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Spatial selectivity of earthquake's precursors

I.I. Rokityansky *

Institute of geophysics, National Academy of Sciences of Ukraine, POB-70, Kiev-146, 03146, Ukraine

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Abstract

Multiparameter monitoring of earthquake's (EQ) precursors reveals their selective localization (selectivity), i.e. a precursor can be observable in relatively small selected sensitive area(s) and not observable over remaining vast region. Selectivity and long distance appearance of precursors are rather strange and difficult for explanation, if the Earth is considered as uniform or horizontally layered, but quite natural for the real Earth, which is saturated by inhomogeneities and channels of different scale and nature. Three kinds of channels are proposed for explanation of selectivity: electrically conductive path (for electrical precursors), hydraulic channel and magma intrusion in the stage of emplacement.

Keywords: Earthquake's precursor; Spatial selectivity; Channeling; Conductivity structure; Magma emplacement

1. Introduction

Posteriori analysis shows that any strong earthquake (EQ) is preceded by a variety of precursors. They are: volatile outcome, level and composition of ground water, variations of electric and magnetic fields, EM-emission, atmosphere luminosity, variations of ionosphere parameters, etc. (Hayakawa and Fujinawa, 1994; Hayakawa, 1999).

In the early 80's P. Varotsos, K. Alexopoulos and K. Nomicos (VAN) discovered in Greece a new EQ precursor which they named seismic electric signal (SES) (Varotsos et al., 1981). Continuous SES observation with 12–18 stations in Greece during 24 years reveals that every SES is followed by moderate or strong EQ. It should be noted that SES appears not everywhere around future EQ, but only in some selected sensitive areas; this property was named selectivity effect. Other types of precursors also exhibit in many cases this feature: selectivity and long distance appearance.

Stress accumulation in the focal zone of impending earthquake is traditionally considered as primary cause of precursory phenomena. Theoretical estimations of a precursor "propagation" in the uniform or horizontally layered (1D) Earth (Bernard, 1992) predict strong monotonous spatial attenuation of the precursor amplitude, and, at the distance (from the source) of the order of few source lengths, precursor should become not observable (below noise level). Such a result contradicts to the observed data, in which spatial change of a precursor is strongly non-monotonous. It leads to a supposition that the real Earth *is strongly non-uniform and it contains channels*, which allow long distance transport of a precursor and create the selectivity effect. This consideration is valid in the framework of traditional paradigm: the source of a precursor is located in the focal volume of the related EQ. Observational data validate also the extended paradigm: precursory phenomena are formed in an area much larger than the source of the subsequent EQ (Keilis-Borok et al., 1999). This approach opens new possibilities for explanation of precursor properties, and one of them will be used below (magma channel).

At least three kinds of channeling can be proposed for the explanation of the SES selectivity effect: conductive,

* Fax: +38044 450 2520.
E-mail address: rokityansky@yahoo.com

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hydraulic and magma channels. We will consider them in the following.

2. Electric conductive channel

For the explanation of the selectivity effect, Varotsos and Alexopoulos (1986) suggested the following model: the earthquake preparation zone lies in the vicinity of a long conductor. When the SES is emitted, the current follows the conductive channel through which most of the current travels. Thus, if the emitting current dipole source lies close to a highly conductive channel and the measuring station lies at a site close to the upper end of this channel, the electric field is appreciably stronger than in the case of a homogeneous or horizontally layered earth. Recently the VAN group published computational results, which yield quantitative estimation of electromagnetic precursor behavior for conductive channels of different configuration (Varotsos et al., 2000a,b). The effect of electric field local enhancement is sufficiently strong to explain observed SES peculiarities. To check the plausibility of this explanation, an independent study of conductive channels should be performed.

