EMSEV 2012
Gotemba Kogen Resort, Gotemba, Japan
October 1–4, 2012
Abstract 4-04

Electromagnetic phenomena for stressed igneous rocks

Dependence of water content in granite and basalt samples

Chihiro Yamanaka, Sinya Tanemori and Masaya Hayashi

Department of Earth and Space Science, Osaka University, 1-1 Machikaneyama, Toyonaka, Osaka, JAPAN

Various hypotheses have been proposed as possible mechanisms of earthquake precursors including seismo-electromagnetic phenomena. In order to cause electromagnetic phenomena on the ground, in air or in the ionosphere, separations and movements of electric charge should be occurred in some ways. Recently a hypothesis of “Positive hole pairs (PHP)” or positive hole conduction relating to the distorted oxygen linkage in silicate was proposed based on the research in laboratory experiments[1,2]. Oxygen linkages in silicate such as $\equiv \mathrm{Si} - \mathrm{O} - \mathrm{O}$ were well known defects through various research by electron spin resonance (ESR) spectroscopy and the paramagnetic forms of the oxygen linkage were known as peroxy centers ($\equiv \mathrm{Si} - \mathrm{O} - \mathrm{O}\cdot$) and non-bonding oxygen hole centers ($\equiv \mathrm{Si} - \mathrm{O}\cdot$)[3]. Such defects are widely distributed in silicate minerals and glasses. In addition, oxygen linkage is not an unique hole emitter in silicate. Impurity centers such as aluminum or titanium centers can be a supplier of holes under the stress. Because the mechanism is not clear yet, we performed further laboratory experiments using granite and basalt samples to check the effects of water content in rocks.

Granite from China and quartz-free Basalt from Nagasaki, Japan were cut to be a size of 10 × 3 × 3 cm. Each sample was carefully selected not to include cracks or major defects. Pyrex glass and quartz glass were also arranged to be the same size. Glass samples were confirmed to contain oxygen linkages by ESR after γ-irradiation. All of samples were kept dry at room temperature. The stress was applied with an uniaxial compression testing machine (A&D, Tensilon, RTC-1310) and current was measured with an electrometer (Advantec, TR8652). The specimen was placed in the electrically shield case, as shown in Fig. 1. At first, the specimen was statically applied 1.11 MPa of stress, giving the current of pA range in case of rock samples: The difference of current from this condition was recorded as the pressure increased up to 6.66 MPa.

Figure 2 (a)-(d) and Figure 3 indicate the results. The stress-induced current at 6.66 MPa was ca. 23pA for granite and ca. 35 pA for basalt, respectively. Both showed a saturation tendency from the loading more than 3-5 MPa. The current flow continued for several hours under the loading. Because of the result for basalt and continuity of the electric current, these stress-induced currents are not due to the piezoelectric effect. Both glass samples did not show the increase of current as the increase of loading. Interestingly, the current flow for basalt sample was the reverse of that for granite. This suggests that “the positive hole conduction” might be modified or wrong, because the distortion of electric configurations of the oxygen linkage should be all similar among various silicates under the stress.

Figure 4 indicates the results after drying of rock samples. Each sample was heated at 100°C and the decrease of weight was accounted for water content in the rock. The results indicated that the induced current at 6.66 MPa decreased as the water content decreased. Although, the samples were initially room-dried, the effect of stream potential would not be negligible. Heater-dried samples hardly showed the stress-induced current, therefore “the positive hole conduction” is unlikely to account for the stress induced current in the rock. In other view, there is another possibility that a small amount of water might contribute to the induced current except the mechanism of the stream potential. However, it is clear that the water content has an important role in this phenomenon. Previous experiments of the stream potential in Inada granite showed 1.5 μA of electric current for the water flow of 1.5×10^{-3} cm^3s^{-1}[4]. In order to produce 20 pA of electric current, we need 7.2×10^{-5} cm^3 of water flow for 1 hour, which is equivalent to the water content of 0.1% in the rock. Therefore, effects of the stream potential is plausible for this phenomenon. The change of polarity for the basalt sample is also explained by the change of the zeta potential depending on the concentration of ions in water.

