DEEP STRUCTURE OF THE POLAR PLATEAUS OF MARS FROM MARSIS RADAR SOUNDING.
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Introduction: The polar regions of Mars are dominated by thick accumulations of deposits of volatiles and other material that comprise the plateaus known as Planum Boreum (north) and Planum Australe (south). The radar sounders MARSIS (Mars Advanced Radar for Subsurface and Ionospheric Sounding) and SHARAD (Shallow Radar) are powerful tools for probing the interiors of the polar plateaus. The polar deposits are very amenable to penetration of the radar signals of these sounders. In the case of MARSIS, which operates at long wavelengths (frequencies between 1.3 MHz and 5.5 MHz), reflections are obtained from the base of the polar deposits in a large majority of areas of the polar deposits. In this paper, MARSIS data processed with a comprehensive ionospheric and geometric correction method are utilized to give a complete and detailed view of the deep structure of both polar plateaus, providing new insights into the early history of the development of the polar deposits.

Background: Initial studies of the polar plateaus using MARSIS data showed that: the wave speed and low loss of the radar signal through kilometers of material were consistent with a composition of nearly pure water ice [1, 2]; and the total volume of H$_2$O contained in the deposits was approximately 10-12 m global equivalent layer (GEL) in the south [2] and 8-10 m GEL in the north [3]. Selvans et al. [3] separately mapped and measured the volume of the finely layered upper unit of the Planum Boreum (north polar layered deposits, NPLD) and the lower so-called basal unit (BU). These units can be distinguished in MARSIS data by their different scattering characteristics (see figure). The NPLD show several bright layered reflectors in the upper ~0.5 km, followed by a zone of relatively low returns and muted layering. A distinct upper contact of the basal unit is observed, below which appears a generally diffuse brightly scattering unit that continues to the basal reflector, presumably the contact with the underlying Vastitas Borealis bedrock unit.

Data processing: The operating frequencies of MARSIS were selected to optimize penetration into the subsurface, as lower frequencies generally sound deeper than higher frequencies. A challenge to operating and processing MARSIS data arises when the plasma frequency of the ionosphere is comparable to the radar frequency [4]. The ionosphere induces several distorting effects on the radar signals, which are manifest as smearing and delaying the returned echoes in the resulting radargram. These effects can be corrected in ground processing. Using the formulation of [4], a new implementation of the MARSIS processing has been developed, which focuses the radar returns and places them in their proper geometric position [5]. In addition, radargrams are produced that automatically compensate for the change in wave velocity in the subsurface medium, under an assumption of the real part of the dielectric constant. The resulting radargrams represent the true geometry of the subsurface, in terms of depth of the reflectors. Interpretation of the subsurface signatures can be much more easily conducted than with prior products.

Interpretation of radargrams: Depth corrected radargrams of the north and south polar plateaus are shown in the figure (next page). In Planum Boreum, the depth correction using a wave velocity expected for pure water ice (real dielectric of 3.1) reprojects the basal contact into a nearly flat, linear reflector. This reflector is continuous and nearly straight beneath both the Gemina Lingula lobe, which consists entirely of NPLD, and the main lobe of Planum Boreum, which has a considerable thickness of the BU. In the radargram shown, the flatness of the lower contact suggests that the BU does not have a high enough fraction of non-ice material to significantly slow the wave speed, compared to pure water ice. Analysis of the geometry of the basal reflector over many radargrams covering the entire plateau can be used to further constrain the impurity fraction of the BU. The geometric corrections are applied to all frequencies obtained by MARSIS, which can then be compared with one another and with similarly processed 20 MHz data from SHARAD. Several prominent subsurface interfaces show different character, and even different positions, in radargrams obtained at different frequencies. These variations can be used to further constrain the mechanisms of radar-interface interactions, and the nature and origin of the subsurface boundaries.

In Planum Australe, MARSIS penetrates the full thickness of the south polar layered deposits (SPLD), to a maximum thickness of 3.7 km [2]. A notable feature of the basal contact is its unusually reflective appearance in some areas. This indicates a very low loss rate of the radar signals through the bulk of the plateau, and raises the possibility of an unusually smooth interface or some exotic composition. Basal melting can likely be ruled out, as the bright reflector often extends nearly to the surface at the margins of the SPLD, where the thermal conditions preclude the presence of liquid even in the form of a depressed-freezing-point brine. Lenses of buried CO$_2$ ice have been identified in
the SPLD using SHARAD data [6]. The newly processed MARSIS data can be used to search for occurrences of such deposits that are not evident in SHARAD data due to their depth or wavelength-dependent scattering.


MARSIS radargrams of Planum Boreum (top) and Planum Australe (bottom) with the groundtrack shown on MOLA shaded relief topography below each. Data are depth corrected assuming a wave speed in ice below all surface reflections. Note the flat basal reflectors below both stacks of deposits.