MAPPING AND CHARACTERIZATION OF THE BOUNDING LAYERS OF THE CO_2 DEPOSIT IN PLANUM AUSTRALE, MARS.

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Introduction: The south polar layered deposits (SPLD) of Mars contain buried CO_2 ice deposits that were formed during times of low obliquity [1-3]. Enhanced mapping efforts of this region using 2 and 3-D Shallow Radar (SHARAD, [4]) data have provided improved volumetric calculations of the CO_2 deposits, revealing that if the deposits sublimated during times of high planetary obliquity, the atmospheric pressure of the planet would double [1-2]. Furthermore, mapping efforts revealed that the buried CO_2 deposit consists of 3 distinct subunits of CO_2 ice contained within bounding layers (BL, Fig. 1) [2].

The bounding layers, believed to consist of H_2O ice [1], can explain the stability of the CO_2 deposits during times of high obliquity [2-3], when the ice should return to the atmosphere. Each BL expresses two reflectors, an upper and a lower that have been interpreted as the top and bottom surfaces of water-ice deposits [2].

Alternatively, each BL reflector may represent a thin, distinct water ice subunit sandwiching a thin CO_2 ice deposit [3]. In that case, the number of water-ice units would be double the current interpretation, and there would be three major CO_2 units and two minor CO_2 units within the BLs. Climate model analysis reveals that planetary conditions may have been supportive of this deposition scheme [3]. Previous mapping efforts have not distinguished between the upper and lower reflectors of each BL. Furthermore, the distinct upper and lower reflectors of the bounding layers have not yet been mapped using 3-D radar data.

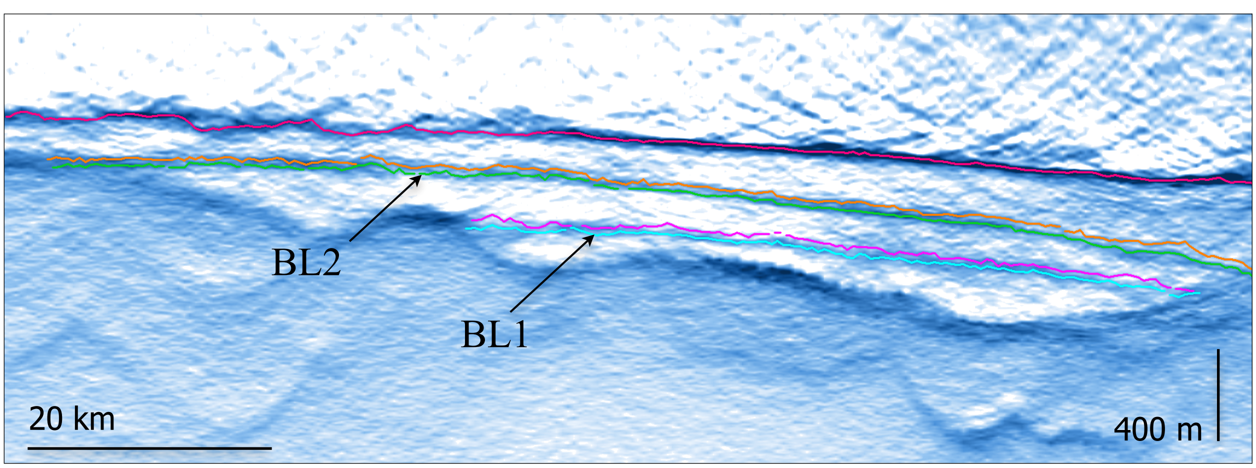
Here, we use a 3-D radar dataset generated from thousands of 2-D single-orbit observations [5-6] to map the upper and lower reflectors of BL1 and BL2 (see Fig. 1) in order to provide a better characterization of the size and composition of the BL, which will subsequently inform the depositional patterns and factors contributing to the stability of the buried CO_2 ice deposits.

Methods: We use 3D-generated radar data from the SHARAD instrument onboard the Mars Reconnaissance Orbiter [5-6]. Previous mapping of the polar regions using 3-D volumes provided improved volumetric estimates of the CO_2 deposit, reduction of off-nadir returns, and structural corrections that enhanced our understanding of subsurface structures in these regions [4]. We therefore utilize this 3-D dataset to map the distinct layers within BL1 and BL2 [2]. Radargrams were interpreted using SeisWare using established techniques [6]. BL thickness is reported as an average of thicknesses interpreted (and interpolated where interpretation was missing) and smoothed.

Results: A 3-D radargram depicting the mapped upper and lower reflectors of BL1 and BL2 is shown in Fig. 1. We find the upper and lower reflectors of BL2 in five distinct regions (Fig. 2a-b), covering a total area of 8245 km^2. The upper and lower reflectors of BL1, however, are found only in the eastern and westernmost portions of the CO_2 deposits and at high latitude (Fig. 2c-d) and comprise an area of 1312 km^2.

We see evidence of regions where the bounding layers converge and diverge in radargrams (Fig. 3a). The distinct layers of BL2 converge to a thickness that cannot be resolved by the instrument, and so the upper and lower reflectors are mapped as a single (upper) reflector in some cases (depicted by region encircled in Fig. 2b). The average thickness and standard deviation

Figure 1: 3-D radargram of the bounding layers capping the CO_2 deposits in the SPLD. Ground track is depicted by the yellow line in Figure 2a.



