EPHEMERAL NEBULAR COMPONENTS IN THE MILDLY AQUEOUS ALTERED CM CARBONACEOUS CHONDRITE LEWIS CLIFF (LEW) 85311. M. R. Lee[1], B. E. Cohen[1,2], D. F. Mark[2], A. Boyce[2] [1]School of Geographical and Earth Sciences, University of Glasgow, G12 8QQ, U.K. (Martin.Lee@Glasgow.ac.uk). [2]Scottish Universities Environmental Research Centre (SUERC), Rankine Avenue, East Kilbride G75 0QF, U.K.

Introduction: The CM carbonaceous chondrites have been aqueously altered to various degrees in a parent body environment. The least altered members of the group are highly sought after as they can provide valuable insights into the nature of the nebular materials that were accreted to form their parent asteroid(s). Those materials that were most susceptible to aqueous alteration were glass, melilite, and the precursors to the phyllosilicate-rich matrices and fine-grained rims, which included amorphous silicates [1].

Various criteria have been used to classify the degree of aqueous alteration of the CMs, which include the modal abundance of phyllosilicates [2,3], degree of hydration (as expressed by the weight % H in water/OH) [4]), and a suite of mineralogical and chemical properties including the abundance of Fe,Ni metal [5]. Using these criteria, the least aqueously altered CMs that have been identified to date include Yamato (Y) 791198 [1], Queen Alexandra Range (QUE) 97990 [5], Paris [6], and Elephant Moraine (EET) 96029 [7]. Here we ask whether Lewis Cliff (LEW) 85311 is another minimally aqueously processed CM that may potentially contain the ephemeral nebular components.

LEW 85311 is a 199.5 g Antarctic find. Its degree of aqueous alteration has been classified as CM2.6–2.7 [8], which is similar to Paris and QUE 97990. LEW 85311 has a petrologic subtype of 1.9 according to the criteria of [4], and only one of the 48 other (unheated) meteorites that was classified in the same study was found to be less altered (i.e., subtype of >1.9). Here we ask whether LEW 85311 has been unusually mildly aqueously altered, as its petrologic subtype suggests, or whether its low concentration of H in water/OH is due to post-hydration heating and concomitant dehydroxylation of phyllosilicates. Alternatively, LEW 85311 could be an anomalous carbonaceous chondrite, as suggested by its bulk oxygen isotopic composition [8], so that the properties and metrics that are conventional used to quantify the degree of aqueous alteration of CMs are not applicable.

Materials and methods: One thin section of LEW 85311 was studied by SEM, and the fine-grained rims were quantitatively chemically analysed by EDX. Electron-transparent foils for transmission electron microscopy (TEM) were extracted from selected sites using the Focused Ion Beam (FIB) technique. The hydrogen isotopic composition of a bulk sample was determined by stepwise pyrolysis at SUERC.

Results: LEW 85311 comprises ~30 vol. % chondrules, chondrule fragments and CAIs, 36 vol. % fine-grained rims that enclose these objects, and 34 vol. % matrix. The thin section lacks a strong petrofabric, although mild compaction is demonstrated by a lineation that is developed within selvages of the matrix between chondrules. The abundance of Fe,Ni metal is 0.30 vol. %. Calcite is very rare in the matrix and absent from fine-grained rims, but occurs in one melilite-bearing CAI (Fig. 1a) and is the main constituent of several elongate objects, each of which is enclosed within a fine-grained rim (Fig. 1b). The scarcity of calcite in LEW 85311 is consistent with the 0.03 vol. % that was recorded by [9], and they also showed that its isotopic composition differs to that of many of the other CMs (δ^{13}C 28.6 ‰, δ^{18}O 19.4 ‰).

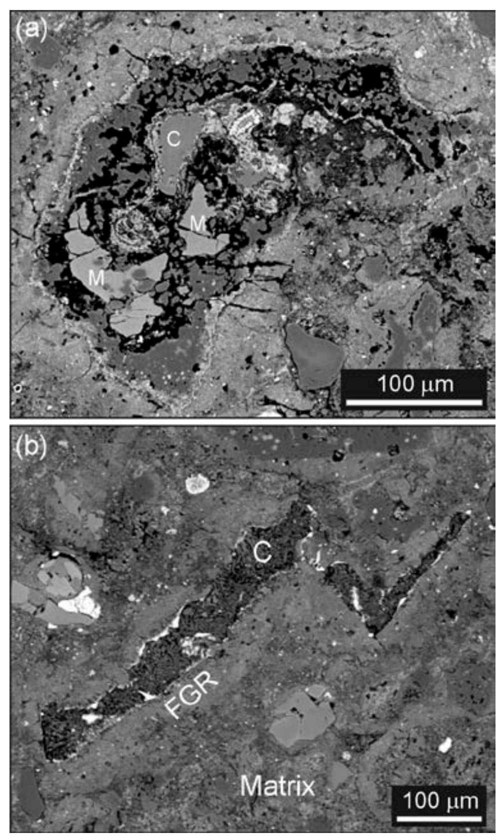

Fig. 1. Backscattered electron SEM images. (a) A CAI containing melilite (M) and calcite (C). (b) An object with an unusually high aspect ratio that is almost entirely composed of finely crystalline calcite. This object has a fine-grained rim (FGR).

