PRESERVED QUENCHED IMPACT MELTS ON THE MARTIAN SURFACE FROM THE DETECTION OF GLASS AND CHROMIAN SPINEL. K. M. Cannon[1], J. F. Mustard[1], and S. W. Parman[1], [1]Brown University, Department of Earth, Environmental, and Planetary Sciences, Providence RI, 02903, kevin_cannon@brown.edu.

Introduction: Rapidly quenched impact glass can preserve complex organic molecules and solid biomass [1,2], and this glass has been advocated for as a future exploration target on Mars. However, quenched impact glass has never been positively identified on the martian surface through orbital remote sensing. There are three possibilities that can explain this nondetection: (1) impact glass was never there in the first place, (2) any impact glass has been devitrified/aqueously altered, or (3) impact glass is preserved but has avoided detection due to its subtle spectral properties. Here we argue that (3) is correct, and from widespread probable impact melt and melt breccia units we provide spectral evidence from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) that is strongly consistent with mixtures of basaltic glass, chromian spinel and olivine.

Data and Methods: We identified probable impact melt or melt breccia units within or proximal to well-preserved impact craters using CTX and HiRISE imagery as described previously [3]. These units are dark coherent indurated draping material, usually found on central peaks associated with uplifted bedrock as is commonly seen in lunar craters [4]. There are 536 central peak craters on Mars with CRISM coverage, and of these we found 22 scenes with sufficient evidence for impact melt and corresponding excellent spectral exposures. These CRISM scenes were processed using standard techniques [5], and we ratioed melt regions to dusty areas in the same scene to obtain our spectra.

Results: Spectra of impact melt units fall broadly into three categories shown in Figure 1. Type I spectra are mostly featureless with strong blue slopes throughout the near-infrared. These are similar to spectra of basaltic glasses with thin leached rinds [6,7], but they also resemble glassy impact melt breccias from terrestrial impact craters [8], and NWA 7034 [9]. Type II spectra have similar strong blue slopes interrupted by broad absorption bands near 1 and 2 µm. Type III spectra show a ‘w’ shape with a tight chevron near 1.5 µm. These look superficially like pyroxene, but as discussed below a mixture of basaltic glass and Cr-spinel/olivine provides a much better spectral match. The distribution of these spectral types is shown in Figure 2. It appears that Type I and II tend to be more prominent in the northern hemisphere, but currently there are not enough observations to support this in a statistically robust manner.

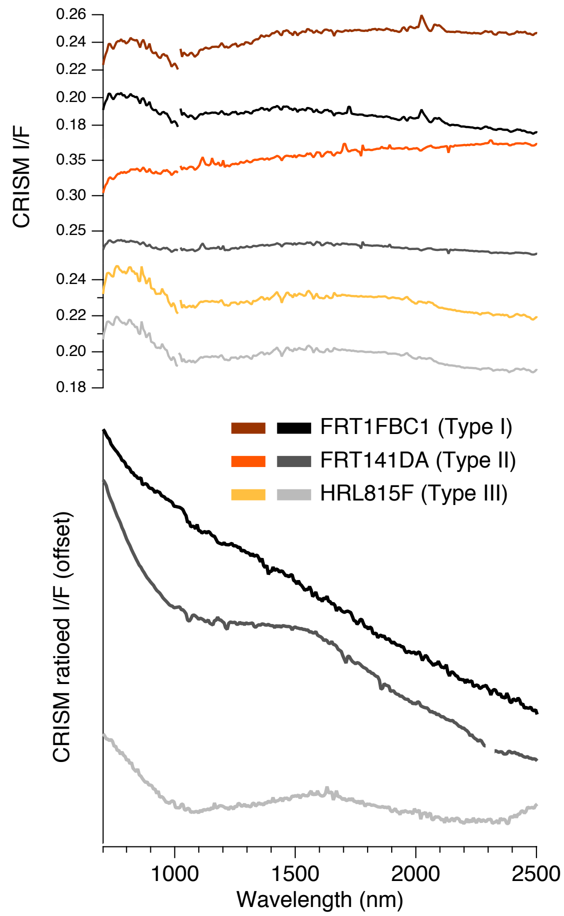

Figure 1. Representative unratioed (top) and ratioed (bottom) CRISM spectra of probable impact melt deposits.

Spectral shape fitting: To determine the possible phases responsible for these spectral shapes we created a spectral library consisting of mafic glasses, olivines, pyroxenes, plagioclase, and (Fe,Cr)-rich spinels [10] with compositions expected for phases crystallizing out of basaltic to ultramafic melts. We removed a linear continuum from the CRISM spectra before algorithmically fitting them with linear mixtures from our library. Spectral mixing at VNIR wavelengths can be highly non-linear, so these results cannot be used as absolute abundances but they are still useful for determining the phases potentially present in mixtures. Results from this spectral shape fitting show that basaltic glasses are the most abundant modeled phase, followed by Cr-spinel then olivine. The robustness of these results can be tested by removing entire groups of phases from the spectral library to see how the error of the fits changes. Crucially we find that the root mean square error increases with a median of +59.5% when all spinels are removed from the library (compared to ~+5% for removing the other groups). This suggests these CRISM spectra are not well modeled unless some type of iron and chromium-rich spinel is used. We find that many of the continuum-removed CRISM spectra can be well modeled by a linear mixtures of ~95% basaltic glass and ~5% Cr-spinel (Figure 3), while others are fit well by glass and olivine mixtures.

