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Thermal property measurements in studying heat and mass transfer processes in crust

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Geothermal and petrothermal experiments have been carried out within a program of continental scientific deep drilling when detailed information on rock's thermal properties had been important. The experiments included (1) numerous high-precision measurements of rocks thermal properties (typically - thermal conductivity (TC), thermal diffusivity (TD), thermal anisotropy) on cores with a non-destructive non-contact optical scanning instrument (no preparations of cores - polishing, preparation of special form and dimensions - are necessary) at normal conditions with sampling interval 1-5 m along most of wells, (2) measurements of TC/TD at elevated pressure and temperature on restricted core collections, (3) periodic temperature logging in wells after finish of the drilling. In most cases the measurements have been performed sequentially on dry and water-saturated cores to estimate pore aspect ratio values and its distribution function for each core from theoretical modeling. Artificial fracturing effect in cores (due to decompression effect after core recovering) has been estimated to exclude its influence on heat flow density (HFD) calculation results. Significant variations in TC/TD are established in most cases along every core and short depth intervals (10-50 m) that is caused mainly by variations in mineralogy, porosity, pore structure and anisotropy when different reasons dominate in different formations. Sometimes weakly consolidated sedimentary rocks could not be water-saturated because of their disintegration. In these cases TC of water-saturated rocks was estimated from rock porosity data and correlations between (1) TC of dry rocks and porosity, and (2) rel-

ative increase in TC after rock water-saturation and porosity. These correlations have been established from corresponding measurements on representative core collections for different types of sedimentary rocks with total amount of cores more than 4000.

Obtained detailed TC logs have allowed us to study the HFD variations along every well. Effective TC and equilibrium temperature gradient values were determined for every 10-50 m depth interval and conductive component of HFD was calculated from these data for every interval. Significant vertical variations and regular positive trend in HFD have been established for many superdeep and deep scientific wells drilled in different geological situations: Kola (crystalline basement, 12261 m, more 8252 cores studied), Ural (fault belt, 6015 m, 4619 cores). Vorotilovo (impact structure, 5374 m, 3715 cores), Tyumen (sedimentary basin, 7502 m, 1243 cores), Kolva (sedimentary basin, 7057 m, 1016 cores) (all – Russia), Noerdlingen-73 (impact structure, 1212 m, 455 cores, Germany). For all 15 scientific wells studied a terrestrial heat flow density value was established to be essentially larger than previous HFD estimates from shallow wells with poor data on rock's thermal conductivity. Established variations in HFD are connected with such factors as paleoclimatic effect, heat flow refraction on formation heterogeneities, fluid migration in formation, transient heat processes in crust, and others.

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