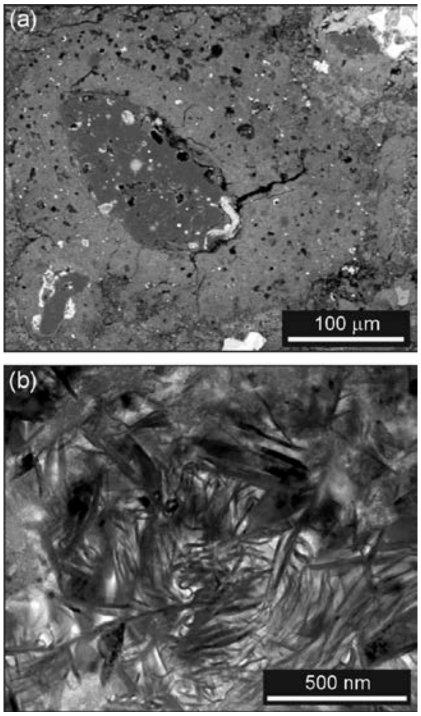

Fig. 2. (a) Backscattered electron SEM image of a chondrule with a micropore-rich fine-grained rim. (b) Bright-field TEM image of serpentine in a fine-grained rim.

The chemical composition of the fine-grained rims is listed in Table 1. These rims characteristically contain abundant micropores that are an average of ~6 μm in size (Fig. 2a). TEM shows that the rims contain serpentine crystals of a variety of sizes and habits, but amorphous silicates were not observed (Fig. 2b). Stepwise pyrolysis of LEW 85311 evolved 6.88 wt. % H_2O with a δD of 83 ‰. If water evolved in the 100 °C step is assumed to be a terrestrial contaminant and removed from the totals, the values change to 6.19 wt. % H_2O and δD of 102 %.

Table 1. Chemical compositions of rims and matrix (wt. %)

Wt. %	LEW 85311 rims	EET 96029 matrix [7]	Paris matrix [10]
SiO_2	20.7	28.0	27.1
Al_2O_3	3.1	3.1	2.5
FeO	32.5	34.3	34.0
Cr_2O_3	na	0.38	0.28
MnO	0.2	0.15	0.21
MgO	11.2	12.1	13.2
CaO	1.1	0.31	0.34
Na_2O	0.6	0.59	1.0
K_2O	0.1	0.06	0.08
S	3.3	2.2	4.2
Total	72.8	83.55	80.9
MgO/FeO	0.34	0.35	0.39

Discussion: Several of the properties of LEW 85311 are consistent with mild aqueous alteration. Fe,Ni metal is highly susceptible, and so assuming that all of the CMs originally contained a similar volume, inter-meteorite differences in its abundance reflect loss by aqueous alteration. The 0.3 vol. % of Fe,Ni metal in LEW 85311 is relatively high, falling between QUE 97990 (CM2.6–2.7; 0.98 vol. %) and Murchison (CM2.5; 0.11 vol. %) [5]. Melilite is also highly vulnerable to aqueous alteration, and has been previously described only from Murchison [11], Paris [6] and EET 96029 [7]. Its occurrence in LEW 85311 is again consistent with mild aqueous alteration. The presence of serpentine in the fine-grained rims confirms that they have been aqueously altered, and their chemical compostion is similar to EET 96029 and Paris, although lower in silica (Table 1). The MgO/FeO ratio of matrices and fine-grained rims should increase with progressive alteration as magnesium is liberated from chondrule silicates. Values for LEW 85311 are comparable to or lower than EET 96029 and Paris (Table 1). The origin of the micropores that characterize these rims is unknown, but they could have formed from dissolution of highly soluble grains, or even ice. The amount of water that was evolved during stepwise pyrolysis (~6.2 wt. %) is low relative to most other unheated CMs [12], but is unlikely to be due to heating as there is no evidence for dehydroxylation or recrystallization of serpentine in the fine-grained rims (Fig. 2b).

Conclusions: Relative to CM carbonaceous chondrites, LEW 85311 has been mildly aqueously altered. The preservation of melilite demomstrates that it contains nebular components that have been lost from most other meteorites by aqueous alteration, and further work will assess whether this primitive material includes an amorphous precursor to the phyllosilicate-rich matrix and rims.

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