ALKALI-HALOGEN METASOMATISM OF METEORITE HILLS 01075 (CM2) DRIVEN BY SHOCK HEATING: AN ANALOGUE FOR RYUGU.

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Introduction: Reflectance spectra of the asteroid 162173 Ryugu that have been recently obtained by the Hayabusa2 spacecraft are similar to those of thermally/shock metamorphosed carbonaceous chondrites, with the CM meteorite Hills (MET) 01072 being highlighted as a good analogue [1]. MET 01072 has a strong petrofabric showing that it has undergone impact deformation, but was not heated sufficiently to dehydrate its phyllosilicates [2]. This apparent contradiction could be reconciled if MET 01072 had been deformed by multiple low intensity impacts that generated little heat [2]. Here we describe evidence from MET 01075 (a pair of MET 01072) for an alternative explanation, namely that heating produced by early shock deformation initiated alkali-halogen metasomatism, most of the evidence for which was later overprinted by lower temperature aqueous alteration.

Samples and methods: MET 01075 was collected by ANSMET in 2001. This study used a chip (MET 01075,8) that was divided into two parts. One was impregnated in epoxy resin, made into a polished block, and studied by scanning electron microscopy (SEM) at the University of Glasgow. The other part was used to determine modal mineralogy by X-ray diffraction (XRD) at the Natural History Museum.

Results: MET 01075 is composed of rimmed chondrules/chondrule fragments and refractory inclusions set in a fine-grained matrix that is dominated by tochilinite-cronstedtite clumps. This lithology is therefore comparable to the 'primary accretionary rock' of [3]. MET 01075 has a modal mineralogy of (vol. %): Mg-serpentine (63.9), Fe-cronstedtite (18.7), olivine (9.7), enstatite (2.8), magnetite (1.4), Fe-sulphide (2.7), calcite (0.6) and gypsum (0.2). Tochilinite was identified but its abundance was not quantified owing to the lack a pure standard for profile stripping. MET 01075 has a phyllosilicate fraction of 0.87, corresponding to a petrologic subtype of 1.3 on the scale of [4], and so has been highly aqueously altered. Its chondrules and refractory inclusions have been flattened (mean aspect ratio = 1.72) and together define a strong foliation petrofabric. One of the refractory inclusions is 0.6 mm in size and contains spinel, perovskite, diopside, calcite, phyllosilicate and ~20-40 µm grains of sodalite. This feldspathoid mineral occurs nowhere else in the sample.

Discussion: In common with its pair MET 01072 and several other CMs, MET 01075 has undergone both aqueous alteration and impact deformation. MET 01075 is however unique among the CMs in containing sodalite. The origin of this mineral may be understood by analogy with the CV carbonaceous chondrites. Feldspathoids are widespread in the CVs where they have commonly formed by the replacement of Ca-aluminosilicates (e.g., melilite) in refractory inclusions during parent body alkali-halogen metasomatism [5]. As the MET 01075 sodalite occurs only in a refractory inclusion, it is interpreted to have formed in the same way (i.e., by relatively high-temperature metasomatic replacement of melilite). Metasomatism must have predated aqueous alteration because melilte is highly reactive in the presence of low temperature aqueous solutions (i.e., it occurs only in the least altered CMs such as EET 96029 [6]) and so would not have survived the intensity of aqueous alteration that MET 01075 has experienced. The preservation of serpentine and tochilinite in the matrix of MET 01075 also argues against significant post-hydration heating that would have been needed for late-stage metasomatism.

We conclude that MET 01075 evolved as follows: (i) accretion of rimmed chondrules, refractory inclusions, fine-grained matrix and water ice; (ii) impact deformation and heating through pore collapse [7]; (iii) alkali-halogen metasomatism leading to the replacement of melilite by sodalite; (iv) lower temperature aqueous alteration, either during post-impact cooling of the parent body or accompanying later radiogenic heating. Further details are provided in [8]. The scarcity of feldspathoids in the other CMs may be because such early shock heating was a rare event, or because the products of alkali-halogen metasomatism have typically been destroyed by later aqueous alteration. The samples that will be returned from Ryugu may help to answer these questions.

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