

DEEP WELLS IN MONITORING OF GEOLOGICAL AND GEODYNAMIC PROCESSES

L.M. Sitdikova

V.G. Izotov

E.U. Sidorova

D.A. Khristoforova

Kazan (Volga region) Federal University, Russia

ABSTRACT

The authors conducted monitoring studies using core and geophysical data on a number of deep wells that penetrated the crystalline basement in the eastern portion of the Russian Plate. Information on the deep structure of the Earth's interior was mainly obtained through geophysical studies that provided data for the construction of various structural depth models. Explicit data obtained through the study of core material from deep and ultra-deep wells can be of great importance. The new methods of studying the deep horizons of the Earth's crust can give more information about the geological and geodynamic processes in zones that were previously thought to be geodynamically stable. The character of geodynamic processes can be analysed through the creation of deep geo-observatories based on deep and ultra-deep wells. Results showed that the crystalline basement undergoes extensive geodynamic and hydrothermal changes mainly within specific mobile zones of the Earth's deep crust.

Keywords: deep wells, basement, monitoring, geological and geodynamic processes

INTRODUCTION

One of the relevant research tasks is establishing a network of deep observations based on deep and ultra-deep wells for Eastern Russian Plate. The problem is directly related to implementation of long-term deep drilling in oil-bearing regions of the Volga-Ural oil and gas province. This allowed seeing in a new light geological structure, tectonic position and geodynamic evolution of the crystalline basement, as well as describing location, formation and reformation of oil deposits within the region.

RESULTS

Nowadays oil and gas potential of the sedimentary cover in the region has almost been evaluated. Further works, carried out in this area, are related to search of non-conventional hydrocarbon objects in deeper horizons of the sedimentary cover and crystalline basement rocks. In this regard, the crystalline basement of the region has been studied in more detail.

Implementation of subsoil deep drilling has significantly widened our understanding of geological structure of region's deep horizons. Long-term works on analyzing geological, geophysical data, and well cores penetrated the crystalline basement at different depth were conducted (Figure 1).

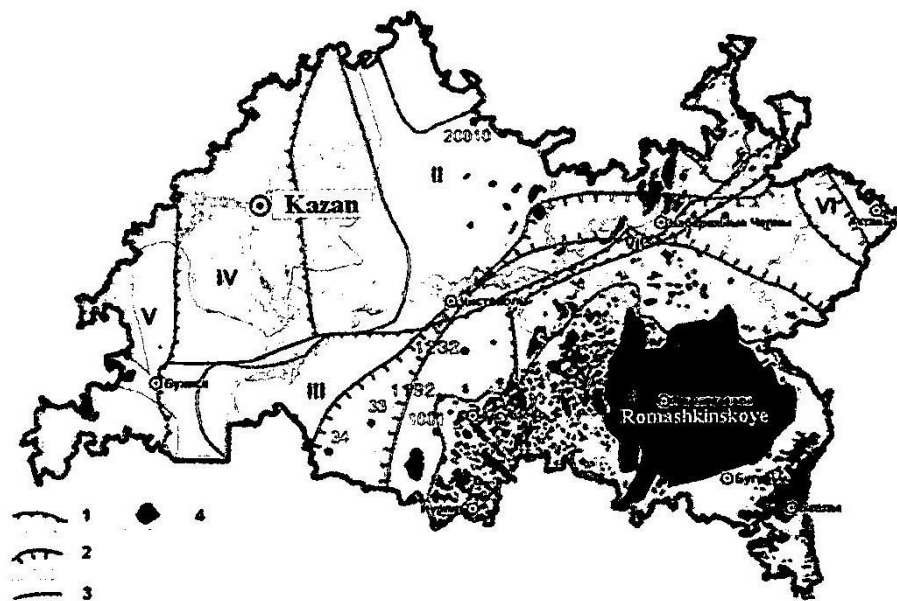


Figure 1. Schematic map of the Romashkinskoye oilfield (Volga-Ural oil and gas province): 1 - boundaries of tectonic structures of the first order, 2, 3 - boundary of the Kama - Kinel system deflections, 4 - oilfields [1]

Many wells have penetrated only the basement surface at other depth of 300-500 m to 1500 m. Within the South-Tatar Arch well No. 20000 Minnibayevsky (depth 5090m) and well No. 20009 Novo-Elkhovsky (depth 5881m) were drilled (Figure 2).

