DISCOVERY OF RINGWOODITE, WADSLEYITE, AND γ-$Ca_3(PO_4)_2$ IN CHASSIGNY: CONSTRAINTS ON SHOCK CONDITIONS. Ansgar Greshake and Jörg Fritz, Museum für Naturkunde an der Humboldt-Universität zu Berlin, Invalidenstraße 43, 10115 Berlin, Germany (ansgar.greshake@museum.hu-berlin.de)

Introduction: High-pressure phases, including high-pressure polymorphs of olivine and pyroxene, and numerous others have frequently been found in and around melt veins in ordinary chondrites and have allowed to constrain the p-T-conditions experienced by the meteorites during shock metamorphism [1 and ref. therein]. Several of such phases were also reported from Martian meteorites. However, the olivine high-pressure polymorph wadsleyite occurs only in traces while ringwoodite was not found at all so far [2 and ref. therein].

We here present the finding of ringwoodite and wadsleyite as well as of the high-pressure phosphate γ-$Ca_3(PO_4)_2$ in large melt pockets of the Martian dunite Chassigny.

Method: A thin section of Chassigny was studied by optical and scanning electron microscopy. Quantitative mineral analyses and x-ray elemental maps were acquired with a Jeol JXA 8500F field emission electron microprobe. Micro-Raman spectroscopy was carried out using a notch filter based Dilor LabRam operating with a HeNe Laser of 632 nm wave length. Spectra in the range of 200 to 1200 cm^{-1} were collected with an optical lens of 100x magnification. The final spectra are accumulations of 5 single spectra, each accumulated for 30 s at the same spot.

Results: Inspection by **optical microscopy** revealed the presence of four distinct, 100 to 300 µm sized, brownish areas all located at olivine-olivine grain boundaries (Fig. 1).

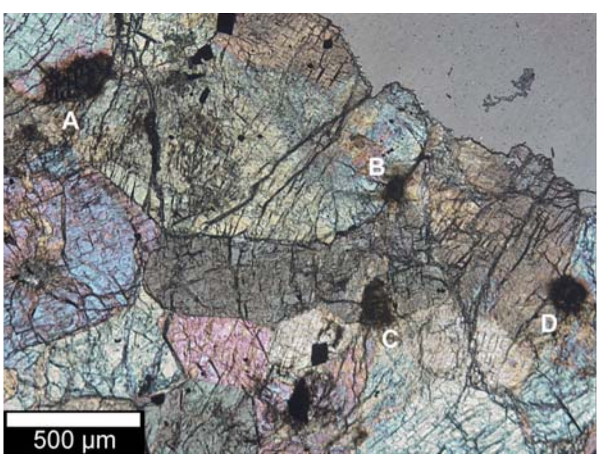

Fig 1. Optical micrograph (transmitted and polarized light superimposed) of 100-300 µm sized areas of high-pressure phase assemblages in Chassigny labeled as A-D.

These dark areas are fractured, have a higher refractive index compared to the surrounding olivine, and - except for a few spots - are optically isotropic. The contact of these areas with the surrounding olivine is gradual and olivine at the contact is recrystallized.

Raman spectroscopic investigations document that: (1) No Olivine is present in these areas as the characteristic double peak at ~818 and at ~840 cm^{-1} is absent in all spectra recorded. (2) Instead of olivine, the indicative peaks for ringwoodite at 794 and 842 cm^{-1} and wadsleyite at 718 and 917 cm^{-1} [2 and ref. therein] were unambiguously identified (Fig. 2). Furthermore, the ringwoodite band positions at 297 and 794 cm^{-1} correspond to ringwoodite with Fo~68 which well matches the composition measured in the high-pressure assemblages in Chassigny [3].

In most regions ringwoodite is much more abundant than wadsleyite. Only in area D wadsleyite dominates locally over ringwoodite.

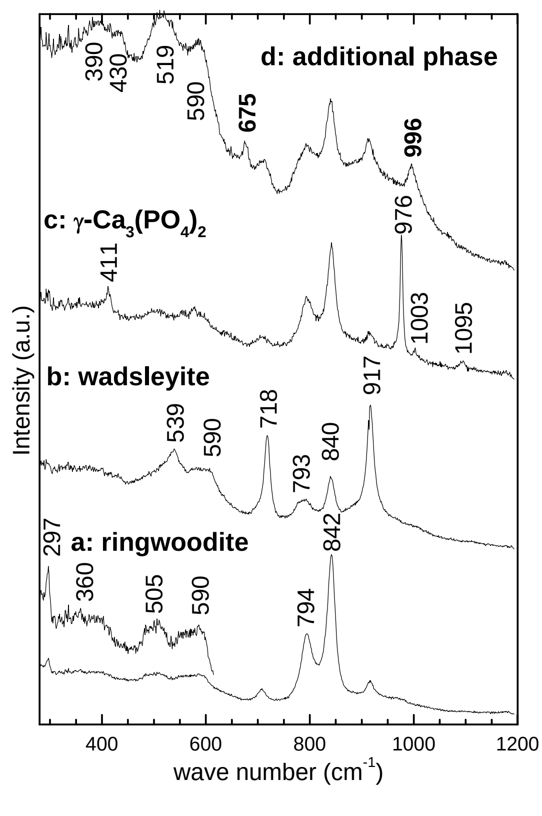

Fig. 2. Raman spectra of different phases observed in the high-pressure phase assemblages. For the plot, the unprocessed spectra were arranged with arbitrary intensities.

