Paleomagnetism of fine magnetic inclusions from faults and meteorites

Norihiro Nakamura[1]

[1] Geo-Environmental Sci., Tohoku Univ.

http://www.dges.tohoku.ac.jp/igps/nakamura.htm

Pseudotachylytes and chondrules appear to be reliable materials for a paleomagnetic study because of their high-temperature regimes in terrestrial and extraterrestrial environments. However, they show different magnetic stabilities due to a protolith variation, a cooling history and an ambient chemical environment. Here, I review rock magnetic and microtextural examinations of Sudbury pseudotachylytes, Nojima fault gouges and artificial chondrules, suggesting that the presence of fine-grained ferromagnetic crystals embedded within silicate crystals is responsible to thermal and chemical stability of magnetic remanence information. 1) Sudbury pseudotachylytes were known as post-impact melt products in large displacement fault systems during gravitational collapse of the impact-generated transient cavity (Thompson & Spray, 1996). These pseudotachylites are 1-8m wide veins in thickness, so that we estimated from an analytical heat conduction calculation that they might have cooled in a several months. Curie temperature determination and scanning electron microscope studies of the pseudotachylites indicate submicron inclusions of a low-Ti magnetite embedded within a cryptocrystalline silicate matrix are the carrier of the remanence. Preliminary determinations from three pseudotachylites meet reliability criteria and yield a virtual dipole moment of $3.48*10\hat{}22$ (am$\hat{}$2) which is in half of the present field. This value is supported by a low paleointensity derived from impact melt sheet in the Sudbury Igneous Complex (Nakamura & Iyeda, 2005). 2) The Nojima fault gouge is an alternating layer of fine-grained gouge (gray, cohesive) and pseudotachylyte (black, brittle), derived from the adjacent low-magnetic granite. Each layer is thinner than a few millimeters, and corresponds to one seismic slip event. Previous X-ray diffraction study showed that the gray-color gouge includes siderite and lepidocrocite, while the black-color pseudotachylyte includes magnetite. A SQUID magnetometer and scanning electron microscopy (SEM) measurements reveals that a remanence carrier is submicron-sized inclusions of iron, which is identified as magnetite through powder X-ray diffraction analysis. Step-wise thermal demagnetization provides subsamples (38%) in the stable samples unblocked the NRM in 450-540C, lower than the Curie temperature of magnetite (580C). Moreover, the orientations of high coercivity component are randomly oriented even in a centimeter apart along the same layer, being no hemispherical bias. These results therefore reveals that some of the pseudotachylyte in the Nojima fault gouge has not been heated up to more than 540C and has been magnetized in a randomly directed external field produced by an inhomogeneous coseismic electric current during seismic slip (Kitagawa & Nakamura 2005). 3) Chondrules are known to have been formed by flash melting event in a protoplanetary nebula disk: the precursor dust aggregates were heated through shock wave to high temperature and cooled back down in several minutes. Previous flash melting experiment and SEM observations showed that dusty olivine chondrules contain fine Fe inclusions that is a carrier of stable remanence, while the olivine host limits natural and experimentally induced alteration (Uehara & Nakamura, submitted). This result suggests the presence of dusty olivine in unequilibrated ordinary chondrites is a good candidate of the less altered and stable magnetic recorder for the early solar magnetic field. Therefore, pseudotachylites and chondrules with fine magnetic inclusions hold great potential for paleomagnetic study of contemporaneous magnetic fields during seismic faulting and paleosolar nebular process.