Evaluation of shock deformation of the basement sandstone around the probable impact site of Australasian Tektite Event using synchrotron X-ray diffraction analysis

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Shocked quartz has been the most commonly used mineral as a barometer of shock metamorphism in the terrestrial impact structures, because of its abundance, durability, and tendency to develop striking and unique deformation features depending on the degree of shock pressure. Various methods have been developed to evaluate the shock pressure that the minerals experienced, such as optical and electron microscope, Raman and cathodoluminescence spectroscopy, and X-ray diffraction (XRD) analyses. However, it is still difficult to quantitatively evaluate the degree of shock metamorphism under the lower range (5–15 GPa) of shock pressure.

Quartz powder samples highly compressed above 25 GPa by shock experiments are known to exhibit lattice expansion that is detected by laboratory powder XRD analyses. However, the lattice expansion of quartz shocked below 25 GPa could not be monitored by a laboratory X-ray diffractometer, resulting in the impossibility of determination of shock pressure in the lower range. In this study, we applied synchrotron XRD analysis, with quite higher energy resolution and X-ray beam intensity than the laboratory instrument, in order to detect a change of lattice constants of quartz in the wide range of shock pressure from 5 to 40 GPa. The experimentally shocked quartz samples, not grinded, were subject to the synchrotron XRD analysis using a high-resolution diffractometer with a multidetector system on beamline BL4B2 at the Photon Factory in the High Energy Accelerator Research Organization (KEK PF). Synthetic Si powder was selected for a standard material for wave energy calibration, leading to monitoring a change of lattice constants at $0.001^\circ\theta$ resolution.

The result of the synchrotron XRD analysis revealed that with increasing shock pressure, the lattice constants of quartz slightly increase in the low shock pressure range of 5–15 GPa and drastically in the high range of 20–30 GPa. Quartz samples shocked above 35 GPa show no XRD signals, indicating that the amorphization has been completed. Similar drastic changes of the lattice constants in the pressure range of 20–30 GPa and absence of XRD signals above 35 GPa have been reported in the previous laboratory XRD analyses. The lattice expansion recognized in the low shock pressure range of 5–15 GPa is up to 0.00059(6) Å (0.01%) for the constant *a*, 0.0003(1) Å (0.006%) for the constant *c* and 0.034(6) $Å^2$ (0.03%) for the cell volume *V*. All of the values cannot be explained by the above-mentioned sample and analytical errors. As this pressure range is corresponding to appearances of mechanical twins and planar deformation features (PDFs), this slight lattice expansion might be caused by a change of quartz structure due to these low-grade shock-induced microtextures. This result indicates that the measurement of lattice constants of quartz by synchrotron XRD analysis is useful to evaluate lower (5–15 GPa) range of shock deformation.

Then we applied this technique to the basement Mesozoic sandstones around the probable impact site of Australasian Tektite Event. The basement sandstone samples were taken from 18 sites in northeastern Thailand and southern Laos. The synchrotron XRD analysis of quartz extracted from the sandstone samples by chemical treatments was conducted to determine the values and distribution of shock pressure around the probable impact site.
The result of the synchrotron XRD analysis demonstrated that the lattice constants of quartz increase eastward, from northeastern Thailand to the southern part of the Thailand-Laos border. The lattice expansion is up to 0.00028(6) Å (0.006%) for the constant *a*, 0.0003(1) Å (0.005%) for the constant *c* and 0.018(6) $Å^2$ (0.02%) for the cell volume *V*. This spatial variation of the lattice constants of quartz in the basement Mesozoic sandstone indicates that the degree of shock deformation increase to the Thailand-Laos bordar and that the impact took place somewhere in the area around the border.

Keywords: Australasian Tektite, Shocked metamorphism, synchrotron X-ray diffraction analysis

