COMPARING CARBONACEOUS CHONDRITIC METEORITES USING MICRO-RAMAN SPECTROSCOPY AND SEM/EDS. A.G. Dall'Asén[1], R. Paul[1], A.R. Stokke[1], R. Kayastha[1], B.C. Bromley[2], and S.J. Kenyon[3]. [1]Department of Physics and Astronomy, Minnesota State University-Mankato, Mankato, MN 56001, USA. E-mail: analia.dallasen@mnsu.edu. [2]Department of Physics and Astronomy, University of Utah, 115 South 1500 East, Salt Lake City, UT 84112, USA. [3]Smithsonian Astrophysical Observatory, 60 Garden St, Cambridge, MA 02138, USA.

Introduction: Meteorites are accessible resources that provide precious evidence about the formation of planets in the solar system. Particularly, carbonaceous chondritic meteorites are considered the most primitive surviving materials from the early Solar System, and thus can contribute to understand how planetisimals (the precursors to planets, of 1-100 km in radius) formed from dust (micron-size grains) [1]. These relics are composed of ancient inclusions, such as chondrules (micro/millimeter-sized inclusions), surrounded by a matrix of microparticles [2].

Here we study in detail several properties (e.g. structure, mineralogical and elemental composition, and topography) of the inclusions and surrounding matrix of carbonaceous chondritic meteorites Moss, Murray, Bali and Allende, using low- and high-resolution micro-Raman spectroscopy, and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM/EDS) [3]. We compare these properties within the chondritic samples and between them. In particular, we analyze their carbon content to study the degree of graphitization and thermal metamorphism in their parent body. Finally, we discuss possible implications about their formation environment and ensuing alteration.

Samples: Four carbonaceous chondritic fragments were studied: Moss (CO3.6, 1.283 g, fell in Ostfold, Sweden, in 2006), Murray (CM2, 3.366 g, fell in Kentucky, USA, in 1950), Bali (CV3, 0.0662 g, fell in Nana-Mambere, Central Africa Republic, in 1907) and Allende (CV3, 5.19 g, fell in Pueblito de Allende, Mexico, in 1969). No sample preparation was required for either Raman or SEM/EDS measurements. Figure 1 shows photographs of these samples with the selected chondrules (marked with a circle).

Experimental and Data Analysis Methods: All the samples were studied using similar experimental conditions. Their topographical features were first analyzed using optical microscopy. Low- and high-resolution Raman spectroscopy measurements were carried out to study their structural and mineralogical composition. These measurements were performed at room temperature using a custom-built micro-Raman spectroscopy system with a 532-nm excitation source, a laser spot of ~3 μm and power of ~5 mW on the sample. Raman spectra were taken from several spots of selected inclusions and surrounding matrix using a 1-s integration time and different number of accumulations (from 5 to 100) to obtain higher signal-to-noise ratios. The spectra peak parameters were analyzed fitting Gaussian and Lorentzian functions using commercial software packages. The morphological structure and elemental composition of the samples were performed and analyzed by a SEM/EDS system (JEOL JSM 6510LV, Thermo-Noran) using secondary-electron (SE) and backscattered-electron (BSE) detection, and data analysis software equipped with the system.

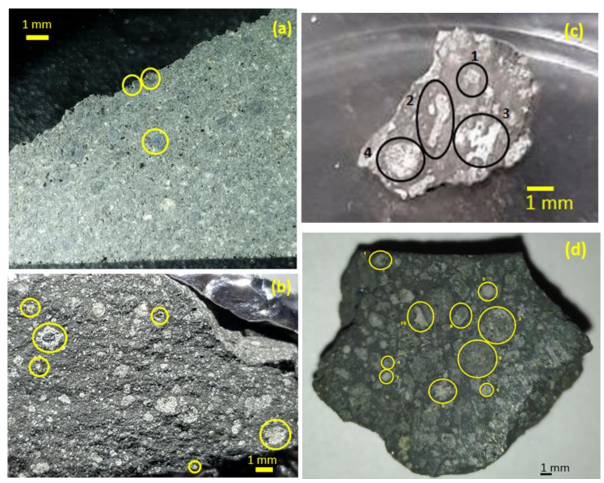

Figure 1. Photographs of the studied meteoritic fragments: (a) Moss; (b) Murray; (c) Bali; and (d) Allende. The circles mark the selected chondrules.

