THE MINERALOGY OF CERES* (*OR SOMETHING AN AWFUL LOT LIKE IT).

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Introduction: Zag and Monahans (1998) are H chondrite regolith breccias that contain 4.5 GY old halite crystals which in turn contain abundant inclusions of aqueous fluids, solids and organics [1-4]. We have previously proposed that these halites originated on a cryovolcanically-active C class asteroid, probably Ceres [3, 4]. We have begun a detailed analysis of the included solids and organics and are re-examining the CI chondrite clast we previously reported in Zag [5]. These new investigations will potentially reveal the mineralogy of asteroid Ceres.

Zag CI Clast: This clast is predominantly a fine-grained mixture of serpentine, saponite, magnetite, Ca phosphates, organic-dominated grains, pyrrhotite and Ca-Mn-Mg-Na carbonates. The carbonates have Mn-rich cores, mantles of Ca-carbonate, and very thin Na-Mg-rich rims. As we reported previously the bulk oxygen isotopic composition of this clast plots among the CI chondrites, though with a high $\Delta^{17}O$ value of +1.41 [5]. The Na-rich rims of carbonates suggests a link between this clast and the halite in Zag. Re-examination of this clast revealed the presence of 10μm-sized (Na,K)Cl crystals which we had previously missed. Owing to the extreme care with which we have treated this sample the halite is indigenous to the clast and thus the CI clast is definitely linked to the halite in Zag.

Mineralogy of solids in the Monahans halite: Abundant solid inclusions are present in the halites, which were entrained within the mother brines during eruption, and should include material from the rocky mantle and surface of the erupting body. The solid inclusions include abundant and widely variable organics [6] that could not have been significantly heated (which would have resulted in the loss of fluids from the halite). Analyses of solids from a single Monahans halite grain by Raman microprobe, SEM/EDX, synchrotron X-ray diffraction and TEM reveal that these grains include macromolecular carbon (MMC) similar in structure to CV3 chondrite matrix carbon, aliphatic carbon compounds, olivine of widely varying composition (Fo99-59), high- and low-Ca pyroxene, feldspars, magnetite, sulfides, metal, lepidocrocite (rust), carbonates, diamond, apatite and zeolites. Phyllosilicates are notably absent from this particular halite crystal, in marked contrast to the CI clast in Zag.

Conclusions: The halite in Monahans and Zag and CI clast in the latter meteorite derive from a water and carbon-rich object that was cryovolcanically active in the early solar system, probably Ceres [3]. If so then the Dawn spacecraft will find that Ceres includes CI chondrite materials. The samples in hand represent both the protolith (unaltered) and aqueously-altered mineralogy of the body, permitting understanding of the alteration conditions. Whatever the parent body, it was rich in a wide variety of organics and warm, liquid water at the dawn of the solar system.

References: [1] Zolensky et al. (1999) *Science* 285, 1377-9; [2] Rubin et al. (2002) *MAPS* 37, 125-142; [3] Fries et al. (2013) *MAPS* 48, A80; [4] Zolensky et al. (2013) *MAPS* 48, A394; [5] Zolensky et al. (2003) *66th MetSoc Meeting*; [6] Fries et al. (2011) *MAPS* 46, A70.