AN INVESTIGATION OF SHOCK EFFECTS ON MARS-RELEVANT PHOSPHATE MINERALS: 
SHOCK-TRANSFORMATION OF CHLORAPATITE.  C. T. Adcock¹, O. Tschauer¹, and E. M. Hausrath¹,
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Introduction: Phosphate minerals have significant importance to martian planetary studies. They are indicators of magma evolution and volatile budgets in late stage magmas, sources of potentially bioessential P, major carriers of REEs, and altered or secondary phosphate minerals can be used as indicators of past surface and near surface aqueous environments [1-11]. However, our only samples of martian phosphate minerals are in the form of SNC meteorites. All meteorites, including those from Mars, have experienced shock. Thus any interpretation based on petrographic evidence from meteorites must take into account the potential alteration of minerals by shock and associated heating.

The overarching goal of this research is to investigate the effects of shock on Mars-relevant phosphate minerals (e.g. whitlockite [Ca₉(Fe,Mg)(PO₃OH)(PO₄)₆], merrillite [Ca₉(Na, Fe,Mg)(PO₄)₃], and Cl-apatite [Ca₅(PO₄)₃Cl]). To address that goal we are performing shock-recovery experiments on natural and synthesized phosphate minerals, and synchrotron studies (micro-diffraction, XANES, and Mossbauer) of both naturally shocked phosphate mineral (i.e. in meteorites) and shock-recovery samples. Here we discuss early results of our shock-recovery experiments and synchrotron studies on chlorapatite, one of the most common phosphate minerals found in martian SNC meteorites.

Methods: Chlorapatite Synthesis: Chlorapatite was synthesized using previously published methods after [9, 12-15] by heating a mixture of hydroxyapatite and calcium chloride to 1100°C for 24 hours in a Pt crucible. After incubation, crystalline material recovered from the vessels was inspected by optical microscope to identify chlorapatite and any other (contaminant) phases. Contaminant phases were usually confined to the <75 um fraction and were removed by sieving. Output minerals were then determined to be pure phases by powder X-ray diffraction (XRD) with a Panalytical X’pert Pro diffractometer using Cu Kα radiation (XXL Laboratory, UNLV). Scans were performed over 5-75° 2θ, 0.008° step size at 0.06° s⁻¹ scan rate, and phase identification was carried out using Panalytical X’Pert High Score Plus software. Mineral chemical compositions and stoichiometry were confirmed by electron microprobe analysis (EMP) on a JEOL JXA-8900 microprobe operating at 20keV and 10nA using a 10µm beam (EMiL Facility, UNLV). In apatites, a change in structure from hexagonal structure (typical of fluorapatite) to monoclinic structure (end-member chlorapatite) can occur at the Cl end-member [16], though hexagonal chlorapatite from high temperature synthesis is documented [17]. EMP and IR data indicated our synthetic chlorapatite is end-member or near end-member chlorapatite [18], and X-ray diffraction confirmed that the structure is hexagonal.

For shock experiments, the chlorapatite was powdered in an agate mortar and pestle. The powder was suspended in ethanol and Stoke's settling law was used to recover the <10μm fraction.

Shock Experiments: Our shock-recovery experiments were carried out using a single-stage light-gas (He) gun located at the UNLV Department of Geoscience. The projectiles were flat polished metal flyer plates mounted on Lexan sabots. Either stainless steel or rhenium was used as flyer- and driver-material. The samples to be shocked were encapsulated in a recovery chamber formed by a front driver plate, rear plate, and an annular ring, all rigidly mounted in a cylindrical holder and launched into a stop plate. Our first chlorapatite shock recovery experiment was run at a peak pressure of 20-25 GPa (within the mid range of shock experienced by SNC meteorites [REF19]) on a sample of synthetic chlorapatite powder (<10μm). Porosity was estimated at approximately 25%.

Synchrotron Diffraction Study: Synchrotron X-Ray Diffraction studies of recovered shocked materials were carried out at beamline 12.2.2 at the Advanced Light Source (ALS), LBNL. Primary beam energy was 22 keV. Diffraction data were collected with a MAR345 image plate detector. Detector parameters are calibrated and corrected for geometric distortions based on a LaB6 NIST powder diffraction standard using the GSE_ADA software [20] and Dioptas [21]. Recorded diffraction images were integrated using Dioptas.

Results: After the shock experiment a significant amount of the sample was recoverable for analysis (Figure 1). Although temperatures were locally in excess of 1000 K during the shock, no indication for phase transformations was observed in Cl-apatite. However, a minor amount of sample material that was trapped between the driver and radial seal was in part transformed into a new phase (Figure 2). This small amount of material has experienced high shear stresses but overall lower peak shock pressures (estimated at <12 GPa) and temperatures than the bulk sample. The
new phosphate phase bears a structural similarity to compact spineloid-like phosphates such as chopinite \([\text{Mg,Fe}_3(\text{PO}_4)_2]\) but the exact structure and composition is not yet determined.

**Ongoing Work:** Our ongoing work includes further shock experiments and synchrotron analysis of chlorapatite. We are also continuing our shock investigations on whitlockite and merrillite as well other high-pressure phosphates which may be present in martian SNC meteorites [22].

**Figure 1.** Chlorapatite recovered from shock experiment GG104 (light material in upper center). This material showed no transformation, however, transformation did occur where the sample was trapped between the driver and radial seal.

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**Figure 2.** Synchrotron XRD patterns. Red pattern is the reference for chlorapatite. Black pattern is material from experiment GG104 (shocked chlorapatite). Arrows and bars highlight peaks and peak shouldering indicative of an additional phase in the shocked chlorapatite.