FIRST DISCOVERY OF ASIMOWITE IN AN ANTARCTIC METEORITE (GROSVENOR MOUNTAINS 17151, L6, ORDINARY CHONDRITE).

I. Baziotis[1], S. Flemetakis[2], S. Xydous[1], C. Sanchez-Valle[2], D. Palles[3], E. Kamitsos[3], K. Mavrogonatos[4], C. Vollmer[2], J. Berndt[2], S. Klemme[2], P. D. Asimow[5]. [1]Department of Natural Resources Management & Agricultural Engineering, Agricultural Univ. of Athens, Iera Odos 75, 11855 Athens, Greece, ibaziotis@aua.gr, [2]Westfälische Wilhelms-Univ. Münster, Institut für Mineralogie, Correnstrasse 24, 48149 Münster, Germany, [3]Theoretical and Physical Chemistry Institute, National Hellenic Research Foundation, Athens 11635, Greece, [4]Hellenic Survey of Geology and Mineral Exploration, 13637, Acharne, Athens, Greece, [5]California Institute of Technology, Division of Geological & Planetary Sciences, Pasadena, California 91125, USA.

Introduction: Ordinary chondrites (OCs) preserve a record of impact events due to collision(s) among their parent asteroids that helps constrain the shock conditions and parameters (in particular, size and relative encounter velocity) of impactors and targets. In turn, the co-evolution of planetesimal sizes and their orbital excitation can distinguish among scenarios for the early evolution of the solar system. Shock parameters can be inferred from high-pressure (HP) minerals that are often found in melt veins (MV). Herein, we report the first discoveries of nine HP minerals in the recently recovered L6 chondrite, GRO 17151 (Grosvenor Mountains, season 2017-2018). Furthermore, we report the first discovery of the Fe-rich analogue of wadsleyite, asimowite, from an Antarctic meteorite (3rd known occurrence altogether).

One large main MV is visible in each of two studied sections. The vein contains HP polymorphs of olivine (ringwoodite + ahrensite + wadsleyite + asimowite), orthopyroxene (majorite), Na-pyroxene (albitic jadeite), phosphate (tuite), silica (stishovite) and oxide (xieite). Using these observations, we are able to constrain the impact record of this meteorite.

Material and methods: The GRO 17151 was recovered by the Antarctic Search for Meteorites (ANSMET) expedition in the 2017-2018 season and classified as type L6 [1]. Two single-polished thin sections (GRO 17151-8, GRO 17151-9) were examined for shock indicators, with a focus on the MVs and their HP phases. We used optical microscopy, a JEOL JSM-IT300LV scanning electron microscope (SEM), a dispersive confocal Renishaw inVia Reflex Raman microscope (514 nm laser), a Zeiss 1550VP field-emission SEM with energy-dispersive X-ray spectrometry (EDS) and electron backscatter diffraction (EBSD) capability, and a JEOL JXA 8530F electron probe micro-analyzer. Around 20 areas of the MV were analyzed for texture, mineral chemistry, and Raman spectroscopy (RS), and a few of them with EBSD.

Petrography, mineral chemistry, and structure: In the groundmass of GRO 17151, olivine grains show strong mosaicism and planar deformation features. The single thick MV is presumed to be the result of a strong shock event; it is in contact with olivine but occasionally also with pyroxene and metal grains. The width of the thickest MV is nearly constant (~500 to 600 μm). The MV consists of glass, silicate clasts (olivine, pyroxene, and plagioclase), sulfides, chromite, and Fe-Ni metal.

HP minerals. We have observed 9 HP phases including ringwoodite (*rw*), ahrensite (*ahr*), wadsleyite (*wd*), asimowite (*asi*), majorite (*maj*), albitic jadeite (*jd*), stishovite (*stv*), tuite (*tu*), and xieite (*xie*) (Fig. 1). The MV matrix is mostly a crystallized assemblage of *maj*+*rw*+*wd*+magnesiowüstite (Fig. 1).

