GEOLOGICAL HISTORY OF THE WINCHCOMBE METEORITE – A NEW CM CHONDRITE FALL

M. D. Suttle[1,2], L. Daly[3], R. H. Jones[4], L. Jenkins[3], M. Van Ginneken[5], J. T. Mitchell[6], J. C. Bridges[7], L. J. Hicks[7], D. Johnson[8], G. Rollinson[9], R. Taylor[10], M. J. Genge[11], C. Schröder[12], E. Bonsall[12], T. Salge[2], R. Heard[2], R. Findlay[1], A. J. King[2], H. C. Bates[2], M. R. Lee[3], N. R. Stephen[6], F. M. Willcocks[6], R. C. Greenwood[1], I. A. Franchi[1], S. S. Russell[2], C. S. Harrison[2], P. F. Schofield[2], N. V. Almeida[2], C. Floyd[3], P-E. Martin[3], K. H. Joy[4], P. J. Wozniakiewicz[5], D. Hallatt[5,13], M. J. Burchell[5], L. S. Alesbrook[5], V. Spathis[5], L. C. Cornwell[5], A. Dignam[5].

[1.]The Open University, UK (martin.suttle@open.ac.uk), [2.]The Natural History Museum, UK. [3.]University of Glasgow, UK. [4.]University of Manchester, UK. [5.]University of Kent, UK. [6.]University of Plymouth, UK, [7.]University of Leicester, UK. [8.]Cranfield University, UK. [9.]University of Exeter, UK. [10.]Carl Zeiss Microscopy, UK. [11.]Imperial College London, UK. [12.]University of Stirling, UK. [13.]Université de Lille, France.

Introduction: The Mighei-like (CM) carbonaceous chondrites are the largest class of hydrated meteorites, representing collisionally derived fragments of water-rich asteroids [1,2]. Most (>95%) are breccias, whose clasts sample a range of aqueous alteration extents [3]. They can therefore act as "snapshots" recording the progression of fluid-rock interaction on the CM parent body. Conversely, analysis of the material between clasts (termed cataclastic matrix) provides an opportunity to study the post-hydration history of the CM parent body, specifically its fragmentation and re-accretion. Here, we investigate both aspects of the CM chondrites' geological history through study of the newly recovered fall: Winchcombe [4, 5].

Methods: Sixteen polished sections with a total area of 190 mm^2 were generated for this work. They were studied under scanning electron microscopy (SEM) using backscattered electron (BSE) imaging, energy dispersive X-ray spectroscopy (EDX) and electron microprobe analysis (EMPA). These sections sample the two largest masses (the main mass [320 g] and the agricultural field stone [152 g]) recovered from the Winchcombe strewnfield [4].

Results: Winchcombe is a breccia, composed of lithological clasts held within a cataclastic matrix. We identified eight distinct lithologies. Their aqueous alteration extents vary between intensely altered CM2.0 and moderately altered CM2.6 [6]. Although no lithology dominates, three rock types represent >70% of the studied area. Several lithologies contain abundant tochilinite-cronstedtite intergrowths (TCIs). Type-II forms with zoned textures are most common, typically they have Fe-rich rims ("FeO"/SiO_2 wt.%: 1-5) and Mg-rich cores ("FeO"/SiO_2 wt.%: < 1), however, forms with hollow cores or cores containing a mix of phyllosilicate and calcite or phyllosilciates and anhydrous silicate are also found. The cataclastic matrix represents ~15% of the studied area. It has a coarse, heterogenous texture and includes abundant subangular fragments. Fragments include the full range of CM chondrite components (e.g. Fe-sulphides, whole chondrules with or without fine-grained rims, olivine and pyroxene grains, serpentine, carbonate grains, TCI clusters, as well as coherent blocks of fine-grained matrix). The cataclastic matrix is, therefore, a complex mix of components, with both heavily altered and mildly altered phases found in close association. Another striking feature is the apparent low abundance (< 3 area%) of identifiable whole chondrules.

Discussion and conclusions: Our data suggest that both anhydrous silicates and carbonates (T1a calcites) act as precursor phases for type-II TCI formation. Cross-cutting relationships allow the sequence of mineralization to be reconstructed. Initially, inward dissolution by Fe-rich and S-rich fluids forms rims composed of intermixed tochilinite and cronstedtite. In the intermediate stages of type-II TCI formation, further dissolution continues without concurrent precipitation, resulting in the formation of hollow structures. These voids were later infilled, most often by Mg-rich phyllosilicates. As alteration advanced, early-formed secondary phases became unstable and were either dissolved (e.g. T1a calcites) or chemically altered (e.g. TCI rims).

The presence of numerous lithological clasts with variable aqueous alteration extents and abrupt boundaries found in close juxtaposition indicates that the cataclastic matrix formed by the deposition of fines, alongside larger fragments (the clasts), on or near the surface of the parent asteroid. Furthermore, the composition of the cataclastic matrix is consistent with formation by fragmentation and mixing of debris derived from the entire clast population. The cataclastic matrix is, therefore, interpreted as an impact-derived fallback breccia. Analysis of grain size and texture suggests that disruption of the original parent asteroid responded by intergranular fracture at grain sizes <100 µm, while larger phases, such as whole chondrules, splintered apart. Re-accretion formed a poorly lithified rubble-pile body. During atmospheric entry, the meteoroid broke apart with new fractures preferentially cutting through the weaker cataclastic matrix and thereby separating the Winchcombe meteoroid into its component- lithological clasts. Thus, the strength of the cataclastic matrix imparts a significant control on the survival of CM chondrite meteoroids.

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