THE MACROSTRUCTURE OF THE SUTTER'S MILL CM CHONDRITE REGOLITH BRECCIA.

R. E. Beauford[1] and S. K. Arnold[2] and D. Sears[3]. [1]Arkansas Center for Space and Planetary Sciences, MUSE 202, University of Arkansas, Fayetteville, AR, 72701, USA. rbeaufor@uark.edu. [2]Arnold Meteorites. E-mail: meteorhntr@aol.com. [3]NASA Ames Research Center. E-mail: Derek.Sears@NASA.gov.

Introduction: The Sutter's Mill CM chondrite fell in and near Coloma, California, on the 22 April 2012, producing many small individuals [1]. One of these, a 5.1 gram specimen owned by one of the authors (SA), was cut into 11 slices and then recorded in a series of photographs and photomicrographs aimed at revealing and recording lithologic heterogeneity. Portions were further detailed in a series of SEM and EDX images directed at constraining specific relationships.

The individual has been designated SM48 in a database produced by the Sutter's Mill Meteorite Consortium, led by Peter Jenniskens, of the SETI Institute, in cooperation with many other researchers and institutions. The SM48 sample was recovered, 13 days after it fell, by Kelly Heavin, subsequent to substantial rainfall at the location of the strewn field [2].

SM48 slices reveal a genomict regolithic breccia containing breccia-in-breccia components and clasts of at least two, and possibly three, precursor lithologies, expressing substantially different degrees of aqueous alteration. These are found within a finely comminuted matrix composed of fragmented remnants of the lithologies represented in larger clasts.

Investigation: SM48 was sliced, at Montana Meteorite Laboratory, on a 0.1 mm wire on a Well Precision Diamond Wire Saw. Surfaces were recorded as macro photographs with a Canon SD1300 IS digital camera and as photomicrographs with a 3.5MP digital camera, in reflected light, under a Spencer dissection scope. Representative clast-clast and clast-matrix relationships were investigated using the Nova Nanolab FEG Scanning Electron Microscope and energy dispersive x-ray spectrometer at the Arkansas Nano-Bio Materials Characterization Facility, permitting the characterization of lithologic boundaries and of finely comminuted materials.

Lithologic Variation: Two dominant lithologies comprise the majority of clasts. These have been labeled, according to their appearance and for purely utilitarian purposes, chondrule-rich dark (CRD, figure 1) and chondrule-poor light (CPL, figure 2).

CRD clasts are angular to sub-angular, make up about 35% of SM48's volume, and are similar in appearance to Murchison. They appear to represent a heterogenous primary accretionary lithology. CRD contains abundant inclusions, easily discernible with a 10x loupe or under a low-powered microscope. Chondrules, CAIs and aggregates are small, clearly visible, numerous, and contrast strongly with the dark, fine-grained accretionary matrix.

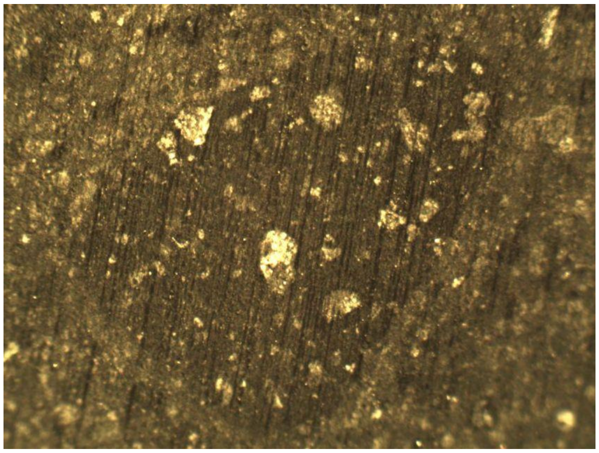

Figure 1. Clast of chondrule-rich dark (CRD) lithology shows distinct chondrules and accretionary texture.

