SOMETHING FLUORESCES IN CARBONACEOUS CHONDRITES – WHAT IS IT AND IS IT IMPORTANT? Laurence A.J. Garvie, Center for Meteorite Studies and School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287-1404, lgarvie@asu.edu

Introduction: The location and distribution of organic materials amongst the various matrix components of carbonaceous chondrites (CC) is poorly known. Knowing this distribution may provide insights into the role of the mineral components on prebiotic chemical evolution. TEM/EELS analysis [1] and osmium staining [2] show the intimate relationship between organic C and clays in CC meteorites. Clemett et al. [3] used fluorescence microscopy of Murchison tagged with molecular probe to reveal the distribution of primary amines. An important step in further fluorescence studies is to reveal the distribution and identity of naturally fluorescent materials. Early studies [4,5] showed the presence of fluorescent particles in a range of carbonaceous chondrites, though the nature of the particles was poorly known. Here I use correlated optical/fluorescence and electron microscopies to identify the fluorescent materials in CC meteorites.

Materials and Methods: The following meteorites were studied - Murchison (CM2), NWA 1152 (C3-ung), ALHA 77306 (CO3.0), LAP0 2342 (CR2), and Tagish Lake (C2-ung). Millimeter-sized fragments of the matrices were gently crushed between cleaned glass slides and a small amount of the powder was dispersed with methanol onto TEM grids coated with an amorphous lacey C film.

The TEM grids were imaged with a Zeiss LSM 510 Meta inverted laser-scanning confocal microscope using both a short-wave UV source and a 50mW 405-nm diode laser. Individual grid squares were first located and imaged with the light microscope before switching over to the UV and laser sources. In order to mitigate potential beam-damage effects, the laser scanning was done with low laser power settings (typically 1 to 5% output) and short pixel dwell times (e.g., 0.64 to 3.2 μs). Higher laser powers (e.g., >20% output) caused melting of grains on the lacey C film, though the fluorescent particles continued to fluoresce.

Fluorescent images were acquired in two modes. In mode 1 a photomultiplier tube detector was used to acquire high signal-to-noise images with minimal scanning time. This mode was useful for locating individual particles on the TEM grid and provided a qualitative fluorescence intensity for each particle. Mode 2 used the Zeiss META detector, which allowed the acquisition of spectrally resolved fluorescence images (called a lambda stack) from 465 to 743 nm. Lambda stacks recorded the change in fluorescence intensity for each particle with respect to fluorescence wavelength.

Correlative studies were undertaken on the same grids used for fluorescence work with scanning (SEM) and transmission electron microscopy (TEM). These studies allowed the same fluorescent particles imaged with the scanning confocal microscope to be found and analyzed with the SEM and TEM.

Results: Imaging the grids with the short-wave UV source and 405-nm laser shows bright fluorescent points associated with the matrix fragments (Fig B): these points are smaller than the fragments suggesting that a specific matrix component is fluorescing. Bright fluorescent points were visible from all the studied samples. Neither the TEM grid nor the amorphous C support film fluoresced (Fig B). The same particles fluoresced with both the short-wave UV source and the 405-nm laser. The matrix materials, which are primarily clays, anhydrous silicates, and sulfides, showed minimal fluorescence (Fig C). SEM images of the matrix fragments that showed a fluorescent component revealed the presence of rounded or globular particles (Fig D). TEM and EFTEM imaging of these globular particles (Fig E, F) showed that the fluorescent points are carbonaceous nanoglobules – the same as those studied previously [6,7]. The same fluorescent nanoglobules occur in the acid residues, showing that their fluoresce is unaffected by water, HCl, and HF.

Spectrally resolved fluorescent images (lambda mode imaging) from Tagish Lake shows that the majority of fluorescent particles exhibit a broad fluorescence that peaks around 550 to 600 nm. A subset of particles shows fluorescence that peaks near 500 nm.

Discussion: From a practical point of view, the laser scanning fluorescence provides an efficient and non-destructive method to locate nanoglobules, without resorting to deleterious electron microscopies. The fluorescence mapping can also be done on polished samples, thus providing important spatial information.

The high fluorescence brightness of the nanoglobules suggests they possess a relatively high fluorescence quantum yield. As such, nanoglobules and similarly structured carbonaceous particles may be a significant contributor to the luminescence of cosmic dust and a component of the extended red emission [8,9].

References: [1] Garvie LAJ and Buseck PR (2007) MAPS **42** 2111. [2] Pearson VK et al. (2002) MAPS **37** 1829. [3] Clemett SJ et al. (2002) LPSC XXXIII Abst#1898. [4] Alpern B and Benkheiri Y (1973) EPSL **19** 422. [5] Murae T (1999) Adv. Space Res. **24** 469. [6] Garvie LAJ and Buseck PR (2004) EPSL **224** 431. [7] Nakamura-Messenger K et al. (2006) Science **314** 1439. [8] Simonia IA and Mikailov KhM (2006) Astronomy Reports **50** 960. [9] Wada S et al. (2009) The Astrophys J **690** 111.

