THE FATE OF WATER IN MELTS PRODUCED DURING NATURAL AND EXPERIMENTAL IMPACTS INTO WET, FINE-GRAINED SEDIMENTARY TARGETS. R. S. Harris[1], P. H. Schultz[1], and P. L. King[2], [1]Department of Geological Sciences, Brown University, Providence, RI 02912 (Scott_Harris@brown.edu), [2]Department of Earth Sciences, University of Western Ontario, London, ON N6A 5B7, Canada.

Introduction: The fate of water is an important consideration in modeling the formation and emplacement of melt ejecta during hypervelocity impacts, especially those that excavate thick successions of porous sedimentary materials [e.g., 1,2]. We have previously reported the occurrence of extremely hydrous glass inclusions (Fig. 1) in 445 ka impact melt breccias from Centinela del Mar, Argentina (UCdM glasses) [3]. Based on electron microprobe (EMP) data, acquired using a Na-decay routine developed by Devine et al. [4], we estimated that water concentrations in some of these glasses are as high as 16 to 24 wt% [3]. These concentrations are comparable to estimates (~10-20 wt%) made by Osinski [5] for hydrous glass clasts in Ries suevites (based on low totals in quantitative SEM/EDS measurements). Textural relationships and cooling fabrics demonstrate that these hydrous glasses could not have resulted from post-impact hydration. The evidence suggests instead that they briefly existed as physically separate, low-viscosity "flows" inside, or attached to, significantly drier melts.

Subsequent observations of similar hydrous melts in six other late Miocene to Recent Pampean impact glass deposits identified by Schultz et al. [6-9] lead us to conclude that they are a common feature of impact melts produced from fine-grained, loosely consolidated sediments. In order to more accurately characterize and quantify the volatiles contained in these melts, we report here the first direct measurements of their water concentrations obtained using three different methods: 1) micro-transmission Fourier Transform infrared spectrometry (μT-FTIR); 2) micro-reflectance FTIR (μR-FTIR); and 3) secondary ion mass spectrometry (SIMS).

We also report the results of hypervelocity impact melting experiments designed to test the plausibility of "trapping" pore water in melts formed from saturated, fine-grained particulate targets.

Natural Hydrous Impact Melts: Although hydrous inclusions occur in all Argentine impact melts, they are particularly abundant in UCdM glasses. They may comprise more than 20-30 vol% of individual melt breccia clasts. The hydrous glasses typically are pale to bright yellow and occur as both irregular patches and distinct flow-like features (Fig. 1).

μFTIR analyses were performed using Thermo-Nicolet Nexus 870 and 670 FTIR spectrometers with Continuum microscopes. μT-FTIR data were treated according to King et al. [10]. Because water concentrations in the hydrous glasses are sufficiently high to saturate the detectors at ~3500 cm^{-1}, total water concentrations were calculated by adding [OH^-] and [H_2O] determined from absorption spectra at ~4300 cm^{-1} and ~5200 cm^{-1}, respectively. Results ranged from ~3 to 9 wt%. Water concentrations in the surrounding colorless glass were also determined by μT-FTIR and generally are <0.1 wt%. The hydrous inclusions have complex geometries; consequently, the volume of glass measured by μT-FTIR unavoidably includes some percentage of nominally anhydrous glass. Corrections were applied after determining the 3-D shape of some inclusions using SEM/BSE mapping. Recalculated water concentrations approach 15 wt%.

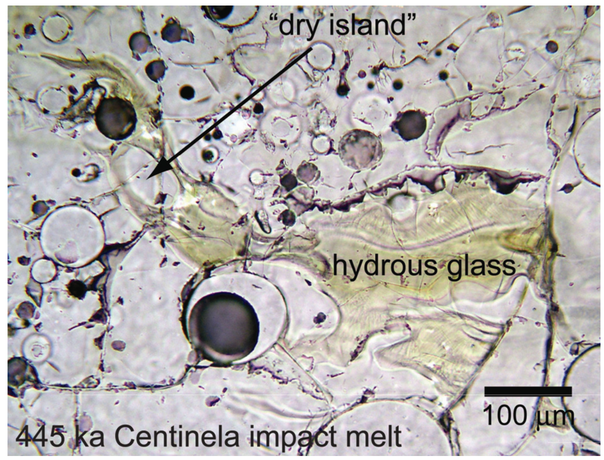

Figure 1. Plane-polarized light (PPL) photomicrograph of a yellowish hydrous glass inclusion in UCdM melt breccia. These melts likely formed during a riverine impact near the present-day village of La Dulce [11]. EMP, μFTIR, and SIMS analyses indicate that water concentrations in the hydrous glasses range between ~3 and 24 wt%. The surrounding colorless glass is essentially anhydrous (<0.1wt% water). Note that the anastomosing, hydrous flow has stranded "islands" of dry glass.