Several Raman spectra obtained indicate the presence of an additional so far unidentified phase with pronounced Raman bands at 675 and 996 cm^{-1} (Fig. 2).

The high-pressure polymorph of chlorapatite, γ-$Ca_3(PO_4)_2$, was also identified by Raman spectroscopy. Band positions at 411, 976, 1003 and 1095 cm^{-1} as well as their relative intensities are in excellent agreement with literature data [4].

Back scattered electron imaging and elemental mapping reveal the complex texture of the brownish areas (Fig. 3).

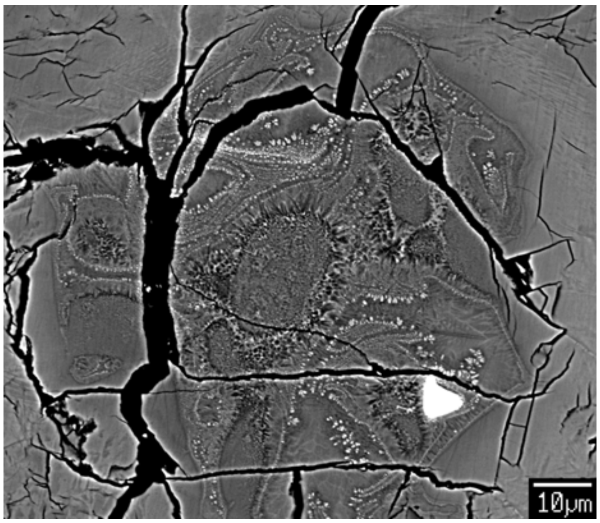

Fig. 3. Back scattered electron image of area D. Small ringwoodite/wadsleyite-crystals nucleate from the margin of a larger ringwoodite clast, which also contains some minor wadsleyite. The bright phase at the lower right is chromite.

They generally represent local melt pockets with completely melted regions and entrained olivine and chromite fragments displaying rounded morphologies and signs of partial recrystallization (chromite). In case of area B, melt veins continue from the melt pocket into the surrounding olivine. Raman spectroscopy revealed that the chemically homogeneous olivine fragments in the melt pockets are transformed into ringwoodite with minor wadsleyite. They frequently serve as nuclei for tiny, ~1-2 µm sized wadsleyite-ringwoodite crystals. These mostly euhedral grains often show a pronounced compositional zoning with a Mg-rich core and a more Fe-rich rim.

Once completely molten, now microporphyritic areas exhibit flow structures (Figs. 3, 4) and contain abundant <1µm sized rounded to dendritic crystals which appear translucent in the optical microscope. Elemental maps show that the crystallites are enriched in Mg and Fe and strongly depleted in Si, while the adjacent regions are enriched in Si. Due to their small grain size these crystals could not be precisely identified yet.

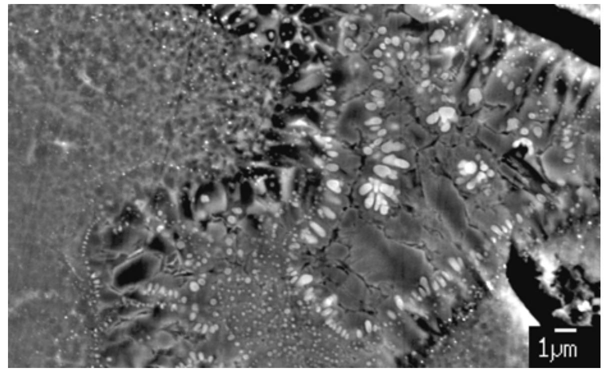

Fig. 4. Back scattered electron image of a region in melt pocket C. Small strongly compositionally zoned ringwoodite/wadsleyite crystals occur with small Mg,Fe-rich droplets of a so far unidentified phase.

Within the flow structures several areas exist which are again composed of 1-2 µm-sized mostly euhedral chemically zoned wadsleyite-ringwoodite crystals.

The high-pressure polymorph of chlorapatite was found in few locations of melt pocket A. In these settings the small grains are closely associated with Fe-metal droplets.

Discussion: The textural setting of the melt pockets all being located at olivine junctions strongly suggests formation by *in situ* melting due to shock wave reflection at grain boundaries. During local melting, various mineral fragments were entrained and adjacent olivine recrystallized partly. Due to the prevailing shock pressure the enclosed olivine clasts transformed most likely via solid-state mechanism to ringwoodite and minor wadsleyite. Under persisting pressure crystallization of chemically zoned composite crystals of ringwoodite and wadsleyite occurred at the margins of the clasts and in completely melted regions. These findings allow to deduce a minimum enduring shock pressure of ~20 GPa.. Compositional heterogeneities observed in the molten regions might be attributed to high pressure decomposition of $(Mg,Fe)_2SiO_4$ and may, thus, point to even higher pressure. This, however, needs to be confirmed in future investigations.

Acknowledgements: Financial support from the Helmholtz-Alliance "Planetary evolution and life" WP 3200 is gratefully acknowledged.

References: [1] Sharp T. G. and DeCarli P. S. (2006) *Meteorites and the Early Solar System*, 653-677. [2] Gillet P. et al. (2007) *Geol. Soc. Am. Spec. Pap, 421,* 57-82. [3] Feng L. and Lin Y. (2008) *MAPS, 43*, A43. [4] Xie X. et al. (2002) *GCA,66,* 2439-2444.