SINOITE (Si_2N_2O) AND SILICA INCLUSIONS (CRISTOBALITE AND TRIDYMITE) INSIDE GRAPHITE GRAINS IN AL HAGGOUNIA 001 ENSTATITE CHONDRITE. M.H. Leili[1], H. Chennaoui Aoudjehane[1], B.Devouard[2], L.Folco[3] and M.Gemelli[3]. [1]GAIA Laboratory,Hassan II University of Casablanca, Faculty of Sciences Ain Chock, Km8 Route d'El Jadida Casablanca, Morocco. [2]Aix Marseille Univ, CNRS, IRD, INRA, Coll France, CEREGE, Aix-en-Provence, France. [3]Dipartimento di Scienze della Terra - Università di Pisa, Pisa, Italia.

Introduction: The Al Haggounia 001 meteorite was recovered from the rural district of Al Haggounia, located 100 kilometers east of Laayoune city, Morocco.

Since 2015 we carried out seven field campaigns during which twenty samples for a total mass of 7 kg were collected. Their geographic distribution confirms the 10 by 60 km extension of the strewn field defined by [1]. The ^{14}C terrestrial age is 23000 ± 2000 years [2]. We concur that Al Haggounia 001 is an enstatite chondrite, not an aubrite, as argued by, e.g., [3] and [4].

Analytical procedures: After sawing certain samples collected on the strewn field, a few millimetric dark-gray grains with semi-metallic luster were detected. Their abundance in the meteorite is very low (≤1 vol%). 52 petrographic thin sections were realized from our samples at CEREGE, totaling a surface ca. 400 cm^2 for observation with a Zeiss Axio-Scope polarizing microscope in transmitted and reflected light, coupled with an AxioCam-105-color digital camera at Pisa. We used two scanning electron microscopes, Hitachi S3000-N with X-Flash Bruker EDX and Spirit software (CEREGE) and FEI Quanta 450 ESEM FEG with (EDS) Bruker QUANTAX XFlash Detector 6-10 (Pisa), to study the mineralogy and acquire elemental mappings.

Micro-Raman analyses were carried out at Pisa, by using Xplora® Raman spectrometer (Horiba), equipped with a motorized x-y stage and an Olympus BX41 microscope equipped with an integrated 10× objective. We used the CrystalSleuth software which removes cosmic rays and corrects background. This software is available to download for free at the RRUFF project, as well as the Raman database [5].

Results: The dark-gray grains with semi-metallic luster were identified as graphite, based on reflected-light properties, chemistry and Raman spectra. Inside those graphite grains (Fig.1), we observed by optical microscope in transmitted light some inclusions with very high birefringence.

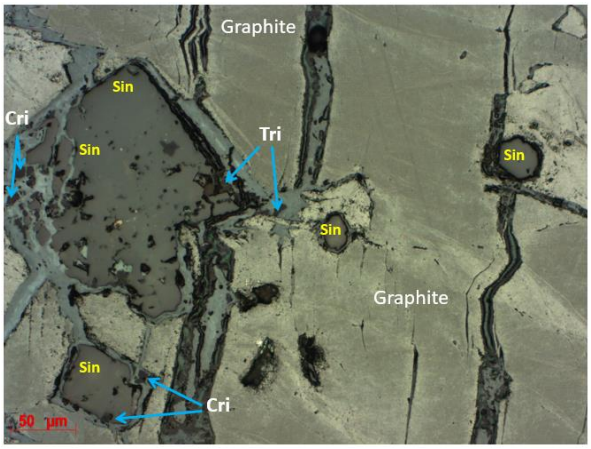

Fig.1: Reflected-light image of relatively large sinoite grains within a 1 mm graphite grain in Al Haggounia 001. (Sin = sinoite, Tri = tridymite, Cri = cristobalite).

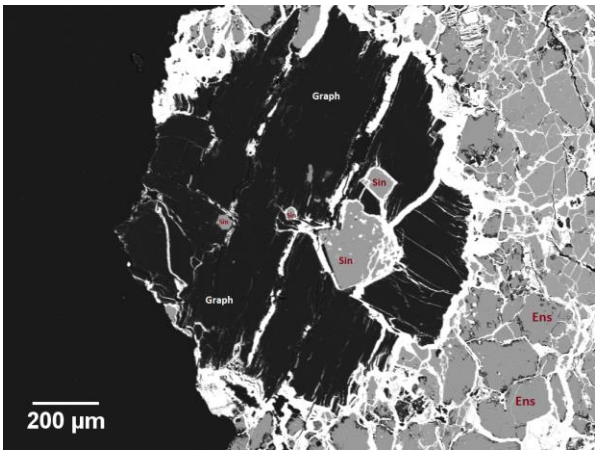

Fig.2**:** Backscattered electron image showing petrographic features of millimetric graphite grain in large irregular enstatite crystals, veins of iron oxides are spreading around and inside the graphite, many sinoite grains are scattered. (Sin = sinoite, Graph = graphite, Ens = enstatite).

