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# SHARAD observations of recent geologic features on Mars

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## Abstract

The Shallow Radar (SHARAD) instrument on the Mars Reconnaissance Orbiter (MRO) observes a variety of recent features on Mars, including deposits of water ice at both poles and in the mid-latitudes, solid $CO_2$ in the south polar region, and volcanics in the tropics and mid-latitudes. SHARAD's view of subsurface layers sheds light on the history of deposition and erosion in these terrains, with implications for the cycle of volatile exchange and for recent volcanism.

## 1. Introduction

The SHARAD instrument generates a chirped pulse of 15–25 MHz at a free-space wavelength of 15 m (~5–10 m in the subsurface). With MRO's 255–320-km orbit, SHARAD achieves a lateral resolution at the surface of 3–6 km, reducible to 0.3–1.0 km in the along-track direction with SAR processing. SHARAD records returned signals that are reflected by the surface and by subsurface interfaces with a dielectric contrast, which may be provided by changes in material properties, either in their composition (e.g., variations in the lithic content of ice layers, $CO_2$ overlying water ice) or in their physical characteristics (e.g., density variations due to changes in pore volume). Lossy or highly scattering materials reduce the strength of transmitted signals and may mask underlying interfaces that might otherwise be detected.

## 2. Polar layered deposits

SHARAD soundings of the north and south polar layered deposits (NPLD and SPLD) have yielded detailed internal structure to depths of several kilometers. The characterization of water-ice deposits is richest in the north, where packets of internal layers can often be traced throughout Planum Boreum. In the south, while the water-ice layering is more complex and discontinuous (consistent with these deposits being substantially older), a newly discovered deposit of massive $CO_2$ ice has exciting implications for recent changes in Mars' climate [1].

NPLD stratigraphy consists of packets of brightly reflective layers alternating with relatively non-reflective zones, and these sequences can be correlated to orbit cycles, suggesting an age of ~4.2 Ma [2]. In detail, the radar shows unconformities, either within the reflective sequences or at their boundaries (Fig. 1). A history of alternating periods of non-uniform deposition and erosion is recorded by these structures. In the upper ~500 m, discontinuities that trace to troughs observable at the surface map out paths of trough migration over time. The poleward migration and SHARAD-observed thickness variations adjacent to the migration path are consistent with a mechanism of katabatic winds eroding from the equator-facing slopes and depositing on the pole-facing slopes [4].

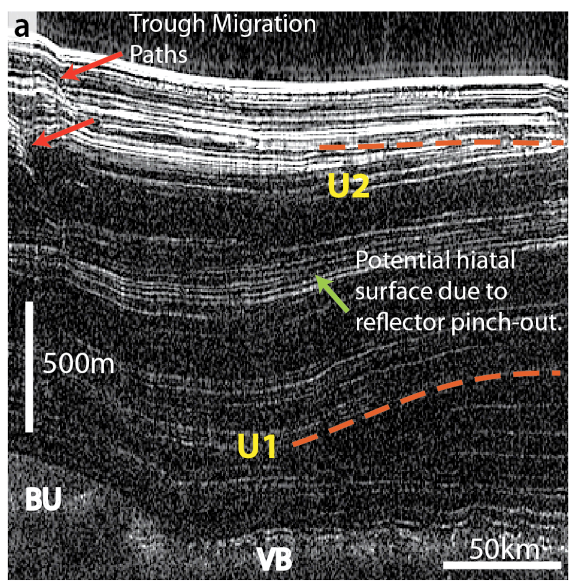


Fig. 1. SHARAD radargram showing sequences of layers, angular unconformities (U1, U2), and structures associated to trough migration (arrows). BU is basal unit underlying some portions of NPLD and VB is Vastitas Borealis deposits inferred to underlie other portions. From [3].

In the SPLD, organized sets of radar reflectors are limited to specific regions, and it is difficult to map SPLD-wide radar stratigraphy. SHARAD results do show four regional reflection-free zones (RFZs) distinguished by their qualitative radar characteristics [1]. In one zone ($RFZ_3$), which occurs beneath the

South Polar Residual Cap (SPRC) and has a good spatial correlation with stratigraphic unit "$AA_3$" [5, 6], multiple techniques were used to invert for the real permittivity, $\varepsilon'$, on 41 SHARAD observations. The resulting $\varepsilon'$ of 2.0–2.2 with standard deviations of 0.1–0.2 is remarkably close to the laboratory-measured permittivity value of bulk $CO_2$ ice and distant from the bulk water-ice value ($\varepsilon' = 3.15$). The permittivity estimates yield a mean thickness of 200–230 m and a volume of 4,000–4,500 km$^3$ for $RFZ_3$ where it is observed by SHARAD. Unit "$AA_3$", which shows good evidence for $CO_2$ sublimation, was used a basis for extrapolating poleward of ~87°S (where MRO's orbital inclination precludes SHARAD sounding), yielding a total volume estimate for $RFZ_3$ of 9,500 to 12,500 km$^3$ (Fig 2). If entirely released to the atmosphere, this volume of $CO_2$ would add 4–5 mbar, nearly doubling the current atmospheric pressure of ~6 mbar. Such a release is likely to have occurred at times of high obliquity, such as 600,000 years ago. GCM simulations predict the increased atmospheric $CO_2$, which should have provided greater stability of surface water against boiling and more frequent and intense dust storms.

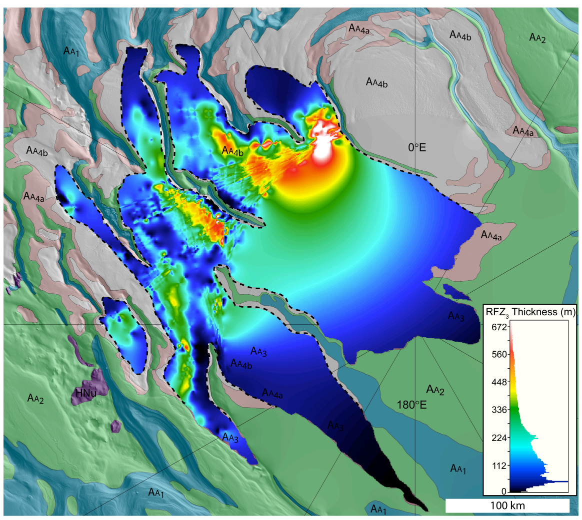


Figure 2: Thickness data from the SHARAD-mapped $RFZ_3$ unit (using $\varepsilon' = 2.1$) extrapolated (smoother color pattern) over and constrained by the lateral extent of the $AA_3$ unit (dashed lines) using a minimum-curvature interpolation function. The histogram shows relative occurrence of thicknesses. Base map (muted colors) shows SPLD stratigraphy [5, 6]. From [1].

## 3. Non-polar deposits

Outside the polar regions, SHARAD also detects subsurface interfaces in regions of recent geological activity. SHARAD observations of features characterized with imagery and other surface data as "lobate debris aprons" reveal that these structures are nearly pure water ice below a thin cover of lithics, and are better termed debris-covered glaciers [7, 8]. Elsewhere, SHARAD detects subsurface interfaces below several areas believed to contain relatively recent, extensive lava flows. Subsurface reflections occur where the lava flows overlie either sedimentary deposits [9], regolith, or other volcanic deposits [10]. In some cases [e.g., 11], it is possible to extract the dielectric constant and loss tangent, allowing a better characterization of the materials.

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