

Low-level shock metamorphism induced by lightning

Tze-Yuan Chen, Li-Wei Kuo, Steven Smith, Ching-Shun Ku, Ching-Yu Chiang, Dennis Brown, and Marianne Negrini

Presenter: Tze-Yuan Chen

National Central University, Taiwan

tzeyuanchen@gmail.com

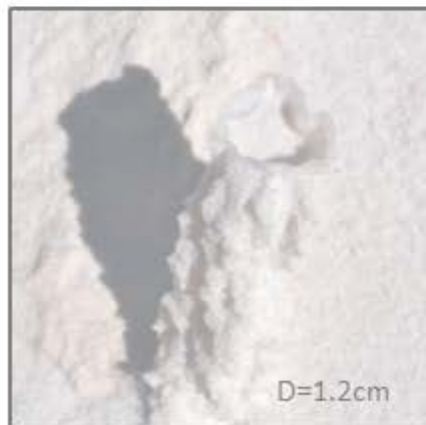
Fulgurite

also known as "fossilized lightning"

Definition: "Solid material undergone physical and chemical change by lightning"

High ^{Joule heating} Temperature features
Pressure _{Shock wave}

Type I: Sand



(Pasek & Hurst, 2016)

Type II: Soil



(Pasek et al., 2012)

Type III: Caliche



(Pasek et al., 2012)

Type IV: Rock

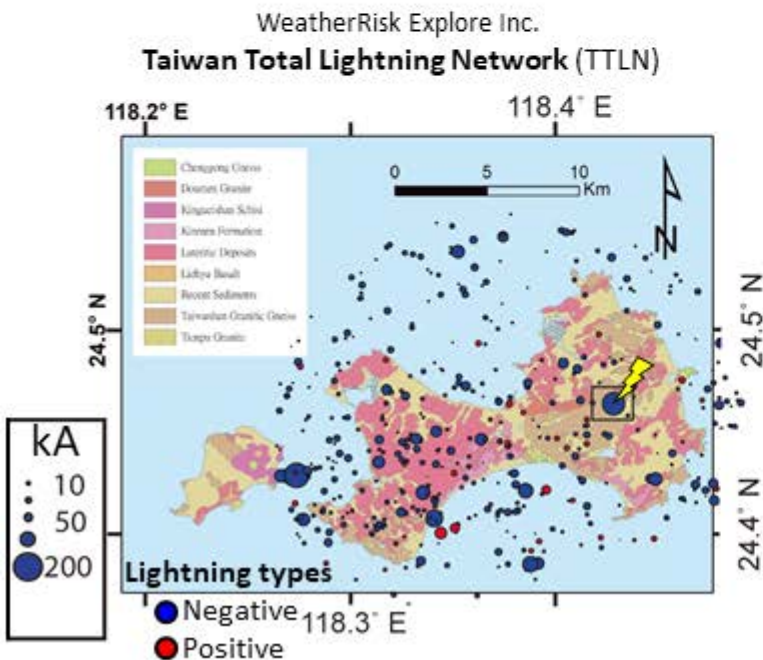


(Elmi et al., 2017)

Kinmen Island on May 7th, 2018

Peak current: 162 kA (typical: 10–30 kA)

