VOLATILES IN A SPHERULE AND IMPACT CLASTS IN THE BUNUNU HOWARDITE. Yang Liu[1], Yang Chen[1], Yunbin Guan[2], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109. [2]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125. (Email: yang.liu@jpl.nasa.gov)

Introduction: Impact products of the surface materials from the Moon have been demonstrated to be a good recorder of H and other volatiles from exogenic sources (e.g., solar-wind or micrometeorites, [1-2]). Similar processes may have happened on the surfaces of airless asteroid bodies. It was suggested that the H/OH signals from certain surface areas on Vesta, observed by the DAWN mission, can be linked to impact mixing of chondrites [3-5]. Howardites, the polymict breccias in the howardite-eucrite-diogenite (HED) meteorite group that originates from Vesta, contain impact products that can be used to assess the OH sources on the parent body. Here we report our preliminary investigation results in the Bununu howardite, an observed fall in April l942.

Sample and Analytical Methods: A small chip of Bununu was allocated by the American Museum of Natural History (AMNH). Bununu contains abundant glass spheres and impact products [6-9]. Bununu is friable, so the chip was easily crushed. One devitrified spherule (**Fig. 1**), vesicular clasts (e.g., **Fig. 2**) and impact clasts (vesicle free, micro-crystals indicative of impact origin, e.g., **Fig. 3**) were found in the crushed chip.

The spherule was embedded in Crystalbond™ adhesive for polishing. The polished spherule was removed and then cleaned with acetone, ethanol, and then repeatedly with dichloromethane, in order to completely remove the Crystalbond™ adhesive. The cleaned, polished spherule was mounted in indium for volatile analysis. We also picked three mm-sized fragments. Given the fragile nature, we mounted them in a small amount of EpoThin epoxy for polishing. After polishing, the fragments were cleaned and then mounted in indium.

The volatile concentrations and hydrogen isotope compositions of the spherule and fragments were measured with a Cameca 7f-GeO Secondary Ion Mass Spectrometer (SIMS) following the procedures in (e.g., [1, 10-11]). To minimize the OH instrumental background, the indium-mounted samples were stored in the SIMS storage chamber (~3×10^{-9} torr) and baked with a tungsten bulb for two days. The vacuum of the main chamber during the analysis was ~3×10^{-10} torr.

Synthetic and natural glass standards [12-13] were used for volatile analysis. Their OH contents were determined using FTIR [11, 13]. Their F, Cl and S

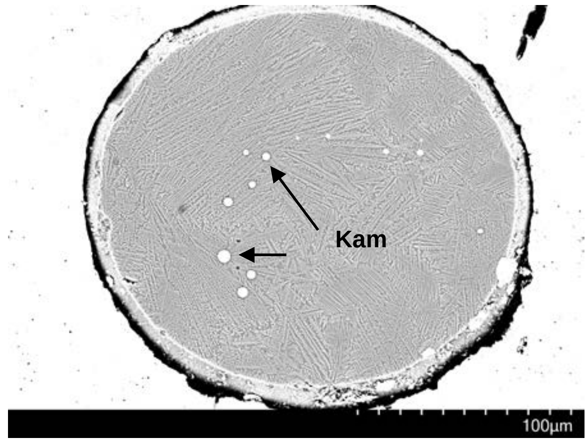

Fig. 1. *Backscattered electron (BSE) image of a devitrified spherule from the Bununu meteorite mounted in indium. Microlites are pyroxenes. Kam, kamacite.*

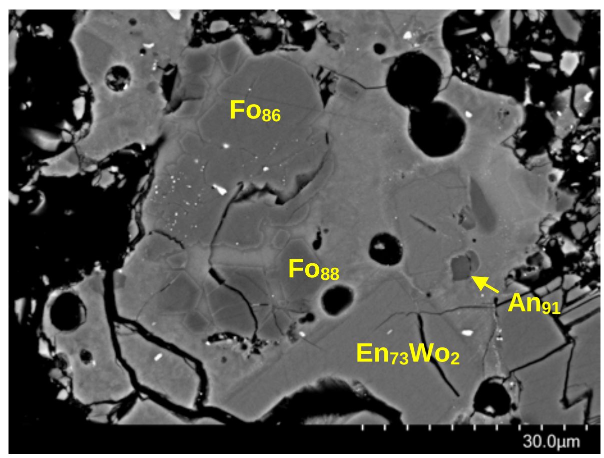

Fig. 2. *BSE image of a vesicular clast in Bununu.*

contents were either acquired with an electron microprobe or from [13] for the MPI-Ding standards. The instrument mass fractionation (IMF) of hydrogen isotope was evaluated using StHs6/80-G and WOK16-2 [12, 14]. All the reported volatile concentrations were corrected for instrumental backgrounds. The hydrogen isotope compositions were corrected for IMF and instrumental background.

The cosmic ray exposure age of Bununu is only ~20-22 Myrs [9, 15]. Even though the production rates of cosmogenic D and H on Vesta are not well known, we assume they are similar to those inferred for the Moon. The measured D/H values were then corrected with cosmogenic production rates of D and H from [16], and an average exposure age of 21 Myrs.

Results:

Volatile concentrations: Concentrations of C and H are reported as CO_2 and H_2O. The devitrified glass spherule contains 11-18 ppm H_2O, 24-35 ppm F, and 470-570 ppm S. Its CO_2 and Cl concentrations are below the background values (10 ppm and 0.3 ppm, respectively).

Measurements of three impact clasts also show 11-13 ppm H_2O, ~20 ppm F, 1-14 ppm Cl, and 1020-2150 ppm S. The CO_2 concentrations in the impact clasts are below the background value.