SEM imaging (Fig.2), EDX compositional mapping and Raman spectroscopy revealed the occurrence of sinoite (the phase with high birefringence; Fig.3) as well as two silica polymorphs, cristobalite (Fig.4) and tridymite (Fig.5).

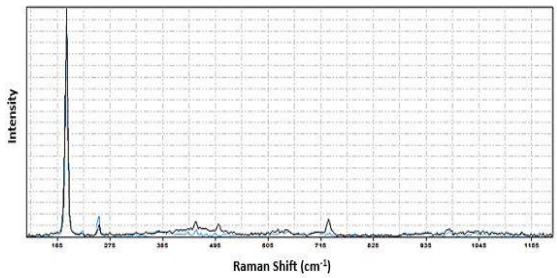

Fig.3: Raman spectrum of a sinoite grain compared to sinoite reference Raman spectrum in blue (Ruff data).

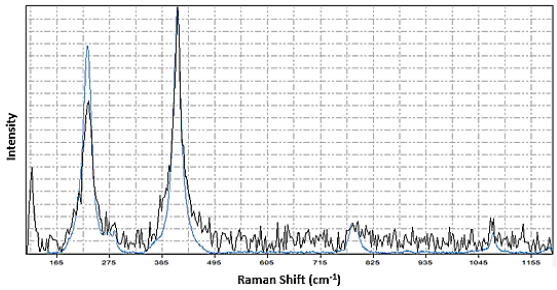

Fig.4: Raman spectrum of a silica grain compared to cristobalite reference Raman spectrum in blue (Ruff data).

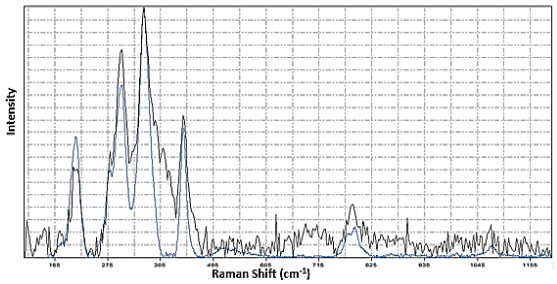

Fig.5: Raman spectrum of a silica grain compared to the tridymite reference Raman spectrum in blue (Ruff data).

Discussion: The occurrence of graphite and sinoite are typical of the extremely reduced assemblages of enstatite chondrites. It has been proposed by [6] that sinoite may crystalize from a liquid formed by impact melting, rather than by high-temperature metamorphism, as was proposed by e.g., [7].

Silica polymorphs (quartz, tridymite, cristobalite, and SiO_2 glass) were found to be ubiquitous in enstatite chondrites by [8], either within chondrules, as isolated grains, or as tiny inclusions in metal. The occurrence of silica polymorphs in close association with graphite and sinoite is more surprising, and the location of those phases at the outer edge of sinoite grains, close to fractures, might indicate a secondary origin. As noted by [8], the occurrence of the tridymite and cristobalite are indicative of rapid cooling of the melt, in addition of high temperature and low pressure.

References: [1] Chennaoui-Aoudjehane H. et al. 2007. 70th Met. Soc#5329 [2] Chennaoui-Aoudjehane H. et al. 2009.72nd Annual Met.Soc #5037. [3] Irving A. J. et al. 2010. 73rd Annual Met. Soc #5378. [4] Rubin A.E. 2016. Meteoritics & Planetary Science, 12679: 1–12. [5] Lafuente B. et al. 2015 The power of databases: The RRUFF project. Highlights in Mineralogical Crystallography, pages 1–30. [6] Rubin A.E. 1997. Sinoite (Si_2N_2O): Crystallization from EL chondrite impact melts. American Mineralogist, Volume 82, pages 1001–1006 [7] Sekine. T. et al.2006. Sinoite (Si_2N_2O) shocked at pressures of 28 to 64 GPa American Mineralogist, Volume 91, pages 463-466 [8] Kimura. M. et al. 2005. Thermal history of the enstatite chondrites from silica polymorphs. Meteoritics & Planetary Science 40, Nr 6, pages 855–868.