18-24 June, 2015, Bulgaria

15th INTERNATIONAL MULTIDISCIPLINARY SCIENTIFIC GEOCONFERENCE SGEM 2015

Science and Technologies in Geology, Exploration and Mining

CONFERENCE PROCEEDINGS
Volume I

GEOLOGY

MINERAL PROCESSING

OIL & GAS EXPLORATION

SGEM

15th INTERNATIONAL MULTIDISCIPLINARY

...fic GeoConference SGEM

EFFECTS OF NEOTECTONIC ACTIVITY ON THE DISTRIBUTION OF PETROLEUM DEPOSITS IN SPACE (BY THE EXAMPLE OF THE VOLGA-URAL PETROLEUM AND GAS PROVINCE)

Assoc. Prof. Dr. Inna Chernova
Assoc. Prof. Ilmir Nugmanov

Kazan (Volga Region) Federal University, **Russia**

ABSTRACT

The goal of this research is to determine characteristic features of petroleum deposits distribution, i.e. to study the spatial variability of the petroleum properties, which are determined by the location and activity of neotectonic uplifts.

Statistical analysis of data on 2152 oilfields located within the Volga-Ural Petroleum and Gas Province (Russia) and 4331 oil deposits located within Romashkinskoye oilfield (Tatarstan, Russia) was performed. STATISTICA Base (Basic Statistical Analysis Methods) for calculating descriptive statistics and performing one-way ANOVA was also used. In order to evaluate the intensity of neotectonic movements morphometric analysis of digital elevation models was carried out.

Analysis of statistical charts showed that the vast majority of deposits (regardless of the rock age) are located in transition zones. Transition zones are areas with medium level of neotectonic activity: petroleum deposits locate on the slopes of neotectonic uplift and experience predominantly upward movements, but the amplitudes of these movements are 2-3 times less than amplitudes in more active zones. Apparently, such a distribution is not accidental: in these conditions, movements are intensive enough to ensure migration of hydrocarbons and deposits replenishment, and at the same time are insufficient to compromise the integrity of the cap rock. One-way ANOVA results reveal the impact which geodynamic (neotectonic) factors have on oil properties: in areas of high geodynamic activity oil density and viscosity decrease. Thus, these data suggest a significant influence of neotectonic factors on distribution of oil in space, as well as on the processes occurring inside the petroleum reservoir.

Keywords: neotectonics, statistics, oilfields

INTRODUCTION

Mechanisms of hydrocarbon deposits formation, preservation and destruction are determined by multifactorial impact which physical, chemical, lithological, hydrogeological and tectonic processes have on the geological environment. These factors contribute to the deposit's evolution in different ways, and sometimes the impact of each and every process cannot be evaluated unambiguously. However, the combination of their effects generally provides for establishment of the geological balance. At present, researches aimed at determining the time sufficient for formation of commercially valuable hydrocarbon deposit have become of particular interest. Results of variable studies on petroleum deposits formation based on geological and other data [1,2,3] show that the range of time estimates falls within the Neogene and Quaternary periods. Uniqueness of the result, regardless of the approach used for deposits age determination, suggests that there might be some connection between the deposits formation and Neotectonic stage.

A number of researches organized at several individual objects showed that petroleum deposits tend to shift and move following the neotectonic activity centers. One of the first scientists known to have summed up the researches on this question was Lastochkin A.N. [1]. He used the data obtained for different parts of the East European and the West Siberian Platforms and found that: 1) in most cases, the higher the amplitude of the local uplift, the higher the probability of discovering hydrocarbon deposit; 2) but in some cases high intensity (amplitude) leads to reservoir destruction.

In recent decades, numerous evidences of intensive vertical hydrocarbon migration within the earth's crust were reported to be found. In [4,5] it is shown that abnormal volumes of produced raw hydrocarbons, their physical and chemical properties and composition are in close connection with abnormal manifestations of modern geodynamic processes.

