EXPERIMENTAL CONSTRAINTS FOR IMPACT INDUCED POST-HYDRATION HEATING ON C-COMPLEX ASTEROIDS

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Introduction: Mighei-like carbonaceous chondrites (CMs) originate from C-complex asteroids and have been aqueously altered, containing serpentine (Srp) and/or tochilinite (Thi) among other phases. Some CMs were heated after aqueous alteration in a process called post-hydration heating, whose cause is unknown, though possibilities include impacts and solar heating [1]. During post-hydration heating, volatile-rich phases become amorphous before forming anhydrous minerals [2]. The temperatures of each phase transition are known, but not precisely constrained. To better understand these phase transitions, we step-heated the CM Allan Hills (ALH) 83100, whose reflectance spectra is similar to the asteroid Bennu [1], and collected synchrotron powder X-ray diffraction (PXRD) data.

Methods: High resolution PXRD patterns were acquired from a powdered 100 mg sample of ALH 83100 on beamline Ill at Diamond Light Source. A PXRD pattern was collected from the sample at 26°C before it was heated from 200-950°C at 25°C intervals in an inert N_2 atmosphere. It was held at each temperature step for 1 hour before a PXRD pattern was collected using multi-analyzing crystal detectors. PXRD data collection took 1 hour for each pattern, making the total time ALH 83100 spent at each temperature step 2 hours, a timescale comparable to impact induced post-hydration heating [3]. The PXRD data was analyzed with Rigaku Smartlab II software.

Results: At each temperature, diffraction peaks change their widths and intensities as phase transitions occur. Key observations include: the weakening of Thi peaks at 200°C prior to its disappearance at 300°C, the appearance of an unknown phase with a broad peak at ~3.56 Å at 525°C due to incipient Srp decomposition prior to its recrystallization into olivine and low-Ca pyroxene (Opx) at 600 °C, and the appearance of clinopyroxene (Cpx) alongside small amounts of oldhamite at 700°C.

Discussion: The lowest temperature that Thi was previously reported to experimentally decompose at was 245°C after 185 hours of heating [4]. Given the weakening of Thi peaks at 200°C, it is likely not stable at 200°C; if Thi were held at 200°C for long enough, it should decompose. Thi disappears at 300°C and cannot remain at that temperature for even short durations.

This is not the first report of an unknown phase appearing due to Srp decomposition. Akai [5] observed an intermediate phase from Srp decomposition in the matrix of naturally heated CMs. Heating experiments on terrestrial Srp have shown it transforming into antigorite [6] or a talc-like phase [7]. This phase is likely present in more moderately heated CMs. This phase's identity cannot be confirmed due to a lack of unique diffraction peaks.

Diffraction peaks matching Cpx appear at 700°C. Other heating experiments on ALH 83100 have also described Cpx forming [1]. Unlike Opx [2], Cpx is not a commonly reported product of post-hydration heating. The growth of Cpx was likely promoted by calcite decomposition while pyroxenes were still forming, which input Ca into the system. Why Cpx is not a commonly observed product of post-hydration heating could be due to two possibilities: 1) it is misattributed to other processes (e.g., primary, aqueous alteration) in heated CMs, 2) ALH 83100 did not have enough S to use up the Ca liberated from calcite to form exclusively oldhamite, and Cpx formed as a result.

Conclusions: The heating of ALH 83100 during PXRD data collection has revealed new insights regarding phase transitions during post-hydration heating. Thi is unstable at 200°C and Cpx can form from calcite and Srp decomposition. An intermediate phase previously reported by Akai [5] was observed forming from Srp decomposition. The timing of this experiment was similar to that expected if impacts were the primary cause of post-hydration heating. If longer timescales like those expected for solar heating were used, phase transitions would occur at lower temperatures and secondary anhydrous minerals would be more abundant.

Future Work: Long-duration experimental heating experiments will be conducted on Thi to better characterize its decomposition. Heating experiments with *in situ* micro XRD will be used to better identify the unique peaks for the intermediate phase, allowing for it to be identified and characterized.

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