RAMAN SPECTROSCOPY OF MERRILLITE IN VILLALBETO DE LA PEÑA L6 ORDINARY CHONDRITE.

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Introduction: The Villalbeto de la Peña meteorite fell in Spain on January 4, 2004, originating a strewn field of ~95 km^2 [1]. From the study of the fireball images and a video record the heliocentric orbit has been determined showing the origin of the body in the main asteroid belt [2]. The meteorite has been classified as an L6 ordinary chondrite with a shock stage S4 [1]. The chondritic host of Villalbeto de la Peña consists of the rock-forming minerals olivine, low-Ca pyroxene, plagioclase, metallic Fe-Ni, and troilite. Accessory components include chromite and merrillite. The collisional history of the 1-m-sized progenitor meteoroid appears fingerprinted in the surviving meteorites that are moderately shocked [1]. Shock effects involving mineral transformations occur in numerous shock veins that are present all over the meteorite, ranging from 0.03 to 0.1 mm in width (Figure 1), with abundant metallic Fe-Ni and troilite (Figure 2). Merrillite, $Ca_9MgNa(PO_4)_7$, is an anhydrous Ca-phosphate found in meteorites [3] that can be used to constrain shock-induced events because it may transform into a high-pressure polymorph with the structure of trigonal γ-$Ca_3(PO_4)_2$ [4]. Here we have conducted a detailed study of merrillite in the Villalbeto de la Peña meteorite, both inside and outside the shock veins, by means of Raman spectroscopy. Vibrational techniques give accurate information about the structure of these phosphate minerals thereby providing constraints on phase identification and peak shock pressure [5].

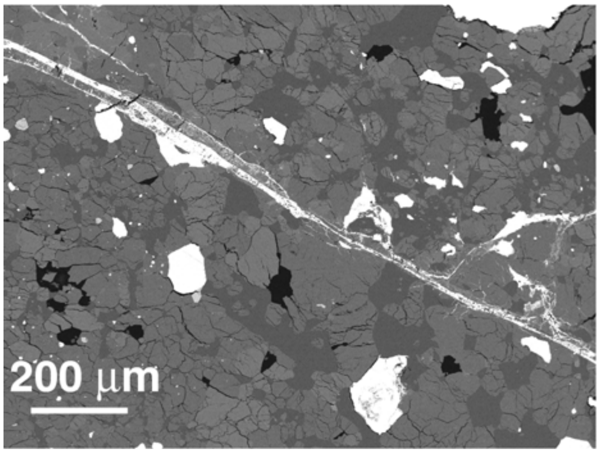

Figure 1. Low-magnification backscattered electron image of a typical recrystallized region and a shock vein in Villalbeto de la Peña.

Experimental methods: Raman spectra were obtained with a Jobin Yvon T64000 spectrometer using an Ar ion laser as an illumination source (514.5 nm) and a CCD detector cooled at 140 K. The Raman instrument was coupled to a standard microscope (x50 magnification) and the collection optics system was used in the backscattering configuration. Mineral compositions were analyzed with a Cameca SX-50 electron probe at 15 keV using a beam current of 20 nA.

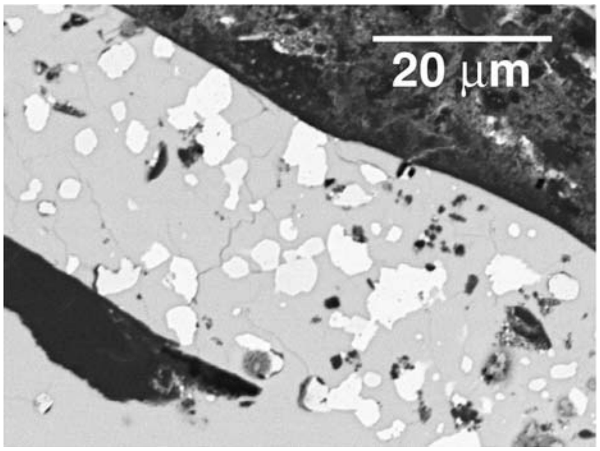

Figure 2. Backscattered electron image of a shock vein in the Villalbeto de la Peña meteorite.