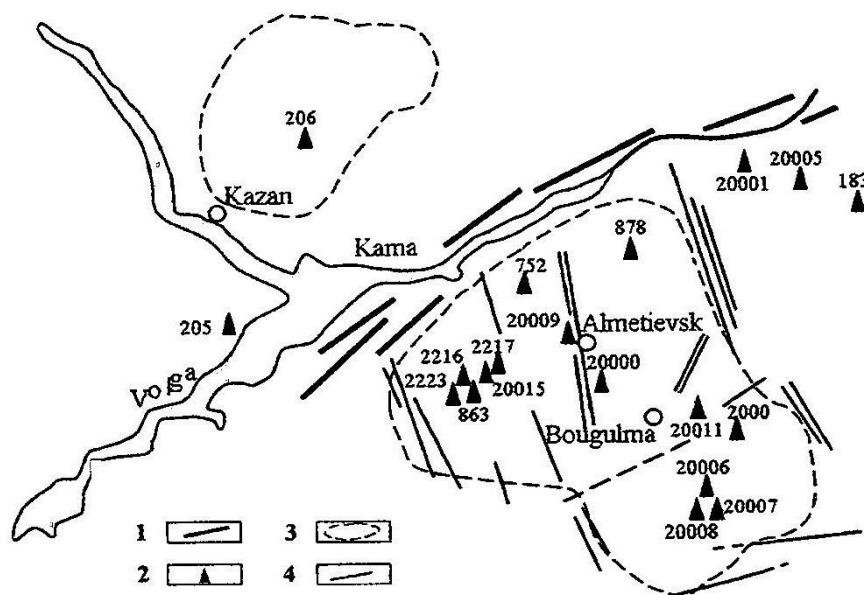


Figure 2. Scheme of location of wells (South - Tatar Arch). 1 - intra-Arch faults, 2 - deep boreholes, 3 - the Arch's boundaries, 4 - deep faults.

Analysis of the data obtained allowed creating different geological and petrographic models of the basement's deep structure, which are represented in works of Sitdikov B.S., 1982; Lapinskaya T.A., Bogdanova S.V., 1986; Postnikov A.V., Popova L.P., 1996; Izotov V.G., Sitdikova L.M., 1995, 2014 and others.

In contrast to previous ideas that viewed the crystalline basement as a solid inert body, analysis of the material obtained by deep drilling allowed us to establish the fact of its geodynamic evolution that led to formation of plate-flake structure and modern tectonic appearance of the basement (Figure 3) [2]. Evolution of the crystalline basement continues at the present development stage in the region, which is confirmed by data analysis of deep, ultra-deep wells and seismic observations.

