DO SHALLOW RADAR SOUNDINGS REVEAL POSSIBLE NEAR-SURFACE LAYERING THROUGHOUT THE NORTHERN LOWLANDS OF MARS? N. E. Putzig,[1] R. J. Phillips,[1] J. W. Head,[2] B. A. Campbell[4], A. F. Egan[1], J. J. Plaut[5], L. M. Carter[4], R. Seu[6], and the SHARAD Team. [1] Southwest Research Institute, Boulder, CO 80302 USA (email: nathaniel@putzig.com); [2] Dept. of Geological Sciences, Brown Univ., Providence, RI 02912 USA; [3] National Air and Space Museum, Smithsonian Institution, Washington, DC 20560 USA; [5] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA; [6] INFOCOM Department, Univ. of Rome "La Sapienza," 00184 Rome, Italy. M. T. Mellon, LASP, University of Colorado, Boulder, CO 80309 USA added to poster.

Introduction: The Shallow Radar (SHARAD) sounder [1] onboard the MRO spacecraft has detected clear evidence for subsurface interfaces not only within polar ices [2,3] but also at various locations in the mid-latitudes, where layers of glacial ice [4,5], volcanics [6], or sediments [7] provide a dielectric contrast with underlying materials. More subtle radar returns that potentially originate in the near subsurface occur in other areas, most notably in the Northern Lowlands. This region includes the Phoenix landing site, where preliminary work by the SHARAD Team [8] shows a probable subsurface interface at depths of ~25–45 m.

Beyond the Phoenix site, shallow radar returns of similar appearance and delay time occur in many other areas across the Northern Lowlands. Whether these features truly correspond to subsurface interfaces remains an open question, which we discuss. Assuming that they do, we consider a range of possible explanations which are by no means exclusive of each other.

Background: The 15- to 25-MHz chirped pulse transmitted by SHARAD and the nearly circular orbit of MRO yield a horizontal ground resolution of 3–6 km, reducible in processing to 0.3–1 km along track. The vertical resolution is 15 m in free-space or ~6–10 m in the subsurface depending on the dielectric constant [1]. Scattering, path, and interface losses limit the depth of signal penetration in the non-icy subsurface to a few hundred meters. Side lobes of the strong surface return, off-nadir surface clutter, and ionospheric interference may complicate the radar signal, requiring special consideration for targets within a few range resolution cells of the surface.

In ascending stratigraphic order, the geologic record in the Northern Lowlands of Mars [9] contains: remnants of ancient Noachian heavily cratered terrain [9]; possible buried sedimentary deposits from Late-Noachian valley-network fluvial activity [10]; Hesperian volcanic ridged plains [11]; Hesperian to Early-Amazonian outflow-channel effluent (the Vastitas Borealis Formation, VBF) [12,13]; Late-Hesperian and Amazonian volcanic deposits emanating from the Tharsis region [14]; Amazonian polar deposits [15] and mid-latitude glacial deposits [16]; Late-Amazonian reworking of the VBF by aeolian and cold-climate processes, and deposition of volatile mantles represented by pedestal crater remnants [17]; and emplacement of a geologically recent, latitude-dependent mantle [18]. The Phoenix spacecraft provided a unique view of the upper surface of this stratigraphic column, which is dominated by near-surface ice [19].

Observations: SHARAD has observed the Northern Lowlands on over 1200 orbits through October 2008. Radar data are typically displayed as log-scaled signal-power images (radargrams) with distance along track on the horizontal axis and delay time (analogous to depth for a radar sounder) increasing downward on the vertical axis (Fig. 2). Processing aimed at reducing surface-return side lobes was employed in this study. Reflections from off-nadir topographic features may appear at delay times similar to those of subsurface returns, and we generate synthetic radargrams using MOLA topographic maps to evaluate such effects.

Two SHARAD observations (459002 and 374601 in Fig. 1) cross near the Phoenix site that resides in the 'Green Valley,' represented as a low-lying (later-delay-time) segment on the north end of the radargrams (upper panels of Fig. 2). As with many other observations over Green Valley, a laterally continuous radar return occurs at a delay of ~0.5 µs from the surface reflection. Since synthetic radargrams do not show these returns and data processing was aimed at reducing side lobes, we strongly suggest that these returns arise from subsurface interfaces. The surfaces immediately outside of the Green Valley are rougher than those within, and the radar observations contain many off-nadir returns, with no clear evidence for subsurface features. Further afield where the surface is again relatively smooth, similar apparent subsurface returns are seen (374601 in Fig. 2). Such features occur on numerous radargrams at similar latitudes all across the Northern Lowlands, demonstrated here by a radargram from a region 20° east of the Phoenix site (472102 in Fig. 2).

To mitigate concerns about ionospheric effects, we examined a series of adjacent observations from both regions taken with solar zenith angles (SZA) ranging from 50° to 130°. In each case, the apparent subsurface returns persist to the highest SZA, well into the night when ionospheric effects are expected to be small. The examples in Fig. 2 all have SZA near 128° at the center of the radargram.