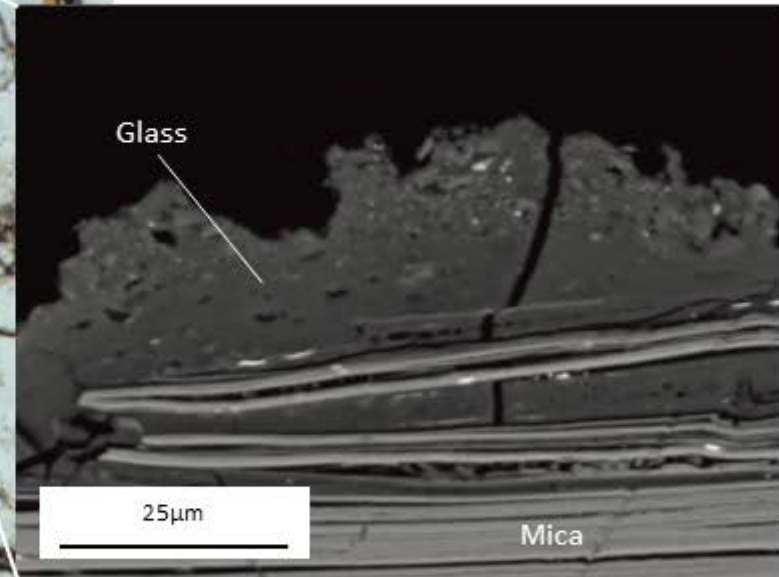
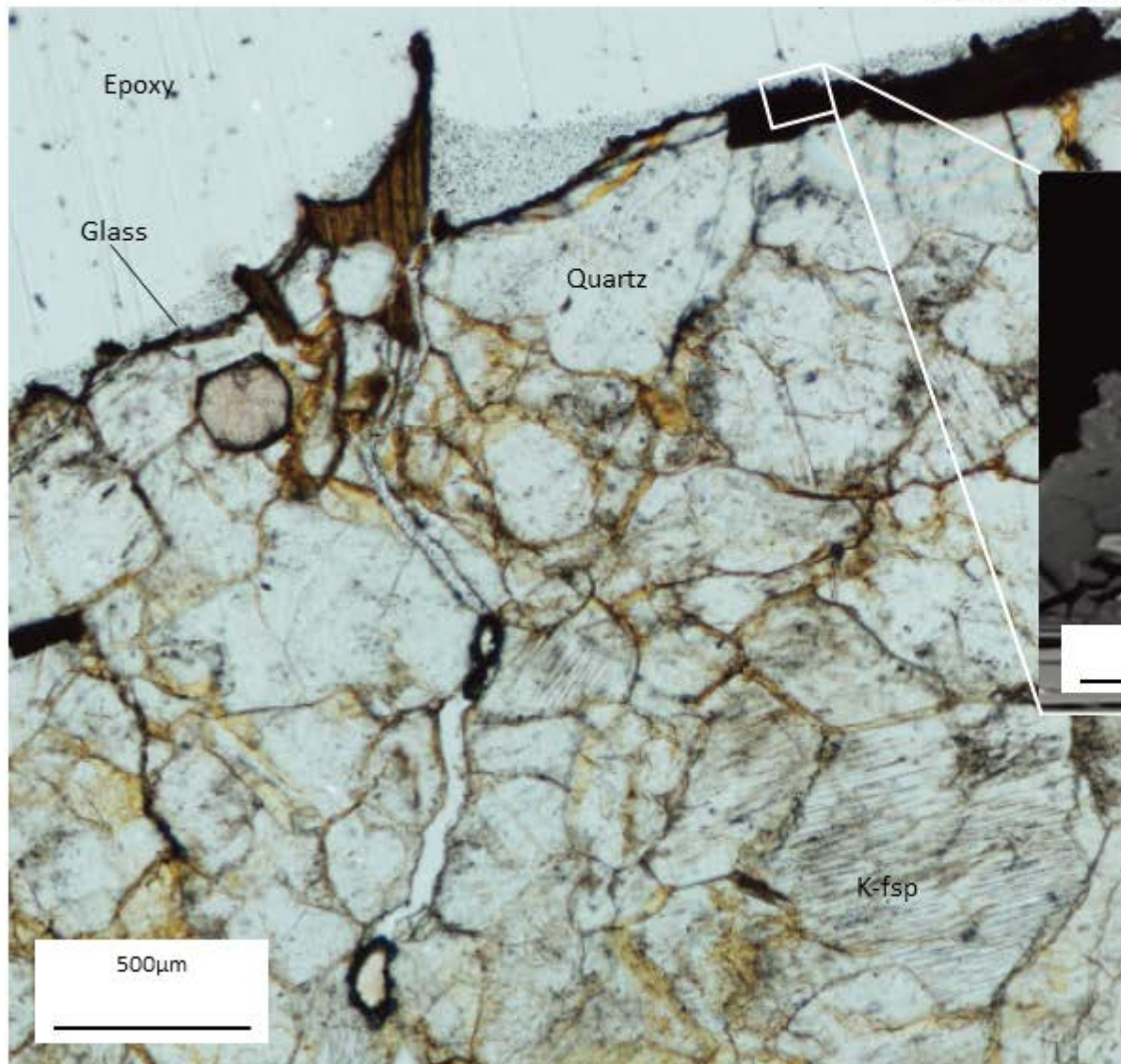
Reference sample



