NEW FINDINGS OF HIGH-PRESSURE POLYMORPHS IN THE L6 ORDINARY CHONDRITE CHÂTEAU-RENARD. I. P. Baziotis[1], L. Ferrière[2], S. Klemme[3], J. Berndt[3], F. Brandstätter[2], D. Topa[2], D. Palles[4], E. Kamitsos[4], and P. D. Asimow[5], [1]Dept. of Natural Resources Management and Agricultural Engineering, Agricultural University of Athens, Iera Odos 75, 11855 Athens, Greece (ibaziotis@aua.gr), [2]Natural History Museum, Burgring 7, 1010 Vienna, Austria, [3]Institut für Mineralogie, Westfälische Wilhelms-Univ. Münster, Correnstrasse 24, Münster, Germany, [4]Theoretical and Physical Chemistry Institute, National Hellenic Research Foundation, 48 Vassileos Constantinou Avenue, Athens 11635, Greece, [5]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125, USA.

Introduction: Shock features in ordinary chondrites preserve a record of impact events due to (multiple) collisions among their parent asteroids (e.g., [1]). As such, meteorites showing evidence of shock and melting at various scales (from cm down to nm) provide an opportunity to explore collision events and to constrain parameters including the P-T-(*t*) conditions of impact metamorphism and hence the relative velocity, size, and density of impactors and targets, respectively. Shock parameters can be inferred from the occurrence and textures of high-pressure (HP) mineral polymorphs (e.g., [2]). In addition, one can use transformation kinetics and melt vein (MV) cooling rates to estimate the duration of the shock pulse [3].

Here, we report on results obtained for the Château-Renard ordinary chondrite, a French historical fall from 1841. It is a highly shocked (shock stage S5) L6 ordinary chondrite (e.g., [4]). Although a number of covered thin sections have been examined by us, the current results are all based on one polished section from the Natural History Museum Vienna (NHMV) collection. We provide new textural, compositional, and microRaman spectroscopy data and infer constraints on the P-T conditions of MV formation. This report includes the first documentation of HP polymorphs in this meteorite.

Methods: We carefully examined the polished section NHMV-L4361 of Château-Renard for shock effects in mineral grains and HP polymorphs within MVs. We used transmitted and reflected light microscopy and the JEOL JXA-8530-F Field Emission Gun Electron Microprobes at both the NHMV and the University of Muenster to characterize the texture and mineralogy, to precisely determine the chemical composition and local variations at the chondrule and MV scale, and to compare different MVs within the section. Finally, microRaman spectroscopy was used to verify the nature of the HP/HT minerals and phases within MVs.

Results: The groundmass of Château-Renard shows strong mosaicism, planar fractures in olivine, and plagioclase glass. Numerous pervasive shock veins crosscut the matrix lithology; they are predominantly in contact with olivine but occasionally also with pyroxene (Fig. 1). The MVs have variable thickness (from ~50 μm to ~200 μm) and are made up of silicate clasts (mostly olivine), sulfides, and Fe-Ni metal grains (Fig. 1). The MVs show characteristic gradation from glass-rich rims, to segregated metal-rich layers (~20 μm from the MV boundary), to silicate clast-rich cores. All the minerals show preferred orientation parallel to the MV elongation.

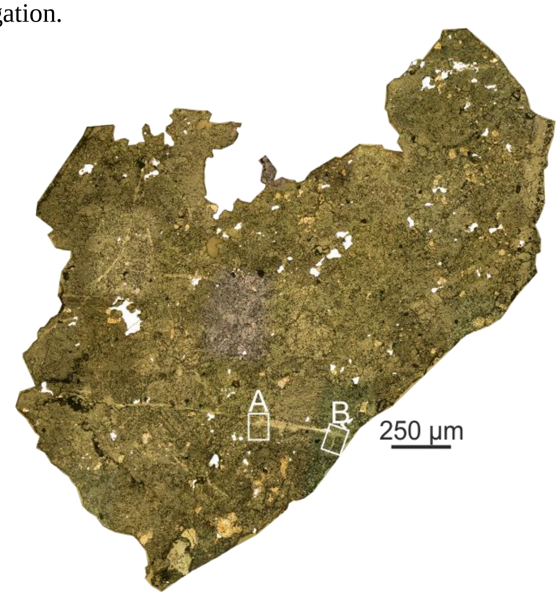

Figure 1: *Mosaic of Château-Renard (NHMW-L4361) built from reflected-light images; the two white frames indicate the areas hosting HP polymorphs, with ringwoodite in A (Figs. 2, 3) and majorite and wadsleyite in B (Figs. 3, 4).*

Although no HP polymorphs have so far been reported for the Château-Renard meteorite, we observed a plethora of HP polymorphs — including ringwoodite, wadsleyite, majorite, and pyroxene glass (Figs. 2-4) — both at the rim and in the core of MVs.

Discussion: The MVs formed from a melt that peaked at temperatures above the liquidus of the matrix material [5]. The maximum vein width of ~100 μm implies a time on the order of ~1 ms for conductive cooling and solidification of the vein. The preservation of HP polymorphs without clear evidence of back-transformation to low-pressure equivalents suggests a HP duration at least this long (i.e., ~1 ms) and hence an impactor at least a few meters in size.

