

Taking account of a given surface relief and sphericity in numerical modeling of Earth's crust deformation

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Numerical calculation of stresses and strains in geological media is conventionally performed on the basis of continuum mechanics methods. However, the solution of geomechanical problems raises a number of specific issues related to the large size of the studied regions and to the lack of information about the properties of the medium and deformation conditions. Another open issue is the influence of sphericity and the necessity of taking it into account when considering deformation processes in regions of different length and depth. The first issue is associated with a significant contribution of gravitational forces to the stress state. Consequently, the initial state for considering processes is the stress state caused by the action of gravity, and its calculation is the first stage of solving the problem. As a result of this calculation with the use of conventional algorithms, we obtain the stress distribution in a deformed medium with a distorted relief that does not correspond to the originally specified one. It is easy to estimate that with a model thickness of tens of kilometers the geometric distortions will be significant even in the elastic state; and in the case of plastic deformation, distortions can be much larger. Therefore there arises a tangible need to calculate the stress state corresponding to a given relief of, for example, a mountain system.

The present paper proposes an algorithm for calculating the stress state of the Earth's crust region under gravity conditions with maintaining the specified relief pattern and geometry of heterogeneities. The developed algorithm was tested for the elastic and elastoplastic behavior of the medium.

As an example, we consider the stress-strain state of a three-layer block model of the Earth's crust and upper mantle along the Tarim–Altai profile with a length of 2500 km and a depth of 90 km. The calculation results have shown that the relief remained unchanged after the initial stress state caused by the action of gravity was calculated using the developed algorithm. The second stage of the calculation explored the effect of tectonic compression on changes in the stress-strain state, the growth of mountain systems, and the Moho boundary shape. The solutions obtained with taking into account sphericity and for a rectangular region were compared. It was shown that taking account of sphericity strongly affects the stress-strain state.

Modeling of deformation processes was performed under plane strain conditions. A system of equations of the dynamics of an elastoplastic medium was solved. Deformation beyond the yield point was described within the modified Drucker–Prager–Nikolaevsky model.

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