The aim of this research is to find certain regularities applying statistical approach to analyze a lot of information on the spatial distribution of hundreds of petroleum deposits relatively to location of neotectonic activity centers. Speaking more exactly, the goal of this research is to determine characteristic features of the deposits distribution, i.e. to study the spatial variability of the petroleum properties, which are determined by the location and activity of neotectonic uplifts.

MATERIALS AND METHODS

Statistical analysis of data on 2152 oilfields (Fig. 1) located within the Volga-Ural Petroleum and Gas Province (Russia) and 4331 oil deposits located within Romashkinskoye oilfield (Tatarstan, Russia) was performed. ArcGIS 10 and STATISTICA 10 were used for calculations, data analysis and graphical presentation of the results. The authors also used STATISTICA Base (Basic Statistical Analysis Methods) to calculate descriptive statistics and perform one-way ANOVA.

In accordance with the purpose of the study, two principal questions were formulated: 1) where are the petroleum deposits usually located in relation to the centers of tectonic activity at various stages of neotectonic history of the region? 2) are there any statistically significant differences in the properties of petroleum deposits located in different geodynamic environments?

In order to answer both questions, a zonation of study area was carried out in accordance with degree of geodynamic (neotectonic) activity – for both modern epoch, and neotectonic period in the whole. In order to evaluate the intensity of neotectonic movements morphometric analysis of digital elevation models was carried out [6]. Morphometric analysis allows dividing the DEM into several components (levels or morphometric surfaces of different orders) corresponding to certain stages of neotectonic history and depicting neotectonic structures of different orders – from regional to local. Isobase surfaces of orders from 8^{th} to 1^{st} were used in this study. All the calculations were performed on the basis of the digital elevation model (scale 1:200000). Implementation of the morphometric method by means of ArcGIS toolbox is presented in detail in [7]. Making use of literary sources and previous study results [8], the authors managed to determine the relative geological age of the isobase surfaces: the 8^{th} order surface corresponds to the Neogene, the 7^{th} order surface corresponds to the N–Q boundary, the 6^{th} order surface corresponds to the Q1–Q2 boundary, surfaces of 5^{th}, 4^{th} and 3^{rd} orders were formed during the Pleistocene, the age of the 2^{nd} order surface corresponds to the Holocene. The 1^{st} order isobase surface is hundreds of years old and corresponds to the local base level of erosion. Using this information, one can reconstruct the topographic history of the region from modern epoch to the beginning of the neotectonic period, and vice versa. And if we subtract one isobase surface from the other, we will obtain a series of surfaces reflecting the degree of neotectonic activity for a certain period, giving quantitative estimates of vertical movements' amplitude and direction [6]. In this study 7 difference surfaces were created (one of them is shown in Fig. 1).

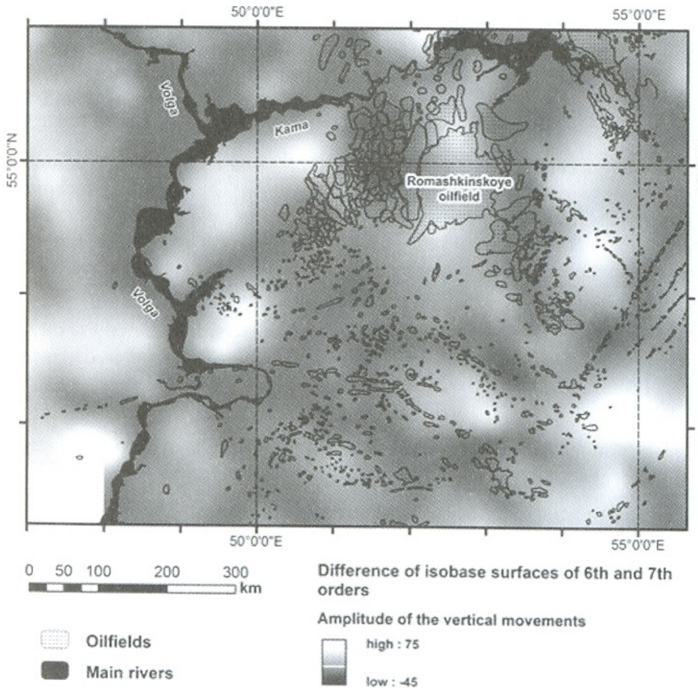

Fig. 1. Oilfields outlines (Volga-Ural Petroleum and Gas Province) overlaying the difference of isobase surfaces of 6^{th} and 7^{th} orders.

