

SOURCES AND MIGRATION OF MERCURY IN THE HYDROGEOCHEMICAL SYSTEM OF THE YAREGA OIL FIELD

Bakulina L.P., Dovzhikova E.G.

Ukhta State Technical University, Komi Republic, Russia

13, Pervomaiskaya str., Ukhta, 169300: luda5200@bk.ru, dovzh57@yandex.ru

Summary. The large Yarega oil field is one of the oldest in the Timan-Pechora province (Komi Republic). The oil from this field is very thick and highly viscous, making it impossible to extract using traditional methods. Therefore, an oil mine was built in the 1930s; it is currently the only one in Russia. The use of shaft mining allowed for a detailed study of the structure of the oil-bearing reservoir. In the past, the field likely had a gas cap. The geological structure of the field, its location near a major tectonic fault, and the geochemical characteristics of groundwater and gases suggest the involvement of deep fluids in the formation of this field.

This study examines the hydrochemistry of mercury in the Yarega mines. For this purpose, 26 samples were collected from the deposit's groundwater. The samples were collected in areas not subjected to thermal steam treatment, which is used to accelerate oil recovery from oil-bearing formations. Mercury was detected in all samples at varying concentrations. As a result, possible causes of the abnormal mercury content in the deposit area and its sources were identified. Geochemical mercury anomalies in groundwater at the Yarega oil field suggest the possibility of new oil and gas deposits in similar geological conditions. Furthermore, the environmental aspects of the research are of great importance for the Yarega field area and the Ukhta district. Six thousand people live in the Yarega workers' settlement, and about one hundred thousand in the Ukhta district. For these people, groundwater quality is of paramount importance.

Keywords: *Timan-Pechora oil and gas province, Yarega field, heavy oil, oil mine, groundwater, mercury, deep tectonic faults, filtration*

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Introduction

Yarega extra-heavy crude oil field is in developed Ukhta area of Komi Republic which is towards 18 km from south-west of Ukhta city by Vorkuta-Kotlas rail (Fig. 1).

This field is found on the northeastern slope of the South Timan on crest of Ukhta brachianticlinal fold and is at depth of 130-300 meters. This large structure of platform type stretched more than 70 km in north-western direction, and in crestal area it is complicated by four local uplifts – structures of tertiary structures. The field is confined to Yareg, Lyayol and Vezhavozh structures which obtain the whole oil-bearing contour and general extension 36 km in the central and southern parts of fold (Fig. 2).

Yarega oil field was found, one of the first, in Timano-Pechor oil-and-gas bearing province in 1932. Since 1935 pilot operation of the field started by surface wells spacing of wells was fulfilled according to triangular well pattern with distance between them from 75 to 100 meters.

Surface exploitation appeared unprofitable and in 1937 the first oil mine building started, but since the end of 1939 – its exploitation and operation was fulfilled on natural recovery drive (at intervals in 1946-50). Average ratio of oil recovery was 0,032%.

Since 1972 thermal mining technology was used for extra-heavy crude oil recovery aimed to reservoir recovery increase.

Middle Devonian Bed III is oil bearing and underlying the Devonian section foundation on a rough surface of sericite – chlorite-quartz shales of Riphean Base. Bed consists of mainly quartz sandstones with low-thickness interlayers and lenses of siltstones, mudstones and conglomerates (Fig. 3).

Reservoir III of fractured-porous-type reservoirs with porosity 26% and permeability 2-3 Darcy is disrupted by blocks often partially isolated by clayey material presenting in area of blocks displacement. Shales are intensively dislocated and fractured by subvertical cracks and

faults with rocks displacement vertically up to 10 meters. Fractures are either gaping fractures or they are filled by different material: clay, silica, ozocerite, and calcite.