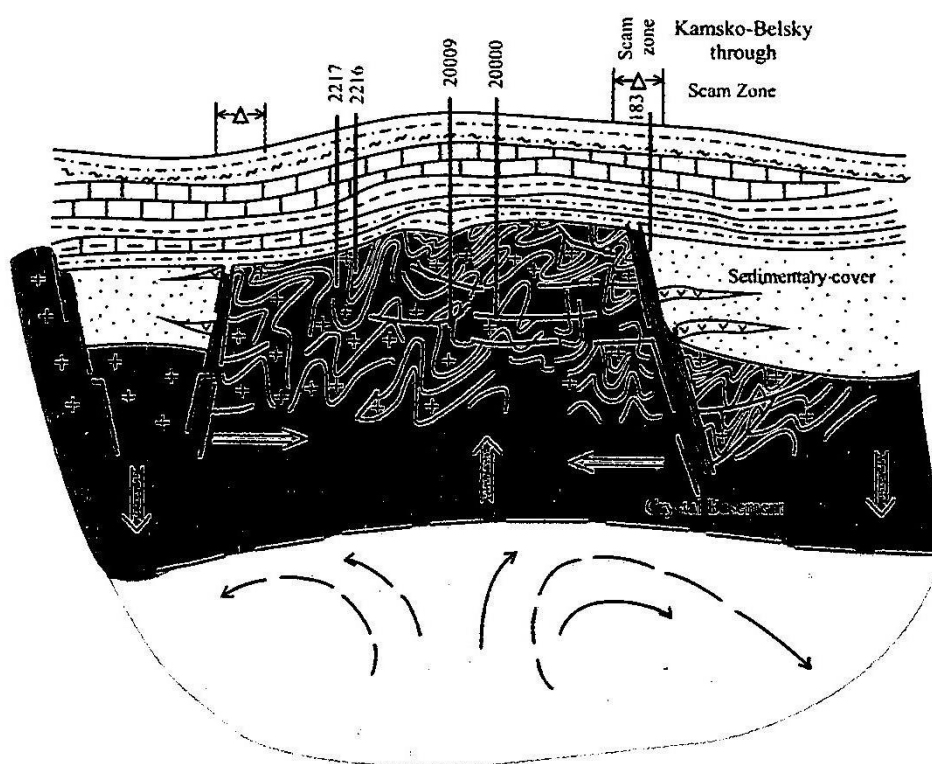


Figure 3. Geodynamic model of the South – Tatar Arch [2].

The most important recent discoveries include establishment of anomalous zones in the basement allocated sharply against major rock formations, so-called zones of decompression or destruction [2]. Formation of these zones is a consequence of the current development stage and dynamic state of the basement rocks in the Tatar arch, which is the central structure of Eastern Russian Plate and its rift frame (Figure 4).

Beginning from the Late Proterozoic geodynamic evolution of the region was determined by periodic vertical movement of large structural elements – arched elevations. Such elements include elevation system of the Tatar arch, and elevation system of Perm-Bashkirian arch. These major structural elements are separated by Kazan-Kazhimovsky and Kamsky-Belsky rift zones.

a need for conduction of complex monitoring studies of processes in deep horizons. In particular, the priorities should be: control in time of mineralogical and petrographic, geochemical, geodynamic processes in deep horizons of the basement, as well as control of heat flows and seismic activity change in the region. The tasks can be solved by establishing a network of deep observations based on deep and ultra-deep wells.

The study of great depths is possible by integrating well logging methods and mineralogical and petrographic analysis of core material in deep wells. These studies confirmed vertical heterogeneity of the basement rocks and development of compression and decompression destruction zones in the region. Destruction zones are associated with certain stages of geodynamic evolution of the Tatar arch. This was the basis for observation of zones, their material composition, and further evolution of the basement in the present development stage.

Modern evolution of the crystalline basement is associated with certain geodynamic and structural zones in the basement body. The most active processes occur on the border of the basement and sedimentary cover. In this contrasting geochemical zone active denudation and encrustation processes took place in post Proterozoic.

Tectonic and climatic conditions in the Upper Proterozoic – Lower Paleozoic of the region contributed to generation of weathering formations. Crust thickness ranges from 1-5 m to 20-25 m for areal type and can reach 100-120 m for linear fracture type [4-6]. Weathering has a staged pattern. Depending on the change degree, rocks elaboration and weathering duration process, there are several zones allocated from the bottom up confirming staged pattern of weathering: disintegration, cementation, hydration and leaching, oxidation and secondary hydration. Data monitoring of deep wells penetrated transition formation between the sedimentary cover and the basement provides valuable information about the structure and composition. Influence of deep fluids on crustal formation occurs at the moment causing a change in remaining weathering profiles. Thereat migration of deep fluids results in change of temperature, disturbance of mineralogical and geochemical balance in the system causing the formation of abnormal inversion of weathering profiles. All this shows that the modern processes are taking place in transition area of the sedimentary cover and the basement.

The most active processes occur in destruction zones that have been penetrated by ultra-deep wells (Figure 2). Formation of these zones is connected to mechanical stress fields in the basement, which led to alternation in deep well sections of compression and decompression destruction zones.

All this determines modern geological and geodynamic processes and enhancing fluid regime in the territory. As a result of these processes there are specific unbalanced geochemical conditions leading to emergence of abnormal geochemical, thermal and geophysical fields that clearly set by logging data, geochemical and thermal studies.

The most important indicator of the crystalline basement evolution is temperature regime of its thermal fields. In the crystalline basement rocks of the Tatar arch there is a certain connection of temperature anomalies, areas of abnormal stress and destruction zones, as well as localization of oil in the sedimentary cover.