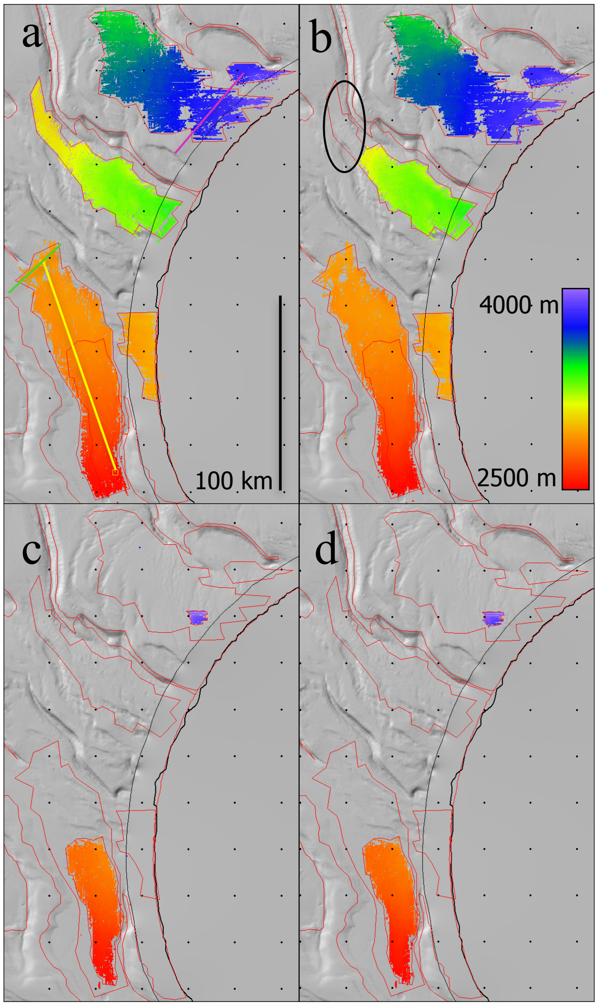


Figure 2: Mars Orbiter Laser Altimeter hillshade maps of the bounding layers of the CO_2 deposit where a, b are the upper and lower reflectors, respectively, of BL2 and c, d are the upper and lower reflectors, respectively, of BL1. Colourful legend indicates elevation.

of BL2 is 33 ± 12 m. The average thickness of BL1 is 30 ± 6.3 m. These are the first thickness measurements of the bounding layers obtained by mapping in 3D and the first to consider the entirety of the reflectors of each BL as distinct layers.

Discussion: Our results provide an improved calculation of the thicknesses of BL1 and BL2 in the SPLD. However, the BL thicknesses obtained in this analysis support neither the Bierson et al., 2016 model nor the Manning et. al, 2018 model because the thicknesses calculated can encompass both models. We therefore turn to a qualitative approach in which the stratigraphy of a lenticular CO_2 deposit in the SPLD is analyzed (Fig. 3b). In one location, BL2 diverges into two distinct BL, and the stratigraphy in the lens region cannot be explained by having a bounding layer comprised entirely of water ice. That would result in only two reflectors instead of the four we observe. As shown in Fig. 3b, this is not the case due to a change in the dielectric constant indicative of a CO_2 deposit. This would support the more recent (Manning et al., 2018) model, whereby the upper and lower reflectors of BL2 are distinct water ice units that encapsulate a thin CO_2 deposit. However, it is possible that the (Bierson et al., 2016) model may be supported by Fig. 3b if we consider that the lower pair of reflectors in the lens region were an extension of BL1, which has merged with BL2. However, this opens the question of why CO_2 ice was deposited in a lenticular manner and in such a small location far from the primary BL1.

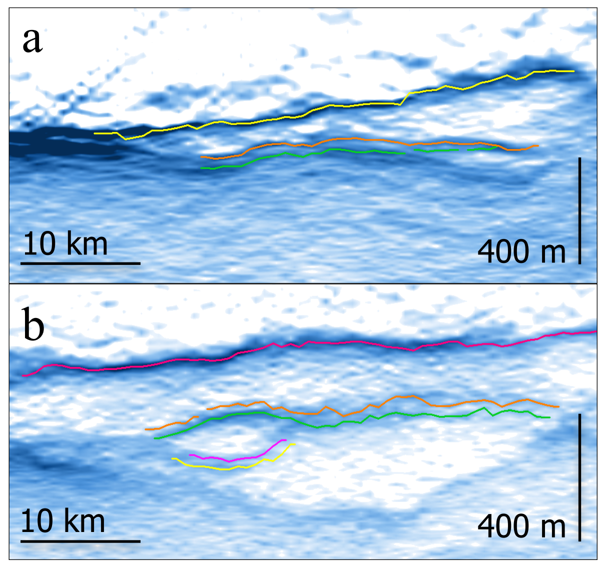


Figure 3: 3-D radargrams depicting a, a region in which the upper and lower reflectors of BL2 converge (ground track shown in green line in Figure 2a) and b, a lenticular CO_2 deposit bound by BL2 and BL1 (ground track shown in purple in line Figure 2a).

Overall, quantitative analysis of BL1 and BL2 thickness is not sufficient to support either model of the stratigraphy composition. Mapping the entirety of the distinct BL layers reveals a more complex stratigraphy than suggested by either models.

Acknowledgements: This work was funded by the Canada Research Chairs grant to IBS.

References: [1] Phillips et al. (2011) *Science, 332,* 838–841. [2] Bierson et al. (2016) *Geophys. Res. Lett.,* 10.1002/2016GL068457 [3] Manning et al. (2019), *Icarus, 317,* 509–517. [4] Seu et al. (2007) *JGR, 112,* E05S05 [5] Foss et al. (2017) *The Leading Edge, 36(1),* 43–57. [6] Putzig et al. (2018) *Icarus, 308,* 138–147.