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Mineralogical and compositional features of rock fulgurites: A record of lightning effects on granite

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Abstract

Fulgurites are a naturally occurring glass formed when sand, rock, or soil is struck by atmospheric electrical discharges (lightning). The aim of this paper is to provide insights into the conditions occurring in rocks during the lightning strike. Rock fulgurites collected from Mt. Mottarone, Baveno (Piedmont, Italy) have been investigated to assess the mineralogical and compositional changes occurring in granite due to a lightning strike. X-ray powder diffraction showed that the samples represent the dominant granitic rock type of the Baveno massif, the so-called "Pink Baveno." Fulgurite coats the surface of the granite as a brown-black, glassy to very fine-grained porous layer. Powder diffraction data for the fulgurite reveal the presence of cristobalite and quartz crystals in a glass matrix, suggesting that temperature exceeded ~1700 °C at near atmospheric conditions, assuming thermodynamic equilibrium. Electron probe microanalysis of the glass revealed that it is mainly composed of SiO_2 and Al_2O_3 and that it has a porosity of 5–7 area% in the studied zones. The presence of the amorphous phase indicates that the abrupt electrical (Joule) heating of the rock surface yielded high temperatures, producing a thin melt layer on the surface, which then cooled adiabatically. Idealized physical model was developed to simulate the effects of Joule heating and subsequent thermal conduction close to the rock surface during and after a lightning strike. The quantity of organic matter in the glass, obtained via Elemental Analyzer, suggests that rapid quenching of the melt trapped NO_x and CO_x gases produced during heating. Raman spectroscopy revealed the presence of polyaromatic hydrocarbon molecules, which, combined with the Elemental Analyzer data, suggest that organic matter was pyrolyzed at around 300–350 °C and then trapped in the glass matrix of the studied rock fulgurites.

Keywords: Lightning, rock fulgurites, mineralogy, compositional features, physical models