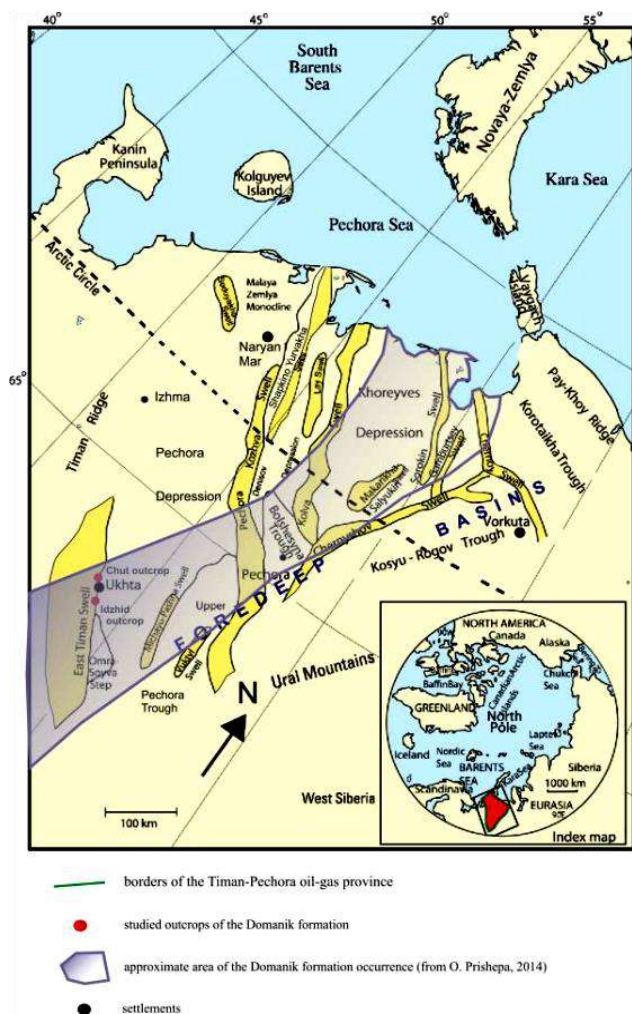


Fig. 1. Location map of the Timan-Pechora basin with indication of the studied outcrops (the map is from Schenk, 2011)

Fractures are followed by areas of fracturing and microcracks. Amplitude increase can be observed by depth in disturbance cutting productive strata: it is more by 2-3 times on superface of shales than on superface of stratum III. In western area of northern perecline of structure fault throw takes a place more than 100 meters. Large deep-seated fault passes at 10 km to east from Yarega field, it is Eastern Timan fault pronounced in basement and sedimentary cover which was bedded in the Riphean and was constantly developed from Devonian to Triassic. Average thickness of stratum is about 70 meters, maximum – 106 meters.

Abovementioned data show a high permeability of section in Yarega field and a possible active filtration of gases from deep horizons of the Earth Crust and mantle to the sedimentary cover, especially during activation period of the Timan.

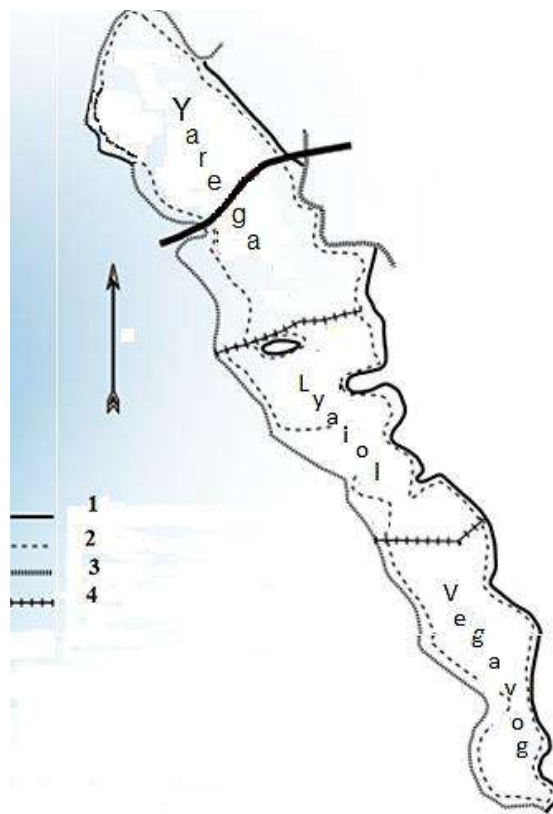


Fig. 2. Overview map of the Yarega field (Нефтегазоносность..., 1999)
 1 – contour of balance oil reserves; 2 – outer contour of oil content; 3 – line of wedging out of Bed III; 4 – boundaries of the area division

Material and methods

Primary objective of this research: clarification of patterns for mercury distribution in groundwaters of the field aimed at further usage of obtained peculiar features of mercury hydrochemistry in order to determine tectonically active areas and to predict oil and gas content of section.

Mercury content was defined in 26 water samples of Yarega field. Samples were cut in areas with natural occurrence of waters which is not affected by steam treatment. Samples were cut in industrial mine of oil-bearing Bed III, Bed “A” bedded above and from Quaternary beds of the field (Fig. 3).

