Research Journal of Applied Sciences 10 (12): 902-905, 2015
ISSN: 1815-932X

Hydro-Geological Features and Prospects of Oil-Bearing Capacity for Archaean and Proterozoic Complex of the Volga-Ural Region

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Abstract: Recently, the solids of Archaean-Proterozoic age attract more and more attention of oil geologists, especially in connection with possible prospects of oil-bearing capacity. In the Tatarstan Republic territory for >20 years within the program of deep structure study for the express deep wells base drilling which allowed to receive new unique information on crystal base structure and prospects of its oil and gas content was carried out. It should be noted that all deep parametrical, explorative and operational wells of Tatarstan which in a varying degree were objects of KF collectors study can be divided into four categories conditionall. The wells which opened crystal solids of the Precambrian on the maximal depth over 3000 m. The wells which opened crystal solids of the Precambrian on the considerable depth from 200-3000 m. The wells which opened crystal solids of the Precambrian on depth from 50-200 m. The wells which opened crystal solids of the Precambrian on depth <50 m. The third and fourth wells categories are the most numerous, total more than one thousand wells drilled since the base opening in the middle of the last century.

Key words: Crystal base, underground waters, hydro-geological researches, gases, hydro-carbons, chemical composition

INTRODUCTION

Among complex methods used for solids studying of this age, hydro-geological researches take an important place. Results of crystal base underground waters researches of the Southern Tatar arch and adjacent areas are given in the study. The short geological and hydro-geological characteristic of the solids Precambrian complex is considered, results obtained by underground waters composition observation in the monitoring mode in five express piezometer-wells are presented. On the basis of underground waters chemical and gas composition study for Archaean and Proterozoic crystal complex, the question of the base oil and gas content prospects and its modern geo-dynamic activity is considered.

MATERIALS AND METHODS

Geological and hydro-geological characteristic of the crystal base solids: The crystal base solids of the Volga-Ural petroliferous area of Russian platform lying under thickness of sedimentary Paleozoic formation long time were considered by many researchers to be almost waterproof. However, results of deep parametrical and search drilling on the crystal base and Riffean-Vendian deposits in Tatarstan showed a different picture (Anisimov *et al*., 1996; Doronkin, 1980; Plotnikova, 2004b; Muslimova and Lapinsky, 1996).

The crystal base solids opened on thickness from 50-3274 m were tested by means of DST, compressor, deep pumps (ESP, NGP type). More than 80 objects were tested in 30% from which flows of water were received. The aquiferous properties are bound, generally to the loosened and fissured zones (Plotnikova, 2004b; Plotnikova, 2004a).

Outputs of wells change over a wide range from 0.17-125 $m^3 day^{-1}$ at dynamic levels in ostium wells of 600-1500 m. Reservoir pressures depending on the loosened zones depth, vary from 19.8-54.0 MPa. The most representative flows of water are received at depression equal coefficients of 0.65-0.8 (Anisimov *et al*., 1996; Doronkin, 1980; Plotnikova, 2004a; Muslimova and Lapinsky, 1996).

Underground waters of upper Archaean and Proterozoic complex are studied in 14 wells, deeper loosened objects of Cheremshansky suite-in one, Well. 20000 of Minnibayevskaya Area (Doronkin *et al*., 1998; Gerasimov, 1968; Plotnikova, 2008).

On chemical composition underground waters are close to waters the Riffean-Vendian deposits and terrigenous Devon. Their density varies within 1.18-1.19 g cm^{-3} with the common mineralization of 234-272 g L^{-1}. The calcium content is in limits of 22-42 mg L^{-1} as well as in terrigenous Devonian deposits and deposits of Riffean-Vendian age. The Na/Cl metomorfization coefficient varies from 0.6-0.4 which marks the high degree of subsoil closeness. Waters contain microcells: iodine, bromine, ammonium, etc.

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The underground waters received in Well. 20000 of Minnibayevskaya Area have a bit different structure. These are almost clear chloride and calcium brines with the common mineralization of 287-332 g L^{-1}. The calcium content reaches 94 g L^{-1} and sodium, on the contrary, decreases to 11.5 g L^{-1}, against 54-74 g L^{-1} in overlying formations. Among trace components underground waters contain (g L^{-1}): 6.3-9.0 iodines, 1606-1932.7 bromines, ammonium up to 3.6.