Long-term experimental geothermal measurements conducted directly in the wellbore show that oil deposits are characterized by high values of reservoir temperatures, thermal gradients and heat flows [7]. There are certain patterns identified in the study of

thermal regime of the crystalline basement related to the spatial location of hydrocarbon deposits in the sedimentary cover (for example, Romashkino field and its satellites) (Figure 5). As a rule, territories with hydrocarbon deposits are characterized by high temperatures and heat flows [8].

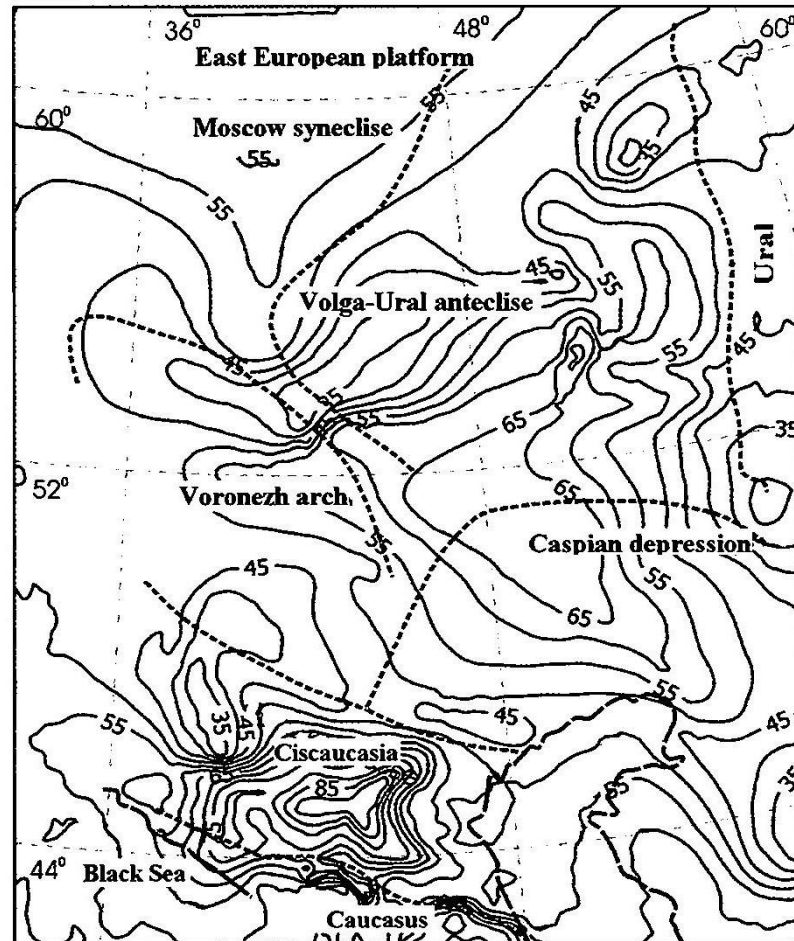


Figure 5. Map of the deep heat flow, mW/m^2 [8].

However, convective heat transfer associated with the processes of diffusion and filtration is the determining factor during formation of hydrocarbon deposits. It is known that movement of fluids in the Earth crust is closely related to the thermal conditions of deep horizons. Migrating deep fluids cause convective heat flow. These processes are related to variation of heat flow both vertically and horizontally. Heterogeneous temperature fields and heat flows affect processes of fluid migration in the Earth crust, and formation of decompressed zones – destruction zones associated with both areas of large plates disrupt, and further development of the substance by deep fluids. Modern dynamics of the substance in the crystalline basement are clearly developed in heat regime. Observations of temperature changes in the crystalline rocks of the region carried out by Neprimerov N.N., Khristophorova N.N. and others directly in the wellbore of deep and ultra-deep wells [7]. In particular, temperature anomalies established in the section of ultra-deep well No. 20009 Novo-Elkhovsky clearly correlate with intervals of destruction zones (Figure 6) [9].

