Raman study of shock effects in plagioclase feldspar from the Mistastin Lake impact structure, Canada

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Introduction: Meteorite impact craters are the dominant surface feature on most terrestrial planets and provide fundamental information about planetary evolution [1]. Many terrestrial impact stuctures have been eroded to such a degree that only the underlying autochthonous target rocks are preserved or the crater structure has been infilled by later sedimentary units. In contrast, the Mistastin Lake impact structure shows an almost complete suite of impactites and the target rocks are dominated by granodiorite, quartz monzonite, and anorthosite [2], providing an excellent opportunity to better understand how impact events modify target rocks and minerals. The objective of this study is to better understand shock processes in plagioclase feldspar, building upon earlier work at Mistastin using optical microscopy and X-ray diffraction (XRD) [3].

Methodology: The Mistastin Lake impact strucuture is located in northern Labrador, Canada (55°53'N; 63°18'W) with an apparent crater rim diameter of ~28 km and was formed ~36 Ma [4]. The majority of the studied samples came from anorthosite target rock or monomict anorthosite breccia, containing a wide range of shock levels and diverse shock metamorphic effects. Rock slabs, thin sections and powder samples under high pressure from center of the crater to the low shocked ones from the edge were studied systematically. Optical petrography was used to separate samples into broad categories of shock level. The main technique used in this study is Raman spectroscopy with a 514.5 nm laser, which can resolve internal crystal deformation precisely. Mineral compositions was determined by electronprobe microanalyses (EMPA) and wavelength dispersive spectroscopy (WDS) and their structures are verified by powder XRD.

Results: Based on the EPMA data, the Mistastin Lake samples contain plagioclase with composition of $An_{28-55.}$ Among the Raman spectra of unshocked plagioclase samples there are approximately 12 distinct Raman peaks and several weak peaks in 0-1400 cm^{-1} range; the exact position of these peaks can vary with composition due to the solid solution within the plagioclase series [5]. For a typical unshocked An_{49} plagioclase sample, peaks at 185, 200, 285, 408, 480, 509, 568, 765, 795, 984, 1186, 1216 cm^{-1} were observed and the peak intensity may varies with its orientations. The intense and diagnostic peaks occur near 480 and 510 cm^{-1}, assigned to Al–O–Si and Si-O-Si stretching modes [6].

At higher pressures, previous studies have reported plagioclase transformation to partly birefringent characteristics, with the pressure up to 30 GPa [7]. These two diagnostic peaks shifted to higher wavenumber with slightly peak width increase from average 16 to 22, whereas other peaks became weaker, broader or even diminished. Nevertheless, we did not observe a significant varation in the peak intensity ratio of these two peaks (480:510). For diapletic plagioclase formed above 30 GPa, we found the two diagnostic peaks merged to form a large hump centering at around 490cm^{-1} together with the other peak around 568 cm^{-1} also changing into a broad peak aroung 580cm^{-1}. Furthermore, the peak intensities decreased as entire plagioclase turned into isotropic melt at above 45 GPa. No recrystallization was observed for the plagiolclase in this study.

Future Work: Although plagioclase is one of the major minerals found in terrestrial impact materials, chondritic and achondritic meteorites, and lunar highland rocks, its application as a shock barometer had not been straightforward owing to the limited experimental data for the amorphization and lack of the kinetic investigation for the formation of high-pressure phases [8]. We aim to use laser-heated diamond anvil cell to model temperature-induced amorphization and crystallization of high-pressure phases using andesine - labradorite plagioclase, to help the interpretation of spectroscopic data from remote and landed missions, and to understand the mineralogical changes occurred during impact events.

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