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Vertical Variations In Heat Flow Inferred From Experiments In Deep Boreholes

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Deep scientific and parametric continental boreholes allow to obtain representative experimental data on combination of the geothermal parameters of the crust – temperature, temperature gradient, rock thermal properties, and, as the result, heat flow density values – which are more reliable compared to the previous data from shallow boreholes. Special advantages of the scientific boreholes include also a possibility for many repeated temperature logging during long time intervals (several years often) after a finish of the drilling that allowed (1) to determine temperatures and temperature gradient values corresponding to thermal equilibrium of the formations studied, (2) to study temporal regularities in temperature and temperature gradient behaviour within different formation layers during the formation recovery process. Scientific boreholes are drilled with numerous coring (often – with continuous coring) that provides the possibility to obtain detailed information on a distribution of rock thermal conductivity along the borehole. As a result, the scientific deep and super-deep boreholes provided the unique possibility for the determination of vertical distributions of the heat flow density that can not be reached normally in other boreholes.

Experimental geothermal and petrothermal investigations performed for the super-deep boreholes Kola, Ural, Vorotilovo, Tyumen, Yen-Yakha (all – Russia), Saatly (Azerbaidzhan), and deep scientific and parametric boreholes Kolva, Timano-Pechora, Tyrnyaus, (all – Russia), Krivoy Rog (Ukraine), Muruntau (Uzbekistan), Nordlingen-72 (Germany), Yaxcopoil-1 (Mexico) allowed us to establish the following important peculiarities in geothermal parameters of the crustal blocks studied with scientific deep drilling were established from the investigations: (1) temperature gradient recovery up to undisturbed values occurs essentially faster than it was assumed earlier; (2) a rate of temperature gradient recovery was found to be different for different formation layers; (3) significant variations in rock thermal properties vary significantly along boreholes within several thousands, hundreds and dozens meters as well as along short depth intervals of 0.5-1 m; (4) conductive component of the heat flow density varies up to 70-100% along boreholes often, regular increase in heat flow density within depth intervals of several kilometers is combined with essential local variations, (5) values of a conductive component of the heat flow density established from the measurements in deep and super-deep boreholes exceeds significantly (by 30-100%) and systematically the previous experimental estimates done earlier for shallow boreholes.

The mentioned regularities in behaviour of the geothermic parameters were confirmed from new experimental data for the scientific and parametric boreholes Severo-Molokovo, Vysokovo, Yarudeyskaya (Russia), Eyreville (USA) and from the revision of previous experimental geothermic data for the Moscow syneclise (the East European platform) and Ural region. The new results obtained from studying vertical variations in the heat flow density demonstrate a regular essential (30-60%) increase in the conductive component of the heat flow density with a depth within upper depth intervals up to 2000-3000 m.

The results show that the determination of heat flow values from averaging the geothermal parameters within long depth intervals can lead to essential underestimation of the crustal heat flow values.