IJABR

International Journal of Advanced Biotechnology and Research (IJABR)
ISSN 0976-2612, Online ISSN 2278–599X,
Special Issue-1, 2019, pp326-330
http://www.bipublication.com

Research Article

Geohydrology of Fresh Groundwater of the Yubileinoye Gas-Oil-Condensate Deposit

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ABSTRACT.

The authors give the results of studies of the hydrogeological features of drinking groundwater in the Yubileinoye gas-oil-condensate deposit within the Yamalo-Nenets Autonomous Okrug of the Tyumen Region of the Russian Federation. Fresh groundwater is intrapermafrost and is characterized by specific hydrogeodynamic and hydrogeochemical features. It has been shown that the perennial freezing and thawing of rocks are often accompanied by changes in velocities and even the directions of movement of groundwater, their chemical and gas compositions. Taking into account the general degradation state of the modern cryogenic stratum in Western Siberia, it has been suggested that the groundwater is desalted for the present period of development. This is confirmed by its bicarbonate sodium-magnesium-calcium ion-salt composition and sweet mineralization (0.07 g/l). There are four stages of formation of the composition of groundwater within the studied area: atmogenic, biogenic, lithogenic and cryogenic ones. The obtained results give an idea of the formation of the chemical composition of the intrapermafrost waters of the Yubileinoye gas-oil-condensate deposit.

Keywords: Permafrost, Metamorphization of the composition of groundwater, Intrapermafrost water, Subpermafrost water, Aquifer, Salinity of subsurface water.

INTRODUCTION

A large number of hydrocarbon fields in Russia are located in the zone of the development of permafrost rock mass (PRM). The functioning of the infrastructure of deposits is impossible without high-quality fresh water. Thus, this problem is quite acute. First, it is connected with the fact that the search for fresh groundwater is complicated by the presence of frozen rocks and the need to “hit” wells in the intrapermafrost place. Second, the quality of intrapermafrost waters often does not meet the requirements of sanitary standards. This study is devoted to the analysis of the characteristics of the intrapermafrost waters of the Yubileinoye gas-oil-condensate deposit, the formation of their composition and the nature of their distribution under the conditions of the development of frozen rocks, which will eventually predict water quality.

METHODS

The study analyzed the hydrogeological conditions of the field, the ratio of aquifer and water-resisting rock. The peculiarities of the chemical composition of the intrapermafrost waters confined to the main aquifer in Western Siberia, Atlym-Novomikhaylovsky, are studied. The stages of formation of the chemical composition of water, sources of salts that form their sweet mineralization and a slightly acid reaction are considered.

RESULTS

One of the main results of freezing of rocks is a change in the nature of the occurrence and hydrodynamic regime of groundwater. It was revealed that the main productive aquifer at the field is the interpermafrost one related to the sands of the Atlym-Novomikhaylovskaya suite. Groundwater is hydrocarbonate sodium-

magnesium-calcium water with sweet mineralization. Analysis of the hydrogeochemical characteristics of the composition made it possible to identify the features of cryogenic desalination and cryogenic concentration of the composition of groundwater.

DISCUSSION

The Yubileinoye gas-oil-condensate deposit is located in the northern part of the Tyumen Region, in the interstream area of the Nadym and Pur rivers. The territory of the deposit is located within the Nadym-Purovskoy permafrost region and is associated with the southern part of the development zone of permafrost rock mass (PRM).

The deposit is in a zone of discontinuous and continuous vertical distribution of permafrost. The transition between these zones is gradual and has no clear boundary. The top of the permafrost corresponds to the bottom of the seasonal thawing stratum. The permafrost bottom stands out at a depth of 370-420m. The continuity of the permafrost is interrupted with subpermafrost and intrapermafrost taliks.

The total number of radiation-thermal taliks, through and open, within the deposit area ranges from 3 to 5%. The territory is characterized by a wide distribution of ice-wedge casts and frozen ground with segregation ice and segregational injection ice in permafrost mound.

Hydrogeological conditions have been studied in the aquifer of the local water-resistant Oligocene-Quaternary complex, which is within the Cenozoic hydrogeological basin of the West Siberian megabasin [1]. The groundwater of this complex contains fresh water, and at the present time is not enough investigated.

Deposits of the Oligocene-Quaternary complex are represented by a thick stratum of sandy-loamy, sandy, and gravel-pebbly Quaternary sediments of various genesis. The thickness of sediments varies from a few meters to 300 m. At the bottom, there are clay deposits of the Turon-Oligocene age.

The Yubileinoye deposit is located in the border zone of the Tazovsky basin of groundwater flow, which (along with the permafrost section state to a depth of 300-350m) has a decisive influence on the distribution, formation mode and fresh groundwater resources of the first hydrogeological complex. Within the territory of the deposit, the first hydrogeological complex is represented by a thick stratum of sandy-loamy, sandy, and gravel-pebbly quaternary sediments.

The complex includes the following aquifers (Fig. 1):

- over-permafrost;
- interpermafrost;
- subpermafrost.

