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The peculiarities of cross-correlation between two secondary precursors — Radon and magnetic field variations, induced by stress transfer changes

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HIGHLIGHTS

- Magnetic field and radon concentrations were measured on Antarctica Peninsula.
- A positive correlation between radon concentration and magnetic field is observed.
- Good agreement with Dobrovolsky stress transfer change model is found.

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ABSTRACT

A model of precursor manifestation mechanisms, stimulated by tectonic activity and some peculiarities of observer strategy, whose main task is the effective measurement of precursors in the spatial area of their occurrence on the Earth's daylight, are considered. In particular, the applicability of Dobrovolsky's approximation is analyzed, when an unperturbed medium (characterized by the simple shear state) and the area of tectonic activity (local inhomogeneity caused by the change only of shear modulus) are linearly elastic, and perturbation, in particular, surface displacement is calculated as a difference of the solutions of two independent static problems of the theory of elasticity with the same boundary condition on the surface. Within the framework of this approximation a formula for the spatial distribution (of first component) of magnetic field variations caused by piezomagnetic effect in the case of perturbed regular medium, which is in simple shear state is derived. Cogent arguments in favor of linear dependence between the radon spatial distribution and conditional deformation are obtained.

Changes in magnetic field strength and radon concentrations were measured along a tectonomagnetic profile of the total length of 11 km in the surroundings of the "Academician Vernadsky" Station on the Antarctic Peninsula (W 64°16′, S 65°15′). Results showed a positive correlation between the annual surface radon concentration and annual changes of magnetic field relative to a base point, and also the good coincidence with theoretical calculation.

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1. Introduction

The information about the concentration of radon isotopes and radon daughters in the air and soil is actively used all over the world for geophysical purposes (Åkerblom and Mellander, 1997; Hakl et al., 1997; Fleischer, 1997; Monnin and Seidel, 1997; Khan et al., 1997; Balcázar, 1997; Guerra and Lombardi, 2000; Zmazek et al., 2003; Kharatain et al., 2002; Majumdar, 2004). Monitoring the tectonic activity of the Earth's crust is performed on the basis of several geophysical and chemical methods, including determination of the radon concentration in soil gas and in underground water (e.g. Monnin and Seidel, 1991). The applicability of radon is based on the fact that the high temperature of aquifers or geothermal water sources, which are neighbors of natural breaks, promotes the transport of radon upward along existing and/or forming breaks (Segovia, 1991; Singh et al., 1991; Durrani and Ilić, 1997). Measurement of the radon concentration is widely used in seismic testing areas to study active tectonic breaks and earthquake precursors. It is considered that radon is removed by underground waters from cracks in the Earth's crust just made in deformation processes. The close correlation of changes of radon concentration with time in underground waters with movements of the Earth's crust before earthquakes is evidence of that. According to an analogous mechanism, the zones of active tectonic breaks are characterized by anomalous radon concentration.

Study of the tectonic activity in the region of the location of the "Academician Vernadsky" Antarctic station (W 64°16′, S 65°15′) is important because large and deep breaks were revealed near the station. Furthermore the recent eruptive activity on Deception Island and neovolcanic zone along of Bransfield Strait show the high geodynamic activity on the North of our region (Smellie, 1988). The distance between the southern earthquakes in Bransfield Strait rift propagation and Vernadsky station is about 230 km.

Present geodynamic and seismic tectonic processes, in particular in break zones, lead to changes of mechanical, electrical, magnetic and other properties of rocks. The physical mechanisms of their influence on the variation of magnetic field are due to piezomagnetism and electrokinetic effects. As a result, the temporary changes of geomagnetic field occur with the periods from a few weeks to several years, and the amplitudes from 1 to several tens of nT. These geomagnetic field variations due to the piezomagnetic effect, which are produced by tectonomagnetic anomalies, are the indicators of active geodynamic processes (current movements of the Earth's crust, earthquakes, vulcanization, etc.). They can be revealed by repeated and precise magnetic measurements (Skovorodkin, 1985).

The present work has a twofold aim. First, it is a long-term study of local temporary changes of geomagnetic fields caused by different physical and chemical processes in the Earth's crust. Secondly, it is a search for a correlation between the radon concentration, which reflects the tectonic activity of the Earth's crust, and temporary changes of the abnormal magnetic field. Our results obtained so far are summarized in the present paper.

2. Theory

It is well known that the tectonic processes due to regular deformation of the Earth crust are the main cause of existent background deformation field.

We consider that unperturbed medium is at background deformation field, which is supported by corresponding (regional) tectonic processes. We also consider that there is the volume V of tectonic activity, in other words, non-regular deformation volume inside a large unperturbed medium limited by the surface $S = S_0 + S_1$ (Fig. 1). This local volume has changed properties

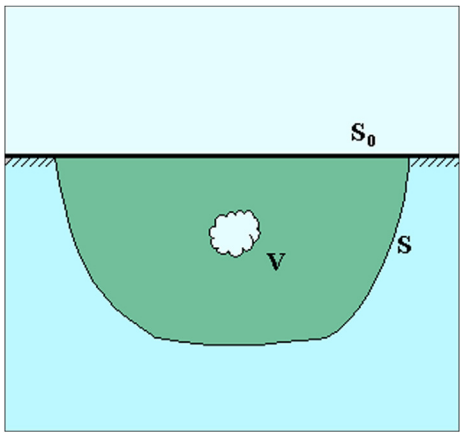

Fig. 1. The tectonic activity area V in medium.

(heterogeneity), which causes the corresponding perturbations of different geophysical fields in the Earth crust. Traditionally we call such perturbations "precursors". The main, or more exactly, primary precursor of tectonic activity is a so-called mechanical precursor, i.e. medium deformation, exceeding background deformation. All the other precursors including those discussed in this paper – anomalies of radon concentration and magnetic variations – are the secondary with respect to Earth crust deformations.

A model describing mechanisms of precursor manifestations stimulated by tectonic activity and some peculiarities of observation strategy for effective precursor measurements in spatial zone of their manifestation on the daylight of the Earth is presented below.

2.1. The distributions of deformations and radon concentrations along the Earth day surface

We define a zone of precursor activity manifestation as a part of daylight, which contains the epicenter of tectonic stress and is limited by a line where precursor perturbations are of the same magnitude as the background variations. Taking into account this definition let us consider the construction of deformation distribution on daylight for a typical case of tectonic activity. Note that the main idea of such problem solution (excluding some modification of process phenomenology) is completely based on Dobrovolsky theory of seismic focus evolution (Dobrovolsky, 1984).

As it is stated above, the Earth crust moves with approximately constant (on regional scale) strain rate, which maintains a constant (in mentioned sense) level of shearing stress against a background of almost hydrostatic stress field due to gravitation.

A viscous-elastic medium is the simplest model of continuous medium, which reflects the stated properties. However the high effective viscosity of the Earth core (which is 10^{20}–10^{22} Pa/s according to different estimates), relatively short duration of investigated processes (1–10 years) and necessity to study the difference of states rather than the characteristics of absolute state make it possible to introduce the following simplification. We consider an approximation, when the unperturbed medium and the volume of tectonic activity (local heterogeneity) are linearly elastic and the perturbation is calculated as the difference of the solutions of two separate static problems of theory of elasticity with the same boundary conditions on surface (Fig. 1). Equal boundary conditions stipulated by the fact that the energy of tectonic processes considerably exceeds the increment of the energy due to the formation of the area of increased tectonic activity and therefore the