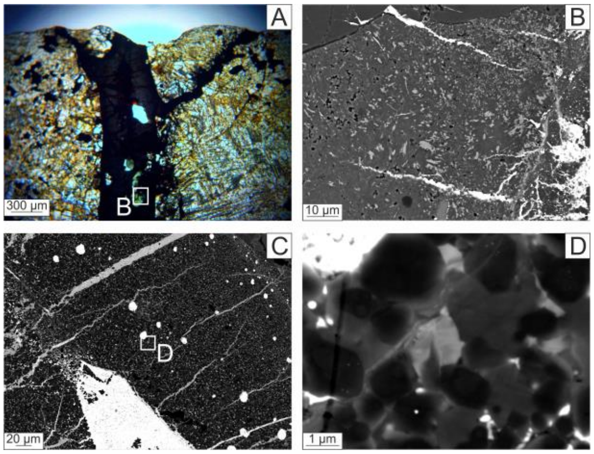

Figure 1: (A) MV in GRO 17151 with large green *wd* crystals. (B) Large *wd* with bright inclusions of *asi*. (C) MV matrix. (D) High-resolution view of *asi* (center) associated with *maj*, *wd*, and magnesiowüstite. Image A is a transmitted plane-polarized light image; B-D are back-scattered electron images.

The large green crystals, up to about 250 μm, have olivine stoichiometry and variable composition from Fa_{15} to Fa_{52}. Co-located RS have strong *wad* peaks and minor *rw* peaks (Fig. 2A). Turning to EBSD analysis coupled with high-spatial resolution co-located EPMA, the small BSE-bright crystals in Figs 1B and 1D are Fe-dominant (Fa>50%), yield structure solutions most consistent with wadsleyite structure (though *ahr* structure is difficult to distinguish by EBSD), and strong *wd* Raman peaks. Hence these are asimowite (Fig. 2).

Crystals of albitic jadeite [2,3] are equigranular to irregularly shaped, up to ~20 μm, and by EPMA yield the formula $(Na_{0.43\text{-}61}Ca_{0.07\text{-}0.08}K_{0.02\text{-}0.085}\square_{0.27\text{-}0.45})(Al_{0.83\text{-}0.86}Si_{0.16\text{-}0.19}Fe_{0.01\text{-}0.04})Si_2O_6$, with Ca# [100×Ca/(Ca+Na)] in the range of 10.4-15.1. The RS of GRO 17151 albitic jadeite has a distinct major peak at 701 cm^{-1} and minor peaks at 204, 377, 436, 525, 574, 989, and 1038 cm^{-1} (Fig. 3A). The RS of near-endmember *jd* has major peaks at 700, 991, and 1040 cm^{-1} and minor peaks at 204, 375, 385, 433, 525, 575 cm^{-1} (RRUFF R050220.2), which is a good match even though our EPMA analysis shows that the GRO 17151 material is *not* near-endmember *jd*. As expected but not often found, the *jd* coexists at fine scale with stishovite, based on mixed RS (spectrum A31 in figure 3A) showing the major *stv* peak at ~751 cm^1 and one minor peak at 231 cm^1. Further, the composition of phosphate has a merrillite-like chemistry with Na_2O in the range 2.58-2.74, MgO 3.38-3.51 and FeO 0.72-1.35 wt.%.

Implications: *P-T-t constraints*. The RS of GRO 17151 phosphate shows a mix of merrillite and *tu* due to partial preservation of *tu* from high pressure; *tu* suggests $P \leq 22$ GPa. The *P* for growth of albitic jadeite and asimowite [5], which lack any stability fields, cannot be assessed. The occurrence of *wd*, however, suggests $P >$ 13 GPa to at most 22 GPa (depending on *T* and Fe content), coexisting *wd* and *ahr* bounds the *P* along the upper limit of the *wd* field. The existence of *maj* suggests *P* of 17–20 GPa and 1800–2100 °C [4].

