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The thermal regime of the southern margin East-European craton

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Abstract. An analysis, a mathematical modelling and interpretation of the thermal field was focused on the southern margin of the East-European Craton. The size and characteristics of the heat flow are determined by tectonic conditions, the sequence of geological developments of the investigation region during the Cenozoic. The close correlation between the heat flow anomalies and the localisation of the oil and gas fields are established.

1. Introduction

The thermal regime and its changes during geologic evolution are known to be one of the most important energetic factors controlling the intensity of oil-and-gas formation and preservation of the oil and gas deposits. As the southern margin of the East-European craton belongs to the oil and gas provinces, the comparison of the localisation of the oil-and-gas deposits with the geothermal situation or the heat flow distribution is undoubtedly of interest.

2. Materials and methods

The southern margin of the East-European Craton is characterised very complicated geological structure, which has not unambiguous understanding. Here are structures of different types, age and genesis. The study area includes the pre-Cambrian platform, the Scythian plate, the Alpine folded belt, represented by the Caucasus and Crimea with the pre-mountain troughs and the Black Sea deepwater depression. An analysis, a mathematical modelling and interpretation of the thermal field was focused on the East-European Craton.

3. Results and discussions

A strikingly differentiated thermal field marks the study area. Here heat flow density varies from 25–30 to 100 mW/m² or more. Low and relatively stable heat flow (35–55 mW/m²) is characteristic of the southern slope of the ancient East-European Platform. On the Scythian Platform the heat flow density differentiation are higher. Here 50–65 mW/m² predominate. Against this background, numerous anomalies of different size, form, intensity and sense are distinguished. Anomalies of maximally high heat flow (more than 80 mW/m²) are distinguished in the Crimean Steppes within the Tarkhankut and Novoselovsk ridges, in the pre-Caucasus on the Stavropol, Prikumsk, Terek-Sunzha and other ridges.



The largest area is occupied by the Stavropol anomaly. Its area on the 70mW/m² heat flow isoline is 300x180km². Within it a number of local anomalies are distinguished which heat flow exceeds 90-100 mW/m². Southward, the Stavropol anomaly continues toward the Great Caucasus through the Nevynnomysk uplift. High heat flow is characteristic of the central part of the Great Caucasus. Elevated heat flow (60–70 mW/m²) is the feature the Karkinit and partly the Manych troughs, the Kalamit, Kaniv-Berezan, Astrakhan swells.

Large areas are characterised by anomalies of the low-level heat flow. They include first of all the West and East Black Sea basins, the Indol-Kuban and Terek-Caspian troughs, the Alminsk, Riony depressions. The regions with relatively low values also include the mountainous folded areas of North Dobruja, Crimea Mountains, the NW and SE plunge of the Great Caucasus. The lowest heat flow density (20–40mW/m²) has been recorded in the Black Sea basin. The mean value is 36±7 mW/m². But the thermal field is inhomogeneous. Remarkable heat flow density variations are observed in the Central Black Sea ridge (Andrusov elevation), near marginal and shelf zones. Very low heat flow (15–25mW/m²) is observed on Tuapse, Sorokin troughs. The ridges and the fault zones exhibit high-level heat flow. On the continental slope continental regularities in the heat flow distribution are presented. The continental anomalies continue in shelf zones, on the continental slope and are, as a rule, cut by the Basin edges [1]. The size and characteristics of the heat flow of the Black Sea are determined by tectonic conditions, the sequence of geological development of this territory in the Cenozoic, underground water dynamics and accumulation of young sediments.

The sediment level any possible variation of the heat flow due to the difference in the level of the thermal field of tectonic blocks. Additional excitation of the thermal field resulted from the activation of young tectonic processes. For example, young volcanism has been activated in the zone where the South-Shore and West-Crimea faults intersect and there are slide displacements of the Odessa fault. These processes were accompanied by alternation of heat transfer conditions, additional emission or absorption of thermal energy and the corresponding alteration of heat flows.

The heat flow is affected by many factors at the depth and surface. Sedimentary deposits that usually have low heat conductivity cause a substantial effect. The effect of young Quaternary sediments is particularly essential. Several attempts were made to provide, on the basis of analytical solutions, a qualitative evaluation of thermal field distortions that occur in the sedimentation process. However the results obtained have been ambiguous because it is not always possible to provide a theoretical consideration of all the processes involved in sedimentation.

