6. Speak A.F., Rothwell J.J., Lindley S.J., Smith C.L. (2012). Urban particulate pollution reduction by four species of green roof vegetation in a UK city. Atmospheric Environment. Pp. 283-293
7. Stobrawa K, Lorenc-Plucińska G. (2008). Thresholds of heavy-metal toxicity in cuttings of European black poplar (Populus nigra L.) determined according to antioxidant status of fine roots and morphometrical disorders. Sci Total Environ. Pp. 86–96.
8. Tchepel O., Dias D. (2011). Quantification of health benefits related with reduction of atmospheric PM10 levels: implementation of population mobility approach. International Journal of Environmental Health Research. Pp. 189-200.

THE INVESTIGATION OF THE ANISOTROPY OF FLOW PROPERTIES OF TERRIGENOUS RESERVOIRS

R.I. Ermekov
The scientific adviso r– associate professor V.P. Merkulov
National Research Tomsk Polytechnic University, Tomsk, Russia

In this paper we consider the problem of studying the anisotropy of the permeability in terrigenous reservoirs during the development of oilfields in Russia. In the conventional representation the anisotropy is the ratio of horizontal Kh and vertical Kv permeability, which reflects unevenly oriented heterogeneities in the texture of the rock. In addition, the magnitude of anisotropy is characterized by scale and the orientation or azimuth of the maximum permeability axis. The existence of anisotropy is confirmed by many studies around the world. In Russia, the most common way of development is waterflooding. Such oilfields at the late stages of development are characterized by high water cut of well and low value of areal sweep efficiency. These results are attributed to the presence of anisotropy and water movement along the selective directions of high permeability formations from injection to production wells [4]. The effectiveness of the very widely discussed method of directional fracturing (fracturing) depends on the direction of the cracks. This direction depends on the ratio of the radial and tangential stresses of the natural stress field in the layers, which in turn is determined by the presence of degree of anisotropy in one direction or another [8].

Thus, the importance of permeability anisotropy is that it can strongly influence the placement of injection and production wells to increase oil recovery, and its magnitude has a significant influence on the flow of hydrodynamic processes in subsequent stages of development.

It is believed that the nature of anisotropy in terrigenous reservoirs is due to the interaction of two or more sedimentation processes in the horizontal / vertical directions and subsequent tectonic impacts, leaching and carbonization processes. As a consequence, these facts lead to change in mineralogy, grain sizes and other petrophysical parameters [7]. Thus, the anisotropy of terrigenous reservoirs depends both on the orientation of the grains, and the presence of impermeable barriers or filtration channels. For comparison in carbonate reservoirs, the degree of anisotropy is determined by the intensity and different orientation of the fracturing, as well as the general processes of recrystallization of carbonate rocks with immersion to depth [2].

The identification and investigation of anisotropy is possible in several ways. The paper describes methods for studying the phenomenon on pre-oriented core samples, indicator studies (tracer analysis) and methods of well testing (well testing). On the basis of these methods, it is possible to estimate the actual anisotropy in the form of comparison of the quantitative characteristics of rock properties. Studies at the micro- and meso levels (cores and its sections) begin with a spatial orientation of the core using the paleomagnetic method. It is based on the ability of the rock, at the time of formation, to retain in its structure the direction of the planet's magnetic field in the form of a remanence vector. In turn, the remanent magnetization consists of the sum of the primary and viscous remanent magnetization. The last term reflects the influence of the modern magnetic field of the Earth. To eliminate the influence of viscous remanent magnetization, the sample is subjected to heating and alternating magnetic fields.

Thus, the core becomes oriented along the origin field of rocks and allows fix the ordering of the structure of rocks. Further study possibly as well as on the phenomenon of remanent magnetization and on the basis of the elastic properties of rocks. The result of these studies can be the construction of rose-diagrams reflecting the anisotropy trends according to the corresponding properties [5]. The investigation at the macro level can be conducted through tracer studies and well test.

The essence of trace studies is the injection into the reservoir of a liquid with an indicator through an injection well and recording the moment of its appearance in production wells. In this case, the following values are obtained: the average and maximum velocity of the indicator's movement and the time indicator appears. Since the permeability and velocity of the indicator are linearly dependent on each other, this makes it possible to characterize the heterogeneity of the interwell space [1,3].

One of the methods of well test, which makes it possible to detect anisotropy, is the well interference testing. The essence of this method consists in changing the selection of fluid in the disturbing wells and recording the moment of change in the level or pressure in the reacting wells. Further on the time of the wave of pressure wave between the wells, a relationship is established between the properties of the formation in the inter-wellbore space. The anisotropy in this case can be expressed in the absence or weak response of the reacting wells, which may indicate a weak hydrodynamic connection between the wells or its absence due to barriers [6].