Neotectonic history of 4331 petroleum deposits located within Romashkinskoye oilfield and several neighbour fields was thoroughly studied by the authors. The deposits are related to different producing horizons of Carbonic and Devonian periods. For each deposit and period of neotectonic history geodynamic environment was determined. It also would be more correct to speak not of the deposits, but of the certain part of the crust, which is now containing the reservoir, since the reservoir could be formed during the Neogene–Quaternary period – beyond the time range of any given geodynamic environment (i.e. could be younger).

As has been noted above, the type of geodynamic environment can be determined through the difference of isobase surfaces. In order to formalize the neotectonic criteria, all surfaces representing the difference between isobase surfaces of neighboring orders have been classified according to the amplitudes of vertical movements and then divided into 3 classes. The first class characterizes geodynamic conditions of tectonic subsidence, the second one is for transition zones (from subsidence to uplift), and the third one describes features of active uplift. During the next step, the dominating state of each deposit was determined with respect to every stage of neotectonic history of the region. Geodynamic regime of every deposit for each of the 7 Neogene–Quaternary period intervals was determined by a simple overlay of geodynamic processes diagram with deposits outlines. The diagram in Figure 2 shows summarized data on geodynamic regimes of several deposits located within different producing horizons. The diagram corresponds to geodynamic conditions which existed between phases 2 and 3. Such diagrams were created for all neotectonic intervals (7–8, 6–7, 5–6, 4–5, 3–4, 2–3,1–2).

In order to answer the second question, the authors used measurements of oil density and viscosity, provided by "Tatneft" since the 1960s. The sampling technique and analysis methods were continuously changing and improving. Therefore, additional dispersion in the measured parameters occurs due to different approaches, though it was not taken into account in this work (mainly because of difficulties in finding the original source of data).

The database contains: 3144 values of physical parameters determined for oil samples taken from Devonian deposits, and 3467 values of physical parameters determined for oil samples taken from Carboniferous deposits.

To test the hypothesis about the effect of neotectonic factor on oil physical properties, the authors performed one-way ANOVA test with oil density and viscosity as dependent variables and degree of modern geodynamic activity as a grouping variable.

Degree of modern geodynamic activity can be estimated from the difference between isobase surfaces of the 1st and 2nd order [9]. Preliminary zonation of study area was carried out in accordance with degree of geodynamic (neotectonic) activity: vertical movement amplitudes were divided into 2 groups (group 1 covers low intensity, from 0 to 10 m; group 2 is a high intensity group, more than 10 m). At the next step, data were exported from the geoinformation software suite and processed in STATISTICA 10.

RESULTS

Figure 2 shows the distribution of oil deposits in space in relation to the centers of neotectonic activity between stages 3 and 2. The diagram shows that the vast majority of deposits, regardless of the stratigraphic depth, are located within transition zones. Diagrams calculated for all the other surfaces show the same pattern. Transition zones are areas with medium neotectonic activity: petroleum deposits locate on the slopes of neotectonic uplift and experience predominantly upward movements, but the amplitudes of these movements are 2-3 times less than amplitudes in more active zones (in the authors' classification it is the 3rd class, areas of uplifts). Apparently, such a distribution is not accidental: areas of medium intensity upward movements are more appropriate for deposit preservation. Under these conditions, movements are intensive enough to ensure migration of hydrocarbons and deposits replenishment, and at the same time are insufficient to compromise the integrity of the cap rock. In highly active areas (with large amplitudes of vertical movements) the cap rock and even the sedimentary cover usually disintegrate, and hydrocarbons migrate freely into the atmosphere.

