

Simulation of quasi-static and dynamic deformation processes in the zones of volcanic activity

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Résumé:

L'étude concerne les processus de déformation quasi-statique et dynamique dans les zones d'activité volcanique, en utilisant à cet effet les méthodes de simulation mathématique. La formulation mathématique du problème est basée sur le principe de déplacements virtuels, et la résolution numérique de l'équation variationnelle est basée sur une méthode aux éléments finis. Les possibilités d'enregistrement de la pression dans la chambre de magma au moyen de mesures de déformation de la croûte terrestre ont été trouvées. Les correspondances avec les vibrogrammes ont été obtenues pour identifier les points de possible localisation des capteurs.

Abstract :

The paper investigates the quasi-static and dynamic deformation processes in the zones of volcanic activity using for this purpose the methods of mathematical simulation. The mathematical formulation of the problem is based on the principle of virtual displacements, and numerical realization of the variational equation is based on the finite-element method. The possibilities of pressure recording in the magma chamber by means of measuring deformations at the outer Earth's crust have been found. The vibrogram relationships have been obtained to identify the points of possible sensor location.

Mots clefs : seismic waves, hydrostatic pressure in the volcanic chamber, elasticity theory, vibrograms, principle of virtual displacements, finite element method, Fourier analysis, wavelet analysis

Investigation of quasi-static and dynamic deformation processes in the earth crust is one of the main directions in studying the volcanic activity. The most widespread approach to this problem is based on the methods of registration and analysis of seismic waves [1 – 3] caused by the volcanic activity. Despite the fact that this is a very important stage of investigation it is generally realized in the state of high eruptive activity. However, the problem of no less importance is the investigation of foregoing processes of quasi static deformation. One of the key factors determining the quasi-static state of the volcanic system is the hydrostatic pressure in the volcanic chamber [4, 5]. The significance of studying the quasi-static state is related to the possibility of using the results of its simulation for prediction of dynamic processes occurring in the volcanic systems.

This paper is concerned with studying the quasi-static and dynamic deformation processes in the zones of eruptive activity by the methods of mathematical simulation. The mathematical simulation of the deformation processes is carried out in the framework of the elasticity theory. The mathematical formulation of the problem is based on the principle of virtual displacements. The variational equation is solved numerically by the finite element method, which in the quasi-static case leads to the finite-dimensional system of algebraic equations and in the dynamic case – to the finite-dimensional system of ordinary differential equations with respect to the time co-ordinate.

The geometrical model of the investigated volcanic system takes into account its basic elements: the structure of a volcano, the magma chamber and the volcanic conduit. These elements are assumed to have typical characteristic dimensions, axi-symmetrical shapes and elastic properties of the rock material.

The analysis of the results obtained from the solution of the quasi-static problem showed that evolution of the pressure in the magma chamber could be recorded by measuring the deformation characteristics at the outer Earth's crust. This analysis was based on the deformation measurements to the accuracy of 10^{-6} and pressure measurements to the accuracy of 10atm. The numerical experiment allowed us to determine the range of variation of rock hardness and the depth of location of the magma chamber.

The main objective of the numerical simulation of the deformation processes is to investigate the relationships describing time variation of the components of the displacement vector (vibrograms) at the points of possible location of seismic sensors. In this research, much emphasis was placed on studying the response of the vibrograms to the type of dynamic disturbances in the magma chamber and in the volcano's conduit.

The developed mathematical model and its numerical realization allows us

- to simulate effectively the quasi-static and wave processes occurring in the volcanic structure-magma chamber-volcanic conduit system;
- to analyze the wave spectral properties, especially at the wave fronts, using the Fourier analysis in combination with the wavelet analysis;
- to obtain the relation characterizing the influence of the type of force impulses on the form of vibrograms obtained at points of possible sensor location;
- to compare the calculated vibrograms with the experimental ones and to carry out their correlative analysis.

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