STRATIGRAPHY OF THE UPPER MARTIAN NORTH POLAR LAYERED DEPOSITS FROM RADAR, VISIBLE AND TOPOGRAPHIC DATA. J.J. Plaut, Jet Propulsion Laboratory, California Institute of Technology, Mail Stop183-601, 4800 Oak Grove Dr., Pasadena, CA 91109, plaut@jpl.nasa.gov.

Introduction: The north polar layered deposits (NPLD) of Mars contain a record of climate variations in recent times, although the timescales are unknown. While the albedo variations that give the deposits a banded appearance in images have previously been ascribed to variations in dust to ice ratio, radar sounding of the deposits indicates that the dust fraction is minimal, no more than 5% [1,2]. Furthermore, high resolution imagery indicates that the banding is mostly due to surficial deposits and textural weathering characteristics, and may not reflect the intrinsic dust/ice composition at all [3-5]. In this study, data from the SHAllow RADar sounder (SHARAD) are compared to visible images and topographic data, including stereo-derived DEMs, to tie the positions of radar reflectors to outcrops of layered deposits visible in high resolution images. The morphologic and topographic characteristics of the reflecting layers can then be used to constrain the mechanism that causes a radar reflection at a particular place in the stratigraphy. The aim is to use this information to understand the physical properties of the layers that may provide information on climate history, beyond the simplistic dust/ice albedo assumption of previous studies.

Data: The SHARAD data used in this study are at 20 MHz center frequency with a 10 MHz bandwidth, which provides an effective vertical resolution in ice of about 9 m [6]. Data are processed with a synthetic aperture focusing algorithm that provides along-track footprint spacing of 300 m. Cross-track footprint size is 3-6 km. The near-polar orbit of Mars Reconnaissance Orbiter (MRO) allows dense mapping coverage of the polar regions, up to latitudes of ~87°. The SHARAD radargrams of the NPLD provide excellent delineation of internal layering, especially in the upper ~500 m of the deposits [7,8], which are the focus of this study. However, subsurface reflections are difficult to acquire within a few km of the scarps where layers are exposed in imagery, due to the geometric constraints of the radar observation and processing. Fortunately, slopes of the internal layers are in general very low (~1°), so extrapolation of the radar reflection to the outcrop is possible, with caveats [9]. Most of the image data used are from the MRO HiRISE and Context Camera (CTX), with supplemental data from other orbital camera systems. CTX data were used extensively to connect and correlate distinctive layers, thanks to the favorable combination of large image size, near-complete coverage, and high resolution (~6 m/pixel) of these data. To avoid complications of time-variable surficial albedo effects, most images were fully frost-covered from the early to mid-spring season. These images tend to emphasize the texture and weathering relief of the layer exposures. MOLA laser altimetry gridded products at 512 pixels/degree provide a topographic basemap. Digital elevation models from HiRISE and CTX stereo pairs allow precise determination of the positions of layers in outcrops. These can then be tied to the elevations of the subsurface reflections of SHARAD, under an assumption of the wave speed in the medium, and a proper extrapolation to the exposed outcrop.

Study area: The area of focus is in the high elevation, near-polar plateaus and troughs of Planum Boreum, within the approximate range of 85.5°-87°N and 50°-160°E. Four major troughs occur in this area, each about 300 km long. Relief on these troughs is typically ~700 m on the equator-facing side, with the plateaus decreasing in elevation in a stair-step fashion by ~300 m on adjacent plateaus. The troughs include the type location for the "marker bed" of [10] and the area studied for detailed stratigraphy using HiRISE DEM and image data by [5,11]. In addition, a CTX stereo-derived DEM was provided by Malin Space Science Systems of a scarp exposure near 86.8°N, 161°E (Fig.1).

Observations: In SHARAD data, subsurface reflectors are remarkably consistent and continuous over hundreds of km [7]. This is true not only along a given plateau, but also across troughs, and in many cases across the entire width of the NPLD. An example of a first-order characterization of the radar layers is shown in Fig. 2. The upper ~500 m is generally characterized by groupings of reflective bands separated by zones of fewer or less reflective bands, referred to as "dark packets" [7]. Certain reflectors are especially strong and regionally consistent, such as the band at 53 m depth in Fig. 2 marked as the "regional bright band." The radar stratigraphy of Fig. 2 is very consistent within the same plateau, but also occurs with some variations in adjacent plateaus at differing latitudes and elevations. This consistency indicates that the accumulation process was not highly dependent on location or elevation within the studied areas of NPLD. In visible image data, the correlation of layers exposed in widely separated areas has been noted by previous workers [e.g., 5,12]. This is generally the observation in this study, however, detailed tracing of layers along troughs several 100s of km long shows variations in outcrop appearance and layer spacing. This may be an...
indication of processes near the troughs [e.g., 13], because the internal areas are more consistent in layer thickness in the radargrams. The well-known "marker bed" [5,10,12] is identifiable in most trough exposures in visible images, although it is not always the most prominent layer showing a resistant erosional profile.

Discussion: The following preliminary correlations are observed: The "regional bright band" noted in Fig. 2 is at a depth of only ~50 m and normally outcrops at the shallow break in slope at the top of exposed scarps. Geometric complications do not allow a precise correlation of this reflector with outcrop morphology, so it is not clear whether the reflector is aligned with the resistant bed commonly seen at the break in slope, or with the adjacent recessive beds. The next distinctive radar reflectors, a pair of bright bands, do not have an associated outcrop signature in visible data. A prominent regional "marker bed" called "U3" in visible data by [5], occurs within the dark radar packet, and may be associated with the weaker reflecting bands within that packet. Finally the original "marker bed" of [10] appears to coincide with a bright reflective band at 302 m depth in Fig. 2, which is the first bright band below a second dark packet. These correlations are preliminary and need further testing for geometric accuracy. While a strong correlation of erosional resistant beds and bright reflectors is not observed, some of the so-called marker beds appear to be associated with bright reflectors. The physical mechanism that leads to both radar reflectivity and resistance to erosion remains to be determined.

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