Hydrogen isotope compositions: The measured hydrogen isotope compositions of the spherule are +198 ±216‰ (2σ) and -179 ±110‰, and those in impact clasts range from -94 ±197‰ to -333 ±145‰. The large errors are resulted from the very low OH concentrations. The cosmogenic-nuclide-corrected values are from +104‰ to -238‰ in the spherule, and -211 to -431‰ in impact clasts.

Discussion: The major-element composition of the spherule in Bununu is similar to some of the very low-Ti (VLT) glass beads from the Moon [17]. The spherule in Bununu also contains comparable H contents and hydrogen isotope compositions as the VLT glass beads, but higher F and S (2.5-12.2 ppm F and 113-270 ppm S in the VLT). The δD values of the spherule are also similar to those of apatites found in eucrites (-37 ±68‰ to -223 ±21‰ [18]). Potentially these hydrogen isotopic signatures may indicate a magmatic source for the volatiles on the HED parent body.

Bununu is a noble-gas-rich breccia, and Ar-Ar ages of its plagioclase and glass are 4.42 ±0.04 Gyrs and 4.24 ±0.05 Gyrs, respectively [9]. The age of the glass likely reflects the impact event. Thus, the recorded δD value in the impact clasts may reflect the surface or near-surface conditions pre-4.24 Ga. The impact clasts contain low amounts, but noticeable D. The devitrification in the impact clasts indicates low- to medium-grade metamorphic conditions as suggested in [19], and potential de-volatilization, which could lead to decrease in H_2O contents and increase in δD (schematic arrow in Fig. 4). Thus, the pre-metamorphism H in the impact clasts may have even lower δD values, suggesting a possible solar wind contribution.

Preliminary results of the vesicular clast suggest it may be rich in C and H. Further verification of this observation for the complicated vesicular clast is currently in process.

Acknowledgement: We thank the AMNH for providing sample for this research and the support from NASA Cosmochemistry Grant NNN13D465T (YL).

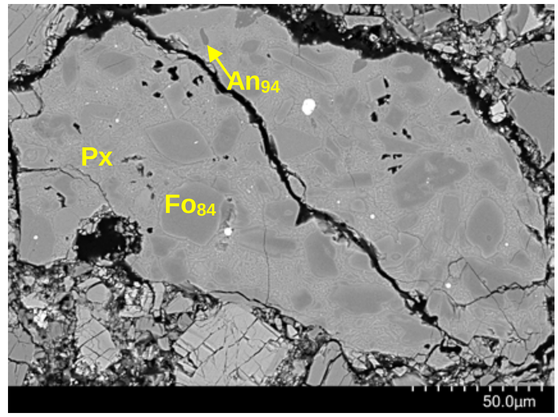

Fig. 3. *BSE image of a devitrified impact clast. The matrix contains small pyroxenes (Px).*

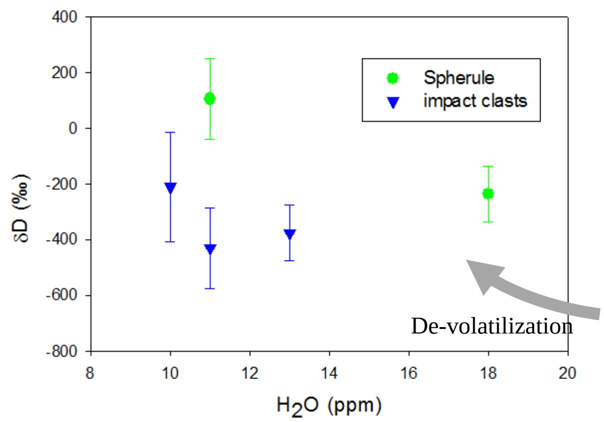

Fig. 4. *Water contents and hydrogen isotope compositions corrected for cosmogenic D and H of a spherule, and impact clasts.*

References: [1] Liu, Y. et al. (2012) *Nature Geosci*, 5, 779-782. [2] Liu, Y. et al. (2013) *44th LPSC* #2203. [3] Prettyman, T. H., et al. (2012) *Science*, 338, 242-246. [4] Nathues, A., et al. (2014) *Icarus*, 239, 222-237. [5] Combe, J.-Ph. Et al. (2012) 43rdLPSC #2463. [6] Desnoyers, C. & Jerome, D.Y. (1974) *Comptes Rendus de l'Academie des Sciences Paris, Sér. D, Tome* 278, 3275 – 3277. [7] Jerome, D.Y. & Desnoyers, C. (1974) *Meteoritics*, 9 354. [8] Noonan, A.F. (1974) *Meteoritics*, 9 233-242 [9] Rajan, R. S. et al. (1974) *EPSL*, 27, 181-190. [10] Chen, Y. et al. (2015) *EPSL* 425, 55-63. [11] Chen, Y. et al. (2016) *EPSL* submitted. [12] Jochum, K. P., et al. (2006) *Geochem. Geophys. Geosyst.*, 7. [13] Newman et al. (2000), Geochem. Geophys. Geosys., 10.1029/1999GC000027. [14] O'Leary (2007), Ph.D. thesis, Caltech. [15] Eugster, O. & Michel, Th. (1995) GCA, 59, 177-199. [16] Saal. A.E. et al. (2013) Science, 340, 1317-1320. [17] Saal. A.E. et al. (2008) Science, 454, 192-195. [18] Sarafian, A.R. et al. (2014) Science, 346, 623-626. [19] Bunch, T.E. (1975) LPSC, 6th, 469-492.