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Geothermal investigations in superdeep and deep scientific wells: methods and results

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Geothermal investigations performed in the Kola, Tyumen, Ural, Yen-Yakhinskaya, Vorotilovo (all in Russia) and Saatly (Azerbaijan) superdeep wells, Kolva and Timano-Pechora deep wells (Russia), Noerdlingen-72 (Germany), Yaxcopoil-1 (Mexico) and Eyreville (USA) deep wells with a depth from 1.6 to 12.2 km drilled in crustal blocks with different geological situations demonstrate some general regularities in the research results. 5 of 11 wells were drilled in large sedimentary basins, 4 wells were drilled in large impact structures and 2 wells in the crystalline basement. Most of the wells were drilled with continuous coring. As a rule, drilling of each well was aimed at many objectives including studies of geothermal parameters of deep horizons of the Earth's crust. The long-term deep geolaboratories have been organized in the Kola and Vorotilovo wells after drilling had been completed.

An approach to experimental geothermal investigations in continental scientific wells includes the following basic stages: (1) periodical temperature logging after completion of drilling, (2) determination of rock's thermal properties on cores at normal conditions with the optical scanning instruments at an average sampling interval of 1-3 m, (3) experimental studies of effects of formation conditions (P and T) on rock's thermal properties; (4) calculation of heat flow density in each 10-50 m long interval; (5) studies of regularities in vertical variations of geothermal characteristics, geological interpretation of results, prediction of a terrestrial heat flow density typical for the drilling area.

Periodical temperature measurements after finish of drilling showed that a magnitude of temporal variations in temperature gradient changes with a broad range throughout the borehole and does not directly depend on depth. In some depth intervals (100-1200 m long) the gradient is quite stable that is unexpected from previous geothermal measurements in shallow wells: Stable-with-time temperaturegradient values were found to be typical for a low-permeable zone of formations, while the zones with significant temporal variations of temperature gradient are characterized by fluid migration and higher porosity and fracturing.

Significant vertical variations in conductive component of the heat flow density (30-60% in most cases) are established practically for all wells. The heat flow density value increases significantly with a depth (up to 50-100% in many cases) that is in a serious contradiction with previous numerous geothermal experiments performed earlier in shallower wells at lack of experimental data on rock's thermal conductivity and undisturbed temperature gradient.

The terrestrial heat flow density values in deep horizons calculated from our experimental geothermal data exceed significantly (by 40-100% for most wells) the previous experimental data inferred from the measurements carried out earlier in shallow boreholes in the areas of deep drilling. These results change significantly a conception about the crustal thermal regime and temperatures predicted for depths below the well bottoms.

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