SHARAD RADAR SURVEY OF ANCIENT BASIN STRATIGRAPY ON MARS. E. S. Shoemaker[1], D. M. H. Baker[2], and L. M. Carter[2], [1]Department of Physics, Astronomy, and Geosciences, Towson University, 8000 York Rd. Towson, MD 21252 (emileighshoemaker@gmail.com), [2]Planetary Geology, Geophysics, and Geochemisty Lab, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

Introduction: Current observations of surface geology suggest that ancient basins on Mars were once host to lakes and possibly oceans that may have been depocenters of sedimentary materials, including hydrated minerals like phyllosilicates[e.g., 1]. Later resurfacing by volcanic and additional sedimentary deposits may have developed a unique stratigraphy within the basins that can be detected from orbit using radar sounding data from the Mars Reconnaissance Orbiter (MRO) SHallow RADar (SHARAD) instrument [2].

Data: We investigated possible evidence of basin stratigraphy through a survey of 797 SHARAD radargrams covering multiple regions of the Martian surface, including the Isidis basin (3-29°N, 78-100°E) and 60 "Open Basin Lakes" (OBLs) with areas larger than 1000 km^2, as classified by Fassett and Head (2008) [1]. Radar simulations of surface clutter ("cluttergrams") were compared with each radargram to confirm the presence of real subsurface returns[3]. Previous geologic mapping has suggested that Isidis basin (diameter 1500 km) has a number of layered sedimentary (mass wasting and fluvial deposits) and volcanic deposits [4,5], making it a good target for radar detection of subsurface stratigraphy. The OBLs are generally smaller than Isidis Basin, ranging in area from ~10^3 to 2 x 10^5 km^2, and have both inlet and outlet channels that suggest that they were once filled with water to at least the topographic level of their outlet channels [1,6]. Several OBLs have been resurfaced by volcanic material which could potentially overlay ancient lake deposits.

Methods: To determine the presence of a real subsurface interface, each radargram was overlaid onto its corresponding clutter simulation (Figure 1). Radar returns appearing in the radargrams but not in the cluttergrams were considered to be "real." We also examined the traverse of the corresponding SHARAD observation within the Java Mission-planning and Analysis for Remote Sensing (JMARS) program to confirm that detected interfaces were within the basin of interest. Further, we used previous geologic maps [7] and a THEMIS daytime IR mosaic [8] for geologic context.

The depth to an identified subsurface interface (h) was calculated using an IDL program that first automatically selects the surface reflection. The subsurface reflection is defined by a manual trace that is then automatically refined based on surrounding maximum power values (Fig. 2). The column height between the surface and subsurface returns (n, in pixels) is then calculated, allowing the depth, h, to be calculated:

$$h = \frac{\Delta t}{2}\frac{c}{\sqrt{\varepsilon\prime}} \quad , \Delta t = n \times 37.5\ ns$$

where Δt is the two-way travel time (37.5 ns), ε' is the dielectric constant, and c is the speed of light in a vacuum. The range of dielectric constants used (ε': 4-9) corresponds to sedimentary and volcanic materials which are assumed to be present in the basins.

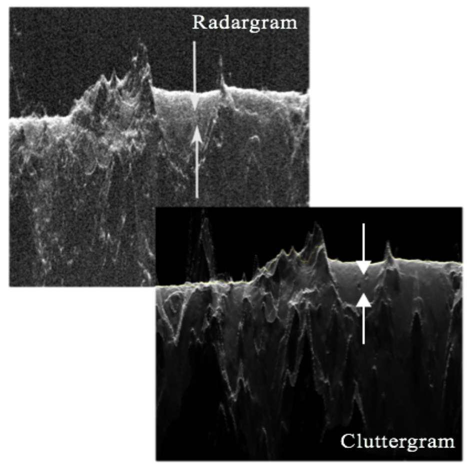

Figure 1: SHARAD radagram S_01967301 (top) and cluttergram (bottom) over OBL 218. The absence of the faint subsurface interface (between arrows) in the cluttergram indicates that it is real.

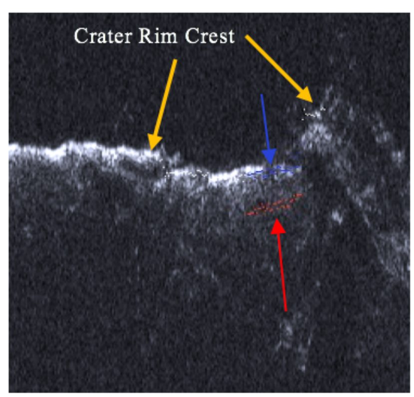

Figure 2: SHARAD Radargram S_00592701 over OBL 218. The IDL program recognizes the bright surface return (blue arrow) and the user-drawn location of the interface at ~93-139 m (red arrow).

Results and Summary:

SHARAD radar survey: Our survey of 123 SHARAD radargrams found no evidence for subsurface reflectors within the interior of Isidis basin. We suggest that the radar signal may be attenuated by a number of factors, including the presence of hydrated minerals such as clays, surface roughness, and volumetric scattering (Fig. 3). Poor dielectric contrasts between subsurface layering could also be factors. Our survey of 674 radargrams covering OBLs returned only one basin ("OBL 218") with distinct subsurface interfaces (Fig. 1). The remaining OBLs had no detected subsurface interfaces and may have had the radar signal attenuated much like Isidis basin.