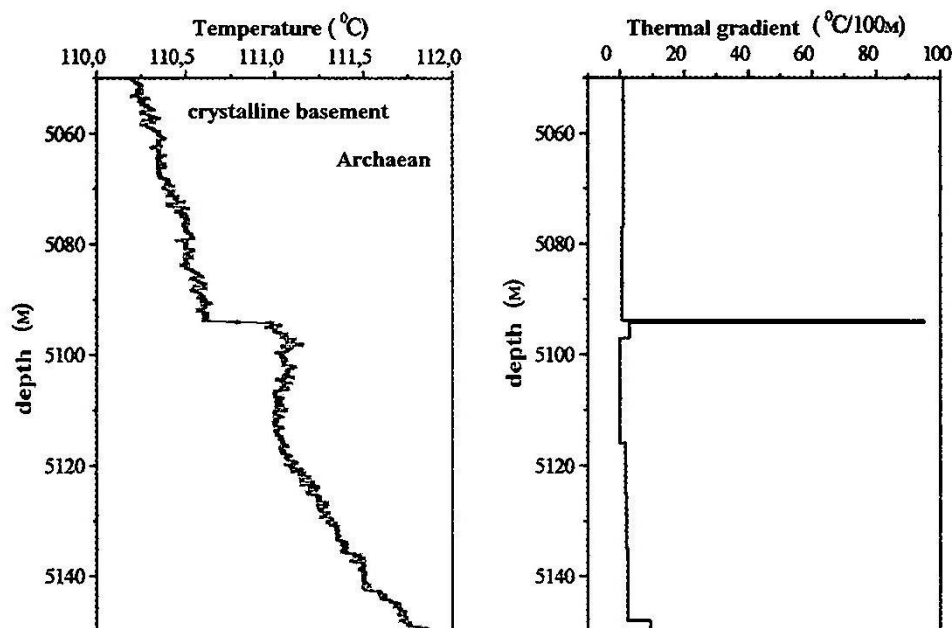


Figure 6. Thermogram of the section of ultra-deep well No. 20009 Novo-Elkhovsky [9].

CONCLUSION

Features of the processes occurring in deep horizons of the Earth crust can be studied by observing geological, seismic, geochemical, thermal and other processes using a network of deep and ultra-deep wells drilled in the Volga-Ural oil and gas province. There is an opportunity with a high reliability to obtain information on forecasting endogenous seismic processes in studied region, their dynamics, tracing the paths of fluid migration, and predicting fluid regime in the basement.

It has been established that modern endogenous processes in the Volga-Ural oil and gas province have undergone continuing geodynamic stress in the basement intensified in recent years. These processes are accompanied by active gas emission and inflow of hydrothermal solutions of increased mineralization, temperature changes in the region and consequently increased hydrothermal processing of the basement rocks and formation of new anomalous zones – destruction zones.

REFERENCES

- [1] Muslimov R.Kh. Optimization of the growth of oil reserves in conditions of high prospecting of depths of the Republic of Tatarstan, Georesources, Russia, vol. 1(15), 2004, pp 2-3 (in russian);
- [2] Sitdikova L.M., Izotov V.G. Formation of hydrocarbon reservoirs in the deep Earth's crust. Journal of Geochemical Exploration, 2006, No. 89, pp 373-375;
- [3] Voitovich E.D., Gatyatullin N.S. Tectonics of the Tatarstan, Russia, Kazan, 2003, 132 p (in russian);
- [4] Sitdikov B.S. Petrography and structure of the crystalline basement of the Tatar ASSR, Russia, Kazan, 1968, 436 p (in russian);

- [5] Lapinskaya T.A., Zhuravlev E.G. Buried weathering crust of basement of the Volga-Ural gas and oil presence province and its geological significance, Russia, Moscow, 1967, 174 p (in russian);
- [6] Precambrian weathering crusts (Precambrian peneplain formation and weathering crusts: era in the Precambrian continental lithogenesis), Russia, Moscow, 1975, 131 p (in russian);
- [7] Khristoforova N.N., Khristoforov A.V. Fluid migration and location of fractured layers in the crystalline basement by temperature logging in the Volga Region, Russia. Journal of Geochemical Exploration, 2006, No. 89, pp 187-190;
- [8] Khristoforova N.N. The thermal regime of the lithosphere in the areas of oil and gas (on the example of the Volga-Ural region and Ciscaucasus). Dissertation, Russia, Kazan, 2002 (in russian);
- [9] Khristoforova N.N., Khristoforov A.V., Muslimov R.Kh. Decompressed zones in the crystalline basement. Georesources, Russia, vol. 1(1), 1999, pp 4-15 (in russian).