

THERMOPHYSICAL PROPERTIES OF ROCKS AND THE MAGNITUDES OF HEAT FLOWS IN CERTAIN AREAS OF THE GREATER CAUCASUS AND CISCAUCASIA

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Abstract**Full Text**

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GEOPHYSICS

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**THERMOPHYSICAL PROPERTIES OF ROCKS
AND THE MAGNITUDES OF HEAT FLOWS
IN CERTAIN AREAS OF THE GREATER
CAUCASUS AND CISCAUCASIA***(Presented by Academician D. I. Shcherbakov, February 17, 1966)*

In 1962-1964 the authors carried out determinations of thermal parameters for several hundred samples of igneous, metamorphic, and sedimentary rocks in air-dry and moist states, in the temperature range from 15-20 to 90-100°. Determination of the thermal properties of rocks and measurements of temperatures in long-standing wells for which these determinations were made make it possible to calculate the magnitudes of the densities of heat flows coming from the Earth's interior. In this connection, the results for the wells Karmadon No. 10, Tamisk No. 1, Metallurg No. 2, Zmeiskaya No. 1, Baksan No. 1, Oktyabrskaya No. 50/25, Veselovskaya No. 10, Zhuravskaya No. 4, Petrovskaya No. 1, and Aleksandriiskaya No. 1 are especially valuable.

The Karmadon No. 10 well is located in the valley of the Genaldon River, 7 km north of Mount Kazbek, in the central part of the Main Caucasus Range. The well penetrated moraine-deluvial deposits and clay shales of the Lower Jurassic. The temperature at a depth of 700 m is 55°. The average value of the geothermal gradient is 20.6 m/deg. The thermal conductivity of the clay shales ranges from 2.66 to 3.54 W/m · deg. The average value of the heat flow for the Karmadon No. 10 well is $14.15 \cdot 10^{-2}$ W/m².

The Tamisk No. 1 well was drilled in the area of the resort of the same name, in the valley of the Ardon River, within the Northern monocline of the Caucasus mountain structure. The well penetrated limestones of the Valanginian, Tithonian, Kimmeridgian, and Lusitanian stages. The temperature at a depth of 950 m is 19.2°. The thermal conductivity of the limestones varies from 1.91 to 3.38 W/m · deg. The geothermal gradient is 172.4 m/deg. The average value of the heat flow for the Tamisk No. 1 well is $1.62 \cdot 10^{-2}$ W/m².

The Metallurg No. 2 well is located on the southern outskirts of the city of Ordzhonikidze. It penetrated Anthropogene, Albion-Aptian, Barremian, Hauterivian, and Valanginian deposits. Thermophysical parameters were determined

for sandstones ($\lambda = 2.00\text{--}3.1 \text{ W/m} \cdot \text{deg}$), siltstones ($\lambda = 1.88\text{--}2.84 \text{ W/m} \cdot \text{deg}$), marls ($\lambda = 2.13\text{--}2.38 \text{ W/m} \cdot \text{deg}$), and limestones ($\lambda = 2.35\text{--}2.51 \text{ W/m} \cdot \text{deg}$). For the temperature-measurement interval of 20–1900 m, the geothermal gradient is 70.9 m/deg. The average value of the heat flow for the Metallurg No. 2 well is $3.46 \cdot 10^{-2} \text{ W/m}^2$.

The Baksan No. 1 well was drilled within the deep Kabardian depression. It penetrated a section of the Miopliocene, Lower Cretaceous, Upper and Middle Jurassic, and Paleozoic. Thermophysical parameters were determined for sandstones ($\lambda = 2.37\text{--}3.35 \text{ W/m} \cdot \text{deg}$), limestones ($\lambda = 2.37\text{--}3.02 \text{ W/m} \cdot \text{deg}$), dolomites ($\lambda = 3.27\text{--}4.44 \text{ W/m} \cdot \text{deg}$), and anhydrites ($\lambda = 2.84\text{--}4.34 \text{ W/m} \cdot \text{deg}$) of the Barremian, Valanginian, and Tithonian stages. For the temperature-measurement interval of 50–1300 m, the geothermal gradient is 45 m/deg. The average value of the heat flow for the Baksan No. 1 well is $7.79 \cdot 10^{-2} \text{ W/m}^2$.