Thus, growth of calcium and bromine concentration with depth is noted, along with simultaneous increase in mineralization and decrease in sodium and ammonium content.

Such waters are peculiar to the long absence of water exchange zone and recovery nature. Similarity of underground waters chemical composition of terrigenous Devon and Riffean-Vendian deposits with waters of Archaean and Proterozoic age can be explained by penetration of the last into overlying complexes as a result of tectonic motions and formation of the loosened zones.

Prevalence in cationic composition of calcium over sodium is obviously explained by the exchange and getter phenomena.

Gas composition of underground waters: Composition of water-soluble gas in upper section is generally metane and nitrogen. Gas saturation of underground waters varies within 0.11-0.35 m^3 L^{-1}. The content of nitrogen in test-tubes is 32-68% of volume for methane from 29-62% of volume.

Waters of the lowermost interval (4703-5099 m, Well. 20000) have gas saturation of 450 cm^3 L^{-1}. Gas is metane and nitrogen by structure. The content of nitrogen in tests is 67.2-76.9% of volume for methane-11-14%, in small amounts (to 5%) heavy hydrocarbons are found. High concentration contain helium of 5.4-7% and argon of 1.4%. Among other gases are found: Hydrogenium of 8.8%, oxygen of 2.6%, carbon dioxide of 0.06-1.4%. The high content of helium can be explained by well location near a tectonic break and Hydrogenium by interaction of water with metal of an upsetting column. After the long-lived well rest (>7 days) the content of Hydrogenium in tests increased to 19.9%.

The underground waters received from the interval of 4446-4493 m have gas saturation of 0.38 mm^{-3} and from an interval of 3230-3380 m, 0.61 mm^{-3}.

In general up a section the hydro-carbonic gases increase in percentage of volume is observed. The content of methane increases in the lower horizons a little.

Organic matter of underground waters: Underground waters of the Archaean and Proterozoic age solids as well as overlying sedimentary formations are considerably enriched with water-soluble organic compounds.

The common content of organic carbon in waters of the crystal base makes 97.6-137.8 mg L^{-1} that is much higher than in waters of Riffean-Vendian deposits of 47-65 mg L^{-1} (Well. 191 Urustamakskaya). In waters of terrigenous Devon in the Tatar arch of 52-86 mg L^{-1}, in the Melekessky hollow of 46-106 mg L^{-1}.

In section upper carbon content of bituminous fraction reaches 0.3 mg L^{-1} and in lower 0.5 mg L^{-1} and more. The content of common organic nitrogen of 0.02-0.2 mg L^{-1} is in limits of background values, common for waters of Pashian-Kyvonian deposits of the Southern Tatar arch.

Concentration of volatile phenols in underground waters above background values of the reference for waters of terrigenous Devon and the Riffean-Vendian deposits also makes 0.1-3.97 mg L^{-1}. On the contrary, it is slightly less than non-volatile phenols.

The content of petroleum and humic acids and oxidizability iodate is slightly higher within background values for waters of Pashian-Kyvonian deposits. In slight concentration benzene is found (Well. 20000) that is a direct indication of hydro-carbonic raw materials congestions detection possibility.

Prognosis evaluation of oil-bearing capacity: Underground waters, their hydrodynamic mode, physical and chemical properties are indicators of mineral congestion discernment. At interaction of oil and gas congestions with underground waters, the last are enriched with organic matters, gas components and microcells.

As it was already noted earlier (Doronkin, 1980; Plotnikova, 2004b), the nature of reservoir pressures change in solids of Cheremshansky suite submits to uniform regularity of sheeted energies change in sedimentary complexes of coal, Devonian and Riffean-Vendian formations. It signifies about close hydrodynamic connection of the loosened Archaean and Proterozoic solids zones with a sedimentary cover of Paleozoic deposits which is carried out through the fissile break sites. The geothermic and hydro-chemical anomalies established in regions of the Altunino-Shunaksky deflection and the Kama breaks confirm this (Muslimova and Lapinsky, 1996).