The presence of pyroxene glass constrains the minimum pressure to ~6–7 GPa, whereas the absence of Mg-wüstite + (devitrified) bridgmanite and Mg-wüstite + stishovite suggests a maximum P ~23–25 GPa [6]. Peak pressures were most likely in the stability range of the olivine polymorph ringwoodite, 18–23 GPa. The wadsleyite occurrence suggests lower P compared to ringwoodite, 14–18 GPa. Their coexistence implies spatially or temporally variable pressure regimes during the shock event. The cooling rate was fast enough (growth rate <1 $m.s^{-1}$) to grow tiny wadsleyite crystals (1–3 μm in size) in the shock melt products before quenching [7]. Pressure indication derived from the occurrence of majorite depends significantly on the presence of Fe; the Château-Renard majorite has Fe/(Mg+Fe) between 0.20–0.27, suggesting growth conditions at 17–20 GPa and 1800–2100 °C [8].

Using the available data from static experiments, we infer a time for complete solidification of the MV of ~0.7 msec. The calculation assumes radial cooling of a 100 micron sphere from superliquidus temperatures (~2000 °C) while surrounded by cool matrix (~100 °C). The preservation of ringwoodite at the center of the MV suggests cooling below ~1273 °K while the rock was still at P > 18 GPa [9,10], otherwise, complete back-transformation of ringwoodite to olivine would be expected. Furthermore, the coexistence of majorite (at the center of MV) and wadsleyite (at the rim of MV) indicates a thermal gradient persisting during the growth of the HP phases.

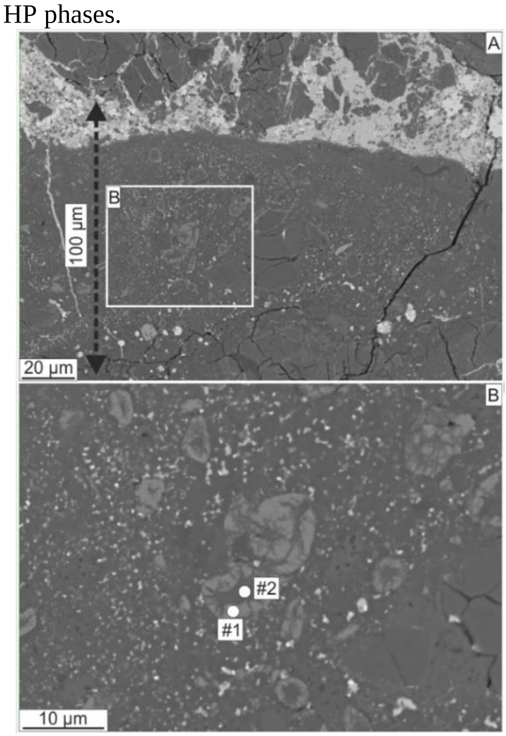

Figure 2: *(A) BSE image of a MV in Château-Renard. (B) Partially converted olivine grain in the MV. The bright part of the grain corresponds to ringwoodite (Spectrum #1 in Fig. 3) which surrounds olivine (Spectrum #2 in Fig. 3).*

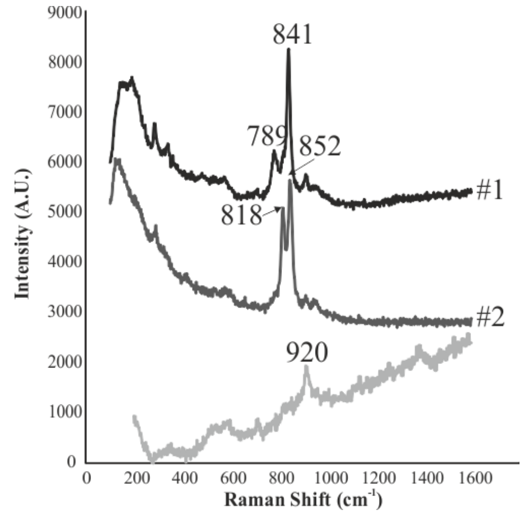

Figure 3: *Raman spectrum #1 with peaks at 789 and 841 cm^{-1} is typical of ringwoodite. For comparison, the olivine spectrum (#2) is also given. The lower spectrum, with the intense peak at ~920 cm^{-1}, corresponds to wadsleyite and is taken from area B (Fig. 1).*

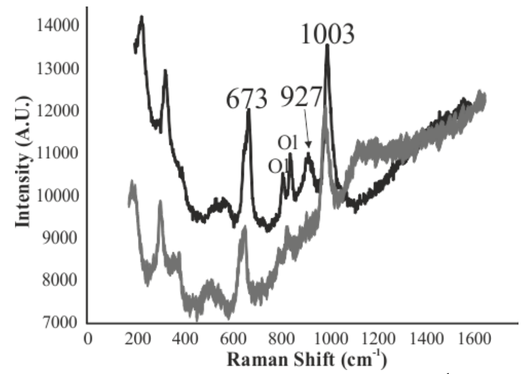

Figure 4: *Raman peaks at ~673 and ~1003 cm^{-1} are typical for pyroxene and are present in both spectra. However, the peak at 927 cm^{-1} in the black spectrum corresponds to majorite.*

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References: [1] Gillet Ph. and El Goresy A. (2013) *Ann. Rev. Earth Planet. Sci., 41*, 257–285. [2] Baziotis I. B. et al. (2013) *Nature Comm., 4*, 1404. [3] Beck P. et al. (2005) *Nature, 435*, 1071–1074. [4] Rubin A. E. (2003) *GCA, 67*, 2695–2709. [5] Ozawa S. et al. (2014) *Sci. Reports, 4*, 5033. [6] Agee C. B. (1998) *Rev. Mineral., 37*, 165–203. [7] Tschauner O. et al. (2009) *PNAS, 106*, 13691–13695. [8] Tomioka N. et al. (2016) *Sci. Adv., 2*, e1501725. [9] Wang Y. et al. (1997) *Science, 275*, 510–513. [10] Miyahara M. et al. (2016) *PEPI, 259*, 18–28.