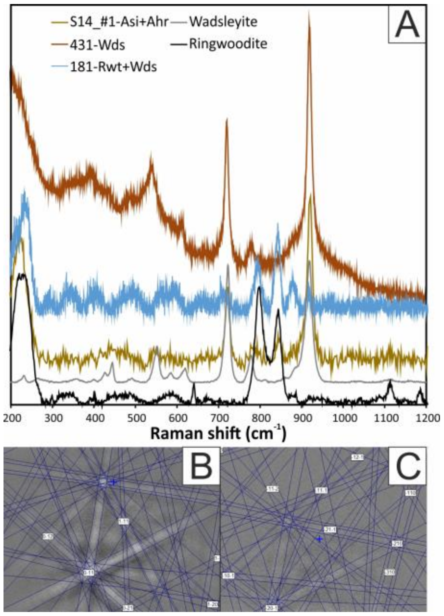

Figure 2: (A) Selected RS of olivine polymorphs in GRO 17151. (B,C) EBSD patterns from Fe-rich areas in Fig. 1B and 1D, indexed in wadsleyite structure. Reference: ringwoodite (RRUFF R070079), and wadsleyite (R090004).

Pending further work, it is clear that GRO 17151 is heavily shocked, hosting at least nine HP phases indicating peak shock conditions > 17 GPa and 1800 °C. It hosts a unique record of the passage of material through space-and-time-variable high-*P*,*T* conditions.

This occurrence of asimowite is the first in an Antarctic meteorite and indicates a very different paragenesis from previous reports [5]. Moreover, all the fine-grained wadsleyite(β)-structured material is more Fe-rich than any experimentally synthesized stable *wd*, even though it is not all asimowite by the 50% rule. We suggest that Fe-rich (~Fo_{50}) olivine suffered a shock strong enough to form ringwoodite(γ), which thereafter, during decompression avoided back-transformation to olivine(α) at the equilibrium α-γ phase loop, reaching instead the metastable branch of β-γ loop and forming a series from ~Fa_{40} *wd* to ~Fa_{55} *asi*, with traces of even more Fe-rich *ahr* still remaining on quench.

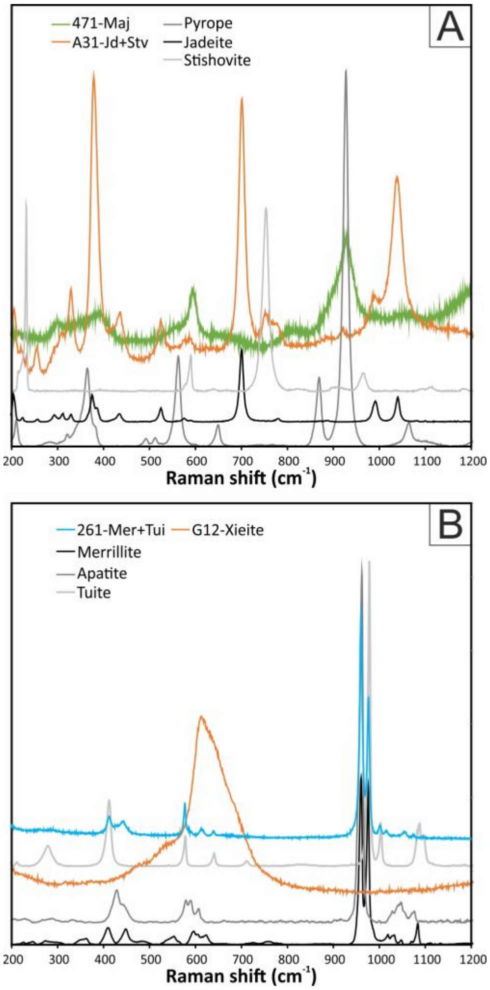

Figure 3: Selected RS from GRO 17151. Reference: merrillite (RRUFF R150063), apatite (R060180), and tuite (R120115).

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References: [1] Antarctic Meteorite Newsletter (2020) 43(1). [2] Baziotis et al. (2021) *Am. Min.*, DOI 10.2138/am-2022-8220. [3] Ma et al. (2021) Am. Min., DOI 10.2138/am-2022-8220. [4] Tomioka et al. (2016) *Sci. Adv.*; 2:e1501725. [5] Bindi et al. (2019) *Am. Min.*, 104:775–778.