As an example of the comparative characteristic of the anisotropy parameters, the results of the anisotropy studying in the northwestern block of the Krapivinskoye oilfield are considered.

Table 1

Results of the investigation of anisotropy of permeability from core samples

	Reservoir characteristics				
Model number	φ ,%	Kr,z, мД	Swc, %	Kr / Kz	Direction of anisotropy
1230-02-A//	18,6	768,8	29,1	2,1	NE
1230-02-B//	18,4	371,2	28,6		NW
1232-02-A//	17,5	165,8	37,4	2,2	NE
1232-02-B//	17,4	74,6	32,7		NW
1234-02-A//	17,5	231,2	36,9	2,1	NE
1234-02-B//	17,5	112,7	32.2		NW
1236-02-A//	18,6	464,7	34,5	2,2	NE
1236-02-B//	18,5	211,5	31,8		NW
1237-02-A//	19,0	594,9	30,5	2,3	NE
1237-02-B//	19,1	256,4	28,6		NW
1250-02-A//	19,0	273,9	24,9	1,9	NE
1250-02-B//	19,1	141,2	26,8		NW

From Table 1 it follows that the predominant direction of anisotropy (with an average coefficient of 2.13) is the northeastern direction. These data correspond to the directivity roses diagram of the long-particle and microcrack diagrams that were formed during the formation of the deposit.

References

1. Bagrintseva K. I. Conditions of formation and properties of carbonate reservoirs of oil and gas. M .: RGGU, 1999 (II). 285 sec.
2. Erlager. R. Hydrodynamic methods of well investigation, eleventh edition 2003, translation from English, M, 2007, 512 p.
3. Glavnova E. N., Merkulov V. P., Glanov N. G. Comparative analysis of the methods for determining the anisotropy of horizontal formation permeability / E. N. Glavnova, V. P. Merkulov, N. G. Glavnov // Proceedings of the Tomsk Polytechnic University. - 2010. - T.317. - №1. - P. 128-132.
4. Kashnikov Yu. A., Ashikhmin S. G. Experience of creation of an oriented fracture of hydraulic fracturing at fields / Yu. A. Kashnikov, S. G. Ashikhmin, S. S. Cherepanov, T. R. Baldina, E. V. Filippov / / Oil industry. - 2014. - №6. - P. 40-43.
5. Krasnoschekova L. A., Merkulov V. P. Petrophysical heterogeneity of oil-bearing collectors of the Igolsko-Talovoye field (Tomsk region) / L. A. Krasnoshchekova, V. P. Merkulov // Oil and gas geology. Theory and practice. - 2014. - T.9. - №2. -pp. 1-12.
6. Pyatibratov P. V., Aubakirov A. R. Estimation of the influence of formation anisotropy on permeability on the efficiency of cyclic water flooding / P. V. Pyatibratov, A. R. Aubakirov // Exposition oil gas. - 2016. - No. 5. - P. 35-37.
7. S. M. Luthi, E. B. Dussan V, and B.J. Pinoteau. Laboratory Characterization of Anisotropic Rock / Auzerais F. M., Ellis S. M., Luthi S. M., Dussan V. J., Pinoteau B. J. // the 65th Annual Technical Conference and Exhibition of the Soclefy of Patroleum Engineere held in New Orleans, LA. - 1990. - September 23-26.
8. Trofimov A. S., Berdnikov S. V., Krivova N. R. Generalization of indicator (tracer) studies at the deposits of Western Siberia / A. S. Trofimov, S. V. Berdnikov, N. R. Krivova, A. A. Alpatov, G. I. Davitashvili, O. M. Garipov // Territory of Neftegaz. - 2006. - №12. - P. 72-77.

TURBULENT FLOW OF HYDROCARBON FLUIDS WITH POLYMER ADDITIVES

Gyamfi-Yeboah Ebenezer

Scientific advisor – professor V.N. Manzhai

National research Tomsk polytechnic university, Tomsk, Russia

The introduction of an extremely small amount of polymer (~10 g/m3 or 0,001% mass.) in a turbulent oil stream leads to partial laminarization of the flow [4] and, as a result, to a decrease in the hydraulic resistance coefficient of the polymer solution (λP) as compared to the coefficient of the pure solvent (λS). In accordance with the Darcy-Weisbach equation (1) a decrease in the resistance coefficient is accompanied by a decrease in pressure loss due to friction (ΔP) at a constant volume flow rate (Q = constant) or an increase in the volumetric flow velocity at a constant pressure drop (ΔP = constant)

$$\Delta P = \lambda \cdot \frac{L}{4\pi^2 \cdot R^5} \cdot \rho \cdot Q^2 \qquad (1)$$