STUDYING CARBONATE GLOBULES IN ALLAN HILLS 84001 TO BETTER UNDERSTAND AQUEOUS ALTERATION IN EARLY MARS. C. E. Moyano-Cambero[1], J. M. Trigo-Rodríguez[1], N. Mestres[2], J. Fraxedas[3], and J. Alonso-Azcárate[4]. [1]Institute of Space Sciences (CSIC-IEEC). Campus UAB, Fac. Sciences, C5-p2, 08193 Bellaterra (Barcelona), Spain. moyano@ice.cat, [2] Institut Ciència de Materials de Barcelona, Campus UAB, 08193 Bellaterra (Barcelona), Spain, [3] Centre d'Investigació en Nanociència i Nanotecnologia (CIN2-CSIC), Campus UAB, 08193 Bellaterra, Barcelona, Spain, [4] Universidad de Castilla-La Mancha (UCLM), Campus Fábrica de Armas, 45071 Toledo, Spain.

Introduction: The study of Martian meteorites has provided valuable information about the present and ancient conditions on Mars. The meteorite Allan Hills 84001 (hereafter ALH 84001) is a currently unique ortopyroxenite specially interesting for the study of the early Mars, as it was formed more than 4 Gyr ago [1]. Due to its age this meteorite contains characteristic features which are consequence of early processes occurred in the red planet, like a high fractured texture [2], the presence of spherical Fe-Mg-Ca carbonates [3], and gases that were trapped during the ejection event or during the formation of the meteorite [4]. The mentioned carbonates led some years ago to the possibility that early biologic activity was present on Mars [5] and have restricted the possible scenarios in which they formed, around 3.9 Gyr ago [6].

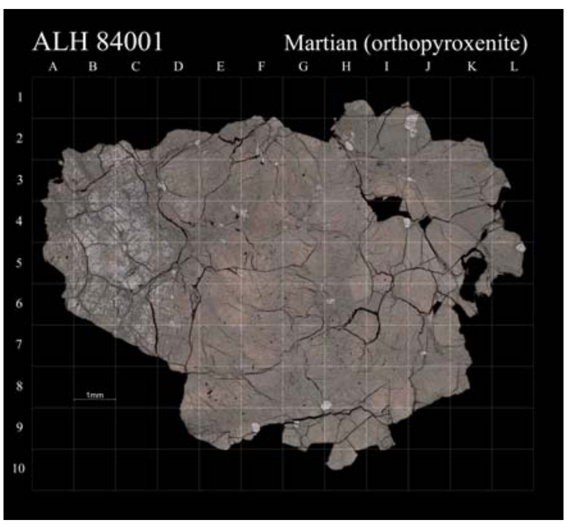

Figure 1. High resolution mosaic of the ALH 84001 studied section. Each square is 1 mm^2. Some carbonate globules can be found between D4 and D5.

Technical procedure: A thin section of ALH 84001 provided by the Johnson Space Center was used for this study. First, a high-resolution mosaic of the section was generated from separate 50X images taken with a Zeiss Scope petrographic microscope (Fig. 1). The mosaics allowed us to study the section and establish features to be characterized by more sophisticated micro-Raman, SEM, and EDS techniques. We used a FEI Quanta 650 FEG working in low vacuum BSED mode. The EDS detector used to perform elemental analyses is an Inca 250 SSD XMax20 with Peltier cooling with an active area of 20 mm^2. The previously selected areas were explored at different magnification, and SEM elemental mapping together with EDS spectra were obtained (Fig. 2-3).

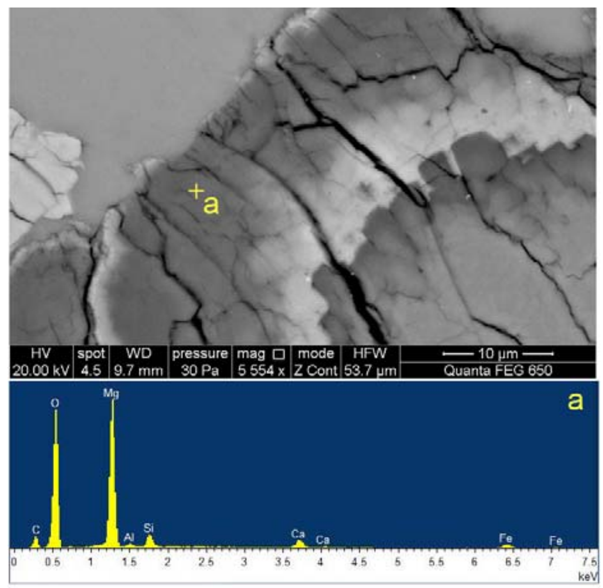

Figure 2. Example of an EDS spectrum that reveals a Mg-rich rim in one of the carbonate globules.