System	Series	Stage	Substage	Superstage	Horizon	Bed	Bedset	Average depth, m	Column	Average thickness, m	Lithological characteristics				
DEVONIAN-D	UPPER-D ₃	Frasnian-D _{3f}						10.6		10.6	Soil and vegetation layer with inclusions of gravel, pebbles and rare boulders				
								17.0		6.4	Clays with interlayers of sand, with inclusions of pebbles and boulders				
								20.0		3.0					
								24.0		4.0					
								30.4	Timanian -D _{3im}	I	30.4		6.4	Argillite-like clays, calcareous, brownish-gray	
								33.1				2.7			
								70.6	A		70.6		37.5	Mudstones with occasional interlayers of limestone and marl. Abundant fauna. Remains of charred flora	
								79.1				8.5	Clayey sandstones with interlayers of clays and limestones		
								121.7	Dz'yer -D _{2dzr}		II	121.7		42.6	Argillites with interlayers of limestone and, less commonly, marl
								127.6					5.9	Clayey sandstones with interlayers of mudstones and limestones	
								133.6					6.0		
								139.0					5.4		
								176.0				Tuffaceous-D _{2'tf}	176.0		37.0
								186.0	Argillite		III	186.0		10.0	Argillites with sandstone interlayers
								188.0					2.0	Coarse-grained leucoxene-quartz sandstones	
212.0	Middle	212.0		24.0	Fine-grained quartz sandstones, cross-bedded, with interlayers of argillites and siltstones										
230.0	Lower			230.0		8.0	Siltstones, mudstones, sandstone lenses with leucoxene								
242.0					12.0	Leucoxene-quartz sandstones from fine-grained to conglomerates with interlayers of argillites and siltstones									
R										Metamorphic schists with quartzite interlayers					

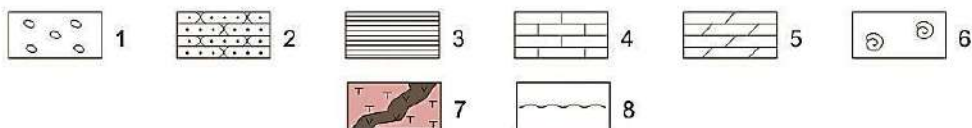


Fig. 3. Summary lithological and stratigraphic section of the Yarega field (Нефтегазоносность..., 1999)
 1 – gravel and pebble inclusions; 2 – sandstones; 3 – siltstones and mudstones; 4 – limestones; 5 – marls; 6 – fauna; 7 – tuffoid horizon (tuffs, dolerites); 8 – unconformity surface

Total mercury content was defined by colorimetric dithizone method with previous destruction of its complex compounds. Mercury is found in all samples in concentrations from traces up to 10 µg/l. Maximum concentrations of mercury are defined in groundwaters of mine No. 2 and reach 10 µg/l. Mercury concentration changes according to traces up to 5 µg/l and on average is 1 µg/l in groundwaters of mine No. 1 and mine No. 3, while average mercury content is by 3 times higher in groundwaters of mine No. 2.

Results and Discussions

Enclosing rocks, oil of the field and gases of the field can be considered as the potential sources of mercury supply to the groundwaters of Yarega field.

Average mercury content in hydrosphere is 1 µg/l. Mercury concentrations from 0,1-10 µg/l are in water diffusion halation, and this differs insignificantly by background readings (Минова, Бакулина, 2005). Mercury concentrations up to 20 µg/l were found only in acid sulphate waters with pH 2-3 in oxidation zones of mercury sulphide deposits (for example, Nikitovo in Ukraine). Water diffusion halation of mercury in ground and surface waters are usually small – 100-300 m.

Low mercury concentrations in waters can be explained by a weak solubility of mercury compounds and its intensive sorption from solutions by clay minerals, hydroxides of metals and calcite.

Hydrogeological conditions of Yarega field are studied well enough and are touched upon in the works of B.N.Lubimov, M.Sh.Modelevsky and other researchers of Yarega field. On chemical composition of water in productive beds – weakly alkaline chloride, sodium and calcium-sodium solutions with mineralization from 36 to 93 g/l. Waters of Bed III directly bedded on eroded surface of shales are similar to waters of shales themselves as there are no waterproof layers between them.

