PHYLLOSILICATES IN THE MATRIX OF THE UNUSUAL CARBONACEOUS CHONDRITE, LEW 85332 AND POSSIBLE AFFINITIES TO CI CHONDrites. Adrian J. Brearley, Institute of Meteoritics, Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131-1126, USA.

Lewis Cliff 85332 is a unique, highly unequilibrated carbonaceous chondrite whose petrological and chemical properties were recently described by Rubin and Kallemeyn [1]. Chemically, it shows some affinities to CI and CR chondrites, but differs significantly from these groups in a number of important respects. Several petrological characteristics of LEW 85332 were found to be similar to those of the CO3 chondrites, but its bulk refractory lithophile ratios are much lower than CO3 values and its common and volatile siderophile ratios are higher. [1] described LEW 85332 as a breccia based on the presence of a number of carbonaceous chondrite clasts, which appeared to have affinities to both CI and CM carbonaceous chondrites. Unique, unequilibrated meteorites such as LEW 85332 can provide important new insights into the nature and origin of meteoritic components, because they have largely escaped the effects of parent body processing. This is especially important for studies of fine-grained matrix materials which will rapidly undergo recrystallization and equilibration during even mild parent body metamorphism. In a continuing effort to understand the origin of fine-grained matrix material in primitive chondritic meteorites, I have undertaken a detailed SEM, electron microprobe and transmission electron microscope study of matrix in LEW 85332.

As noted by [1] LEW 85332 has undergone quite extensive Antarctic weathering, which has resulted in the alteration of much of the Fe,Ni metal to limonite. As a result red/brown staining is pervasive throughout the meteorite. Reflected light microscopy shows that thin veins of limonite often cross-cut the matrix, but the regions of matrix between the veins appear to be largely unaffected. Matrix occurs in three main forms in the sample studied. The dominant form is as dark, opaque material interstitial to chondrules, metal and isolated silicate grains, which essentially forms a continuous groundmass within the meteorite. This material is extremely fine-grained (<1μm), although it also contains larger grains of magnetite (sometimes as framboids and platelets) and sulfides (<15μm). The second occurrence of matrix is of distinct clasts (<70μm), which are rare in the sample studied. Abundant carbonaceous chondrite clasts such as those reported by [1] were not observed, although one relatively large (500μm) clast which contained chondrules was found. Finally, one fine-grained rim on a porphyritic olivine chondrule was observed, which strongly resembles rims in CO3 chondrites such as ALH A77307 [2,3]. BSE imaging of the main type of matrix in LEW 85332 shows that it is compositionally relatively heterogeneous on a very fine-scale. The matrix often contains small, irregularly-shaped clast-like regions (~5-20 μm in size) with varying Fe-contents. The composition of meteorite matrix, clasts and one fine-grained rim in LEW 85332 was determined using broad beam (10μm) electron microprobe analyses. The bulk matrix analysis is reported in Table 1. Element ratio patterns (normalized to Si and CI values) underscore the unusual character of LEW 85332. Matrix and rim patterns are very similar and show moderate enrichments in Al and Ni and large enrichments in K. Significant depletions in S and Na are evident, whilst Ca, Ti, Mg, Cr, Fe and Mn are all close to CI values or slightly depleted. In detail the patterns are very different from CM and CO matrix, but in terms of their shape and the presence of a large enrichment in K, they appear to have some features in common with CI matrix [4,5,6].

The possible links to CI matrix are further supported by the fine-grained mineralogy of the matrix. Detailed TEM studies show that phyllosilicates are extensively developed throughout the areas of matrix studied and are associated with rare grains of magnetite and troilite. No anhydrous phases such as olivine or pyroxene have been observed. The phyllosilicates occur in...
three principal morphologies: a) sheaves of subparallel, platy phyllosilicates <40 nm in width, b) regions of randomly oriented, interlocking phyllosilicates 5–20 nm wide and c) ultrafine-grained protophylosilicates which are typically < 5 nm in width. In some areas of matrix the effects of Antarctic weathering are apparent and a Fe-hydroxide occurs interstitially to the phyllosilicates. High-resolution TEM studies of the matrix show that the phyllosilicates present vary slightly from location to location, but indicate that the dominant phase present has a basal spacing between 1.0 and 1.3 nm, consistent with a saponitic clay. Frequent coherent interlayers with a 0.7 nm basal spacing occur within the saponite, indicating the presence of serpentine. Serpentine has not been observed as a discrete phase where saponite is abundant. In addition, layers with a 1.4 nm spacing consisting of a 0.9 and 0.5 nm repeat occur occasionally within saponite, indicating the presence of chlorite interlayers. One area of matrix was found which contained a number of crystallites of a phase with a 1.7 nm basal repeat, which is consistent with tochilinite. This phase occurs in association with discrete serpentine crystals.

Analytical electron microscopy of the phyllosilicate minerals was carried out using a liquid nitrogen cold stage at -150°C to minimize elemental volatilization. The data, plotted in a ternary (Si+Al)-Fe-Mg ternary diagram, show an extremely broad range of compositions, but the majority of the analyses all lie within the area bounded by the ideal smectite and serpentine solid solution lines. These results are consistent with the HRTEM data which show that the most abundant phyllosilicates in the matrix are coherent intergrowths of saponite and serpentine. The variation in Mg/(Mg+Fe) ratios is extremely large and ranges from 0.10 to 0.75 showing that in terms of composition the phyllosilicates are extremely heterogeneous. The majority of the phyllosilicates are, however, Mg-rich with Mg/(Mg+Fe) ratios >0.55.

The matrix of LEW 85332 is clearly unique in terms of its chemistry and mineralogy. The bulk of the matrix material appears to have some distant affinities with CI chondrite matrix and the presence of tochilinite indicates that clasts of CM-like material may also be present. The occurrence of intergrowths of saponite with minor serpentine has only been previously observed in CI chondrite matrices [5,6,7] and the normalized element ratio patterns are closest to CI matrix. LEW 85332 matrix differs from CI matrix in lacking discrete crystals of serpentine and carbonates and the compositions of saponite/serpentine intergrowths are much more variable than those in CI matrices [5,6,7]. Several lines of evidence suggest that LEW 85332 matrix may represent a very early stage in the formation of CI-like matrix material. For example, Ca, Mn and Fe are not as depleted in LEW 85332 matrix as CI chondrite matrices [4,6]. Ca and Mn are mobilized from the matrix and reprecipitated into veins as carbonates during alteration in CI chondrites [8]. As a consequence, both these elements will become progressively depleted within the fine-grained matrix as vein formation becomes more advanced. Such reactions essentially involve oxidation of carbonaceous material in the matrix [8] and will also result in the oxidation of Fe-rich saponite and serpentine to produce magnetite or ferrihydrite [6,7]. The Fe-rich compositions of saponite and serpentine and the rarity of magnetite in LEW 85332 indicates that such oxidation has not proceeded to any great extent. In short, it appears that the water/rock ratio experienced by LEW 85332 was relatively low, although the conditions of alteration may have been similar to CI chondrites. Funded by NASA grant NAG 9-30 to J.J. Papike (P.I.).


| Table 1: Bulk matrix composition for LEW 85332 determined by electron microprobe (element%). |
| Si | Ti | Al | Cr | Fe | Mn | Mg | Ca | Na | K | Ni | S |
| 13.47 | 0.045 | 2.12 | 0.27 | 25.53 | 0.19 | 8.97 | 1.03 | 0.22 | 0.23 | 1.94 | 1.37 |

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