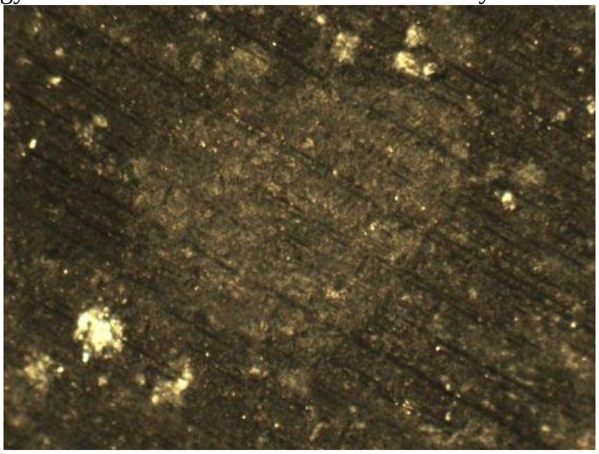

Figure 2. chondrule-poor light (CPL) clast with no visible inclusions in aqueously homogenized field.

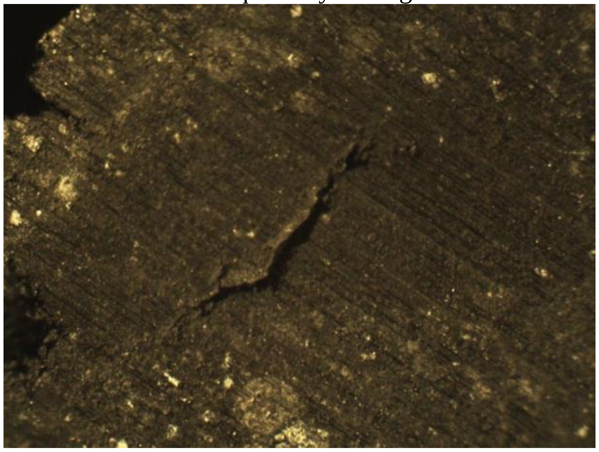

Figure 3. Fine grained dark inclusion (DI) similar to clasts observed in CV chondrites [ref].

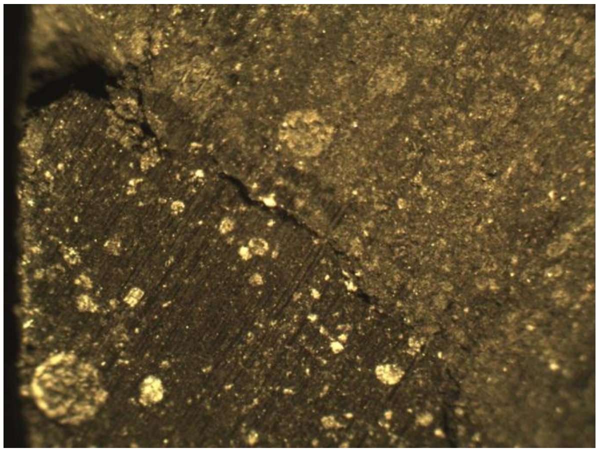

Figure 4. A CRD clast abuts a CPL clast along a well-defined boundary. Finely comminuted matrix is intermediate in color between these clastic components.

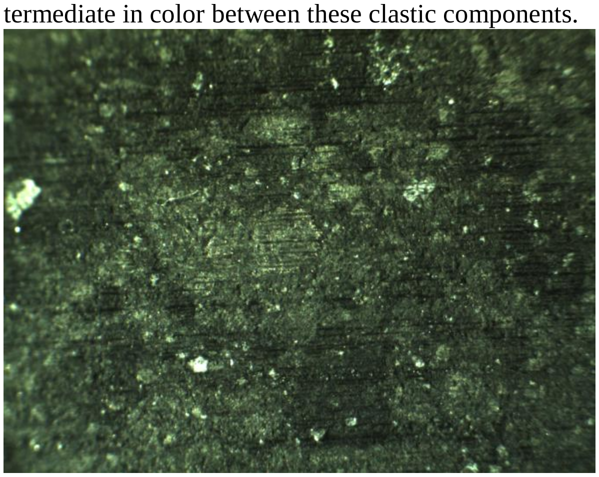

Figure 5. Breccia-in-breccia clasts represent previous generations of indurated regolith that have been fractured and entrained during subsequent impacts.