Zmeyskaya Well No. 1 is located within the western termination of the Sunzha anticlinorium. The temperature at a depth of 1930 m is 65.2°. The average value of the geothermal gradient is 33.9 m/deg. Thermophysical parameters were determined for clays ($\lambda = 1.41\text{--}1.84 \text{ W/m} \cdot \text{deg}$), sandstones ($\lambda = 1.46\text{--}2.50 \text{ W/m} \cdot \text{deg}$), marls ($\lambda = 1.99 \text{ W/m} \cdot \text{deg}$), and limestones ($\lambda = 2.06\text{--}2.40 \text{ W/m} \cdot \text{deg}$) of Maeotian, Sarmatian, Foraminiferal, and Upper Cretaceous ages. The value of the heat flow in Zmeyskaya Well No. 1 is $(5.04 \pm 1.08) \cdot 10^{-2} \text{ W/m}^2$.

The Oktyabrskoye oil field is located on the southern outskirts of the city of Grozny. Tectonically, it is a brachyanticlinal fold complicating the eastern periclinal part of the Sunzha anticlinorium.

Well No. 50/25, in which the heat-flow value was determined, penetrated a section of the Sarmatian stage and the Karagan and Chokrak horizons. Thermophysical parameters were determined for sandstones, siltstones, and clays. The mean harmonic value of the thermal conductivity of the rocks for the Middle Miocene deposits is 2.31 W/m · deg. The average value of the geothermal gradient is 15.7 m/deg. The heat-flow value in Well No. 50/25 of the Oktyabrskoye field is $14.7 \cdot 10^{-2} \text{ W/m}^2$.

The Zhuravskoye uplift is located in the zone of junction of the Terek-Kuma depression with the Stavropol arch. Deposits of Meso-Cenozoic age take part in the geological structure of the Zhuravskaya area. Thermophysical parameters were determined for clays ($\lambda = 1.84$), argillites ($\lambda = 1.85\text{--}2.49$), siltstones ($\lambda = 3.02\text{--}3.64$), sandstones ($\lambda = 3.63\text{--}4.18$), and limestones ($\lambda = 1.87\text{--}2.70$), confined to deposits from the Maikop to Lower Cretaceous age. The average value of the geothermal gradient is 33.6 m/deg. The heat-flow value for the section from the Maikop suite through the Lower Cretaceous inclusive is $7.58 \cdot 10^{-2} \text{ W/m}^2$.

Veselovskaya Well No. 10 is located within the Severo-Nagutsk-Veselovsk brachyanticlinal uplift. The well penetrated a section of Quaternary, Maikop, Eocene-Paleocene, Cretaceous, and Jurassic deposits. The temperature at a depth of 3240 m is 136.5°. Thermophysical parameters were determined for

clays ($\lambda = 1.56\text{--}1.79$), siltstones and sandstones ($\lambda = 2.50\text{--}4.28$), limestones and marls ($\lambda = 1.63\text{--}2.55$), and argillites and tuffites ($\lambda = 3.47\text{--}3.68$), sampled in the depth interval 1400–3262 m and confined to deposits from Eocene to Jurassic age. The average value of the geothermal gradient is 42.9 m/deg. The heat-flow value in Veselovskaya Well No. 10 is $6.29 \cdot 10^{-2} \text{ W/m}^2$.

