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Coseismic electric currents and the pseudotachylyte magnetic blackbox

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The existence of coseismic electric currents traveling along an active fault plane has been in question for some time. Repeated and reliable observation of earthquake lightnings during large magnitude events constitutes a compelling reason to look further into this problem. The extremely transient, catastrophic and low degree of predictability of major earthquakes makes direct recording of coseismic currents very unpractical. Even in the favorable cases of instrumented faults, such as the SAFOD experiment, separation of electric currents of natural origin from those resulting from disruption of a man-made power grid is difficult. Under these adverse conditions, an alternative consists in turning to the geologic record, i.e. examining rocks formed during an earthquake.

Pseudotachylytes are rocks formed by frictional melting of a host rock and they commonly form along fault planes during large magnitude seismic events. They typically occur as thin (<50 mm) planar veins. Upon melting, at temperatures between 1400 and 2300 K, a substantial volume of ferromagnesian and quartzo-feldspathic minerals break down resulting in the formation of melt. As seismic slip stops, heat is transferred to the host rock and the melt is quickly quenched, facilitating growth of only small grains of ferrimagnetic magnetite (single domain, SD) and microlites of feldspar and quartz. Most pseudotachylites (natural or artificial) display a magnetic susceptibility substantially greater than that of the host, reflecting new ferrimagnetic material.

Several natural pseudotachylytes have natural remanent magnetization (NRM) of intensity far greater than their host (up to 300 times) and oblique to the ambient geo-

magnetic field at the time of their cooling. The intensity of the ambient geomagnetic field is insufficient to explain such very large and anomalous NRMs and therefore an explanation other than TRM acquisition in a weak geomagnetic field is needed. Heat transfer numerical models have shown that cooling to the blocking temperature range of fine (SD) magnetite grains must occur with minutes after seismic slip termination. The electric conductivity of the pseudotachylyte vein system is complex but numerical modeling robustly shows that the conductivity of the melt is 4 orders of magnitude lower than that of the host rock before seismic failure. In such conditions the pseudotachylite vein acts as a lightning rod during an earthquake.

New magnetic data, including first order reversal curves (FORC), frequency dependence of magnetic susceptibility (K_{FD}), isothermal remanent magnetization (IRM) and transmitted electron microscopy (TEM), are used to better define the magnetic character of the pseudotachylite and thus the origin of the magnetizing field. The normalized derivative of NRM and IRM (Verrier and Rochette, 2002) is used to prove that the NRM is acquired via the passage of a high electric current similar to that of a lightning strike. In this sense a pseudotachylyte acts as a blackbox recording coseismic signals.

Several non-exclusive mechanisms may explain the generation of large coseismic electrical currents: piezo-electricity due to deformation of quartz-bearing rocks, triboelectricity, or peroxy bond networks. Further investigation of pseudotachylyte characteristics in different host rocks and analogue experiments should provide insight regarding the most effective mechanism. The implications of this research are considerable for detection of seismic electromagnetic signals by satellite magnetometers (CHAMP , DEMETER).