The over-permafrost horizon is widely developed within the seasonally thawed layer (STL) and over-permafrost taliks. STL water is characterized by significant contamination with organic substances.

Over-permafrost taliks are confined to river valleys and hollows and have a thickness of 5-7 to 30-50 m. Deep taliks are closed with interpermafrost taliks, through taliks.

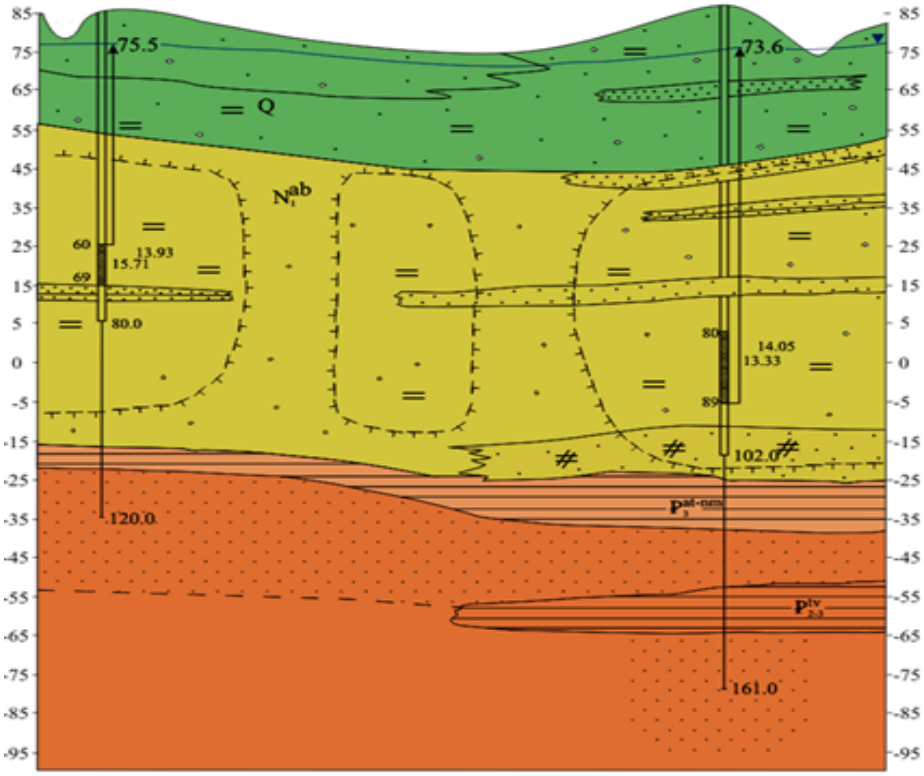
The interpermafrost aquifer is associated with the valley of the Sede-Yaha River and some valleys with streams flowing into it. The aquifer is related to the sands of the Abrosimovskaya suite N1ab and the Atlym-Novomikhaylovskaya suite, P3at + nm. The top of the aquifer is fixed at depths of 28-32m, the bottom – 68-93m.

The subpermafrost aquifer is associated with sands and aleurites of the Tibeysalinskaya suite. Water has sodium chloride composition and is (3g/l) salty by mineralization. The interval of occurrence is 350-450m.

The perennial freezing of the upper horizons of the lithosphere leads to the transition of water-bearing and permeable rocks, as well as wet, slightly permeable, predominantly clayey sediments into frozen impervious rock [2, 3]. As a result, cryogenic waterproof rocks are formed; in most cases, they are absolute waterproof rocks. The section shows the development of such cryogenic waterproof rocks (Fig. 1).

One of the main results of freezing of rocks is a change in the nature of the occurrence and hydrodynamic regime of groundwater [3]. The perennial freezing and thawing of rocks are often accompanied by changes in velocities and even the directions of movement of

groundwater, their chemical and gas compositions.



	Continuous permafrost
Q	Quaternary water-bearing formation
N_1^{ab}	Abrosmovsky water-bearing formation
P_3^{at-nm}	Atlym-Novomikhaylovskywater-bearing formation
P_{2-3}^{tv}	Tavdinsky impervious horizon
	Clay sand
	Fine sand
	Inequigranular sand
	Sandy clay
	Gravel and pebble
	Clayey silt
#	Sand with impurities of organic remains
75.5 / 60 / 13.93 / 15.71 / 69 / 80.0	The filter installation interval (69-60 m) abs mark; the arrow means pressure. The number at the arrow – abs. mark of the piezometric level, m: in a numerator – capacity, l/s; in a denominator – decrease, m; the number below is the absolute mark of a bottom hole
	Piezometric level

Fig. 1 Hydrogeological section of the Yubileinoye deposit. 2p-4p wells.

According to modern concepts [3-7], the perennial freezing of the upper horizons of the lithosphere leads to the transition of water-bearing and permeable rocks, as well as wet, slightly permeable, predominantly clayey sediments into frozen impervious rock. As a

result, cryogenic waterproof rocks are formed; in most cases, they are absolute waterproof rocks. They hold gravitational water even under very big pressure. Often, cryogenic waterproof rocks do not coincide with lithological waterproof rocks. As a result, cryogenic waterproof rocks can spatially break single hydrodynamic systems; they weaken the connection of their individual parts and sometimes may lead to their disappearance over a geologically long period of time. It is important to note that in the course of geological development, during the degradation of frozen strata, these hydrodynamic systems are restored.