Petrovskaya Well No. 1 is located in the crest zone of the Petrovsk-Blagodarnensk brachyanticlinal uplift of the East Stavropol depression. Meso-Cenozoic deposits (from the Maikop to the Lower Cretaceous) take part in the geological structure of the uplift. The temperature at a depth of 2604 m is 126.1°. Thermophysical parameters were determined for clays ($\lambda = 1.51\text{--}1.54$), argillites ($\lambda \sim 3.0$), marls and limestones ($\lambda = 1.81\text{--}2.78$), and siltstones and sandstones ($\lambda = 2.98\text{--}4.06$), confined to deposits from the Maikop to Lower Cretaceous age. The average value of the geothermal gradient is 24.1 m/deg. The heat-flow value in Petrovskaya Well No. 1 is $7.17 \cdot 10^{-2} \text{ W/m}^2$.

Aleksandriyskaya reference well No. 1 is located in the northeastern part of the Terek-Kuma depression. The temperature at a depth of 2750 m is 97.1°. Thermophysical parameters were determined for clays ($\lambda = 0.84\text{--}1.74$), sandstones ($\lambda = 1.79\text{--}2.49$), and siltstones ($\lambda = 1.68\text{--}2.68$), confined to deposits from Akchagyl to Maikop age. The average value of the geothermal gradient is 35.8 m/deg. The heat-flow value in Aleksandriyskaya reference well No. 1 is $(4.07 \pm 0.58) \cdot 10^{-2} \text{ W/m}^2$.

Thus, the average value of heat flows coming from the depths varies over a wide range from $1.62 \cdot 10^{-2}$ to $14.15 \cdot 10^{-2} \text{ W/m}^2$. Oscilla-

These deviations are entirely regular and are caused by the geological structure, hydrogeological factors, the manifestation of recent tectonic movements, etc.

The highest values ($14.7 \div 14.15 \cdot 10^{-2} \text{ W/m}^2$) of heat-flow density were established from wells No. 50/25 of the Oktyabrskoye field and Karmadon No. 10. In the first case this is connected with the influence on the temperature conditions of the subsurface of hot waters entering the limits of the Oktyabrskoye oil field from the recharge area through the deep Sunzha syncline; in the second, with the high position of the roof of the Kazbek volcanic center.

Low values of heat-flow density in the Tamisk No. 1 well ($1.62 \cdot 10^{-2} \text{ W/m}^2$) and Metallurg No. 2 ($3.45 \cdot 10^{-2} \text{ W/m}^2$) are due to the cooling influence of cold water masses infiltrating into the Upper Jurassic and Lower Cretaceous deposits, which are widely exposed at the surface in these areas.

For wells in some regions of the Greater Caucasus and Ciscaucasia we have analytically taken into account the influence on the magnitude of heat-flow density of the filtration of cold (or hot) waters through beds, of the relief of the locality, of the form of occurrence of the rocks, and of changes in climatic conditions that took place in Quaternary time. After introducing the corresponding corrections for each of the above-mentioned wells, the following values of heat-flow densities were obtained: for the Karmadon No. 10 well, $14.18 \cdot 10^{-2} \text{ W/m}^2$; for the Tamisk

No. 1 well, $7.16 \cdot 10^{-2}$ W/m²; for the Metallurg No. 2 well, $7.93 \cdot 10^{-2}$ W/m²; for the Baksan No. 1 well, $(8.57 \pm 0.51) \cdot 10^{-2}$ W/m²; for the Zmeiskaya No. 1 well, $(5.04 \pm 1.08) \cdot 10^{-2}$ W/m²; for well No. 50/25 of the Oktyabrskoye oil field, $(8.13 \pm 0.37) \cdot 10^{-2}$ W/m²; for the Zhuravskoye uplift, $(7.80 \pm 0.67) \cdot 10^{-2}$ W/m²; for the Veselovskaya No. 10 well, $(6.83 \pm 0.31) \cdot 10^{-2}$ W/m²; for the Petrovskaya No. 1 well, $(7.17 \pm 0.72) \cdot 10^{-2}$ W/m²; for the Aleksandriyskaya reference well, $(4.07 \pm 0.58) \cdot 10^{-2}$ W/m².

The influence of local relief, water filtration through beds, and the form of occurrence of rocks with different thermal conductivity will be studied more precisely by the authors in the future by means of electrical modeling.

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Note: Figure translations are in progress. See original paper for figures.

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