Kuo et al., 2021

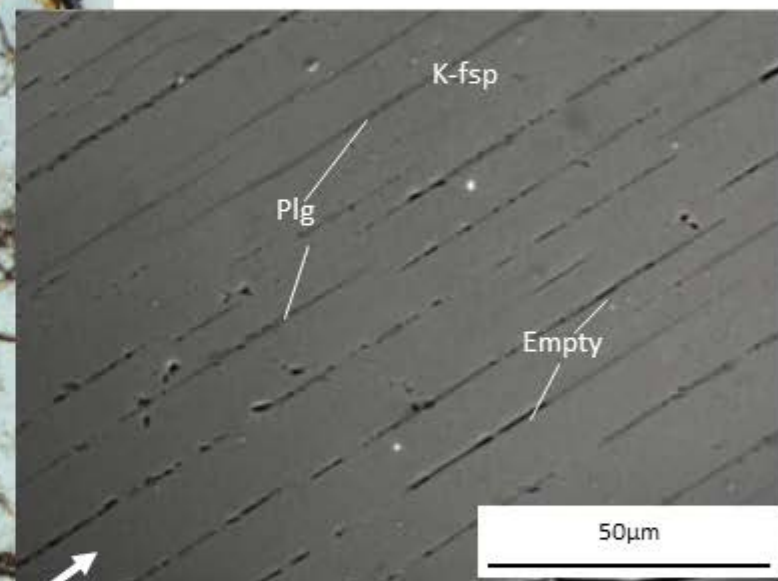
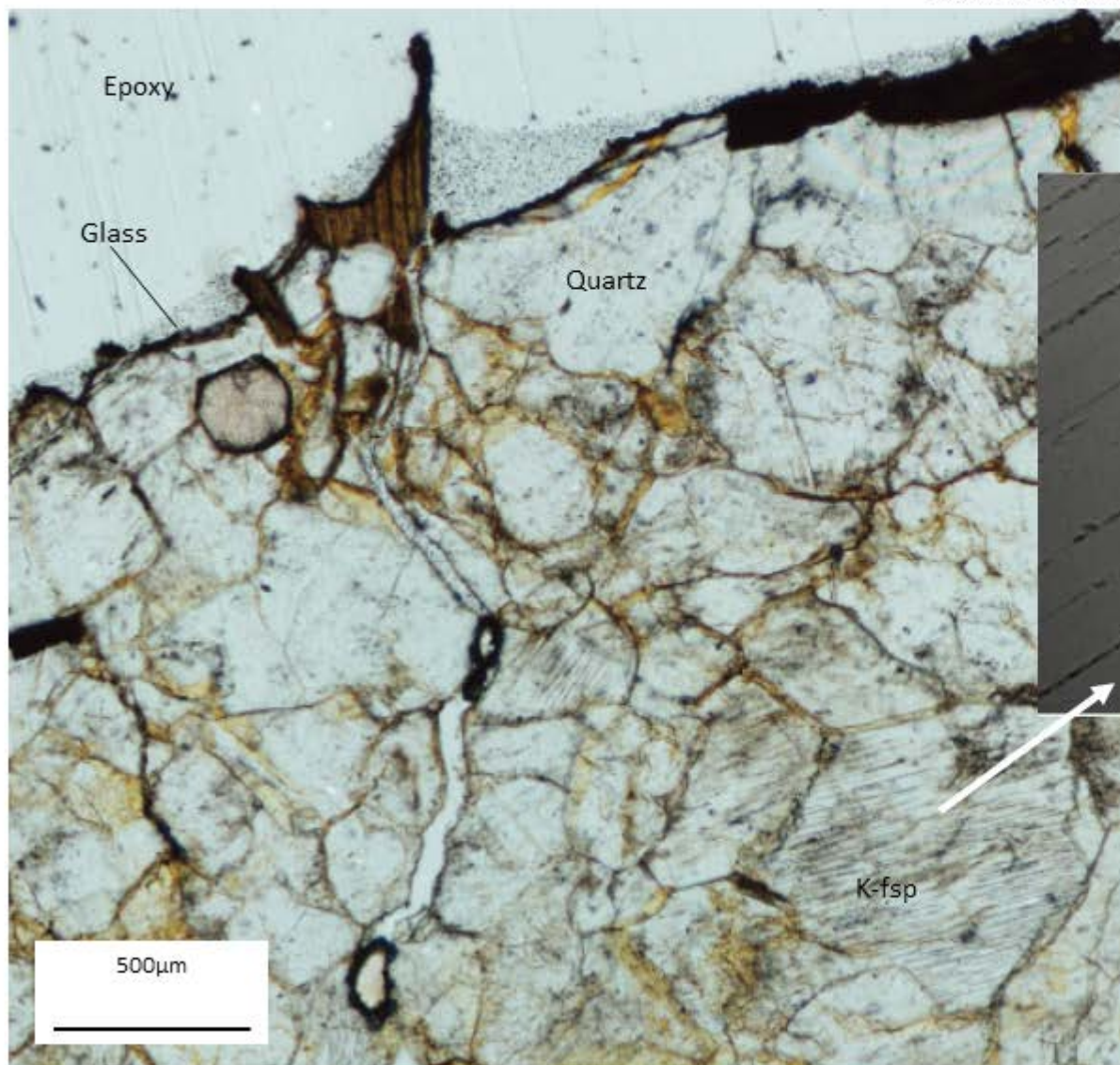
Microstructure

