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Properties of seismo-electric variations induced by microcracks in the nucleation stage of earthquake occurrence

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Characteristics of dominant three phases (P_f, S, EM) of seismoelectrical waves have been investigated using waveform which are suggested to be induced by microcrack in the nucleation stage of the 2011 Tohoku Earthquake (Fujinawa *et al*., 2013). Twelve B-type events having clear P, S phases and apparent EM phase with dominant frequency 500 Hz have been selected from the catalog of B type events. Slight traces of EM phases are searched at around the origin time. We estimated focal distances of those events using S-P time assuming the P and S wave velocity, which are corrected on the basis of arrival time of the identified EM phase. The corrected velocities are well in agreement of the measured logging data at the borehole. The accumulated number of events is found to follow the Gutenberg- Richter relation with the b ?value equal 0.7, indicating that the B-type events are of natural micro-earthquake. We can conclude that the seismoelectric mode of the SES related with natural earthquake can be observed by using high sensitive sensor.

The electric strength of fast- P, S, and EM modes of the shear tensile type events are compared with each other. Averages of observed amplitude order as As >Apf >Aem, which is partly different from those of previous numerical simulations (*e.g*., Gao and Hu, 2010). Those amplitudes are analytically estimated on the basis of the seismo-electromagnetic formulation of Pride (1994) assuming the isotropic homogeneous medium filled with confined solvent. The force field is the double couple model of Gao and Hu (2010) in consistent with the hypothesis that the source is microcrack. The typical value for physical parameters of elastic material, solvent and the streaming coefficient for seismic frequency result in the ordering Apf >As >Aem, a little bit different from the observational result. The contradictory relation between the observed result and numerical simulation may be attributed to the assumed whole space model other than the half space model.

Overall agreement between the observed and estimated results suggest that, 1) pulse-like events of B-type detected before the Tohoku Earthquake are induced by rupture of microcrack in the nucleation period of main shock, 2) observed phases of waveform (P_f, S, and EM) are corresponding to co-seismic Pf, S and free electromagnetic wave in the unified formulation, 3) the SES phenomena in the field can be analyzed by the formation.

Precursory phenomena of earthquake have been investigated by analyzing seismic activity, crustal deformation, groundwater anomalies, and electromagnetic anomalies. Present finding of the overall agreement of the observation and estimation on suggests that those multiple kind of phenomena can be discussed by means of the Pride's formation of on the basis of concept that those phenomena are induced by variety of the cracks taking place in the nucleation period. We have already impressive observation of magnetic ULF band anomalies (Han, 2012) occurred simultaneously with the slow slip at deep plate boundary by means of high sensitive seismometer (Ozawa et al., 2003). Many of observational electric anomalies (Hayakawa and Fujinawa, 1994) can be more satisfactory interpreted on the basis of the unified scheme. Multidisciplinary approach on the basis of the unified theory is expected to open new window for practical earthquake prediction methods as well as for geophysical survey. For instance we can investigate the fluid motion associated with fracture in a porous medium as conducted in the laboratory (Haas *et al*., 2013).

Keywords: seismo-electromagnetics, short-term forecasting, micro-crack, porous medium, Electrical properties, Acoustic property