CARBON ISOTOPIC COMPOSITION AND PETROGRAPHIC SETTING OF GRAPHITE IN THE VACA MUERTA MESOSIDERITE. M. Saavedra[1], Z. Jin[2], S-L Hwang[3], M. Bose[2], M. E. Varela[1], P. Shen[4], T.F. Yui[5] and H-T Chu[6]. 1- ICATE-Conicet, Av. España 1512 sur, JS5402DSP, San Juan, Argentina. 2- School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287-1404, USA; 3-Department of Materials Science and Engineering, National Dong Hwa University, Hualien, Taiwan, ROC; 4-Department of Materials and Optoelectronic Science, National Sun Yat-sen University, Kaohsiung, Taiwan, ROC; 5-Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan, ROC; 6- Central Geological Survey, PO Box 968, Taipei, Taiwan, ROC.

Introduction: Carbon isotopic heterogeneity of graphite has been previously reported in primitive achondrites, chondrites and in the IAB iron meteorites Canyon Diablo and Campo del Cielo [e.g., 1-4]. For mesosiderites, previous studies have shown the presence of isotopically heavy and heterogeneous carbon in the graphite of Vaca Muerta [5].

Here we report on the carbon isotopic composition of graphite associated with the metal in Vaca Muerta mesosiderite and on a petrologic study of a new polished section of this meteorite. The petrographic evidences (e.g., the presence of long graphite veins) revealed new information that is crucial for understanding the carbon isotopic composition.

Sample and methods: The polished thick section of Vaca Muerta (K) (Natural History Museum, Vienna - NHMV), previously studied by [5], has been the focused of a new carbon isotope study. Carbon isotopic composition of graphite were measured with the CAMECA Ametek NanoSIMS 50L in the Center for Isotope Analysis at the School of Earth and Space Exploration, Arizona State University. A Cs+ beam of 110 pA was rastered in a 5*5 µm area. An entrance slit (ES3) was employed in order to get high mass resolving power (>6000) and resolve 12CH- and 13C-. An electronic gating was used to collect secondary ion signals from the internal 50% of the rastered area. Each measurement includes 40 cycles with a dwell time of 300 µs/pixel.

In addition, a petrographic study of the silicates and metal-graphite objects was performed in a new polished-thick section (Vaca Muerta DR from Icate meteorite collection) by optical microscopy and analytical scanning electron microscopy (National Dong Hwa University, Taiwan). Both samples, Vaca Muerta K and DR, have silicate clasts and Fe-Ni metal in about equal proportions.

Results and Discussion: Vaca Muerta K and DR show silicate aggregates cemented by troilite. Metal fills the space in between these aggregates with Ni contents in kamacite and taenite from 5.7 wt% Ni and 36.6 to 50.2 wt% Ni, respectively. In both samples two types of metal areas are observed: 1) the carbon-rich areas characterized by a fine-grained graphite filigree showing a plessite-like texture and 2) the carbon-free areas with kamacite plates separated by thin taenite plates – resembling Widmanstätten pattern (Fig. 1).

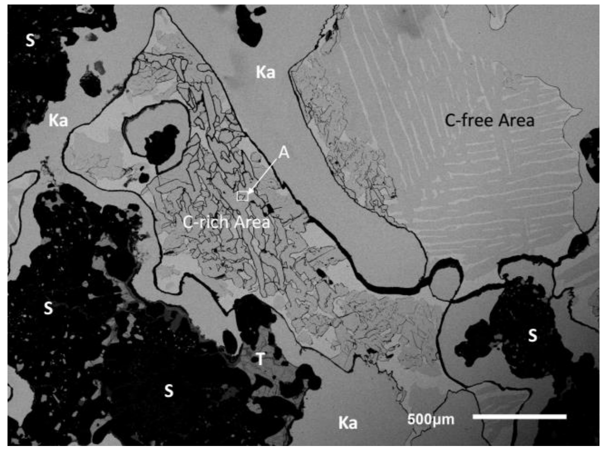

Figure 1: *Scanning electron microscope image of Vaca Muerta DR showing the carbon-rich and carbon-free areas. The troilite (T) is cementing silicates (S) and the kamacite (Ka) is in contact with the silicate aggregates. A indicates the location of figure 2.*

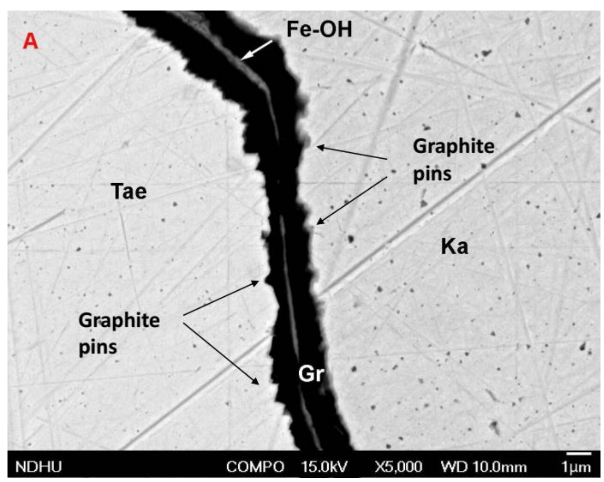

Figure 2: *Graphite vein in contact with kamacite and taenite. Note the Fe-OH at the center of the vein and the well developed graphite pins in contact with both, kamacite and taenite.*

Both areas are covered by a thin or thick graphite mantle. Beyond that only kamacite is observed in contact with silicates (Fig. 1).