Kuo et al., 2021



Microstructure

Kuo et al., 2021

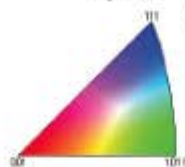


Exsolution lamellae

Reference granite

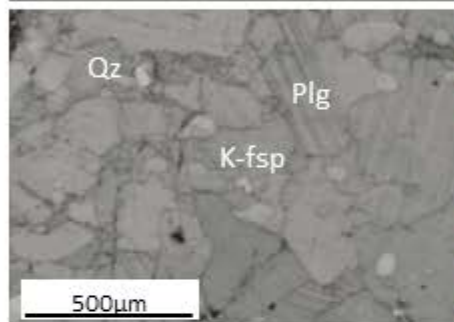
K-feldspar have no internal structure

K-feldspar is monoclinic



monoclinic feldspar triclinic feldspar quartz

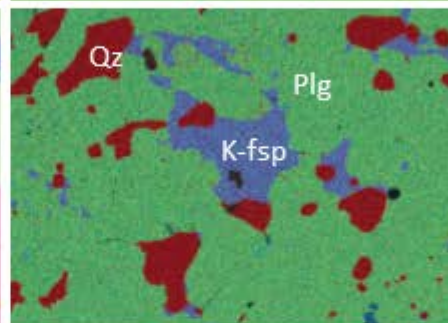
EBSD band contrast image



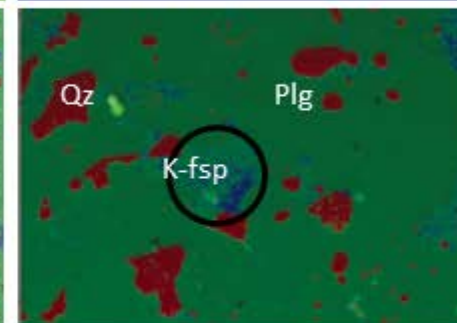
Crystallographic orientation



EDS chemical map



EBSD phase map



Kuo et al., 2021

Fulgurite sample

K-feldspar have exsolution lamellae

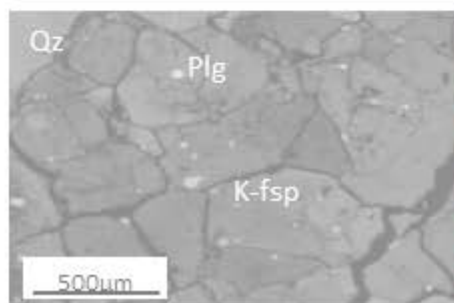
Subparallel to (100) plane