RESULTS AND DISCUSSION

On the basis of the analysis and generalization of regional hydro-geological research materials of the oil and gas horizons of Tatarstan Paleozoic deposits the most informative criteria are allocated: the gas-gas saturation, gaseous tension, the sum of hydrocarbons and carbon nitric coefficient; the chemical and organic carbon of bituminous fraction, phenols (volatile and nonvolatile), iodate oxidizability; ion-composition of salt

Table 1: Hydro-geological indexes of oil-bearing capacity

	Gas	Chemical and organic							
Complexes	Gas factor (m^3m^3) G^1	Rg (Mpa)	ΣUV (sp.%)	ΣUV_2 /N_2	S-bit (mg L^{-1})	Fy. mg L^{-1}	O iod (mg L^{-1})	NH_4 (mg L^{-1})	SO (mg-e L^{-1})
Background values									
Terrigenous Devon STA (in general)	0.28-0.3	5-6	40-50	0.5-0.7	0.3-0.5	0.2-0.4	0.7-2.0	90-130	25-150
East slope of the Tokmovsky arch (Well. 407,425)	01.-0.2	2-5	8-26	0.1-0.3	0.5	0.1-0.7	1.4-6.0	100-110	10-48
Actual data									
Riffean-Vendian Southeast slope of STA	0.3-0.33	8.4-8.6	43-67	0.7-2.1	0.3-0.5	0.2-1.3	1.4-2.6	42-222	28-250
Birsky upfold. Well. 20005, 203	0.25-0.3	-	46-57	0.9-1.1	0.2-0.7	0.7-1.1	1.6-3.7	145-222	124-298
Archaean and proterozoic deposits(depth of the loosened zones 1793-2026 m)									
STA. Well. 2092,966,29419, etc.	0.14-0.4	-	22-65	0.3-2.0	0.12-0.31	0.4-1.2	0.5-2.5	20-200	24-159
Depth of the loosened zones 3230-5099 m									
STA, Well. 20000	0.38-0.61	19-20	12.39- 34	0.2-0.7	0.3-0.7	0.1-1.4	0.8-5.7	0-20	20-300

Table 2: Limits of hydro-carbonic part of underground waters gas composition change. Archaean and Proterozoic age during 1998-2000

		Common content of hydro-carbons (m^3/m^3)		
No. well	Area	Min.	Max.	Net-weighted
2092	Cheremshanskaya	0.019	0.137	0.072
10179 d	Alkeevskaya	0.035	0.248	0.112
11921 d	Berezovskaya	0.009	0.146	0.094
966	Uratminskaya	0.011	0.138	0.067
Net-weighted value of the region		0.018	0.167	0.086

ammonium solution, sulphate content. Background (regional) and abnormal (caused by influence of hydro-carbonic congestions) values of these indexes for water bearing complex of terrigenous Devon of the Southern Tatar arch (the developed lands) and east slope of the Tokmovsky arch (the unpromising areas) are given in comparison with water bearing complexes of Riffean-Vendian deposits and crystal base solids (Table 1). From the provided data, it is visible that such indexes of oil and gas content as gas factor of 0.14-0.40 mm^{-3} in an upper section of the crystal base and 0.38-0.61 mm^{-3} in the deep horizons (Well. 20000), the sum of hydro-carbons (22-65 and 12-23%) in the common composition of gas and hydro-carbonic and nitrogen coefficient (0.2-2.0 and 0.2-0.7) in waters of Archaean and Proterozoic age correspond to their sizes in the Riffean-Vendian formations and above values for waters of terrigenous Devon.

From 1998-2000, regime observations in the piestic wells located on the STA various tectonic elements were found (Well. 2092, 966, 29419). The analysis of results showed that in 1999 and 2000, in comparison with 1998, the common mineralization from 224 increased to 256-302 mg L^{-1}. Change of the trace components maintenance happened in slight limits. Exceeded the background values of the water dissolved organic matter components. Especially, it concerns such indexes of oil-bearing capacity as iodate oxidizability and volatile phenols. Change of the iodate oxidizability maintenance in time is ranging from 2-5-11-14 mg L^{-1}, of volatile phenols from 0.4-0.9-1.6-2.5 mg L^{-1}. Upper limits of their concentration correspond to the abnormal values and are common for waters of oil and gas fields. More essential changes happened in the maintenance of hydro-carbonic part of underground waters gas composition (Table 2).