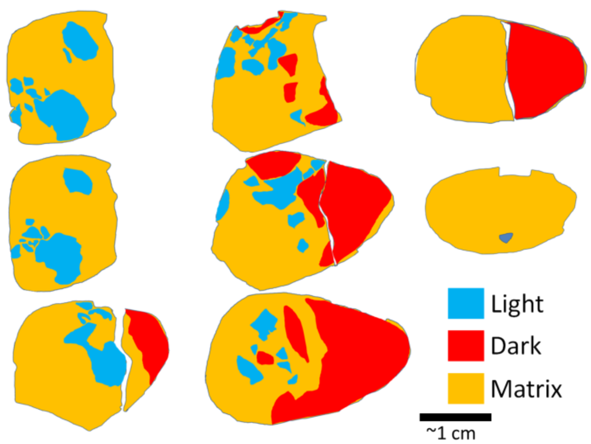

Figure 6. In SM48, macroscopic CPL clasts make up about 15% of volume, CRD about 35%, and finely comminuted matrix and minor components (eg: dark inclusion and breccia-in-breccia clasts) comprise the remainder. Lithologic proportions may vary significantly in other samples.

CPL clasts are less easily distinguished from matrix than CRD. They are lighter in color and homogenous in texture and appearance. They contain few distinguishable chondrules or other inclusions and are predominantly rounded. Fragmenting boundaries are sometimes poorly defined. CPL appears to represent a primary, accretionary lithology that has been highly aqueously altered.

A Dark Clast (figure 3) resembling dark inclusions in the Allende CV3 [3] was tentatively interpreted as a third primary accretionary lithology. The object was rounded, fine grained, and nearly featureless at less than 100x magnification.

Dark-Light Breccia Though variation is limited to a range of dark grays, SM48 can be described as a dark-light breccia (figure 4), with comminuted matrix intermediate in between darker and lighter macroscopic clasts. This is consistent with several previously examined CM chondrites [4, 5, 6].

Breccia-in-breccia clasts (figure 5) represent previous generations of brecciated material that have been indurate and later entrained as clasts during continued regolithic plowing by subsequent impacts.

Lithologic variation – In SM48, CPL represents about 15% of volume, CRD about 35%, and finely comminuted matrix and minor components the remainder (figure 6). The presence of clasts $\geq$ 1 cm in SM48 suggests that lithologic proportions, due to random differences in clast grouping, could vary substantially from individual to individual.

Conclusions: Macroscopic lithologic variation in the Sutter's Mill meteorite preserves not only precursor lithologies that were repeatedly brecciated, mixed, and indurated in an increasingly comminuted regolithic environment, but also a 3-dimensional record of the order in which many of these changes took place. Understanding the origin and timing of lithologic variation in this meteorite provides insights into processes on the parent body surface upon which the meteorite was formed, and by extension, into the timing and nature of changes in the early solar system.

Acknowledgment: Thanks to Dr. Peter Jenniskens for organizing the Sutter's Mill Meteorite Consortium, to Jerri Stevens for assistance during research, and to Mourad Benemara and the Arkansas Nano-Bio Materials Characterization Facility at the U. of Arkansas, Fayetteville, for instrument access and electron microscopy expertise.

References: [1] Jenniskens P. et al. (2012) *Science* 338 (6114), 1583-1587. [2] SM consortium: http://asima.seti.org/sm/ [3] Varela M. E. et al. (2012) *Meteoritics & Planet. Sci.*, 47(5), 832–852. [4] Heymann D. and Mazor E. (1967) *JGR* 72:2704–2707. [5] Metzler K. (2004) *Meteoritics & Planet. Sci.*, 39, 1307–1319. [6] Greenwood R. C. et al. (1993) *Meteoritics* 28(3):357-358.