Such a study is available by using magnetotelluric sounding (MTS) and especially magnetovariational profiling (MVP) methods. The electrical conductivity anomalies, detected by MVP method, are in many cases conductive channels, i.e. long narrow conductors, composed of mineralized water solutions in fractured zones, or of electronically conducting minerals, or melt/magma formations. Having before 1990 preferably long period ($T > 10$ s) instruments, MVP method detected large scale (channels hundreds km long) anomalies (Rokityansky, 1982). In the last decade, magnetotelluric instruments allow us to register short period variations ($T > 0.001$ s) and many local scale conductivity anomalies appeared on the records. Unfortunately, this fact does not have yet wide recognition and adequate geological evaluation. One example of conductive channels detection is the detailed MTS-MVP study of the SES sensitive Ioannina area in Greece (Eftaxias et al., 2002).

In MTS-MVP methods, the source of the field is located in the ionosphere. Looking for an analog with SES propagation from focal volume, let us consider the experiment "Khibiny" with strong man made MHD-source (Velikhov, 1989; Rokityansky and Zhamaletdinov, 2004). A current up to 20,000 A was injected via a special electrode system into sea water at two sides of the narrow (7 km) isthmus of peninsula Rybachy at the northern tip of the large Cola Peninsula in the north-western part of Baltic shield (Fig. 1). Current loops in the sea and leakage currents into the lithosphere create electromagnetic fields, which were measured in more than hundred sites at the distance up to 700 km from the source. In the area of investigation, two regional conductivity anomalies were known as outcrops of ore containing minerals with electronic conductivity. The first one, Imandra Varzuga runs to the East, the second one, Pechenga, runs to the West. The latter one was crossed by 4

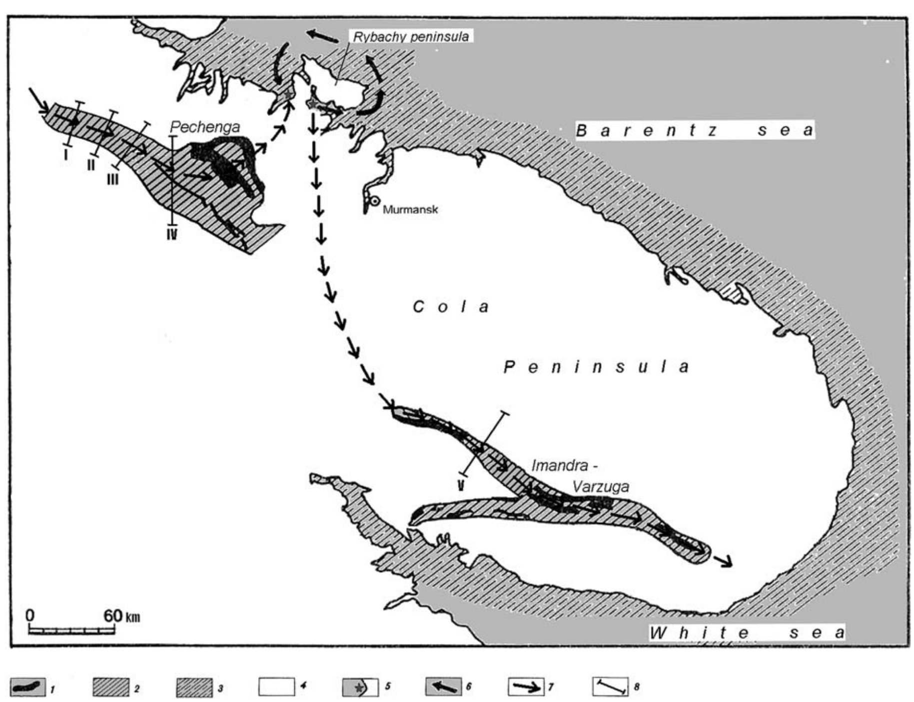

Fig. 1. Channeling of the currents generated by MHD source into conductive zones Pechenga and Imandra-Varsuga in Cola peninsula, north-eastern part of Baltic shield. 1 – outcrops of electronic conductors, 2 – good conducting formations, 3 – sea water, 4 – resistive blocks, 5 – electrodes in sea connected to impulsive MHD source, 6 – currents in sea, 7 – currents channeling in land, 8 – profiles of EM measurements in the western part of Pechenga structure (composed by data (Velikhov, 1989) and (Rokityansky and Zhamaletdinov, 2004)).