Results and discussion: Several Raman spectra of merrillite grains were recorded in various locations of the meteorite matrix as well as in different shock veins (Figure 3). In all cases strong absorption bands at 959(3) and 974(1) cm^{-1} dominate the spectrum. These bands originate from the ν_1 symmetric stretching mode of PO_4^{3-} ions [6]. Bands of intermediate intensity at 1020(5) and 1082(4) cm^{-1} result from antisymmetric ν_3 vibrations. Additional bands at lower wavenumbers, 174(3), 414(4), and 452(4) cm^{-1} also correspond to merrillite [5]. No evidence of high-pressure polymorph of merrillite was encountered in the shock veins of the Villalbeto de la Peña meteorite, which should exhibit a characteristic Raman spectrum with only one intense peak at about 974 cm^{-1} [4]. According to this, compositions of merrillite from microprobe analyses were similar in all cases, and that of merrillite inside the shock veins were indistinguishable from merrillite in the matrix: <0.04% TiO_2, 0.34(5)% FeO, 3.41(3)% MgO, 46.5(2)% CaO, <0.04% NiO, 2.13(5)% Na_2O, 0.12(3)% K_2O, and 47.5(2)% P_2O_5. These values are similar to merrillite in many other ordinary chondrites. Considering that shock veins in Villalbeto de la Peña are thin, they likely cooled rapidly and should retain shock-induced high-pressure phases, like γ-$Ca_3(PO_4)_2$, if they formed during shock events. A back transformation from γ-$Ca_3(PO_4)_2$ to merrillite can only take place in thick shock veins, which are slower-cooling [4]. The solely existence of merrillite in the shock veins of Villalbeto de la Peña as revealed by Raman spectroscopy indicates that this meteorite was not severely shock-metamorphosed.

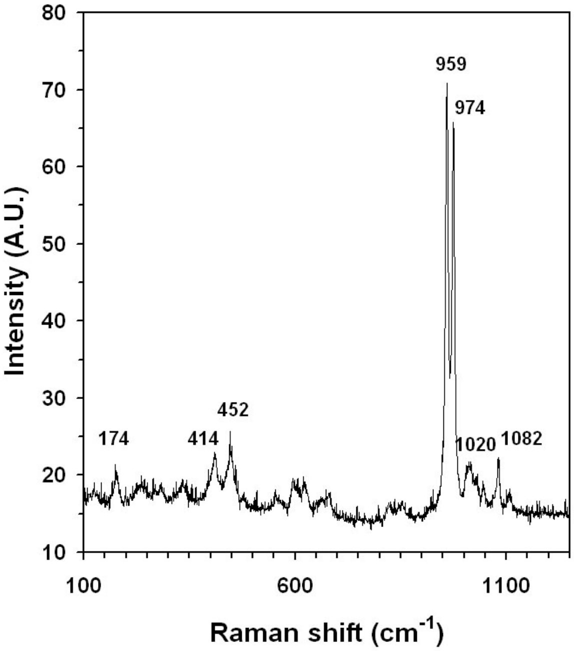

Figure 3. Confocal micro-Raman spectra of merrillite in Villalbeto de la Peña found inside a shock vein.

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References: [1] Llorca J. et al. (2005) *Meteoritics & Planetary Science, 40,* 795–804. [2] Trigo-Rodríguez J.M. et al. (2005) *Meteoritics & Planetary Science*, in press. [3] Rubin A. E. (1997) *Meteoritics & Planetary Science*, *32*, 231–247. [4] Xie X. et al. (2002) *Geochimica et Cosmochimica Acta*, *66*, 2439-2444. [5] Cooney T. F. et al. (1999) *American Mineralogist*, *84*, 1569-1576. [6] Mooney R. W. et al (1968) *Journal of Inorganic and Nuckear Chemistry*, *30*, 1669-1675.