Evaluation of coseismic EM signals due to the piezoelectricity of crustal rocks: A case study related to a finite fault motion

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Assuming a fault motion with a realistic finite size in a conducting, elastic and piezoelectric uniform half space, electromagnetic (EM) signals due to the piezoelectricity of crustal rocks, expected around the fault were evaluated. A numerical code evaluating the signals was constructed on the basis of both the time-evolving stress field for calculation of the EM source, and Green's functions of EM fields. By substituting realistic parameters, EM signals solved on the ground surface showed that, if the magnitude of the piezoelectric coefficients is 7% of that of quartz single crystals, comparing the results with observations associated with the 1995 Hyogo-ken Nanbu earthquake, the amplitude of expected electric signals can be of the same order of magnitude as those of observed ones.

Since piezoelectricity is a property that a substance shows electrical polarization due to mechanical stimulation, derived from the anisotropy of the substance, if crustal rocks are piezoelectric, generation of coseismic electromagnetic signals due to the piezoelectricity is expectable.

Based on the experimental facts that some kinds of quartz-rich rocks show bulk piezoelectricity, coseismic piezoelectric electromagnetic signals, if detectable by geoelectromagnetic field observations, would inform us the crustal anisotropy.

In this study, assuming a vertical unilateral strike slip with a realistic finite size in a conducting, elastic and piezoelectric uniform half space, electromagnetic signals due to the fault motion, expected around the fault were evaluated. A numerical code evaluating expected electromagnetic signals was constructed on the basis of both the finite-difference time-domain method to obtain the time-evolving stress field for calculation of the electromagnetic source, and Green's functions of electromagnetic fields in a uniform half space. By substituting realistic parameters, electromagnetic signals expected on the ground surface numerically showed that (1) Radiation patterns of signals reflect the direction of the symmetry axes of the anisotropy of the space that causes the piezoelectricity. (2) Smaller attenuation of signals with increasing distance from the focal area, compared with the solutions in a uniform whole space was found, indicating that the presence of the ground surface intensifies the signals at a distant point. (3) The finite size of the fault can cause asymmetric distribution of the signals in the space, due to propagation of rupture and therefore the electromagnetic source. (4) Comparing the modeling results with observations associated with the 1995 Hyogo-ken Nanbu earthquake, the amplitude of expected electric signals can be of the same order of magnitude as those of observed ones, if the magnitude of the piezoelectric coefficients is 7% of that of quartz single crystals, which is the largest value experimentally known for quartz-rich rocks. Under the condition, the electric signals of a few tens of mV/km could be expected in a region with a radius of a fault length from the epicenter. Therefore, it is possible to ascribe the generation mechanism of observed electric field changes associated with the earthquake to the piezoelectricity of the focal area. And (5), piezoelectricity is not an effective mechanism for generating magnetic field changes.

It is concluded that coseismic electric signals due to the piezoelectricity of the crustal rocks in the focal area are detectable. If adequate observations are realized, it is also concluded that physical parameters describing the anisotropy of the crust will be determined by combining geoelectric field observations and forward modeling of expected signals.