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## Low-level shock metamorphism induced by lightning

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Cloud-to-ground lightning can result in high-temperature metamorphism of rocks, forming rock fulgurite. Here, we characterize a rock fulgurite on granitic gneiss from Kinmen Island, Taiwan, and demonstrate that high-pressure metamorphic features can be also generated by lightning. With the lightning monitoring system, we detected a lightning event with a peak current of 162 kA and the associated fulgurite. We conduct microanalytical methods on rock fulgurite, including optical microscope, scanning electron microscope with electron backscatter diffraction (EBSD), focused ion beam-transmission electron microscopy, and in-situ synchrotron Laue diffraction analyses. The fulgurite is characterized by an up to 200  $\mu\text{m}$  thick glassy crust overlying host rock for around 10 square meters. Within the glassy crust, typical high-temperature features, such as vesicles, relic mineral fragments, and reduced oxidation-state iron oxides spheres, can be recognized. Below the glassy crust, EBSD analysis documents phase transformation (from monoclinic to triclinic) and planar features (exsolution lamellae) of alkali feldspar (sanidine) grains. Synchrotron Laue diffraction analysis indicates that these planar features are parallel to the (100) plane and preserve residual stress of up to 1.57 GPa, well above the 0.38 GPa recorded in feldspar grains (reference sample from borehole cores) that are not affected by lightning. The findings, including glassy crust, phase transformation and planar features of alkali feldspar grains, and high residual stress, suggest that lightning can result in both high-temperature and high-pressure metamorphic features. Because these assemblages are reminiscent of shock metamorphic textures produced by meteorite impact, we interpret them to be shock-related features. Given that the recognition of shocked minerals (with planar features) and glasses are both parts of the set of diagnostic criteria for meteorite impacts, in the absence of a broader suite of criteria, we recommend caution, since our identification of the Kinmen Island fulgurite indicates lightning can result in low-level shock metamorphic features.