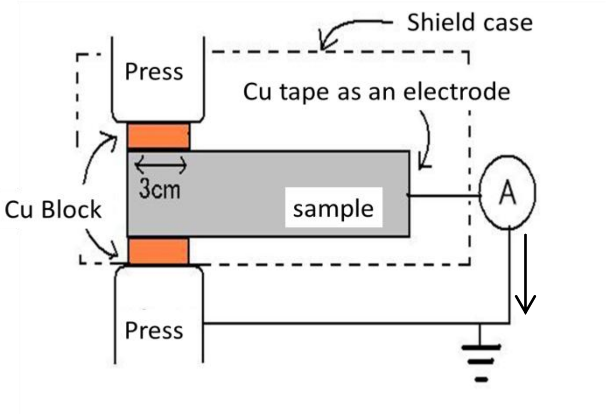
References

[1.] F. T. Freund, A. Takeuchi, B.W.S. Lau, “Electric currents streaming out of stressed igneous rock - A step towards understanding pre-earthquake low frequency EM emissions,” *Physics and Chemistry of the Earth* **31**. pp. 389-396. (2006).

[2.] F.T. Freund, M.A.S. da Silva, B.W.S. Lau, A. Takeuchi, H.H.Jones, “Electric currents along earthquake faults and the magnetization of pseudotachylite veins”, *Tectonophysics*, **431**, pp. 131-141, (2007).

[3.] D.L.Griscom, “Electron spin resonance investigations of defects and defect processes in amorphous silicon dioxide”, *Rev. Solid. State Sci*., **4**. pp. 565-599. (1990).

[4.] S. Yoshida, “Convection current generated prior to rupture in saturated rocks”, *J. Geophys. Res*., Vol., **106**, B2, pp. 2103-2120. (2001).



Schematic diagram of the experiment. The edge of each sample was connected to an electrometer (indicated as A) and electrically grounded.

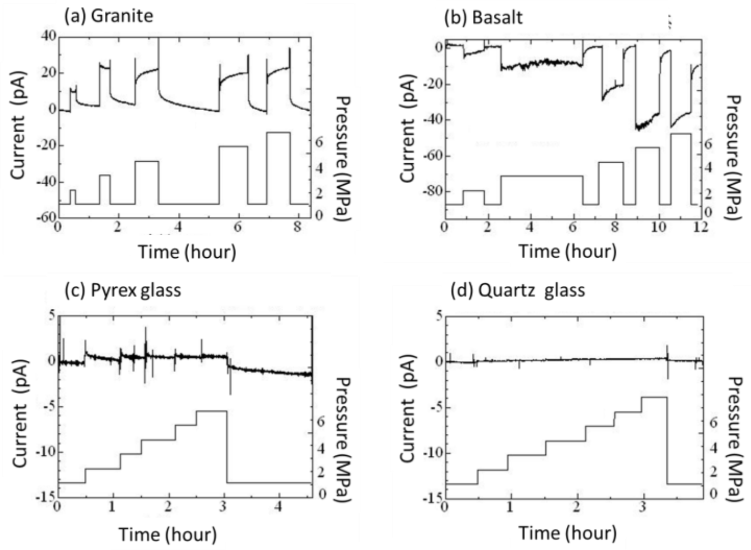


Fig. 2. Pressure dependence on the current-flow in samples: (a)granite , (b) basalt, (c) Pyrex glass, (d) quartz glass. The sign of current flow is set to positive in the direction from sample edge to the electrometer as shown in Fig 1. Note the difference in the direction of current between granite and basalt samples.

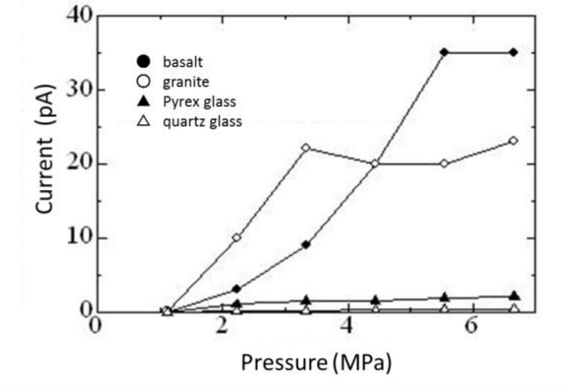


Fig. 3. Pressure dependence of stress-induced current for rock and glass samples.

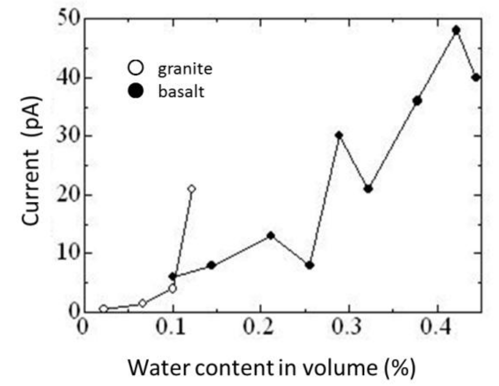


Fig. 4. Relations between the stress-induced current and water content in rocks.Fig. 1: