie formation and its analogues. Favorable conditions for the regional formation of natural reservoirs - future storage facilities, were created by the nature itself in the geological past. Now it is necessary to use the results of geological and geophysical studies in order to establish their tightness, consistency in the thickness of the reservoir, the area of the structure extent and establish the presence of tectonic disturbances in the section.

5. Conclusion

The creation of underground storage facilities for helium concentrate is one of the most important tasks in the development of fields in Eastern Siberia. The natural reservoirs of the Vendian-Cambrian oil and gas complex, with a powerful salt-bearing impervious fluid - the Usolie formation regionally distributed in the south of the SP, became accumulators for the richest hydrocarbon reserves in Eastern Siberia. Due to their unique structural and lithological features, favorable paleofacial conditions of formation, these geological bodies are also promising as objects for the helium reserves storage.
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