Discussion: Possible sources of the SHARAD near-surface detections include: 1) ice-rich layers up to

~100 m thick that represent the sublimation residue of outflow channel effluent and make up the Vastitas Borealis Formation [13]; 2) remnant ice-rich lag layers from extensive Late-Amazonian ice-rich mantles in the mid-to-high latitudes (remnants of these deposits up to ~100 m thick likely remain below pedestal craters [17,20]); 3) dusty ice deposits emplaced atmospherically during recent obliquity excursions, with subsequent sublimation to produce surface lags that protect underlying ice layers [18,21-23]; and 4) vapor-diffusion-emplaced shallow ice lenses and layers in the upper part of the regolith, subject to time-dependent ice stability factors [24,25].

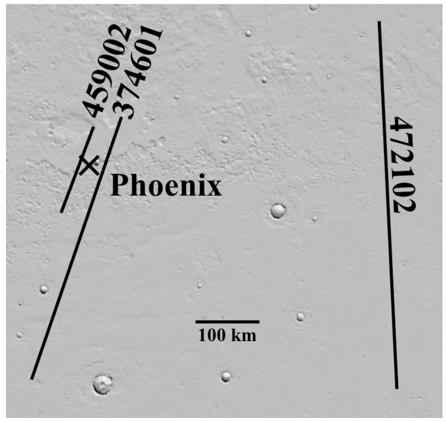

Figure 1: Location map showing SHARAD ground tracks for radargrams in Figure 2. Two radargrams pass near the Phoenix landing site (×) while a third is located about 20° to the east. Basemap is a polar projection shaded relief from MOLA data.

Development of a means to distinguish between these and other potential explanations of the SHARAD returns is ongoing. In any case, because the signal strength appears relatively weak, one may discount those hypotheses that require an abrupt interface with a large dielectric contrast. Prior studies have shown that SHARAD will typically yield a strong reflection in such cases [4,5,7]. Rather, possible explanations might include a lower dielectic contrast (e.g., lower ice content in the upper layer) or a more gradual transition between the upper and lower materials.

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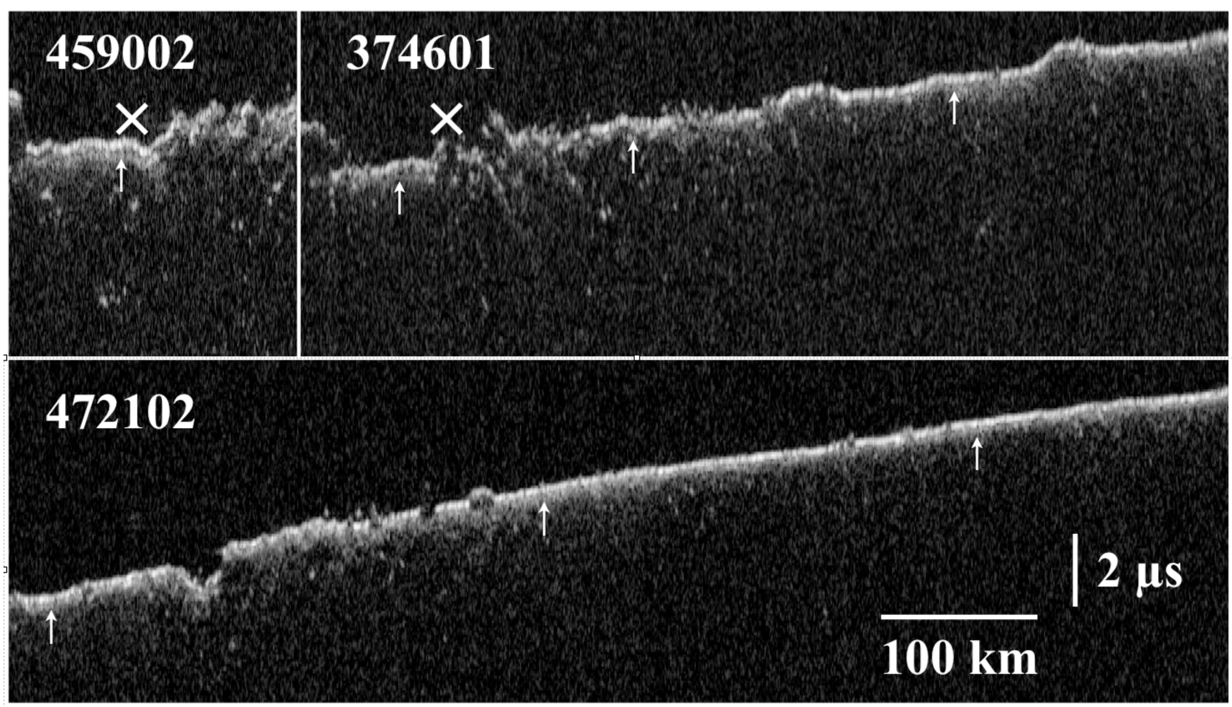

Figure 2: Focused SHARAD radargrams labeled with observation numbers corresponding to ground tracks in Figure 1. Upper radargrams cross the Green Valley on the left (north) side of radargrams near the Phoenix site (× shows closest point along ground track). White arrows indicate apparent subsurface detections that occur at ~0.5 µs, both within Green Valley and well outside of it. Scale bars apply to all radargrams.