Therefore an attempt has been made to evaluate the sedimentation effect in the Black Sea basin on the basis of experimental data on the heat flow and on the actual thickness of sediments, their age and the sedimentation rate for the Cenozoic [2]. Analysis of experimental data has shown that heat flow distortions are associated chiefly with sedimentation of the youngest (Quaternary) sediments. Non-distorted heat flows are 40-55 mW/m². More or less the same heat flows (45-50 mW/m²) were obtained in two bore holes, drilled from the vessel "Glomar Challenger" north of the Bosphorous strait, where the thickness of Quaternary is low.

In the Indol-Kuban trough heat flow varies from 40 to 60 mW/m². Low values tend to its central part. The heat flow increases over the anticlines in the near-marginal zones. The same regularities in the heat flow distribution are observed in the Terek-Caspian trough. But its field is more differentiated. In the Terek-Sunzha dislocation zones heat flow increases to 70–80mW/m².

The geothermal zones strike, as a rule, so as do the tectonic structures, but the anomalies of maximally high values often cut there. In particular, the pre-Caucasus anomalies strike submeridionally and the Scythian plate and Great Caucasus structures are sublatitudinal NW orientation. This evidences a different-age and multiplex manifestation of tectono-thermal events in this territory. The geothermal anomalies are seen to superpose the formed tectonic background.

An analysis, a mathematical modelling and interpretation of the thermal field of the territory, considered allow us to conclude its multiple character and the different nature and age of its anomalies [3]. The anomalies are due to a) crustal structure (first of all sediment accumulation); b) changes of heat transfer condition their, c) tectonomagmatic processes. The latter is of the crucial role in the formation of intensive anomalies.

The empirical dependence of the heat flow density with the age of the structures and the time of their last tectonomagmatic activation, the results of the mathematical modelling of the thermal field enable us to determine the age of the anomalies in the territory considered. The slight heat flow increase by 8–0 mW/m² within the Scythian plate is due to long heating of the lithosphere at the final stage of Hercynian tectogenesis. The tectomagmatic activity manifested in late Triassic-Jurassic in relatively limited zones along the northern margin of the Scythian plate (Kalamit, Berezan, Azov swells) against the background of the high flow of the Scythian plate is slightly apparent. The high heat flow is the features of the late Jurassic – Cretaceous of activation and riftogenesis. But the most significant thermal field distortions are due to active Oligocenic-Quaternary tectonic and magmatic processes.

The anomalies of the Stavropol, Tarkhankut, Novoselovsk highs are produced by crustal sources whose age does not exceed 2-6 my. According to the modelling results, the anomalous character of the thermal field in the pre-Caucasus may be due to two cycles of thermal activity. At the first stage (20–0 my ago) temperature increased in the upper mantle and the crustal base. At the second one (3–9 my ago) heat was emitted significantly in the crust and upper mantle due to tectonic processes, the heated masses intruded into the Earth's crust, crustal melting domain formed.

The oil and gas fields in the region considered are mainly localised in the areas of high heat-level flow and frequent tectonic activation. By the way, the gas fields being situated within areas with increased and high flow and the oil fields occur on their periphery. This close correlation between the localisation of the oil and gas fields and the geothermal regime which as notes above, predetermined the post oligocenic geodynamic events evidences the post oligocenic age of the fields. Here the fields were presumably formed not only by hydrocarbon generation in the sediments of young troughs but also by redistribution of the hydrocarbon potential of older oil and gas formation zones. An analysis of the present localisation of oil and gas fields allows us to assume that the former formed by generation of liquid hydrocarbons in young sedimentary basins and the latter mainly resulted from redistribution of the hydrocarbon potential of ancient basins.

The oil and gas accumulation zones of the region considered mainly strike sublatitudinally along the margin of the ancient craton. Evidences their primary role in tectono-geodynamic features of the evolution of the continental margin that predetermined the origin and evolution of the sedimentary basins, the thermodynamic and hydrodynamic conditions of the hydrocarbon formation the lithologic and structural factors (conditions) of their preservations. But in the distribution of the field violations of this general zonation, due to young postoligocenic tectono-thermal events are clearly manifested. They activated the processes of the local Earth's crust extension, faulting, splitting, and fluid dynamics, which resulted in the

change of the thermobaric situation and the hydrocarbon potential redistribution. This energy factor in the formation of the zones of oil and gas provinces should be necessarily taken into account in working out the strategy of search and exploration for the oil and gas fields.

4. Conclusions

The size and characteristics of the heat flow are determined by tectonic conditions, the sequence of geological developments of the southern margin of the East-European Craton during the Cenozoic. The close correlation between the heat flow anomalies and the localisation of the oil and gas fields are established.

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