OBL 218: OBL 218 has a diameter of 50 km and current depth of 303 m as measured from the present rim-crest to its floor. Based on published crater depth-diameter trends for Mars from [14] where $d = 0.36D^{0.49}$, the basin's original depth was ~2.45 km, suggesting that approximately 2 km of material is currently filling OBL 218 (Fig. 4). Geologic maps of the Hellas Planitia region suggest that OBL 218 was most recently resurfaced by volcanic lavas [13,14]. We detected two distinct subsurface interfaces: one upper interface in a single radargram and one lower interface spanning four radargrams covering the interior of OBL 218. If we assume that the surface volcanic materials mapped in the interior of the basin extend to depth, and assume an appropriate range of dielectric constants for Martian lava flows of 7-9, mean thicknesses of 93.00 to 105.46 m are calculated for this unit. However, if there are inter-layered sediments or less dense materials present in the subsurface, lower dielectric constants of 4-6 are possible, yielding thicknesses of 113.91 to 139.51 m. We interpret these subsurface returns to represent lavas closer to the surface with some underlying sediments possible [9,10,11,12]. These returns make OBL 218 unique as it may possess fewer attenuating factors or a stronger dielectric contrast between subsurface layering than others in the survey. These observations support the presence of layering in ancient basins on Mars as inferred from surface geology. Such basins could aid in understanding the role that water played in Mars' history.

References: [1] Fassett, C. I., Head, J. W. 2008, Icarus, 198, p. 37-56; [2] Seu, R., et al. 2007, JGR, 112, E05S05; [3] Choudry, P., et al. 2016 IEEE Geoscience and Remote Sensing Letters 13, p. 1285-1289 [4] Ghent et al. 2012, Icarus, 217, p. 169-183; [5] Ivanov et al. 2012, Icarus, 218, p. 24-46; [6] Goudge et al. 2012, Icarus, 219, p. 211-229; [7] Leonard, G.J., and Tanaka, K.L., 2001, USGS, Map I- 2694, scale 1:4,336,000.; [8] Edwards, C.S. et al., 2011, JGR 116.; [9] Mustard et al. 2009, JGR, 114; [10] Stillman, D. E., and R. E. Grimm (2011), JGR, 116, E03001; [11] Ehlmann et al. 2011, Nature, 479, p. 53-60; [12] Campbell et al. 2013, JGR Planets, 118, 436–450; [13] Goudge et al. 2012, JGR, 117; [14] Boyce et al. 2005, JGR, 110. [15] Campbell, B. A. et al. 2013, JGR 118, p. 436-450.

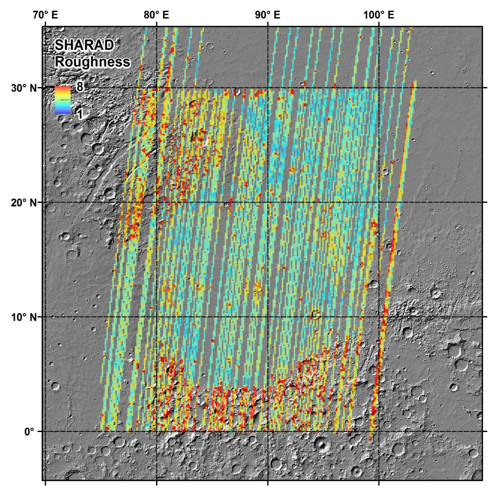

Figure 3: The SHARAD-derived roughness values [15] for Isidis basin. The floor of the basin appears relatively smooth indicating surface roughness may not be the sole cause of the attenuated signal [11].

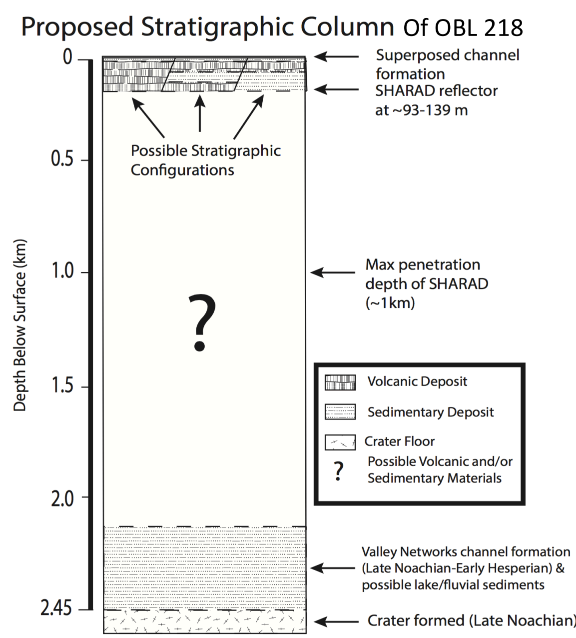

Figure 4: A proposed stratigraphic column for OBL 218 based on SHARAD radargrams and previous geologic mapping [7].