K-feldspar is monoclinic & triclinic



monoclinic feldspar triclinic feldspar quartz

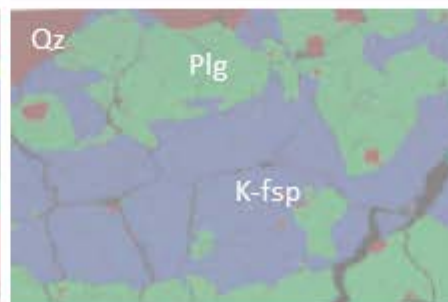
EBSD band contrast image



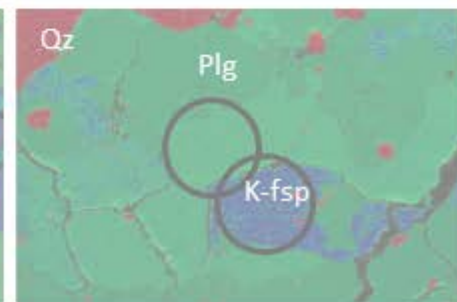
Crystallographic orientation



EDS chemical map



EBSD phase map



Reference granite

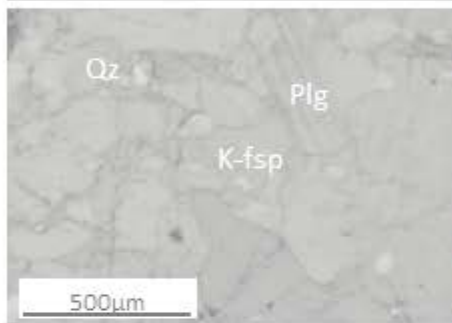
K-feldspar have no internal structure

K-feldspar is monoclinic



monoclinic feldspar triclinic feldspar quartz

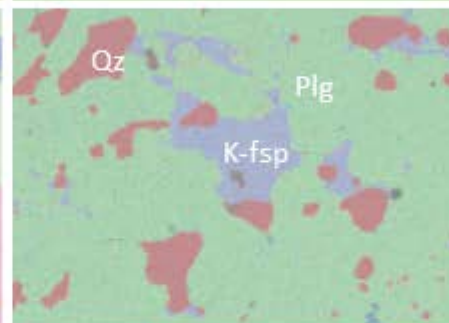
EBSD band contrast image



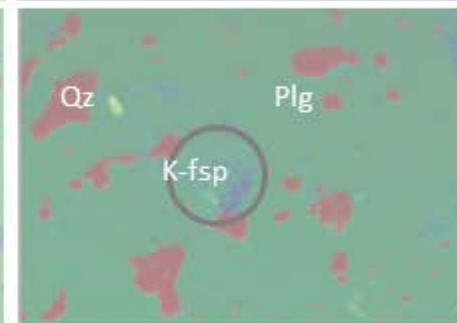
Crystallographic orientation



