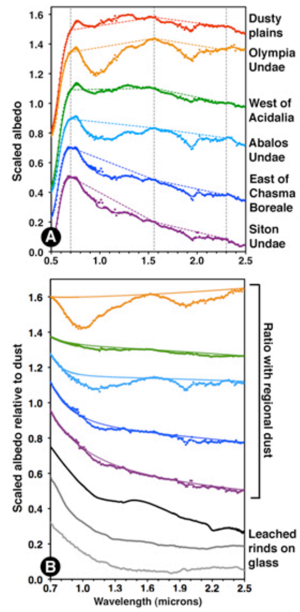
WIDESPREAD WEATHERED GLASS ON THE SURFACE OF MARS. B. Horgan, J.F. Bell III, School of Earth and Space Exploration, Arizona State University (briony.horgan@asu.edu)

Introduction: Low-albedo sediments mantle the northern lowlands of Mars and form the north polar sand sea, which encircles the north polar cap. Unlike many other low-albedo regions on Mars, most of the northern lowlands does not exhibit spectral characteristics consistent with a typical basaltic surface. In the mid-infrared, the model-derived composition of these deposits requires a poorly crystalline high-silica phase, the nature of which is not well constrained [1-3]. Previous studies in the near-infrared (NIR) have not resolved this ambiguity, as the dark plains are nearly spectrally featureless [4,5]. Here we show that the overall continuum shape and subtle absorptions in NIR spectra of the northern plains are consistent with iron-bearing glass partially obscured by a silica-enriched leached glass rind, potentially implying widespread acidic leaching and a history of explosive volcanism in the northern plains [6].

Methods: We have analyzed Mars Express OMEGA visible and NIR (0.36–2.5 μm) spectra from the first year of observations above 45°N. Spectra were converted to estimated Lambert albedo and mapped into regional mosaics [7] prior to analysis. While most spectra in the northern lowlands have concave down shapes between 0.7 and 2.5 μm, we have found a class of spectra that exhibit unusually strong concave up slopes between 0.7 and 1.5 μm (Fig. 1). We parameterize this concavity by comparing a ratio in the concave part of the spectrum to a ratio at longer wavelengths: $A(0.73)/A(1.54) - A(1.54)/A(2.30)$, where A is the average albedo of three channels near the indicated wavelength. Positive values of this parameter indicate a concave up continuum.

Typical mafic minerals may be discriminated based on the wavelength position and shape of the 1 μm iron absorption band [8]. In this study, we have examined the position of the 1 μm band center in OMEGA spectra, after contributions from the atmosphere, dust, instrumental artifacts, and the overall continuum shape were suppressed or removed. The band center is derived by locating the reflectance minimum between 0.75 and 1.3 μm, fitting a second-order polynomial to the channels within 0.075 μm of the minimum, and finding the wavelength of the minimum of the fit.

Results: One of the largest dune fields in the north polar sand sea (Siton Undae) and much of Acidalia and Utopia Planitiae exhibit high concavity values and relatively broad, shallow, and symmetric bands centered between 1.10 and 1.16 μm (Fig. 2). This is beyond the band center range for olivine or pyroxene, but is consistent with high abundances (80-90%) of iron-bearing glass (Fig. 1) [9]. We hypothesize that the concave spectral slope we observe associated with the glass-rich deposits is consistent with the spectra of thin (3–10 μm) silica-enriched leached glass rinds (Fig. 1), formed when silicate glass is exposed to acidic fluids [10]. During acidic leaching, diffusion into the glass causes migra-



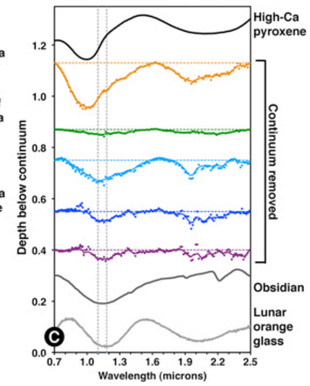


Figure 1: OMEGA spectra consistent with iron-bearing glass, compared with north polar average dust (red) and a spectrum consistent with pyroxene (orange). (A) Variations in concavity. (B) Spectra from A ratioed with average regional dust spectra, compared to leached glass rinds [10,18]. (C) Spectra from B after continuum removal, compared to lab spectra of mafic phases. Vertical lines indicate range of glass band centers in lab spectra.

tion of lower-valence cations (e.g., Mg^{2+}, Fe^{2+}, Ca^{2+}) out of the glass surface, leaving behind the higher-valence cations that form the structural network (e.g., Si^{4+}, Ti^{3+}, Al^{3+}) [11]. Thus, the rind is still structurally similar to the source glass, but is relatively enriched in SiO_2. Leached glass rinds are distinct from depositional silica coatings, which are formed by dissolution of silicates and precipitation of amorphous silica [10]. While rinds retain the loosely bound structure of the host glass, coatings have an opaline structure distinctly different from their substrate [11]. Also, coatings have not been observed to exhibit concave up spectral signatures [12].

