DISTINGUISHING MILD AQUEOUS ALTERATION FROM THERMAL METAMORPHISM IN THE LEWIS CLIFF (LEW) 85311 CM CARBONACEOUS CHONDRITE

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Introduction: The CM carbonaceous chondrites have been aqueously altered to different degrees [1], and a subset of them have also undergone later thermal metamorphism [2]. Given such a range of evolutionary histories, these meteorites have the potential to provide unique and valuable insights into parent body formation and internal structure. For example, the CM carbonaceous chondrite Elephant Morraine (EET) 96029 has been unusually mildly aqueously altered, as evidenced by the preservation of melilite in CAIs and glass in chondrules, yet has also been thermally metamorphosed [3]. Post-hydration heating has therefore affected parent body regions with contrasting degrees of prior aqueous alteration. In common with EET 96029, the CM carbonaceous chondrite Lewis Cliff (LEW) 85311 has been reported to contain melilite [4], which is consistent with mild aqueous alteration, but has also been suggested to have experienced post-hydration heating given its low volatile content [5]. Here we have sought to understand the history of LEW 85311, and in particular whether it's unusual properties reflect mild aqueous alteration alone, or it has also been thermally metamorphosed.

Methods: A thin section of LEW 85311 was imaged and chemically analysed by SEM, and electron-transparent samples for transmission electron microscopy (TEM) were prepared using the focused ion beam (FIB) technique. The amount and hydrogen isotopic composition of water/OH in a 78 mg bulk sample was determined by stepwise pyrolysis at SUERC, and the mineralogy of a ~50 mg bulk sample was quantified using Position Sensitive Detector X-ray Diffraction (PSD-XRD) at the Natural History Museum, London.

Results: LEW 85311 is petrographically and mineralogically typical of a CM – it is composed of chondrules and CAIs that are enclosed by fine-grained rims, and these objects lie within a fine-grained matrix. One of the CAIs contains melilite, but no glass-bearing chondrules were observed. TEM shows that the fine-grained rims and matrix are phyllosilicate-rich, although tochilinite is scarce. Ca-carbonate is extremely rare in the matrix, but occurs along with melilite in one CAI, and is the main constituent of several other rimmed objects. Stepwise pyrolysis evolved 6.88 wt. % H_2O with a δD of 83 ‰; if water evolved at <100 °C is assumed to be a terrestrial contaminant and removed, these values change to 6.19 wt. % H_2O/δD 102 ‰. PSD-XRD results yield the following modal mineralogy (in vol. %): olivine 21.4, enstatite 10.1, magnetite 1.2, Fe-sulphide 0.5, metal 0.3, gypsum 1.7, phyllosilicates 64.8. The phyllosilicate fraction is 0.67 so that LEW 85311 is classified as 1.7 on the scale of [6].

Discussion: The water/OH content of LEW 85311 is very low, as was also observed by [7], but several lines of evidence argue against this property reflecting post-hydration heating: (i) the unusually high bulk δD of LEW 85311 is inconsistent with thermal metamorphism, which lowers δD by destruction of the carriers of D-rich water/OH [7]; (ii) there is no evidence from TEM or PSD-XRD for thermal damage to the crystal structure of phyllosilicates. The modal mineralogy of LEW 85311 confirms that LEW 85311 is unusually mildly aqueously altered; its 1.7 classification is equal to DNG 06004, the least altered of 28 CMs listed in [6]. The whole-rock oxygen isotope composition of LEW 85311 (δ^{18}O 1.21, δ^{17}O -2.98, Δ^{17}O -3.61) [8] adds further weight to the argument of mild aqueous alteration. Whilst there is no straightforward correspondence between bulk oxygen isotopic composition and degree of alteration, [9] found that the least altered CMs do tend to have lighter values, and LEW 85311 plots very close to QUE 97990, another mildly altered CM [10]. Having identified LEW 85311 as a CM that has been unusually mildly aqueously altered but unaffected by post-hydration heating, this meteorite will provide a great opportunity to further explore and understand the range of materials that were accreted to form the CM parent bod(ies).

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