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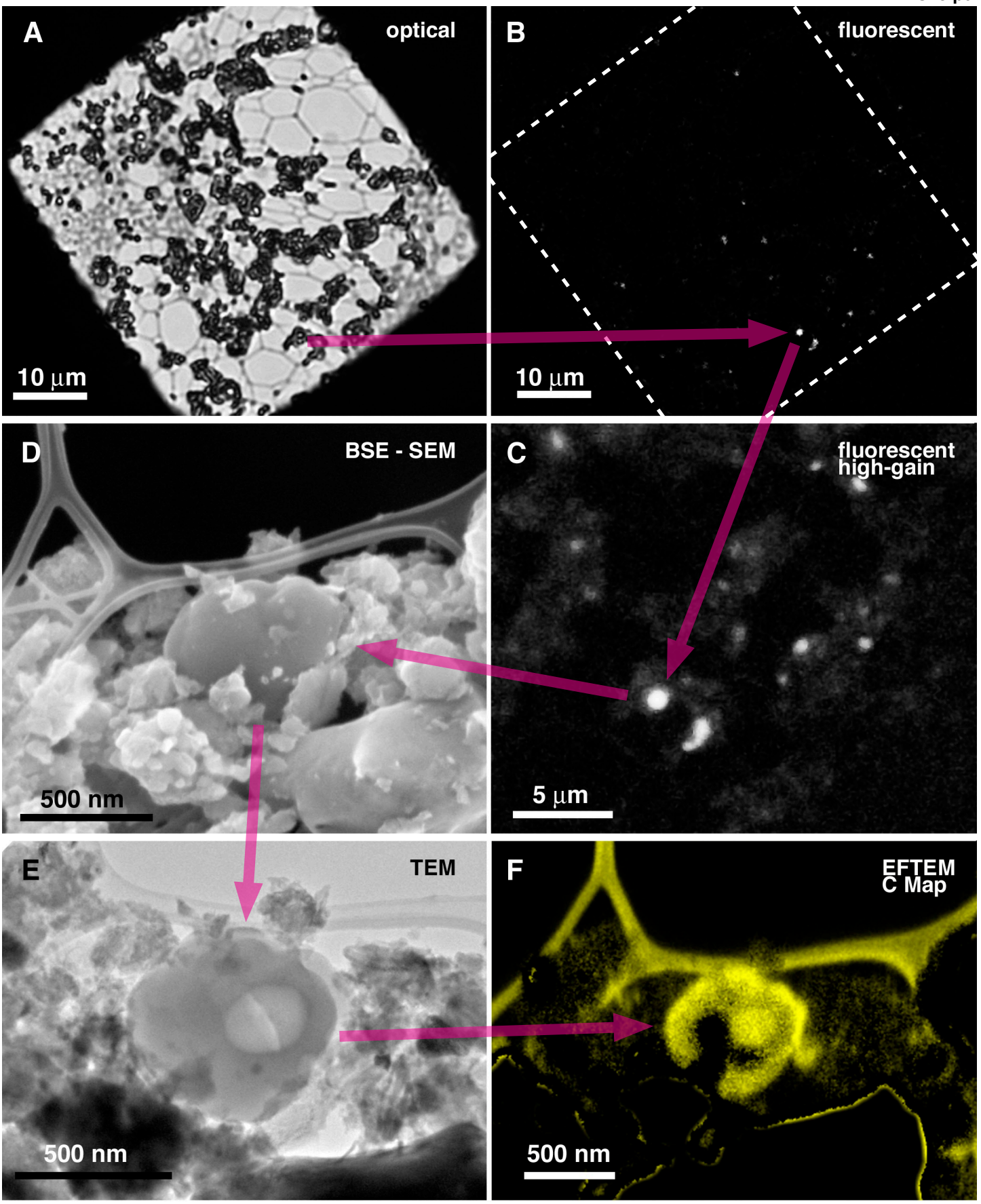

A) Optical image of particles of disaggregated Murchison matrix supported on a TEM grid. Particles are supported by the lacey amorphous C mesh (spiderweb-like mesh). B) Image of the same grid square irradiated with a 405 nm laser showing the distribution of fluorescent particles (bright spots). The dotted line outlines the edge of the grid square in (A). C) Higher magnification image of (B) showing several bright fluorescent particles. The matrix material shows a weak fluorescence. D) SEM image of the round, bright fluorescent particle in (C). E) TEM image of the same particle in (D) revealing a hollow rounded particle. F) Energy-filtered TEM carbon map of the same region in (E) showing that the hollow rounded particle is a carbonaceous nanoglobule.