Rocks with high mercury content are not found in the section of Yarega field which could allow mercury concentrations observed in waters. Even the deeper horizons of basement area enriched by mercury are not be able to transfer mercury to solution by alkaline groundwaters

(pH>8). Thus, rocks which build up the section of Yarega field cannot be the source of mercury in its groundwaters.

The second source is oil. In Western Siberia mercury was found in all water samples of oil, gas and gas condensate deposits of the West-Siberia oil-and-gas bearing basin (Матусевич, Прокопьева, 1976). Maximum concentrations of mercury were monitored in waters of outline zone in gas fields (up to 30 µg/l). Its concentrations are minimal in waters of oil fields, and negative diffusion halations form nearby oil deposits.

Lab research was carried out on inter-reaction between water solutions of mercury and oil. After 10 days joint thermostation by 60°C oil and water solutions of mercury concentrations 50 µg/l (ratio water:oil as 1:5) mercury content reduced in water solution up to 5 µg/l.

This evidence indicates oil possibility to absorb mercury from its water solutions and do not allow to consider oil as a potential source of mercury from Yarega field.

The third possible source is gas. Deposit of Bed III doesn't possess gas cap, but abundant gas seep was monitored during penetration and layer test in many wells (Кремс, Вассерман, Матвиевская, 1974). It was observed that accumulations of free gas were seen in areas with sandstones of argillitic interlayers which probably provided screen for them and protected these accumulations from diffusion. Maximum gas-saturation of oil is defined in mine No. 2 (225 m³/t), and maximum mercury content is found in its waters. Gas-saturation of oils from mine No. 1 is 145 m³/t; mines No. 3 – 122.

Gas seeps from fractured zones of metamorphic shales as small accumulations of free gas and gas dissolved in waters of basement were found in many wells on structural high of Ukhta uplift and on its northern pericline. The most of free gas accumulation is confined to hypsometric rised crest positions of Ukhta fold. Wells drilled for metamorphic shales usually gushed water. These wells are on the aqua field situated in the crest of fold which is northern of Yarega. Gas factor is 1 m³/m³.

Composition of free gas and gas dissolved in groundwaters of Bed III and metamorphic shales consist of methane (prevails), heavy carbons (about 1%), nitrogen, hydrogen, helium,

argon, carbon-dioxide gas. Helium, hydrogen, methane, argon being in gases of Yarega field are connected with deep horizons of the Earth Crust and mantle, and this evidence allows to consider gases from the field as the mercury source in its groundwaters.

It is well-known about high volatility of mercury and its possible migration in gas phase from geochemistry of mercury. Study of volcanic exhalations of fumarolic and solfataric sources of Kamchatka and Kurils defined mercury can migrate to phase of post-volcanism together with sulphur trioxide and chloride gas. And cinnabar deposit (HgS) directly from volcanic gases which transfer mercury as HgCl₂ is found on some large mercury deposits. N.A.Ozerova considers mercury accumulation in different geological settings of lithosphere as a result of mantle degassing and indicates that “mercury breath of the Earth” fulfills through

the largest lineaments of global regmatic network (Озерова, 2010).

Conclusions

So, it can be proved, migration of Yarega field gases from mantle and low horizons of the Earth Crust fulfilled by filtration on zones with rupture anomaly of folded basement of high rock fracturing in sedimentary cover. Presence of mercury in waters of field shows its entry to sedimentary cover on preexistent faults of basement currently. Otherwise mercury was in-took by oil or sorbed by minerals of enclosing rocks.

This research can be used for prediction of oil and gas content section on mercury geochemical anomalies on zones with large tectonic faults. Moreover, environmental study is of special significance for field area and for region as a whole.

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ИСТОЧНИКИ И МИГРАЦИЯ РТУТИ В ГИДРОГЕОХИМИЧЕСКОЙ СИСТЕМЕ ЯРЕГСКОГО НЕФТЯНОГО МЕСТОРОЖДЕНИЯ

Бакулина Л.П., Довжикова Е.Г.

*Государственный технический университет,
Республика Коми, Россия*

169300, Ухта, ул. Первомайская, 13: luda5200@bk.ru, dovzh57@yandex.ru

Резюме. Крупное Ярегское нефтяное месторождение одно из старейших в Тимано-Печорской провинции (Республика Коми). Нефть этого месторождения очень густая и высоковязкая и добывать ее традиционным способом оказалось невозможно. Поэтому еще в тридцатых годах прошлого века была построена нефтяная шахта, в настоящее время она единственная в России. Шахтный способ разработки нефтяной залежи позволил довольно детально изучить строение нефтеносного пласта. В прошлом, весьма вероятно, месторождение имело газовую шапку. Геологическое строение месторождения, расположение вблизи крупного тектонического разлома, а также геохимические характеристики подземных вод и газов позволяют предполагать участие глубоководных флюидов в формировании этого месторождения.