Results and Discussion: From all the employed techniques, the inclusions studied in Moss and Allende showed that they had the typical characteristics of chondrules, while the inclusions examined in Murray corresponded mainly to olivine crystals, and those ones found in Bali were small crystals and irregular inclusions that could either be mostly amoeboid-olivine-aggregates (AOAs) or calcium-aluminum-rich inclusions (CAIs) [4]. Raman spectroscopy results showed that Moss chondrules mainly contained graphitic carbon, olivine (high forsterite content) and pyroxene (high enstatite content), while the surrounding matrix not only contained these minerals but also hematite and magnetite. In Murray, only olivine was mainly found in the crystal inclusions, and graphitic carbon and pyroxene (enstatite) in the matrix. In both Bali and Allende, graphitic carbon and olivine (high forsterite content) were found. Allende had also pyroxene (enstatite, diopside and ferrosilite) and quartz. Other spectra obtained from Bali showed similar features corresponding to larnite, magnetite and awaruite. A few more minerals were found in all the meteoritic samples but they could not be identified yet.

SEM/EDS results showed that, in general, oxygen, iron, magnesium and silicon were the main elements found in these samples, and secondary elements were carbon, sulfur, nickel, calcium, aluminum, sodium and chromium. For all the samples, the studied inclusions had higher relative composition of magnesium and silicon, while the matrix had higher relative composition of iron combined with sulfur or nickel. This Mg/Fe complementarity was also found in other meteoritic samples (e.g. NWA 3118 (CV3) [3]) and it could be due to different formation processes discussed in the literature [e.g. 5,6]. Iron-sulfur rims, veins and patches were found in Moss and Murray, while sulfur rims were observed in Bali and Allende. These features also could be attributed to diverse formation processes [e.g. 4,7-9]. In general, areas with exclusively carbon content (~10-20 μm smooth structures) were found in all the samples. As an example, Figure 2 shows SEM/EDS images of Bali with distinguish observed features.

In addition, the presence of graphitic carbon in the studied meteoritic samples was analyzed as an indicator of secondary processes that affected their parent body. In particular, the thermal alterations of these bodies were examined through the peak metamorphic temperature (PMT) using the main Raman bands of graphitic carbon (D- and G-bands) for those samples with high Raman signal-to-noise ratios (Moss, Bali and Allende). Two mathematical models were applied [10,11] obtaining that the PMTs for Moss, Bali and Allende were (630 ± 20)°C, (583 ± 15)°C and (638 ± 23)°C, respectively, for the first model, and (540 ± 20)°C, (504 ± 18)°C and (604 ± 13)°C, respectively, for the second model. For both models, these values indicated that Allende had relatively high degree of graphitization and its parent body experienced relatively more thermal metamorphism, while Bali had the lowest degree of graphitization and its parent body was the least thermal altered.

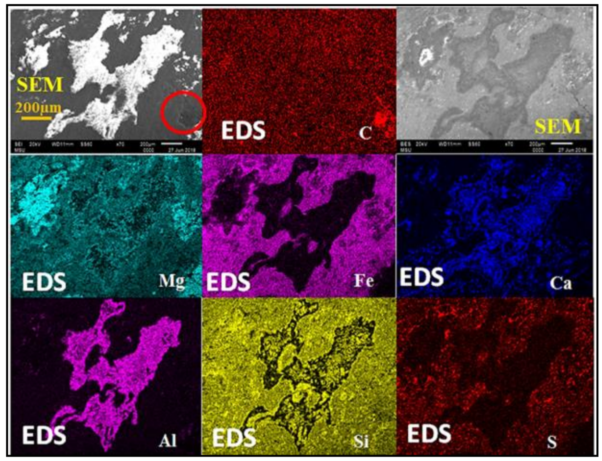

Figure 2. SEM (left: SE; right: BSE) and EDS images obtained from inclusions and surrounding matrix of the meteoritic sample Bali showing distinguish features observed in the sample (C spots, Mg/Fe complementarity, S rims, etc.).

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