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Abstract**Full Text**

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GEOFYSICS

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HELIUM IN GROUNDWATER ON A DEEP SEISMIC SOUNDING PROFILE IN THE TRANS-URALS*(Presented by Academician A. N. Tikhonov on 21 January 1970)*

1. Helium is generated in the Earth through α -decay in the uranium and thorium series. According to A. P. Vinogradov ⁽¹⁾, at present the rate of formation of radiogenic He is 4550 tons/year, and the amount of He formed over the geological history of the Earth, 4.5 billion years, is $3.1 \cdot 10^{13}$ tons, which is equivalent to approximately 0.62% of the mass of the present atmosphere. Somewhat more than half of the He is formed in the Earth' s crust; the rest is formed in the mantle and core. Depending on assumptions about the distribution of uranium and thorium in the deep layers of the Earth and about the ratio between the masses of granites and basalts in the Earth' s crust, the calculated rate of formation of He is found to vary within one order of magnitude ⁽²⁾.

If we assume that the leakage of He into the atmosphere and space is small compared with the rate of its generation, then the He content in the Earth' s crust will be $0.43 \cdot 10^{-6}$ g/g of rock. In practice, taking into account the approximate nature of the calculation, this value coincides with the abundance of He in the atmosphere, $0.7 \cdot 10^{-6}$ g/g of air. Accordingly, the volumetric concentration of He in the Earth' s crust is $1.4 \cdot 10^3$ times higher. This difference in concentrations ultimately determines the directed migration of He from the Earth' s crust into the atmosphere.

2. Being a highly mobile component, He is released from the solid phase into micro- and macropores, forming a constituent part of natural gases and of gases dissolved in groundwater. Subsequent migration of helium occurs, in particular, together with groundwater. It is natural to suppose that tectonic rupture disturbances, especially deep faults, are those zones along which increased transport of He from deep horizons takes place. One of the known examples of such transport is the high helium content of springs near Lake Tanganyika in Africa, formed in the zone of the largest fault of the Earth' s crust ⁽²⁾. In addition, the high fracturing and additional mineralization of rocks that fill fault cavities may increase the specific

Fig. 1

Figure 1: Fig. 1

release of He into the pore space. For example, increased emanation of radon makes it possible in a number of cases to map tectonic fractures that approach the daytime surface. However, this method is not a deep one because of the short lifetime of radon.

To test the assumption of a connection between elevated concentrations and faults, a section of the DSS profile about 110 km long was selected in the Trans-Urals.

3. Water samples were taken mainly from pumped wells at depths of 80–100 m. A gas volume of 20 cm³ was extracted from the sample by a vacuum method; in this gas the He concentration was determined with a PTI-6 helium leak detector.

On the profile section (Fig. 1), deep faults of the Earth's crust were identified by the DSS method; some of them have roots below the Conrad discontinuity and reach the surface of the basement, crossing the intermediate (dioritic) and granitic layers (3). Parts of the faults correspond to a local increase in the magnetic field. The profile section passes through the junction zone of the East Ural trough and the Trans-Ural uplift.

In the eastern part of the profile there is a cover of Meso-Cenozoic deposits, reaching a thickness of 300–400 m.

The helium survey revealed a sharp change in the He content. Against a background of low values of 0.5–2.0 · 10⁻³ vol. %, anomalous contents of up to (20–30)10⁻³% stand out, corresponding to deep faults. At the same time, higher helium anomalies are associated with faults having a greater depth of occurrence (below the Conrad surface). Anomalies of He content in the aquifer of Paleogene and Upper Cretaceous deposits indicate ruptural disturbances in the Mesozoic rocks, representing a manifestation of the development of deep faults (4). The complexity of the structure of the faults themselves and of the broad zones of disjunctive dislocations of platform formations may lead to displacement of concentration peaks relative to the fault line established from seismic data (5). Apparently, this also explains the westward displacement of anomalous peak 5. A helium anomaly of medium intensity 3 correlates with a peak of the magnetic field, but is also displaced westward of the fault.

Fig. 1. 1 –observed values of helium concentration, **2** –values of the vertical component of the magnetic field ΔZ , **3** –diffraction points according to DSS, **4** –Meso-Cenozoic sediments of the Trans-Urals, **5** –zones of tectonic disturbances in the Earth's crust according to seismic data. d_0^M –Mohorovičić boundary, d_4^K –Conrad boundary, d_3^K –base of the granite-gneiss complex. *a* –East Ural trough, *b* –Trans-Ural uplift.

Determination of the concentration of He in groundwater makes it possible to identify and trace deep faults as pathways of intensive He migration to the Earth's surface and provides an economical method of regional geophysical investigations.

It should be noted that in the water samples there was no correlation between the content of He and of radioactive elements.

4. Along with He, Ar is produced in the Earth's crust through electron capture by K^{40} . If, as an approximation, the average potassium content in the Earth's crust is taken to be 2%, then the rate of argon formation is about 4400 tons/year, which is roughly twice the annual generation of He. The preservation of argon in minerals, as shown by the potassium-argon method of determining absolute age, is somewhat higher than that of He. However, argon is present in natural gases in weight concentrations comparable to He⁽²⁾. Therefore the study of the distribution of argon in groundwaters may also provide information on rupture tectonics. The range of increase in potassium content from ultrabasic rocks to acid rocks is at least an order of magnitude smaller than that for the radioactive elements that are sources of He⁽⁶⁾. Therefore, combining helium and argon surveys may provide additional information on tectonic structures and on the composition of rocks through which groundwater movement occurs.

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