Данная работа посвящена изучению гидрохимии ртути в районе Ярегских шахт. Для этой цели были отобраны 26 проб из подземных вод месторождения. Пробы отбирались на участках, не подвергшихся паротепловому воздействию, которое используется для ускорения нефтеотдачи нефтеносного пласта. Ртуть обнаружена во всех пробах в различных концентрациях. В результате были выявлены возможные причины аномального содержания ртути в районе месторождения и ее источники. Геохимические аномалии ртути в грунтовых водах Ярегского нефтяного месторождения предоставляют возможность предполагать наличие новых месторождений нефти и газа в сходных геологических условиях. Кроме того, важное значение имеет экологический аспект исследований для района Ярегского месторождения и Ухтинского района. В рабочем поселке Ярега проживают шесть тысяч человек, в Ухтинском районе около ста тысяч. И для этих людей качество подземных вод имеет огромное значение.

Ключевые слова: *Тимано-Печорская нефтегазоносная провинция, Ярегское месторождение, тяжелая нефть, нефтяная шахта, подземные воды, ртуть, тектонические глубинные разломы, фильтрация*

YAREQA NEFT YATAĞININ HİDROGEOKİMYA SİSTEMİNDƏ CİVƏNİN MƏNBƏLƏRİ VƏ MİQRASİYASI

Bakulina L.P., Dovjikova Y.G.

Dövlət Texniki Universiteti, Respublika Komi, Rusiya

169300, Uxta, Pervomay küç., 13: luda5200@bk.ru, dovzh57@yandex.ru

Xülasə. Böyük Yareqa neft yatağı Timan-Peçora vilayətində (Komi Respublikası) ən qədim yataqlardan biridir. Həmin yatağın nefti çox qatı və yüksək özlülüklü olduğu üçün onun ənənəvi üsullarla hasilatı mümkün deyil. Bu məqsədlə keçən əsrin 30-cu illərində Rusiyada tikilən neft mədəni günümüzə də yeganə olaraq qalır. Neft yatağının işlənməsi üçün mədən üsulu neftli təbəqənin strukturunu kifayət qədər ətraflı öyrənməyə imkan verirdi. Keçmişdə yataqda qaz parağının olması güman edilir. Yatağın geoloji quruluşu, böyük tektonik qırılmaların yaxınlığında yerləşməsi, yeraltı suların və qazların geokimyəvi xüsusiyyətləri bu yatağın əmələ gəlməsində dərinlik fluidlərinin iştirakını deməyə əsas verir.

Bu tədqiqat Yareqa mədənlərində civənin hidrokimyasının öyrənilməsinə həsr olunmuşdur. Həmin məqsədlə yatağın yeraltı sularından 26 nümunə götürülmüşdür. Nümunələr neftli laylardan neftin çıxarılmasını sürətləndirmək üçün istifadə olunan termik buxar emalına məruz qalmayan ərazilərdə toplanmışdır. Bütün nümunələrdə müxtəlif konsentrasiyalarda civə aşkar edilmişdir. Nəticədə, yatağın yerləşdiyi rayonda civə səviyyəsinin normadan kənar çıxmasının mümkün səbəbləri və onun mənbələri müəyyən olunmuşdur. Yareqa neft yatağında qrunt sularında civənin geokimyəvi anomaliyaları oxşar geoloji şəraitdə yeni neft və qaz yataqlarının mövcudluğundan xəbər verir. Bundan əlavə, Yareqa yatağı və Uxta rayonunda aparılan tədqiqatların ekoloji aspekti mühüm əhəmiyyət kəsb edir. Yareqa fəhlə qəsəbəsində 6000, Uxta rayonunda isə təxminən 100.000 nəfər yaşayır. Bu insanlar üçün yeraltı suların keyfiyyəti böyük əhəmiyyət kəsb edir.

Açar sözlər: *Timan-Peçora neft və qaz vilayəti, Yareqa yatağı, ağır neft, neft mədəni, yeraltı sular, civə, tektonik dərinlik qırılmaları, filtrasiya*