Hydrogeochemical Features of the Groundwater Composition in the Yubileinoye Deposit. The physical properties and chemical composition of permafrost waters are presented in Table 1.

Table 1: Results of chemical analysis of groundwater confined to the Atlym-Novomikhay lovskaya suite

Serial number	Component	Value
1	Smell	3
2	Color, grade	17
3	Taste, [point]	3
4	Muddiness, [mg/l]	0.9
5	Hydrogen index	6.43
6	Sulphates, [mg/l]	ND
7	Hydrocarbonates, [mg/l]	48.98
8	Chlorides, [mg/l]	6.9
9	Calcium, [mg/l]	7.6
10	Magnesium, [mg/l]	4.44
11	Soda and potash, [mg/l]	5.75
12	Ferrum, [mg/l]	0.51
13	Ammonia, [mg/l]	0.7
14	Fluorine, [mg/l]	0.09
15	Salinity, [g/l]	0.07

The formula of the ion-salt composition is as follows:

$$M_{0.07}\frac{HCO_3^-80Cl^-20}{Ca^{2+}38Mg^{2+}37Na^+ + K^+25}pH\,6.2 \quad (1)$$

Waters are hydrocarbonate sodium-magnesium-calcium and slightly acid waters with sweet mineralization.

The chemical composition of the considered groundwater consists of salts brought by precipitation, elements leached from the host rocks, soils and plant residues, as well as ions synthesized from water and carbon dioxide.

There are four stages of formation of the composition of groundwater within the studied area:

- atmogenic;
- biogenic;
- lithogenous;
- cryogenic.

As noted by the authors [4-6] who are involved in the issues of composition of water in areas of development of PRM, the proportion of the atmospheric component of chemical runoff within aluminosilicate rocks (these are the main rocks of the Yubileinoye deposit) is 30-35% taking into account some concentration of chemical elements due to evaporation of precipitation.

Another important source of salts of groundwater is the organic matter of the soil horizon, through which precipitation flows. Organic matter synthesized from water and carbon dioxide absorbs many other elements through the root system, especially nitrogen, calcium, sulfur, phosphorus, potassium, silicon, etc. These elements along with the residues fall into the soil and with the help of mineralization, humification and dissolution of organic matter pass into the groundwater [8, 9].

The HCO_3^- ionis formed by carbon dioxide and the OH^- hydroxyl group. The main source of carbon dioxide bound to the HCO_3^- ion is organic matter under the conditions of the hypergenesis zone.

Groundwater receives from organic matter only air migrants, which play a crucial role in the overall balance of elements. Among air migrants, carbon plays a primary role. In the total composition of dissolved salts in the interfrost ground waters of the deposit, the share of $HCO_3^-$is up to 80%.

In the northern taiga landscapes, the processes of mineralization and humification of organic compounds are extremely weakened and the total salinity of groundwater in the territory is composed of 30-35% of salts of atmospheric origin, 35-40% of salts (mainly anions) of a

hydrogenic and biogenic nature, and 25-35% of salts (mainly cations) borrowed from rocks [6].
Changes in the ratio of ions during freezing (probably the main process affecting the hydrogeochemical conditions of the Yubileinoye deposit) are due to dissolved carbon dioxide, which leads to the formation of carbonate ions from bicarbonate ones:

$$Ca^{2+}+2HCO_3^-\rightarrow CaCO_3\downarrow+ CO_2\uparrow+ H_2O. \quad (2)$$

A hardly soluble calcium carbonate that precipitates is involved in the ice phase. As a result, the relative role of Mg^{2+} and Na^+ increases in the resulting solution.

CONCLUSION

The precipitation of $CaCO_3$ causes calcitization of frozen rocks. In the ice phase, the desalinated water is predominantly sodium in composition. The prevalence of magnesium ions in bicarbonate waters is evidence of significant cryogenic metamorphization of fresh waters in the stage of cryogenic concentration. The prevalence of the sodium ion is evidence of cryogenic transformation at the stage of cryogenic desalination. In the interpermafrost waters of the Yubileinoye deposit, magnesium ions prevail (Mg2+ = 37% equ/l), which probably indicates the stage of cryogenic concentration. Although, on the other hand, taking into account the general degradation state of the modern cryogenic stratum, it can be assumed that as a result of degradation of the frozen rock mass from below, groundwater is desalinated in many basins, and in some basins the thickness of the freshwater zone increases; that is, probably, the case in the studied deposit.
The formation of the chemical composition of fresh groundwater in the zone of development of PRM is a complex multi-faceted question. When aquifers freeze, certain cryogenic transformations occur in the content of trace elements, biogenic and organic substances, silicic acid, dissolved gases, and pollutants. The authors' further studies are related to the analysis of behavior in the conditions of the development of permafrost rocks of these components.

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