Lightning-induced shock metamorphism at depth

Li-Wei Kuo[1,2]*, Chien-Chih Chen[1,2], Ching-Shun Ku[3], Ching-Yu Chiang[3], Dennis Brown[1,4], Tze-Yuan Chen[1]

[1] Department of Earth Sciences, National Central University, Taoyuan 320, Taiwan
[2] Earthquake-Disaster & Risk Evaluation and Management Center, National Central University, Taoyuan 320, Taiwan
[3] National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan
[4] Institute of Earth Sciences "Jaume Almera", CSIC Barcelona, Spain

liweikuo@ncu.edu.tw

Abstract

Minerals with planar microstructures, referred to as shocked minerals[1-4], have been shown to form at pressures of several gigapascals. Shocked minerals are diagnostic criteria for evidence of meteorite impact[4-6]. Nevertheless, recent reports of shocked quartz in lightning-induced metamorphic rock[7], called rock fulgurite, indicates that planar microstructures are also developed during lightning strikes. Here, we describe two rock fulgurites from Kinmen Island, Taiwan, that demonstrates that shock metamorphic features found at the surface are also developed at depth, within fractures. The surface fulgurite is characterized by an up to 100 μm thick glassy crust overlying fractured grains whereas within the fractures the glassy melt is patchy and it is intermingled with brecciated rock. We document planar microstructures within alkali feldspar (sanidine) from both fulgurites. Synchrotron Laue diffraction analysis indicates that the planar microstructures in sanidine are parallel to the (*l00*) plane. We interpret these to be shock features. These grains record a residual stress of up to 1.57 GPa, well above the 0.38 GPa recorded in grains that are not affected by lightning. We carry out 1-D numerical modeling to simulate a lightning strike on rocks with subsurface, fluid-saturated fractures. The model shows that electric current density in fractures up to 20 meters deep can be as high as that on the surface, suggesting that lightning-induced low-level shock metamorphism may form at depth.

Keywords - lightning, shock metamorphism, fulgurite, Laue diffraction.

References

1. Stöffler, D. Progressive Metamorphism and Classification of Shocked and Brecciated Chrystal-line Rocks at Impact Craters. J. Geophys. Res. 76 (1971).
2. Stöffler, D., Keil, K. & Scott, R.D. Shock metamorphism of ordinary chondrites. Geochimica et Cosmochim Acta 55, 3854–3867 (1991).
3. Stöffler, D. & Langenhorst, F. Shock metamorphism of quartz in nature and experiment: I. Basic observation and theory. Meteoritics and Planetary Science 29, 155–181 (1994).
4. French, B. M. Traces of Catastrophe - A Hand-book of Shock-Metamorphic Effects in Terrestrial Meteorite Impact Structures. Lunar and Planetary Institute 120 pp (1998).
5. Cavosie, A., Timms, N. E., Ferrière, L. & Rochette, P. The only terrestrial mineral diagnostic of high-pressure and high-temperature shock deformation. Geology 46, 891–894 (2018).
6. French, B.M. & Koeberl, C. The convincing identification of terrestrial meteorite impact structures: What works, what doesn't, and why. Earth-Science Reviews 98 (1-2), 123–170 (2010).
7. Gieré, R., Wimmenauer, W., Müller-Sigmund, H., Wirth, R., Lumpkin, G. R. & Smith, K. L. Lightning-induced shock lamellae in quartz, Am. Mineral. 100(7), 1645–1648 (2015).