EMSEV 2012
Gotemba Kogen Resort, Gotemba, Japan
October 1–4, 2012
Abstract 4-05

Are Positive Charge Carriers Generated by Crustal Loading?

M.J.S. Johnston [1)] and R.P. Dahlgren [2,3)]

1) *U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA, 94025, USA*

2) *SETI Institute, 189 Bernardo Av., Mountain View, CA, 94043, USA*

3) *NASA Ames Research Center, Moffet Field, Mountain View, CA, 94035, USA*

From loading experiments on dry crystalline rocks in the laboratory, Freund (2002, 2006, 2007) proposed that positive charge carriers are activated (in a semiconductor sense) and that these might be used to infer the failure state near active faults. Freund (2008) extrapolated these results to suggest that stress-induced charge episodes could occur before earthquakes, currents of 10,000-100,000 A could be produced for extended periods of time, infrared emission (IR) could be produced prior to earthquakes and that the charge involved could couple into the ionosphere and magnetosphere to generate ionospheric earthquake precursors. This provided a basis for claims of IR anomalies (Ouzounov et al., 2007) and ionospheric anomalies (Pulinets and Boyarchuk, 2004) before earthquakes. While aspects of the model are appealing, testable predictions are in conflict with many basic geophysical observations. In particular: [1] The conductivity of the fluid-filled fault zone crustal rocks in seismically active regions (0.01-1 S/m, Unsworth et al.,1999) precludes the storing of electric charge in the Earth's crust, [2] Electric charge accumulation before earthquakes is not apparent in telluric current measurements near active faults during crustal loading (Johnston 1998; Park, 2007), [3] Crustal stress transients prior to earthquakes, required by the model to produce electric charge before earthquakes, are not observed on high-resolution borehole strain or GPS instruments currently installed throughout regions of active faulting in either near-field (0-10 km) or far-field (10-1,000 km) epicentral distances (Johnston et al., 2006a), [4] EM fields observed prior to earthquakes do not show indications of anomalous behavior at levels exceeding about 1 mV/km and 0.2 nT, respectively (Johnston, 1998; Johnston et al., 2006b), provided corrections are made for external global and cultural noise sources (although EM changes at the time of earthquakes are readily observed and generally agree with model expectations), and [5] Other laboratory experiments suggest that mostly electrons and some positive ions (ratio 4:1) are produced during loading or fracturing of dry crystalline rocks (Enomoto and Hashimoto, 1990) as a result of physical mechanisms such as piezoelectricity, triboelectricity, micro-fracturing, fluid flow, etc.

To attempt to reconcile these conflicts, new collaborative laboratory experiments have been completed that focus on: 1) replication of Freund's earlier results using the same setup, apparatus and rock type (gabbro), 2) extending the suite of rocks to include those commonly encountered near fault zones including those with possible semiconductor properties (granite, sandstone, etc) and those without (marble, limestone, etc), and 3) using rock types saturated with fluid such that electrical conductivity matched that observed in fault zones.

Preliminary results indicate: 1) a fundamental disagreement in sign of the charge produced by loading and unloading steps compared with previous results obtained from dry gabbro and other crystalline rocks, 2) evidence that electrode and insulator loading effects may have contaminated the earlier results, 3) the behavior of rocks with possible semiconductor properties is similar to that from rocks with no semiconductor properties and 3) no evidence of change in charge generation, either positive or negative, when crystalline rocks, saturated with fluids that occur naturally near active faults in the Earth's crust, are cyclically loaded. In conclusion, the preponderance of evidence from laboratory and field observations indicates that significant positive hole generation in the Earth's crust due to tectonic loading or earthquake nucleation does not occur.

References

[1.] Y. Enomoto and H. Hashimoto, Emission of charged particles from indentation fracture of rocks, Nature, 346, 641-643, 1990.

[2.] F. Freund, Charge generation and propagation in rocks, J. Geodyn., 33, 545-572, 2002.

[3.] F.T. Freund, A. Takeuchi, and B.W. Lau, Electric currents streaming out of stressed igneous rocks – A step towards understanding pre-earthquake low frequency EM emissions, Phys. Chem. Earth, 31, 389–396, 2006.

[4.] F.T. Freund, Stimulated IR emission from rocks: Assessing a stress indicator, eEarth, 2, 1–10, 2007.

[5.] F.T. Freund, Earthquake probabilities and pre-earthquake signals, Current Science, 94, 1-2, 2008.

[6.] Johnston, M.J.S. Review of electrical and magnetic fields accompanying seismic and volcanic activity, Surv. Geophys., 18, 441-475, 1997.

[7.] M.J.S. Johnston, Y. Sasai, G.D. Egbert and R.J. Mueller, Seismomagnetic Effects from the long-awaited September 28, 2004, M6 Parkfield Earthquake. Bull. Seis. Soc. Am., 96, 206-220, 2006a.

[8.] M.J.S. Johnston, R.D. Borcherdt, A.T. Linde, and M.T. Gladwin, Continuous borehole strain and pore pressure in the near-field of the September 28, 2004 Parkfield earthquake: Implications for nucleation, fault response, earthquake prediction and tremor, Bull. Seis. Soc. Am., 96, 56-72, 2006b.

[9.] D. Ouzounov, D. Liu, C. Kang, et al.: Outgoing Long Wave Radiation Variability from IR Satellite Data Prior to Major Earthquakes, Tectonophysics, 431, 211–220, 2007.

[10.] S.K. Park, W. Dalrymple, and J. C. Larsen, The 2004 Parkfield earthquake: Test of the electromagnetic precursor hypothesis, J. Geophys. Res., 112, B05302, doi:10.1029/2005JB004196, 2007.

[11.] S. Pulinets and K. Boyarchuk, Ionospheric precursors to earthquakes, 350pp, Springer Verlag, 2004.

[12.] M. Unsworth, G. Egbert, and J. Booker, High-resolution electromagnetic imaging of the San Andreas fault in Central California, J. Geophys. Res., 104(B1), 1131–1150, 1999.