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Waste Burial to the Pressure Deficit Areas in the Eastern Siberia

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Abstract**—**Important executive decisions on oil and gas production stimulation in Eastern Siberia have been recently taken. There are unique and large fields of oil, gas, and gas-condensate in Eastern Siberia. The Talakan, Koyumbinskoye, Yurubcheno-Tahomskoye, Kovykta, Chayadinskoye fields are supposed to be developed first. It will result in an abrupt increase in environmental load on the nature of Eastern Siberia. In Eastern Siberia, the introduction of ecological imperatives in hydrocarbon production is still realistic. Underground water movement is the one of the most important factors of the ecosystems condition management. Oil and gas production is associated with the forced displacement of huge water masses, mixing waters of different composition, and origin that determines the extent of anthropogenic impact on water drive systems and their protective reaction. An extensive hydrogeological system of the depression type is identified in the pre-salt deposits here. Pressure relieve here is steady up to the basement. The decrease of the hydrodynamic potential towards the basement with such a gradient resulted in reformation of the fields in process of historical (geological) development of the Nepsko-Botuobinskaya anteclise. The depression hydrodynamic systems are characterized by extremely high isolation and can only exist under such closed conditions. A steady nature of water movement due to a strictly negative gradient of reservoir pressure makes it quite possible to use environmentally-harmful liquid substances instead of water. Disposal of the most hazardous wastes is the most expedient in the deposits of the crystalline basement in certain structures distant from oil and gas fields. The time period for storage of environmentally-harmful liquid substances may be calculated by means of the geological time scales ensuring their complete prevention from releasing into environment or air even during strong earthquakes. Disposal of wastes of chemical and nuclear industries is a matter of special consideration. The existing methods of storage and disposal of wastes are very expensive. The methods applied at the moment for storage of nuclear wastes at the depth of several meters, even in the most durable containers, constitute a potential danger. The enormous size of the depression system of the Nepsko-Botuobinskaya anteclise makes it possible to easily identify such objects at the depth below 1500 m where nuclear wastes will be stored indefinitely without any environmental impact. Thus, the water drive system of the Nepsko-Botuobinskaya anteclise is the ideal object for large-volume injection of environmentally harmful liquid substances even if there are large oil and gas accumulations in the subsurface. Specific geological and hydrodynamic conditions of the system allow the production of hydrocarbons from the subsurface simultaneously with the disposal of industrial wastes of oil and gas, mining, chemical, and nuclear industries without any environmental impact.

Keywords**—**Eastern Siberia, formation pressure, underground water, waste burial.

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I. Introduction

IN the present days, the petroleum production in the East Siberia is limited. The important executive decisions on stimulation of the oil-and-gas production in East Siberia have been made recently. In the East Siberia, there are many unique and large oil-and-gas, gas-condensate fields. They include such fields as Levoberezhnoe, Verkhnechonskoe, Dulisma, Sobinskoe, Srednetyungskoe, Srebnebotuobinskoe, Srednevilyuyskyoe and many others. However, the initial hydrocarbon's extent of exploration in the East Siberia is still very low. The Talakanskoe, Koyumbinskoe, Yurubcheno-Tahomskoe, Kovyktinskoe, Chayadinskoe fields are supposed to be developed firstly. It will lead to load's abrupt increasing on the environment and nature of the East Siberia, which creates the same danger environmental problems as in the West Siberia. The introduction of ecological imperatives to the hydrocarbon's production in East Siberia is still practical. Ground water's movements are the one of the most important factor of the ecosystems condition's management. Oil and gas production is related with forced movements of the huge water masses, mixture of the different composition, and origin waters. It determines the anthropogenic impact's level on the water drive systems and their protective reaction.

The possibility of industrial waste utilization due to the hydrodynamic features of the Nepsko-Botuobinskaya anteclises' subsalt formations (Eastern Siberia) is considered in this paper.

II. Working Procedure

Data for researches are formation pressure, depth, samples length of productive and water-bearing formation's absolute depth marks and chemical content of the water, and hydrocarbon's phase state data. The data were collected from the free and fund sources from different years starting since seventies, the twentieth century.

Besides the mapping technique of the geological characters, the hydrodynamic potential calculation under the Hubbert's methods [1] and reduced pressure calculation were made (Table I). For the suprasalt sequence the hydrodynamic illustration is given for Tas-Uyryahskoe field (Table II).

TABLE I
PRESSURE DIFFERENTIALS IN THE DIFFERENT INTERVALS OF THE NEPSKO-BOTUOBINSKAYA ANTECLISE'S SUBSALT SECTIONS

Fields, wells	Formations		Pressure differential
	upper	lower	
Iktehskaya, 650, 651	Botuobinskiy	Talahskiy	+0,0014
Buk-Tanarskaya, 718	Osinskiy	Botuobinskiy	-0,0005
Peleduyskaya, 751	Hamakinskiy	Talahskiy	-0,0134
Taas-Yurahskoe, 574, 575	Osinskiy	Botuobinskiy	+0,0010
Taas-Yurahskoe, 575	Botuobinskiy	Talahskiy	-0,00025
Taas-Yurahskoe, 574, 575	Osinskiy	Talahskiy	+0,0008
Sredne-Botuobinskoe, I	0-II	Botuobinskiy	+0,00053
Sredne-Botuobinskoe, 10	0-I	Botuobinskiy	-0,0036
Sredne-Botuobinskoe, 2	Botuobinskiy	Talahskiy	+0,00151
Sredne-Botuobinskoe,30, 37	Osinskiy	Talahskiy	-0,0030
Verhneveluchanskoe, 603	Haristanskiy	Viluchanskiy	-0,0076
Verhneveluchanskoe, 626	U-II	Viluchanskiy	+0,0013
Viluysko-Dzherbinskaya, 640	U-II	Telgespitskaya	+0,0014
Viluysko-Dzherbinskaya, 643	U-I	Bochugonorskaya	+0,00146
Viluysko-Dzherbinskaya, 643	Bochugonorskaya	Viluchanskiy	+0,00183
Viluysko-Dzherbinskaya, 646	U-I	Viluchanskiy	+0,00098
Talakanskaya, 809	Hamakinskiy	Talahskiy	-0,0054
Nizhnehamakinskaya, 842	Hamakinskiy	Hamakinskiy	-0,00185
Markovskaya	Osinskiy	Parfenovskiy	-0,0047
Yaraktinskaya, 55, 21	Osinskiy	Yaraktinskiy	-0,00376
Bolshetirsko-Ayanskaya, 204, 30	Osinskiy	Verhnetirskaya	-0,373
Uyzhno-Surindunskaya, 47, 65	Osinskiy	Yaraktinskiy	-0,00275
Buyaginskaya, 661, 662	Uyryahskiy	Viluchanskiy	+0,00184
Verhneviluchanskaya, 609	U-I	Viluchanskiy	+0,0054
Verhneviluchanskaya, 612, 614	U-I	Viluchanskiy	+0,00224
Viluysko-Dzherbinskaya, 649	U-I	Betinchinskaya	+0,024
Danilovskaya, 144, 145	Osinskiy	Preobrazhenskaya	+0,0018

TABLE II
HYDRAULIC HEAD'S ALLOCATION IN THE UPPER HYDRODYNAMIC ZONE F THE TAAS-UYRYAHSKOE FIELD

Well	Horizons	Intervals	Pressures		P_{form}/P_{yr}	Horizon's characteristics
			P_{form}	$P_{redused}$		
561	mt-ič	130-308	2,67	7,84	0,88	Limestones
553	ol-čr	148-788	6,72	7,69	0,89	Crumbling traprocks
557	tlb2	874-879	7,29	6,94	0,83	Crumbling traprocks

The hydrogeological conditions of the East Siberia are quite complicated. An extensive hydrogeological system of the depression type is identified in the subsalt deposits here. Depression water-pressure systems (DWS) are a special type of water-pressure systems, where there is an excess of water and hydrocarbons outflow volumes through the discharge zone compared to the inflow through the feed zone. As a rule, in the infiltration water drive systems, the reservoir pressure corresponds to the hydrostatic pressure, and water movement is often subordinate to the lateral change of hydrodynamic potential. The super hydrostatic pressure predominates in the reservoir rocks and the upward movement is mainly developed in the expelled water drive systems. A deficit of reservoir pressure is appeared in the depression systems and its gradient is directed from up to down.

Currently, DWS are studied less than others, but the hydrocarbons fields data with low hydrodynamic potential become more and more in the last decades [2]. At the same time, there are various proposals on the use of zones with a deficit of reservoir pressures for industrial waste burial. Thus, in the Urals, the zones which are favorable for the disposal of environmentally harmful liquids (EHL) are found by distributing low pressure here. The absorbing horizons occur in the areas with new inherited tectonic uplift [3].

The industrial waste burial is conducted to the lower reservoir pressure zones at the field Pendhell in Texas. Download of liquid radioactive waste in the reservoir pressure deficit areas is carried out in the Central Alps into the reservoir with the subhydrostatic pressure located at a depth of 400 m.

The research of the ecological functions of sedimentary basins is actively conducted in China. The forecasts of the speed and nature of the carbon dioxide movement in the subhydrostatic reservoir pressure zone within the Sanjay depression (Sunlyao basin) in the Cretaceous (Yaojia formation), lying at a depth of 1300 m, presented by sandstones overlaid by the impermeable thick deposits are obtained [4]. It is based on a mathematical simulation.

Such examples can be continued, but it should be noted that reservoir pressures deficiency is significantly lower in the geological situations mentioned above than in Eastern Siberia.

The largest depression type's water drive system is related with the Nepsko-Botuobinskaya anteclise and adjoining structures not only in Russia but also in the whole planet.

Pressure relieve here is steady up to the basement. This is proved by the actual data on distribution of gas, oil, water, and energy potential through the subsalt section in the Sredne-Botuobinskoe, Verhne-Vilyuchanskoe, Vilyuisko-Dzharbinskoe, Taas-Yuryakhskoe, and other fields. In this case, the lack of formation pressure close to the basement with respect to the nominal hydrostatic pressure reaches 6.0-7.0 MPa in a number of fields and exploration areas and even above that within the Vilyuchansky trough of the Nepsko-Botuobinskaya anteclise [5]. The areal gradients of the hydrodynamic potential in the depression type's water drive systems are negative and are different in value from the areal gradients approximately a thousand times (Table I).

The depression hydrodynamic systems are characterized by the extremely high isolation and can exist only under such closed conditions. Within the Nepsko-Botuobinskoe anteclise, it is ensured by a number of factors, specifically by occurrence of salt at different stratigraphic levels: in the Torsal suite of the Vendian deposits, in the Usolye suite of the Lower Cambrian deposits and in the Angara suite of the Lower and Middle Cambrian deposits.

The main fluid-resistive properties of the cover are associated with the total thickness of the salt rocks and anhydrite interlayers. Although these thicknesses within the area of the Nepsko-Botuobinskaya anteclise are different, geographically they can be found everywhere. Hydrochemical processes in the areas of evaporite screens in the subsalt deposits contribute to increasing of both the resource potential of the underlying deposits and isolating properties of shale thicknesses. In the depression type's water drive systems, no or poor recharge areas are identified. Therefore, reservoir energy is not recharged if a part of reservoir fluids is removed from the system to the fault zones of the basements during tectonic movements, including neotectonic ones [6].

Water injection to maintain reservoir pressure is a widely recognized process used even at normal and high reservoir pressures. Under subhydrostatic pressure conditions, water injection to maintain the reservoir pressure becomes the main source of reservoir energy recovery. The change of natural water from surface or underground sources for environmentally harmful liquid substances is the basis of the modern concept of development of the fields within the depression type's water drive systems. Environmentally, a number of negative features typical of oil-and-gas bearing fields with low reservoir potential can be identified. The first one is the development of subsidence. Subsidence is known and well observed even in the areas where the hydrodynamic potential of the system was initially high [7].

When the reservoir pressure of the system is lower than nominal hydrostatic one before the field's development, then these negative processes are developing rapidly.

Gases dissolved in water are very responsive to any decrease in reservoir pressures. It is well known that the composition of gases dissolved in water depends on reservoir pressure.

At great depths, where the proportion of carbon dioxide increases, the reservoir pressure relief will cause a shift of the carbonate equilibrium in the "water-rock" system, which, in turn, will result in calmatation of reservoir pore space and respectively in degradation of the deposits porosity and permeability. The reservoirs will be relieved at lower production rates by means of pulsed hydraulic fracturing. Disturbance of the natural hydrochemical balance will be an incentive for hydrate formation. These negative processes are minimized under the conditions of the water depression type's drive systems through the negative pressure gradient of ground water heads stable in geological time. It should be noted that risk of the considered above consequences of hydrocarbon field's development will not be increased during injection of the industrial waters and gases. For example, waste water containing salts of numerous metals and organic compounds will serve as inhibitors of hydrate formation process. It is also important that the hydrogeological conditions of the depression type's water drive systems allow unrecoverable disposal of industrial wastes as well as disposal with their further recovery. That differentiation of disposal's places and ways is possible due to the block structure of the hydrodynamic system. Small pre-depleted gas fields can be used as gas storages. In the Nepsko-Botuobinskaya anteclise, the appropriate object is the Hotogo-Murbaisky gas field close to the Lensk town. After its forced production, the Hotogo-Murbaisky structure could serve as a reliable trap proven by nature for the disposal of environmentally harmful liquid and gaseous wastes [8].

A unique set of lithosphere properties creates the conditions for the natural self-defense mechanism manifestation of the geological environment within Nepsko-Botuobinskaya anteclise.

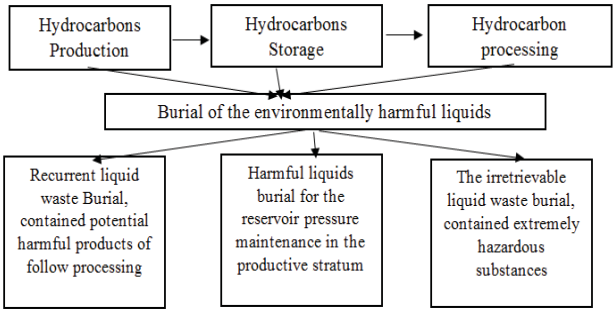

Fig. 1 The ecologization concept principal scheme of the oil and gas production in relation to Eastern Siberia

This concept proves the feasibility of the combining of the hydrocarbon production process, storage and protection of earth subsoil as a single technologic process (Fig. 1).

Disposal of the most hazardous wastes (wastes of nuclear and chemical industries) is the most expedient in the deposits of the crystalline basement in certain structures distant from oil-and-gas bearing fields. The distance between them can be calculated based on the laws of mass transfer taking into account the actual porosity and permeability of the medium [9]. If the products of disposal are produced from water, wastes of oil and gas, or mining industries that can be used for

reservoir pressure maintenance, the distances should be taken as optimal minimum ones (calculated in accordance with the existing procedures).

It is important that they can be extracted to the surface and used for their intended purpose at any moment. In this paper, the fields with lack of reservoir pressure caused by natural factors were considered.

There are numerous hydrocarbon fields where the lack of reservoir pressure resulted from depletion of productive formations and, consequently, from reducing of the hydrodynamic potential of the field. Substantiation of the environmental concept for hydrocarbon field's development will be very useful for effective use of such fields.

III. Conclusion

Inhomogeneity of the formation pressures is characterized with Botuobins horizon of the Sredne-Botuobinskoe field. It is shown that it is the overall trend of the pressure changes from west to east. Except that, the numerous drilling mud losses occur under the drilling of the eastern part of Ust-Marhinskaya fracture zone.

Successful object for injection is Taas-Uyryahskoe field. The pressure decreasing and pressure deficit are observed with depth in the subsalt and supra-salt complexes (plane of reference is -500 m), (Table II).

In the subsalt formations of Taas-Uyryahskoe fields, the non-hydrostaticity coefficient is 0.73-0.75 in Botuobinskiy horizon and is 0.71-0.72 in Talahskiy horizon.

Regionally, three separate zones appear in the subsalt deposits. The central block is lower, no hydrodynamically isolated hydrocarbon's accumulations separate a high hydrodynamic potential zone and low hydrodynamic potential zone. The low hydrodynamic potentials are fixed where the local faults are developed. These faults are used like a pit guide for hydrocarbons migration from up to down.

Central block of the field can be used for the liquid waste injection. They will migrate down the faults to the basement.

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