Water concentrations determined from the μR-FTIR technique developed by King et al. [12] range from ~9 to 24 wt%. SIMS measurements, performed using a Cameca IMS 3f ion microprobe, range between ~5 wt% and 18wt%.

From the results of multiple analytical techniques, we have shown that hydrous glass inclusions in UCdM melt breccias contain, at a minimum, between ~3 and 24 wt% water. Petrographic and geochemical observations support the hypothesis that these glasses formed by melting small packets of waterlogged sediment. The packets may have melted as they became entrained in superheated, devolatilized shock melts formed earlier in the formation of the crater. The resulting wet melt inclusions probably failed to degas due to rapid quenching inside the engulfing anhydrous melts. However, it may be possible that some or all of the hydrous inclusions formed directly from shock melting of water-rich sediments. The retention of water may be due to a combination of the high solubility of water in silica-rich melts at high pressure and low diffusion rates for water in silica-rich melts [13] particularly at the high temperatures likely in a shock event. It is notable that the upper limits of water concentrations measured in hydrous impact glasses are consistent with the solubility of water in alumino-silicate melts formed at approximately 1 to 3 GPa (at temperatures >1100ºC) [e.g., 14, 15].

Experimental Hydrous Impact Melts: Pyrex® spheres were fired at 5 km/s into targets composed of water-saturated, very fine-grained fragments of rhyolitic pumice at the NASA/Ames Vertical Gun Range. Melts recovered from these experiments appear to be amalgamations of the impactor and target materials. The alumino-silicate melts contain fluid inclusions (Fig. 2) that are morphologically similar to hydrous glasses in UCdM and other Argentine impact melt breccias. Water concentrations in these inclusions were measured using μR-FTIR. The inclusions— and some regions of the glass where no obvious inclusions are observed— contain at least 8 to 10 wt% water. Most of the glass surrounding the inclusions has water concentrations below the reliability of the μR-FTIR technique (i.e., <1 wt%).

Implications: Our observations of natural and experimental impact glasses show that significant concentrations of water may be preserved in impact melts formed from wet, fine-grained sediments. Our results highlight and extend the point made by Osinski et al. [16] that models of impact processes cannot assume that volatile-rich sediments are simply "degassed and dispersed." We also show that hypervelocity gun experiments can produce reasonable analogs for studying impact melts formed from hydrated sediments. We may be able to examine how volatile behavior in melt ejecta changes for different environmental and impact parameters and how these variations affect the production and dynamics of impact melts.

The concept that hydrous melts commonly are produced by impacts into wet, loessoid sediments has important implications for other sectors of the planetary science community. Impacts into a water/ice-rich regolith, such as we might expect on Mars, should produce hydrous impact melts. Some workers [e.g., 17] have assumed that volcanic and impact melts can be distinguished from one another by the paucity of volatiles in the latter type. That assumption possibly should be reversed. Martian impact melts might at least contain significant water-rich melt inclusions affecting both the spectral properties and alteration products we might observe from such melts. Trapped water will also affect melt rheologies influencing the morphology of melt sheets and melt-rich ejecta deposits.

Finally, if impact melts can trap water from target sediments, it might be possible they could capture volatiles from ice-rich impactors. This is a key question we hope to explore through continued experiments and geochemical investigations of natural hydrous melts.

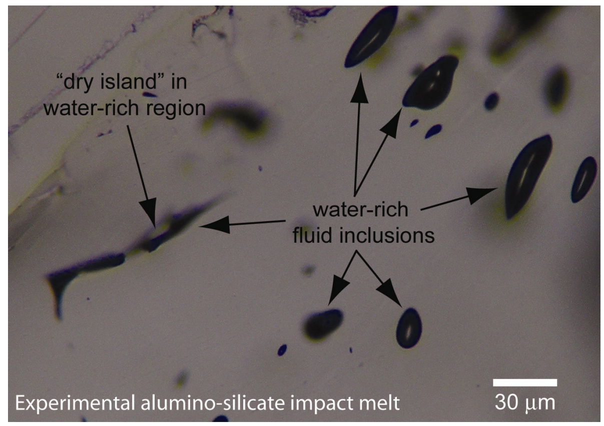

Figure 2. PPL photomicrograph of an experimental melt produced by an impact into water-saturated, fine-grained particulate material. Some target water appears to have been trapped within fluid-rich inclusions. μR-FTIR measurements indicate that these inclusions contain approximately > 8 to 10 wt% water. Note that some inclusions are morphologically very similar to hydrous glass inclusions in natural impact melt breccias (Fig. 1).

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