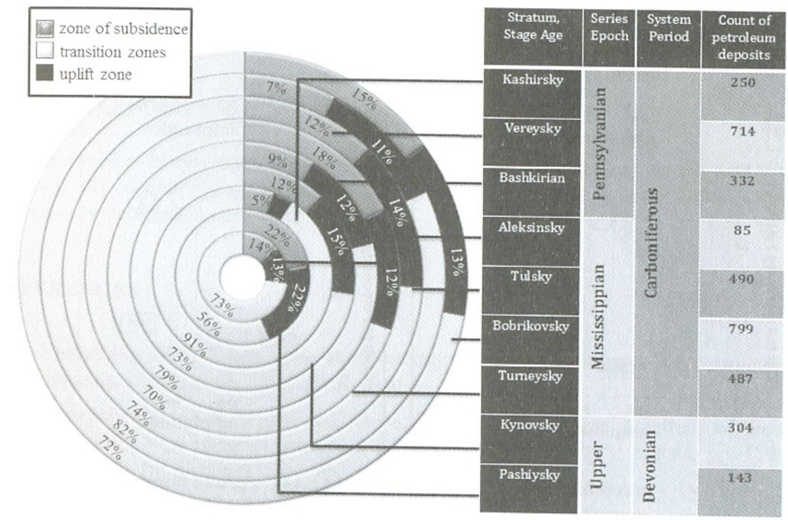

Fig. 2. The number of deposits (as a percentage of the total) located in different geodynamic environments which have existed during the neotectonic history, represented by difference of the isobase surfaces of the 2nd and the 3rd order.

Thus, the results obtained from the study can be interpreted as an outcome of two different processes with different intensities, i.e. formation (reformation) and destruction of petroleum deposits in various geodynamic conditions.

Oil samples analysis showed that differences in the averages were statistically significant only for the groups of density values (with p-level equal to 0.05). Figure 3 shows that in case of oil deposits located in Carboniferous sediments these differences are highly significant, even with internal variations within groups taken into account. In areas with low geodynamic activity oil is denser than in areas with high geodynamic activity. There is the same tendency for the samples taken from Devonian sediments, but there are no statistically significant differences. There are also no significant differences in oil viscosity (Fig. 3). Thus, one can speak confidently of the differences in density of oil saturating the reservoirs located in areas with low or high geodynamic activity.

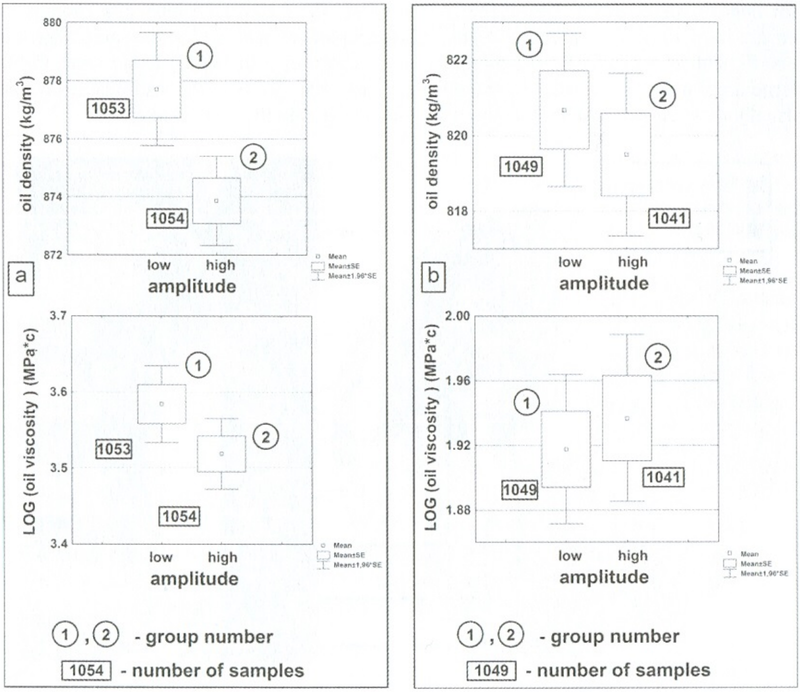

Fig. 3. Distribution of oil physical properties for different geodynamic settings: a) Carboniferous deposits; b) Devonian deposits.