EDS chemical map



EBSD phase map



Kuo et al., 2021

Fulgurite sample

K-feldspar have exsolution lamellae

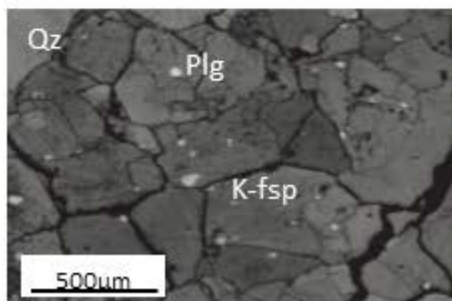
Subparallel to (100) plane

K-feldspar is monoclinic & triclinic

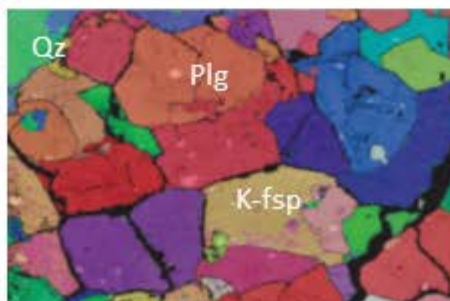


monoclinic feldspar triclinic feldspar quartz

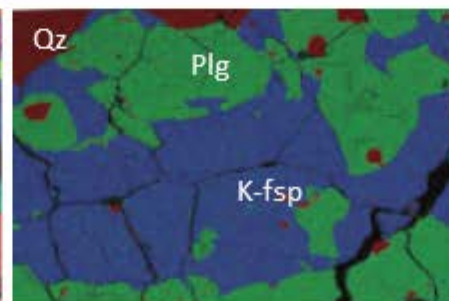
EBSD band contrast image



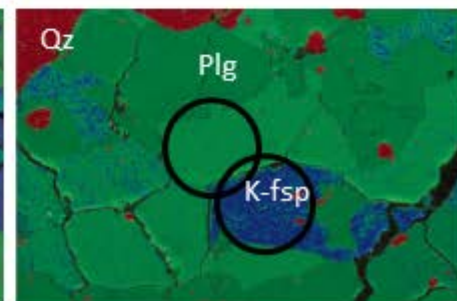
Crystallographic orientation



EDS chemical map



EBSD phase map

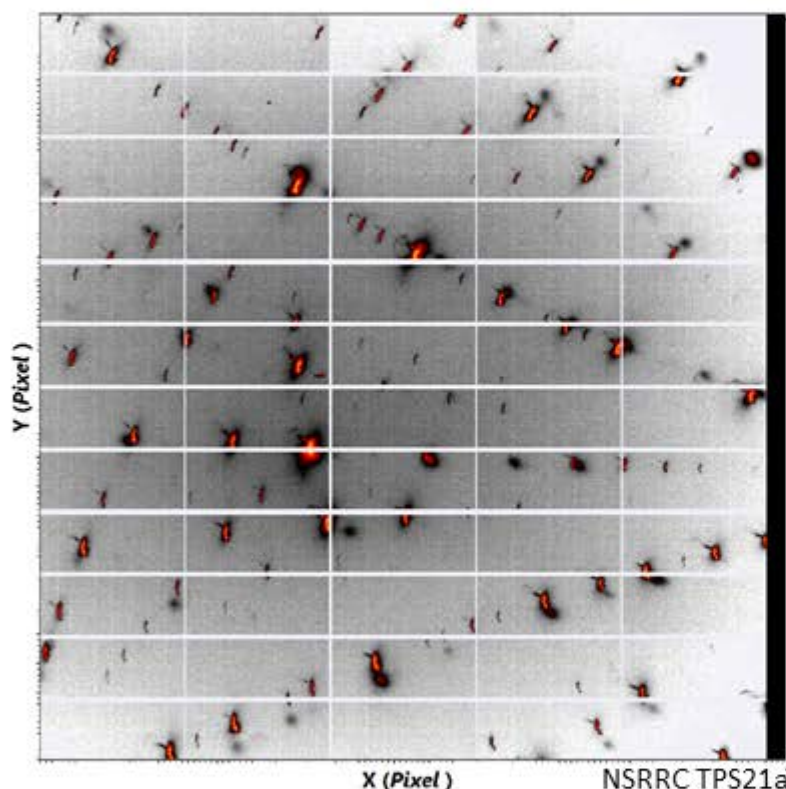
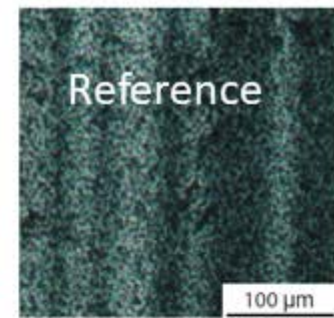
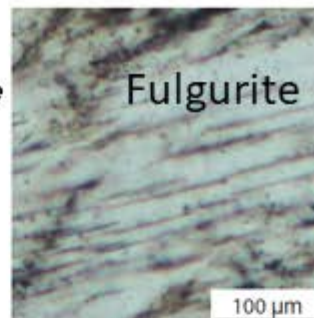