The $\delta^{13}C$ values of graphite in the carbon-rich areas in metal of Vaca Muerta K cover a range from –8 ± 2.6 ‰ to +2.7 ± 0.6 ‰ (rel. to PDB) (Fig. 3). Carbon isotopic heterogeneity is observed not only in different carbon-rich areas but also inside a single C-rich area on a nanometer scale. This additionally corroborates with the previous measurements done on the micrometer scale by [5].

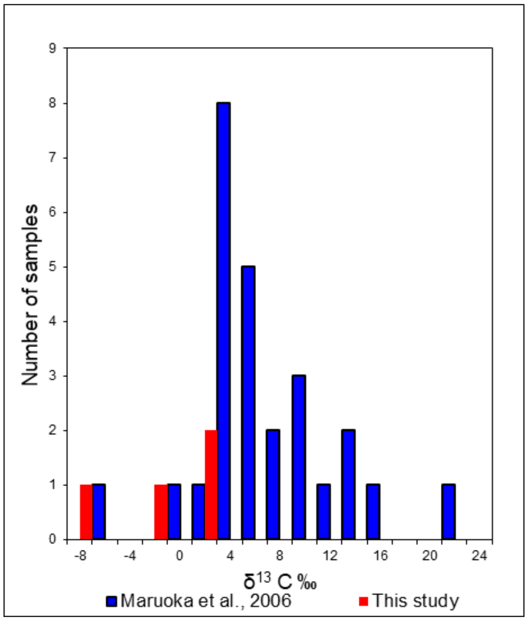

Figure 3: *Histogram of $\delta^{13}C$ of graphite in metal of the Vaca Muerta mesosiderite.*

The inhomogeneous distribution of graphite in the carbon-rich and carbon-free areas indicates that the reaction with a carbon-rich fluid took place at grain boundaries and was governed by the accessibility of the metal (metal having a plessite-like texture was more prune to reaction) (Fig. 1).

The carbon isotopic heterogeneity of graphite in Vaca Muerta mesosiderite in a micro and nanometer scale cannot be explained by a process like that invoked for IAB irons [3]. Such a mixing process requires high temperature to dissolve carbon into the metal. The nanoscale heterogeneity of graphite $\delta^{13}C$ is not in agreement with an exsolution process, as both, distribution and isotopic composition should be homogeneous. This implies that these graphite veins have never experienced a high temperature event.

The $\delta^{13}C$ values ranging from –8 ± 2.6 ‰ [this study] to +22.2 ± 1.2 ‰ [5] require an isotopically heavy C ($\delta^{13}C$ > +30 ‰) source. Although we cannot firmly conclude about the source, a possible scenario involving solar system carbon with in situ reduction of CO_2 followed by carbonyl formation ($Fe(CO)_5$), as previously suggested [5], could have activated the precipitation of carbon mainly at metal grain boundaries. The great abundance of graphite -almost exclusively occurring in metal- suggest that this phase must have been a necessary reaction partner (see the well developed graphite pins in Fig. 2).

Additional evidence for deciphering the origin of the graphite was identified in the polished section of Vaca Muerta DR that show a unique long graphite veinlet decorating the metal-silicate and metal-sulfide contacts and penetrates within the silicate (Fig. 4).

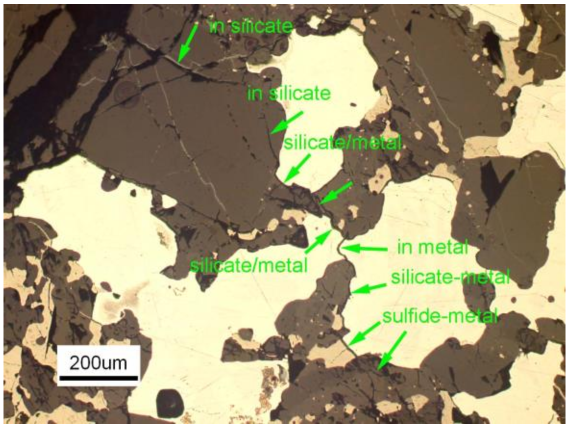

Figure 4: *Optical image of Vaca Muerta DR showing the long graphite veinlet in contact with different phases.*

This unique petrographic evidence and the carbon isotopic heterogeneity indicate that graphite is one of the last phases that was introduced into the Vaca Muerta rock, possibly by a carbon-rich fluid during a low-temperature late stage.

References: [1] El Goresy A et al (2005) GCA 69, 4535-4556; [2] Mostefaoui S et al (2005) MAPS 40, 721-743; [3] Deines P and Wickman FE (1975) GCA 39, 547-557; [4] Maruoka T et al (2003) LPSC XXXIV, 1663; [5] Maruoka et al (2006) LPSC XXXVII #1449.