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Magnetic properties of frictional volcanic materials

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During dome-building volcanic eruptions, highly viscous magma extends through the upper conduit in a solid-like state. The outer margins of the magma column accommodate the majority of the strain, while the bulk of the magma is able to extrude, largely undeformed, to produce magma spines. Spine extrusion is often characterised by the emission of repetitive seismicity, produced in the upper <1 km by magma failure and slip at the conduit margins. The rheology of the magma controls the depth at which fracture can occur, while the frictional properties of the magma are important in controlling subsequent marginal slip processes. Upon extrusion, spines are coated by a carapace of volcanic fault rocks which provide insights into the deeper conduit processes.

Frictional samples from magma spines at Mount St. Helens (USA), Soufriere Hills (Montserrat) and Mount Unzen (Japan) have been examined using structural, thermal and magnetic analyses to reveal a history of comminution, frictional heating, melting and cooling to form volcanic pseudotachylyte. Pseudotachylyte has rarely been noted in volcanic materials, and the recent observation of its syn-eruptive formation in dome-building volcanoes was unprecedented. The uniquely high thermal conditions of volcanic environments means that frictional melt remains at elevated temperatures for longer than usual, causing slow crystallisation, preventing the development of some signature "quench" characteristics. As such, rock-magnetic tests have proven to be some of the most useful tools in distinguishing pseudotachylytes from their andesite/ dacite hosts.

In volcanic pseudotachylyte the mass normalised natural remanent magnetisation (NRM) when further normalised with the concentration dependent saturation remanence (Mrs) was found to be higher than the host rock. Remanence carriers are defined as low coercive materials across all samples, and while the remanence of the host rock displays similarities to an anhysteretic remanent magnetisation (ARM), as expected for a thermal origin, the remanence of volcanic pseudotachylyte has been found to be comparable to an isothermal remanent magnetisation (IRM). Thus, the pseudotachylyte has experienced a strong magnetic field that overwrote the previous thermoremanent magnetisation of the magma, such as the strong local electric current that occurs in faults (e.g. Ferré et al., 2005). Additionally, the pseudotachylyte seems more often to comprise of uniaxial non-interacting single-domain particles compared to pseudo-single in the host, and to have a single Curie temperature whereas the host more commonly exhibits multiple phases. Differences in rock-magnetic parameters between the pseudotachylyte and host are significant, but not as high as those observed in granites by Nakamura et al. (2002) or Ferré et al. (2005), probably because granitic host rocks do not already carry a strong and stable remanence as do these extrusive volcanic rocks.

The application of rock-magnetic tests in volcanology will undoubtedly continue to be a "go-to" tool for identification of pseudotachylytes, which are increasingly being recognised to play an important role in dome-building eruptions.

Refs:

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Nakamura, N., Hirose, T. and Borradaile, G.J., 2002. Laboratory verification of submicron magnetite production in pseudotachylytes: relevance for paleointensity studies. . Earth and Planetary Science Letters, 201(1): 13-18.