Source of the glass: We have detected spectra consistent with iron-bearing glass in pixels totaling over one million sq. km north of 45°N on Mars, and several million additional sq. km of glass-rich surfaces may be obscured under a dusty mantle. Because the glass is durable enough to form sand dunes, some fraction of the glass must be sand-sized with, at most, minor vesicle content. Glass derived from distant impacts could be consistent with these constraints [13], but it is not clear if impact processes could produce such a large, concentrated deposit. Instead, we propose that a more plausible origin for these deposits is explosive volcanism, which may have produced extensive ash deposits across the planet [14]. Possible causes of explosive volcanism on Mars include interactions with ice/water, high silica or volatile content, or eruption under modern atmospheric conditions [14]. While we cannot currently rule out any of these possibilities, the apparent low vesicularity of the glass may

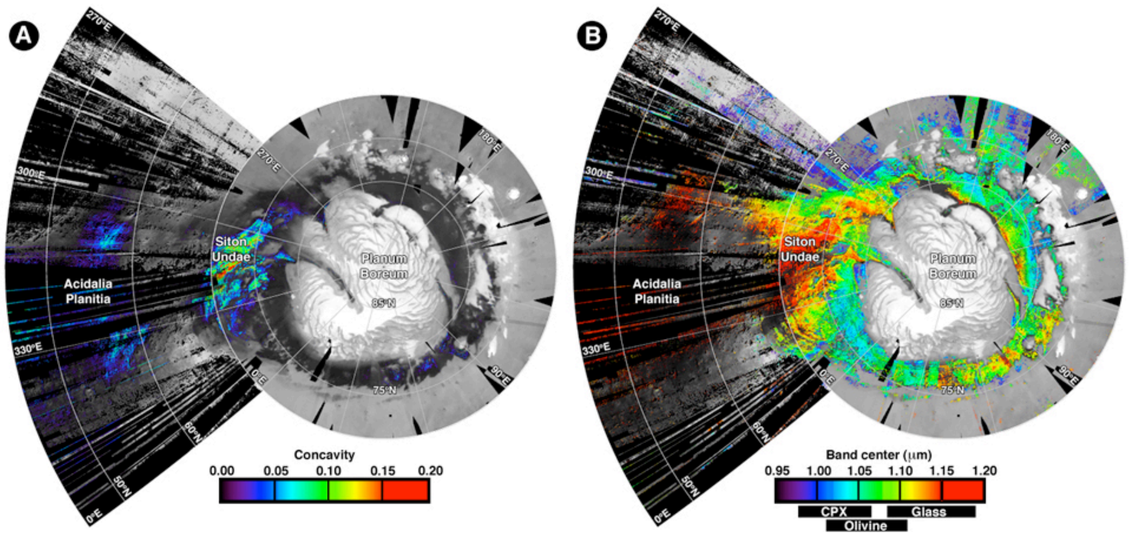


Figure 2: (A) Concavity parameter mapped over the Mars north polar region and northern Acidalia Planitia, showing only positive values. (B) 1 μm band center mapped over the same region. Blue and green regions are consistent with pyroxene (CPX) or olivine, while yellow and red regions are consistent with iron-bearing glass. 1°N ≈60 km.

be consistent with ice-magma interactions [15], and these deposits could be related to putative Late Hesperian or Early Amazonian sub-glacial volcanism in Southern Acidalia [16].

Origin of the leached rind: We interpret the leached glass rinds on the northern lowlands glass as the result of post-depositional weathering, as these rinds are a common weathering product on glassy materials in arid volcanic environments on Earth. In the Ka'u Desert (Hawaii), leached rinds and silica coatings have formed on chilled lava-flow surfaces and ash grains due to interactions with precipitation acidified by volcanic aerosols [10,11,17]. These surfaces exhibit concave up slopes in aerial spectra similar to those observed at lab scale. Laboratory studies have also confirmed the formation of rinds on sand-sized grains (Fig. 1B) [18]. The chemistry of glass leaching constrains the processes that may have produced these rinds. As basalt alteration tends to alkalize solutions, the fluid that creates the rind must be either initially very acidic (pH <2-3), moderately acidic (pH 3-6) and constantly renewed, or moderately acidic with high water:rock ratios [9]. Without invoking abundant surface water during the arid Late Hesperian or Amazonian, a plausible constantly renewed fluid source is melt from surface ice sheets or snow packs, acidified due to oxidizing conditions [19]. Atmospheric water or seasonal frost melt are also plausible fluid sources; however, Phoenix results suggest that these phases promote neutral-alkaline soil conditions [20].

Consistency with other data sets: Our interpretations appear to be consistent with Phoenix Optical Microscope observations. Soils at the 68°N landing site include non-vesicular black sand grains with rounded morphologies and muted surfaces, interpreted as evidence for a weathering rind [21], all of which would be consistent with leached volcanic glass grains. Furthermore, our interpretations are also broadly consistent with TES spectral models of the northern lowlands. Our most concentrated leached glass detections correlate well with the highest concentrations on the planet of both the Surface Type 2 high silica component and basaltic glass [1,22]. The qualitative correlation between our leached glass detections and Surface Type 2 may have major implications for the composition, sources, and alteration histories of global martian sediments. Surface Type 2 appears to be at least as widely distributed as Surface Type 1, and we propose that this distribution may be consistent with globally distributed glassy sediments, most likely produced by explosive volcanism. Such a scenario would require widespread late stage explosive volcanism on Mars, and suggests that glass may be a major component of martian sediments.

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