MODELS OF FUNCTIONING OF SEISMIC NAILS

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The signs and properties of “seismic nails” are considered, which are subvertical accumulations of earthquake hypocenters located at depths of 20–80 km with an epicentral projection 5–10 km in diameter and an anomalously short time (1–4 weeks) of formation.

In a number of publications, the main reason for such structures was the deep degassing of light gases (hydrogen, helium) in the form of emerging mantle plumes. Leaving aside questions about the geochemical influence of mantle fluids on the Earth’s interior, let us list the main geophysical facts.

1. The main feature of hydrogen dissolved in the minerals of the upper mantle is its anomalously high mobility.

2. Heated hydrogen is an effective coolant - when it moves in a continuous medium, the diffusion channels become very hot.

3. Hydrogen in the medium reduces the surface energy, so these diffusion-thermal channels become analogous to slip areas (microcracks), which can grow into long macrocracks.

4. Amorphous (saturated with hydrogen) medium has 30-50 % lower values of Young’s moduli and shear, but higher density.

This list shows that it is hardly possible to create a quantitative model that adequately describes the properties of seismic nails at the micro- and macrolevels.

However, models that describe seismic nails and a number of their properties 1–4 at a qualitative macrolevel can be proposed based on the analogy of mass and heat transfer processes. Taking into account the anomalously fast formation of seismic nails, we consider the process of dimensionless temperature propagation in the blow-up regime based on a quasi-linear parabolic equation with a source.

With the help of a space-time change of coordinates and temperature, this equation is reduced to an elliptic equation, the solution of which in the earth’s interior describes thermal spiral waves on the surface of a long and thin cone - the outer boundary of a seismic nail.

As confirmation of the adequacy of this thermal model, we consider two related macromodels from the theory of a deformable solid body and hydrodynamics.

The first model is substantiated in the dissertation of O.P. Bushmanova, where an approach was developed to solve a plane problem under conditions of shear localization in the form of a system of spirals near a horizontal working. This approach allows one to describe the intermediate state of the medium: between elasticity (absence of slip lines) and plasticity (slip lines are close). In vertical mining, the helical slip lines along a cylindrical surface will not be flat.

The hydrodynamic model of the operation of seismic nails is based on a generalization of the previous model and item 4 of the properties: amorphization of the medium by hydrogen occurs with a decrease in volume, i.e. between the outer boundary of the seismic nail and the enclosing geophysical medium, an interlayer in the form of a quasi-cylindrical macrocrack should appear, along which mantle hydrogen rises in the form of a circulating Gromeko-Beltrami flow or an axisymmetric flow with swirl according to J. Batchelor.