It is especially common for ethane (Well. 29419). The interval of their time history is in limits of 1.3-10.2 volume percent. The content of helium changed from 0.38-1.55 sp. percent. Bursts in their increases have the common tendencies with growth of methane in reservoir waters.

As a part of water gas in solution (Well. 2092) in September growth of carbon dioxide from 0.25-0.55 volume percents is observed. The maximal growth of helium was noted in August-September, practically at one time with growth of carbon dioxide. Approximately growth of methane concentration and the sum of heavy hydrocarbons falls on this period. Growth of carbon dioxide from July to August inclusive is observed (Well. 966). Small growth of helium concentration (from 0.24-0.6 volume percentage) took place in June-July and in September (0.3-0.52 volume percentage). The content of methane as well as carbon dioxide, increased in the same time spans. The peak of heavy hydrocarbons increase is a little displaced in relation to methane. Apparently, it is bound to various intensity of their migrations during the periods of geological processes activation.

All this confirms possibility of fluids migration from sedimentary solids cover in crystal base solids on break and fissured zones (Plotnikova, 2003, 2006). The hydrodynamic interrelation of gas-bearing complexes, the considerable content of hydro-carbons and other hydro-chemical indexes allows to assume possible oil-bearing capacity of the Archaean and Proterozoic age solids.

On chemical and organic indexes the underground waters of the crystal base are at the level, common for Riffean-Vendian deposits and above the background

values characterizing reservoir waters of terrigenous Devon of the Southern Tatar Arch (STA) developed areas. The sulphate content of Archaean and Proterozoic solids waters is at the same level as for waters of Riffean-Vendian and terrigenous Devon deposits. In general, on set of all prospect criteria of oil-bearing capacity the Archaean and Proterozoic solids are estimated above unpromising lands (terrigenous thickness of east Devon slope of the Tokmovsky arch) and the Riffean-Vendian deposits and terrigenous Devon solids are more comparable to STA prospects.

Summary: Thus, by results of the performed researches, it is possible to draw the following conclusions and recommendations.

Analysis of chemical, gas composition of underground waters of terrigenous Devon, Archaean and Proterozoic age shows that they are close among themselves which shows the hydrodynamic interrelation of terrigenous Devon and Archae an and Proterozoic formations water bearing complexes.

Gas-hydro-chemical indexes of oil-bearing capacity of Archaean and Proterozoic solids correspond to oil and gas content criteria established for high-perspective and perspective deposits of terrigenous Devon deposits.

The interrelation of the underground waters hydro-carbonic part maintenance sum from intensity of geological processes which points to possibility of receiving the padding portions of gas from the crystal base loosened zones in sedimentary formations of Devon is noted.

In general on set of all prospect oil-bearing capacity criteria of Archaean and Proterozoic deposits are estimated above the unpromising of lands (terrigenous thickness of east Devon slope of the Tokmovsky arch) and are more comparable to prospects of Riffean-Vendian and terrigenous Devon solids of the Southern Tatar arch.

CONCLUSION

Results of well research which opened the crystal base on the considerable depth showed that collectors of KF possess filtrational and capacitor properties. In crystal solids of the base there is a capacitor space in which fluids can freely circulate and which can be considered to be a potential trap, a place of naphtha and gas accumulation.

Gas-hydro-chemical indexes of Archaean and Proterozoic crystal base solids oil-bearing capacity correspond to oil and gas content criteria established for high-perspective and perspective deposits of sedimentary cover (Devon terrigenous deposits).

In general on set of all prospect oil-bearing capacity criteria of Archaean and Proterozoic deposits are estimated above unpromising lands (terrigenous thickness of Tokmovsky arch east Devon slope) and are more comparable to prospects of Riffean-Vendian and terrigenous Devon solids of the Southern Tatar arch.

ACKNOWLEDGEMENT

The research is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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