Residual stress

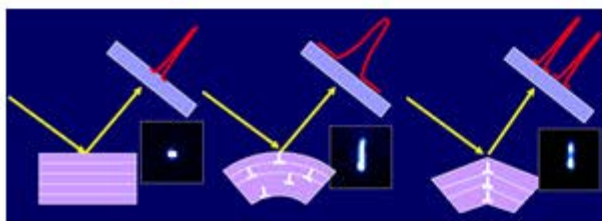
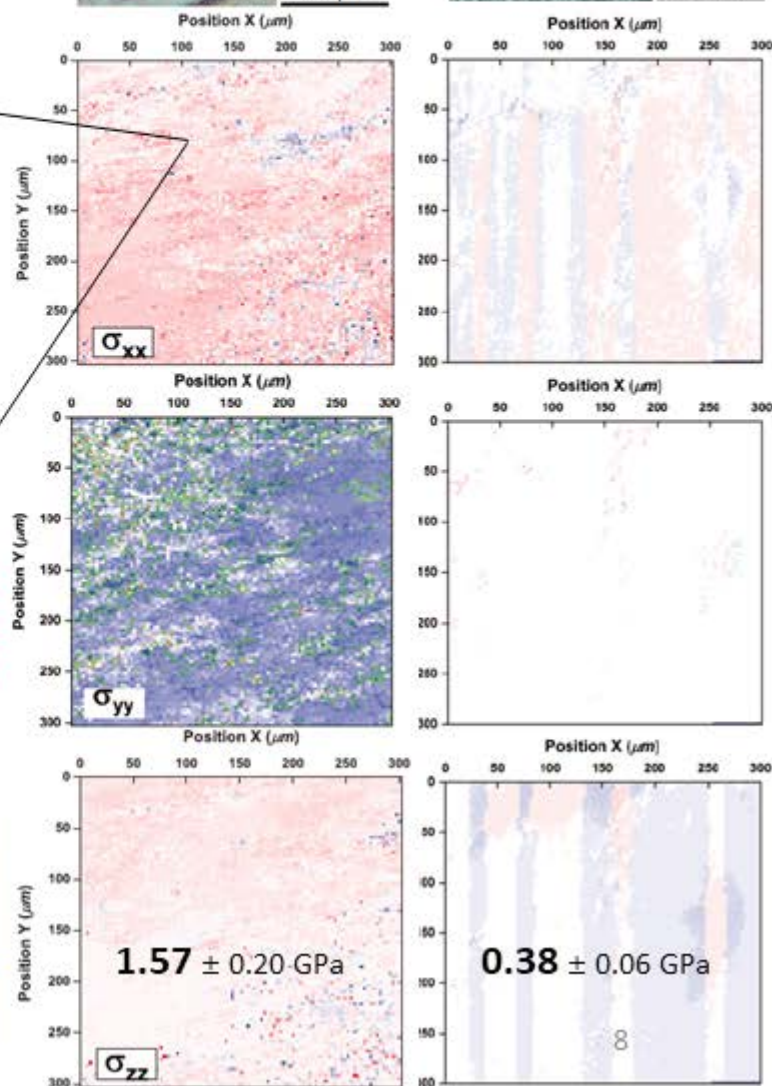
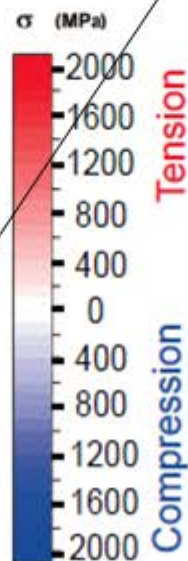
National Synchrotron Radiation Research Center