Geological Model: Our analyses show spectra of impact melts on Mars are consistent with mixtures of basaltic glass and Cr-spinel/olivine, but is this petrologically realistic? On Mars impact melting is expected to produce basaltic liquids with compositions similar to bulk martian crust. Chromian spinels and olivine are both plausible liquidus phases for these compositions, especially at the surface where the highly oxidizing martian atmosphere enhances the stability of spinel. After spinel/olivine crystallization the exposed upper layer of the molten impact melt quenches to a basaltic glass. This same configuration occurs in terrestrial impact spherules: spinel is commonly found as the only crystalline phase set in a glass matrix [e.g., 11]. Impact melt clasts in NWA 7034 contain 25% quenched olivine and pyroxene set in a matrix of basaltic glass [12], confirming that such material is present on the martian surface. Subsequent leaching of this quenched melt in low-pH fluids at very low W:R ratios may lead to the negative spectral slopes seen in many of the CRISM spectra. The leaching scenario is consistent with the current view of alteration on Mars [13], although we note that negative spectral slopes can also arise from fine-grained glassy melt breccias [8,9] or possibly dust coatings. It may be difficult to distinguish between these scenarios.

Conclusion: We have identified many probable proximal impact melt deposits through their geomorphic character. Compositional remote sensing data suggest that a mixture of basaltic glass and Cr-spinel provides the best spectral fit for these units. This is consistent with a rapidly cooled impact melt crystallizing spinel and/or olivine before quenching to a glass, and if confirmed we suggest that quenched impact glasses are common on the martian surface. We emphasize the importance of these materials as possible future exploration targets [1,2] and encourage further study of impact melting on Mars.

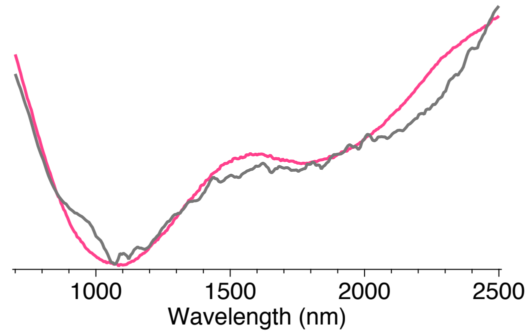

Figure 3. Continuum-removed Type I CRISM spectrum (gray) compared with re-created spectrum (pink) that consists of a linear mixture of 95% basaltic glass and 5% Cr-spinel.

References: [1] Schultz P. H. et al. (2014) *Geology,* doi:10.1130/G35343.1. [2] Howard K. T. et al. (2013) *Nature Geosci.*, *6*, 1018. [3] Cannon K. M. et al. (2014) *LPSC XLV*, Abstract #1954. [4] Wöhler et al. (2014) *Icarus*, *235*, 86. [5] Murchie S. L. et al. (2009) *JGR*, *114*, E00D07. [6] Minitti M. E. et al. (2007) *JGR*, *112*, E05015. [7] Horgan B. and Bell J. F. (2012) *Geology*, *40:5*, 391. [8] Craig M. A. et al. (2014) *LPSC XLIV*, Abstract #2417. [9] Cannon K. M. et al. (2014) *This meeting*. [10] Cloutis E. A. et al. (2004) *MAPS*, *39*, 545. [11] Margolis S. V. et al. (1991) *Science*, *251*, 1594. [12] Udry A. et al. (2014) *LPSC XLV*, Abstract #1948. [13] Hurowitz J. A. and McLennan S. M. (2007) *EPSL*, *260*, 432.

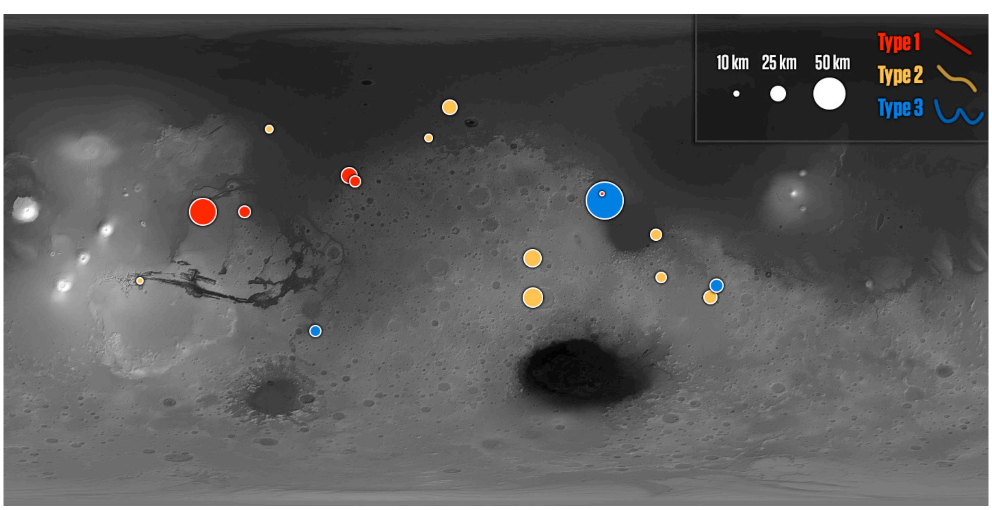

Figure 2. Map of craters included in this study. Colors refer to the type of spectra observed (see Fig. 1), and symbol size represents the crater diameter. A list of CRISM observations is available upon request.