Results and discussion: One of the most interesting facts on ALH 84001 is the presence of Fe-Mg-Ca-carbonates found along fractures and cataclastic areas [3] and formed 3.9 Gyr ago, after plagioclase had been converted to maskelynite [6] and during the time of Ar-degassing of plagioclase [7]. There are different opinions about the radiometric age of these carbonates [1], which could be related to the fact that there are different types of carbonates and maybe even different generations [8], although similar zoning profiles seem to indicate that they were formed in a single event [3]. It has been suggested that most of the carbonates formed from a CO_2 enriched aqueous fluid in an already brecciated rock, at the same time when the compositional zoning was established, but after the first carbonates formed by replacement of plagioclase or maskelynite [1]. This formation processes appears to have coincided with impact metamorphism, perhaps via precipitation from a transient impact crater lake [1].

These carbonates usually appear as globules or rosettes strongly zoned in composition, with Ca-rich cores surrounded by concentric and alternating rims of siderite and magnesite [8] but they can show a multitude of varieties [3] (Fig. 3). Multiple features related to these carbonates found with SEM and other techniques, led to the premature conclusion that early biologic activity was present on Mars [5]. The presence of polycyclic aromatic hydrocarbons (PAHs), the shape of some magnetite grains resembling those formed by magnetotactic bacteria and bacteria-like structures, among others, gave support to this idea, which made the public and scientific interest in planetary science to grow. However, it has been proven that all this features can also be explained by abiogenic processes [9], so by now none of them is a strong enough proof for the existence of Martian biologic activity, but the mere possibility led to many studies about life in extreme terrestrial environments.

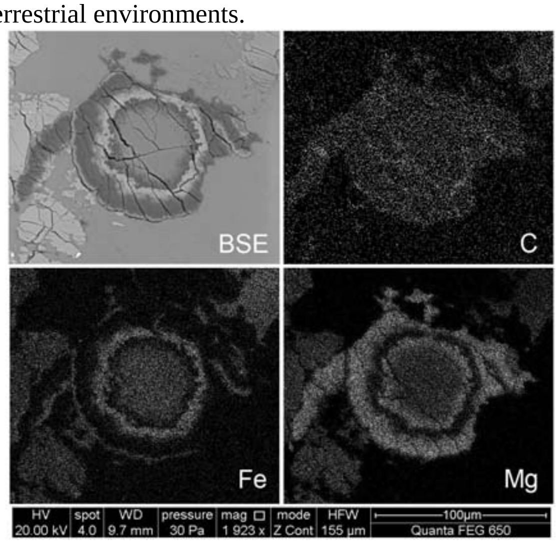

Figure 3. This 4 images show one of the carbonates globules studied in ALH 84001 in a BSE image, and mappings of C, Fe and Mg content, respectively.

These carbonates can also provide clues about the environmental conditions under which they were formed. There is still debate around these conditions, whether suggesting low temperature (270 to 380K) precipitation [2], which is quite common on Earth and increases the plausibility of life on Mars, or precipitation from a fluid with high concentrations of CO_2, possibly over a short time, at higher temperatures (>920K), which results prohibitive to life and could be the result of an impact and subsequent hydrothermal activity [10]. More recently, it was suggested that the high temperature conditions were not really consistent with the formation of carbonates [11]. As explained, these carbonates have Mg-Fe rich compositions, like other secondary mineral formations in ALH 84001, which can provide strong constraints about the aqueous processes that took place on Mars when they were formed, and about the chemical composition of the fluid where they come from [12]. It has been suggested that the fluid underwent significant isotopic changes during carbonate precipitation, which can be explained if the fluid obtained its CO_2-rich character in the subsurface and later was exposed to an arid atmosphere which prompted rapid evaporation, CO_2 degassing, and carbonate precipitation [12]. This implies that the carbonate globules found in ALH 84001 could be a small sample of the carbonates present in the subsurface of Mars, where they would escape remote detection [13].

It is also interesting to notice that these carbonates show some anomalies in magnetization that have not been found in the younger regions of Mars, which could indicate that the shut-off of the Martian magnetic field occurred between the age of formation of the carbonates and the transition from the late Noachian to Hesperian periods [14].

Conclusions: The carbonates found in the Martian meteorite ALH 84001 were formed around 3.9 Gyr ago, so their formation points towards the existence of a template climatic period that produced pervasive aqueous alteration of this rock at that time. Preliminary compositional analyses confirm the mineralogy of the carbonate globules, but this issue is work in progress.

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