ONSET OF MAGMATISM ON A CARBONACEOUS CHONDRITE PLANETESIMAL

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Introduction: Chondritic meteorites and differentiated achondrites were long assumed to sample solar system objects with different planetary evolution. However, paleomagnetic studies and magma ocean models indicate that some carbonaceous chondrite parent-bodies may have undergone core-mantle differentiation at depth, while keeping a surficial chondritic crust [e.g. 1,2]. High precision isotopic analysis of heavy elements such as Cr, Mo, W unambiguously demonstrated the link between some differentiated materials including iron meteorites and carbonaceous chondrites [e.g. 3,4]. However, direct evidence of magmatic activity testifying of the onset of partial melting and partial differentiation is extremely rare and has not previously been reported for carbonaceous chondrites. Here we report the mineralogy, petrography, O and Mg isotopic study of a differentiated clast enclosed in the CR chondrite El Djouf 001 and evaluate its relationship with carbonaceous chondrites.

Methods: UH154-11 was found in a thin section of El Djouf 001 from the University of Hawaii. Its mineralogy and petrography were studied using various Scanning Electron Microscopes (SEM) including Field-Emission-Gun SEMs in UCLA, GEOPS, ICCMO and ENS Paris and Electron Probe MicroAnalysis at the CAMPARIS facility in Paris. O and Mg isotopes were measured in-situ by IMS 1270 SIMS in UCLA and NanoSIMS 50 in the National Museum of Natural History in Paris, respectively.

Results: UH154-11 has a fine-grained doleritic texture typical of magmatic dykes. It is dominantly composed of andesine plagioclase laths (plag, An_{40-50}) about 10 µm in width and up to 100 µm in length, approximately equant sometimes skeletal Fe-rich olivine (ol, Fo_{40-50}) less than 10 µm in size and augitic clinopyroxene (cpx) of variable shape, typically 5 µm in size or less. Plag crystals have skeletal rims enclosing tiny cpx and ol. Shards of cpx are found enclosed in plag and ol enclosed small cpx and minute melt inclusions. UH154-11 is almost completely crystallized but still contains interstitial melt pockets with glassy areas too tiny for analysis, dendritic sub-µm Ca-phosphates and minute nm-sized Fe-sulfides and Ti-oxides. Its highly silica-undersaturated bulk composition is consistent with that of an Fe-rich trachybasalt having 5.8 wt% Na_2O and 15.1 wt% FeO at the limit with the tephrite field. The bulk Na/K wt% ratio (Na/K = 17.5) and O isotopic composition ($\Delta^{17}O = -2.8 \pm 0.7$ ‰, 2σ) are comparable to those of CV chondrites from the oxidized subgroup (CVox). No ^{26}Mg excesses resulting from the decay of ^{26}Al were found in plag, yielding a crystallization age younger than 3.3 My after Ca-Al-rich inclusions (2σ upper limit).

Discussion and conclusion: The skeletal rims of plagioclase are indicative of crystallization during cooling at an increasing cooling rate as observed in ascending magmas on Earth and opposite to that expected for impact melts. Additionally, the bulk chemical composition is close to those of melts produced during partial melting experiments of chondritic materials [5,6] indicating that UH154-11 is not an impact melt but a partial melt from a chondritic body. The best match between experiments and UH154-11 is obtained for partial melts produced at ~1100°C, near the IW buffer. However, the enrichment in Na and depletion in Si relative to these compositions point to very low degree of melting, problably down to 5% or less. Being unfractionated during partial melting, the high Na/K ratio relative to most chondrites but similar to some CVox, CO and CK chondrites suggests that the initial chondrite source was previously enriched in Na by metasomatism. The ^{16}O-rich isotopic composition, identical to that of the Mokoia CV chondrite, further link the source of UH154-11 with carbonaceous chondrites and more specifically with CVox chondrites. UH154-11 therefore formed by a very low degree partial melting at ~1100°C of a carbonaceous chondrite, most likely from the CV parent body, at a depth, where previous metasomatism/metamorphism occurred. It subsequently crystallized during ascent through the carbonaceous chondrite crust with a degree of supercooling induced by the thermal difference between the magma and host rock. It was finally excavated by an impact and incorporated to the regolith of the CR parent-body, which has to be located in a close nebular region. UH154-11 can thus be considered representative of the first partial melts produced at the onset of planetary differentiation in a large carbonaceous chondrite body.

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