CONCLUSION

The results of this study confirm certain modern ideas about formation, reformation and destruction of oil deposits – in particular, the idea of significant influence which amplitude of neotectonic movements has on formation and preservation of petroleum deposits. A certain relationship between physical properties of the oil and the nature of tectonic movements in the Neogene–Quaternary Period was also found and statistically validated. In areas with low geodynamic activity oil is denser than in areas with high geodynamic activity. During reservoir "aging" process, the light fraction diffuses through the cap rock or (if it is possible) migrates up the pore channels. This usually leads to an increase in oil density and viscosity. Oil density will not increase, if a very thick cap rock does not allow the light fractions to flow away from the deposit, and also if there are no migration paths for oil to go upwards along the pores. Oil density may drop only if the reservoir is constantly inflated with light fractions, or in the face of increasing temperature. These processes occurred in the study area several times, and subsequently led to destruction of oil deposits in Devonian sediments and formation of oil deposits in Carboniferous and Permian sediments. Another important assumption based on the aforesaid results is that all deposits of the study area cannot be very old, because it is unlikely that they would be able to survive several tectonic phases.

ACKNOWLEDGMENTS

This work was funded by the subsidy of the Russian Government to support the Program of competitive growth of Kazan Federal University among world class academic centers and universities.

REFERENCES

[1] Lastochkin A.N. Neotectonic movements and space distribution of petroleum deposits, USSR, p. 68, 1974. (in Russian)

[2] Nourgaliev D.K., Nourgalieva N.G. Age of oil deposits and dynamics of their formation, New ideas in petroleum geology and geochemistry, Russia, pp. 179-181, 1999. (in Russian)

[3] Krooss B., Leythaeuser D., Schaefer R. The quantification of diffusive hydrocarbone losses through cap rocks of natural gas reservoirs – a reevaluation, AAPG Bull, USA, vol.76, No 34, pp. 403-406, 1992.

[4] Nourgaliev D.K., Muslimov R.H., Sidorova N.N., Plotnikova I.N. Variation of i-butane/n-butane ratio in oils of the Romashkino oilfield for the period of 1982–2000: Probable influence of the global seismicity on the fluid migration, Geochemical Exploration, Russia, vol. 89, pp. 293-296, 2006.

[5] Kasianova N.A., Briukh O.V. Geodynamic dependence of abnormal changes in composition and physical and chemical properties of oil and gas (Pamyatno-

Sasovskoye oilfield, Lower Volga Region), Geodynamics of petroleum basins, Russia, vol. 1, pp. 58-61, 2004.

[6] Filosofov V.P. Basic morphometric method in search of tectonic structures, USSR, p. 232, 1975. (in Russian)

[7] Chernova I.Yu., Nugmanov I.I., Dautov A.N. Application of GIS analytic tools to improvement and development of structural and morphological methods for neotectonic studies, Geoinformatica, Russia, No 4, pp. 9-23, 2010. (in Russian)

[8] Chernova I.Yu., Nourgaliev D.K., Nurgalieva N.G., Nugmanov I.I., Chernova O.S., Kadyrov R.I. Reconstruction of history of the Tatar Arch in the Neogene-Quaternary Period by means of the morphometric analysis, Neftyanoe Khozyaistvo (Oil Industry), Russia, issue 6, pp. 12-15, 2013.

[9] Nourgaliev D.K., Chernova I.Yu., Nurgalieva N.G., Khasanov D.I., Kostina A.A., Fattahov A.V., Krylov P.S. Spatial variability of oil properties within oil fields of the Republic of Tatarstan , Neftyanoe Khozyaistvo (Oil Industry), Russia, issue 6, pp. 8-11, 2013.