Laue diffraction analysis

Kuo et al., 2021
Sample coordinate
YY
XX
ZZ



NSRRC TPS21a



Pressure-related features

Exsolution lamellae

Grain loses solubility during cooling or decompression (> 6 GPa) (Zhu and Ogasawara, 2002)

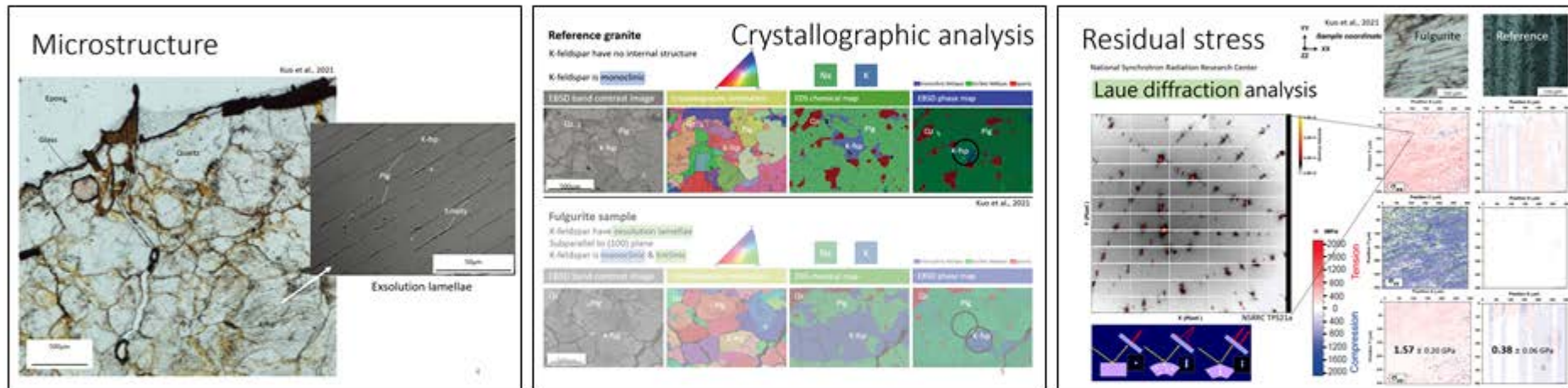
Phase transformation

K-feldspar transforms into triclinic under high pressure (Hazen, 1976)

Residual stress

High residual stress in K-feldspar grains

Fulgurite



lightning strike -> shock metamorphic features

doi:10.1038/s41598-021-01559-x

Reference

- Elmi, C., J. Chen, D. L. Goldsby, and R. Gieré (2017), Mineralogical and compositional features of rock fulgurites: A record of lightning effects on granite, *Am. Mineral.*, doi:10.2138/am-2017-5971.
- Hazen, R. Sanidine: Predicted and observed monoclinic-to-triclinic reversible transformations at high pressure. *Science* 194, 105–107 (1976).
- Kuo, L.-W., Smith, S. A. F., Chen, C.-C., Ku, C.-S., Chiang, C.-Y., Brown, D., . . . Chen, T.-Y. (2021). Lightning-induced high temperature and pressure microstructures in surface and subsurface fulgurites. *Scientific reports*, 11(1), 22031. doi:10.1038/s41598-021-01559-x
- Pasek, M.A., Block, K., Pasek, V. (2012): Fulgurite morphology: a classification scheme and clues to formation. *Contrib. Mineral. Petrol.*, 164, 477–492.
- Pasek, M., & Hurst, M. (2016). A Fossilized Energy Distribution of Lightning. *Scientific reports*, 6, 30586. doi:10.1038/srep30586
- Zhu, Y. F. & Ogasawara, Y. Phlogopite and coesite exsolution from super-silicic clinopyroxene. *Int. Geol. Rev.* 44, 831–836 (2002).

Thank you