U–Pb isotopic systematics on shock-metamorphosed baddeleyite

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The issue of the duration of Martian magmatic activity is one the controversial debates recently [e.g. 1]. The young radiometric ages of ~180 Ma for shergottites, a class of Martian meteorites, reflect the timing of crystallization from a magma or rather later events related to shock metamorphism or fluid infiltration. Baddeleyite (ZrO_2) occurs as an accessory mineral in Martian meteorite and is useful for U–Pb isotopic analyses as well as zircon ($ZrSiO_4$) [e.g. 2-4]. Martian meteorites contain varied shock effects; however, there are no available data on the effect of high-pressure/temperateure lead or uranium diffusivities in baddeleyite. To examine whether the U–Pb isotopic systems of baddeleyite are easily reset by shock metamorphism, our group have undertaken shock-recovery and annealing experiments using a propellant gun at NIMS and a vertical gas-mixing furnace and at Univ. of Tokyo, respectively [5].

High-shock pressure slightly caused damages on baddeleyite crystal structures. The brightness of Cathode Luminescence emission increased with the shock pressure of up to 57 GPa. Annealed sample did not show any detectable change from pre-annealing sample (shocked at 47 GPa sample). In addition, Raman peak shifts of 2-4 cm^{-1} from unshocked baddeleyite were observed associate with shock pressures. Those peak shifts were reported on high pressure static experiments [6]. However, there is no evidence on phase transformation from baddeleyite to high-pressure and temperature phases [5].

Lead loss from baddeleyite was not observed for the experimentally shocked samples. In addition, the U–Pb and ^{206}Pb–^{207}Pb ages of shocked and heated baddeleyites are indistinguishable from those of unshocked baddeleyite within errors except minor lead loss from the baddeleyite shocked at 57 GPa and heated 1 h at 1300 ^{o}C. Although duration of peak shock-pressure and grain size of baddeleyite are different from the nature of shock events, our experimental results suggest that it is hard to completely reset U–Pb isotopic systematics of baddeleyite by shock metamorphism.

In some terrestrial crater, occurrences of some baddeleyite grains are explained as breakdown products from zircon to baddeleyite and silica ($ZrSiO_4 \rightarrow ZrO_2+SiO_2$) by shock effects. The baddeleyite grains in RBT 04261, shergottites, do not associate with zircon or silica materials and no signature of Raman peak shift; it imply that grains are not breakdown products from zircon and not affected by shock pressure so much. Three large grains (~10 μm) are found for isotopic analyses, two grains occurred with ilmenite and one grain found in melt pocket. U–Pb age of ~200 Ma was obtained from these grains although the grain sizes are still slightly smaller than primary ion beam of SHRIMP, and may imply the magmatic activity on Mars [4].

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Rapid reductions in North Atlantic Deep Water during the last interglacial period and their relationship to Greenland ice sheet variability

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One uncertainty in future climate and CO_2 projections involves changes in the Atlantic meridional overturning circulation (AMOC) and its response to climate change. Models and proxy data suggest that AMOC is vigorous under interglacial climate conditions with minor changes on millennial timescales. Yet, with the exception of the notable changes associated with the 8.4 kyr BP flood outburst, little is known about the stability or thresholds of deep ocean circulation on shorter timescales. Here we use deep-sea sediment cores to assess the response of North Atlantic Deep Water (NADW), the main constituent of the deep limb of AMOC, to source region warming, Greenland ice sheet (GIS) melting, and ocean freshening.

We present new high-resolution (~20 yr/sample) foraminiferal $\delta^{13}C$ and $\delta^{18}O$ records of near surface and bottom water properties spanning MIS 5e from a core site on the Eirik Drift south of Greenland (MD03-2664). The site lies at 3440m, just below the main axis of the sediment-laden Western Boundary Undercurrent and is optimally situated for recording changes in newly formed NADW. In addition, we use ice rafted detritus (IRD) and foraminifera-based surface property proxies ($\delta^{18}O$, MAT-SST's, Mg/Ca) to assess changes in the GIS and Arctic to North Atlantic freshwater transport.

Bottom water $\delta^{13}C$ values gradually increase through MIS 5e. Superimposed on this trend are large-amplitude (>1‰) reductions in bottom water $\delta^{13}C$, similar in scale to those observed during the 8.4 kyr BP event. These $\delta^{13}C$ decreases last a few centuries before recovering to background values. Using an array of records spanning the abyssal Atlantic we show that the magnitude and spatial geometry of the deep water anomalies is consistent with an expansion of southern source deep water as the influence of NADW waned—a geometry analogous to deep ocean changes during the 8.4 kyr BP event and to millennial scale events of the last glaciation. Surface water proxies and IRD content suggest that these NADW changes occur during a period of rapid GIS retreat and surface water freshening. Taken together, our results demonstrate that "8.4kyr-style" deep ocean property changes occurred at a time when North Atlantic climate was similar to that projected for our future.