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SOME PROPERTIES OF DEEP CRYSTALLINE ROCKS FROM DEEP AND SUPERDEEP BOREHOLES (SG-3, KTB, SG-4 AND ODB)

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One of the goals of the programmes for deep scientific drilling is to construct a standard model of properties and state of the upper and middle earth crystalline crust. The most complete results were obtained when investigating the core and sections of the Kola (SG-3), German (KTB), Ural (SG-4) and Finnish ODB deep and superdeep boreholes. No marked depth dependence of the rock volume density and seismic wave velocity was observed in the SG-3 and SG-4 sections. Deep metamorphosed rocks are, as a rule, elastic anisotropic.

The Russian scientific programme for the study of the Earth's interior included drilling deep and superdeep boreholes both in sedimentary and in crystalline rocks. [Kola Superdeep, 1984]. Among the programmes aimed at the study of the properties and state of the earth crystalline crust the most interesting results were obtained when drilling the Kola (12261 m), Ural (~6010 m) Saatly (8267 m), Krivoi Rog (3600 M) etc. boreholes [1]. Among foreign scientific projects also aimed at the study of the crystalline crust, Gravberg-1 (Sweden) and KTB (Germany) are best known. Gravberg-1 superdeep borehole drilled in the Silyan astrobleme in southern Sweden reached a depth of 6.6 km and was terminated due to technical reasons [2]. The German superdeep borehole KTB located at the town of Windischeschenbach, Bavaria, reached a depth of 9.1 km [3]. Not long ago the ODB research drill hole was drilled near the Outokumpu polymetallic deposit in Finland [4]. It reached a depth of 2516 m. Until now the Kola Superdeep Borehole (SG-3) has been the world deepest.

The core and sections of the Kola SG-3, Ural SG-4, German KTB and Finnish ODB bore holes were most extensively studied by us. An analysis of the structural-textural peculiarities of the rocks composing crystalline massifs cut by these boreholes pointed to the existence of two specific blocks in their geological-geophysical sections [5]. One of them contains mainly homogeneous, as a rule, volcanic metamorphosed rocks united by one or several close formation stages. Isotropic and weakly anisotropic rocks prevail in this block. Within the second block one can observe the consequences of intensive deformation, a high degree of re-crystallization and anisotropy of rocks and their interbedding. Crystalline schistose structures prevail. They are typical of deeply deformed and metamorphosed sedimentary, volcanic and igneous rocks that have been subjected to dislocation metamorphism under unequal pressure (strain). Such structures are typical of the SG-3 and SG-4 lower sections and virtually for the entire sections of the KTB and ODB boreholes.

As follows from the obtained vertical velocity sections of the crystalline massifs, the difference in the velocity characteristics determined by the vertical seismic profiling (VSP) and sonic logging methods and by simulating the massif's PT-conditions is minor [6, 7]. Virtually no depth dependence of the velocities measured by these methods was observed. The velocity of compression waves is in the 4.5-6.4 km/s range, that of shear waves – in the 2.5-3.7 km/s range. The calculation method for determining compression and shear wave velocities by mineral composition allows obtaining, at least down to the 15-20 km depths, the results close, on the average, to the real massif. The rocks density is mainly determined by their mineral composition.

As follows from the analysis of petrophysical determinations, compression wave velocities are more sensitive to the changes in the rock composition than shear waves. Accordingly, compression waves can be more useful for distinguishing boundaries between rocks with different composition, between faults and between decompaction zones filled, for instance, with fluids. At the same time, the use of shear waves, especially the VSP polarization method, is rather efficient for distinguishing highly anisotropic areas in the massif under study.

A new result of the investigations is revealing highly anisotropic rocks in the sections of SG-3, SG-4, KTB and ODB [5, 6, 8, 9]. For instance, in the massifs of SG-3 and KTB such rocks prevail in the stripped sections. The characteristics of the rock velocity anisotropy are great and essentially exceed the value at which this property can be neglected [10].

Among the rocks with marked and substantial anisotropy rhombic elastic symmetry dominates. This suggests the rock formation under geostatic and tectonic stresses. The direction of the stress tectonic component, as a rule, is close to subhorizontal. A close relation between the values of the rock elastic anisotropy and the borehole lateral dimension was found within the zone of cavern formation.

The presence of velocity anisotropy as well as a complex structure of rocks composing crystalline metamorphic units greatly hampers the interpretation of the seismic results obtained at the surface.

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