Decoupling Lava Flow Composition and Emplacement Processes from Eolian Mantling Deposits Using Thermal Infrared Data

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INTRODUCTION:

Sediment/regolith history, mobility, and its mantling of the underlying bedrock are important topics for Mars science. Eolian processes significantly influence Mars and cover many bedrock surfaces with sand and dust [1]. These eolian deposits can be derived locally and therefore retain the chemical/spectral signatures of the underlying rocks [2], or more commonly they become globally-homogenized obscuring the surface below and hindering accurate identification from orbit [3]. Although not as pervasive on Earth, surface mantling can also arise from a variety of processes (e.g., eolian reworking, pyroclastic airfall).

In order to better understand the volcanic history of the SW Arsia Mons flow field and aid in geologic mapping, the compositional and thermophysical properties of these flows are being examined using thermal infrared (TIR) data from the Mars Odyssey Thermal Emission Imaging System (THEMIS) and the Mars Global Surveyor Thermal Emission Spectrometer (TES) [4,5]. Complementary work is focused on terrestrial analogs and advanced image processing techniques in order validate the approach and ultimately to decouple the spectral contribution of the mantling from that of the underlying lava flows for both terrestrial and planetary applications.

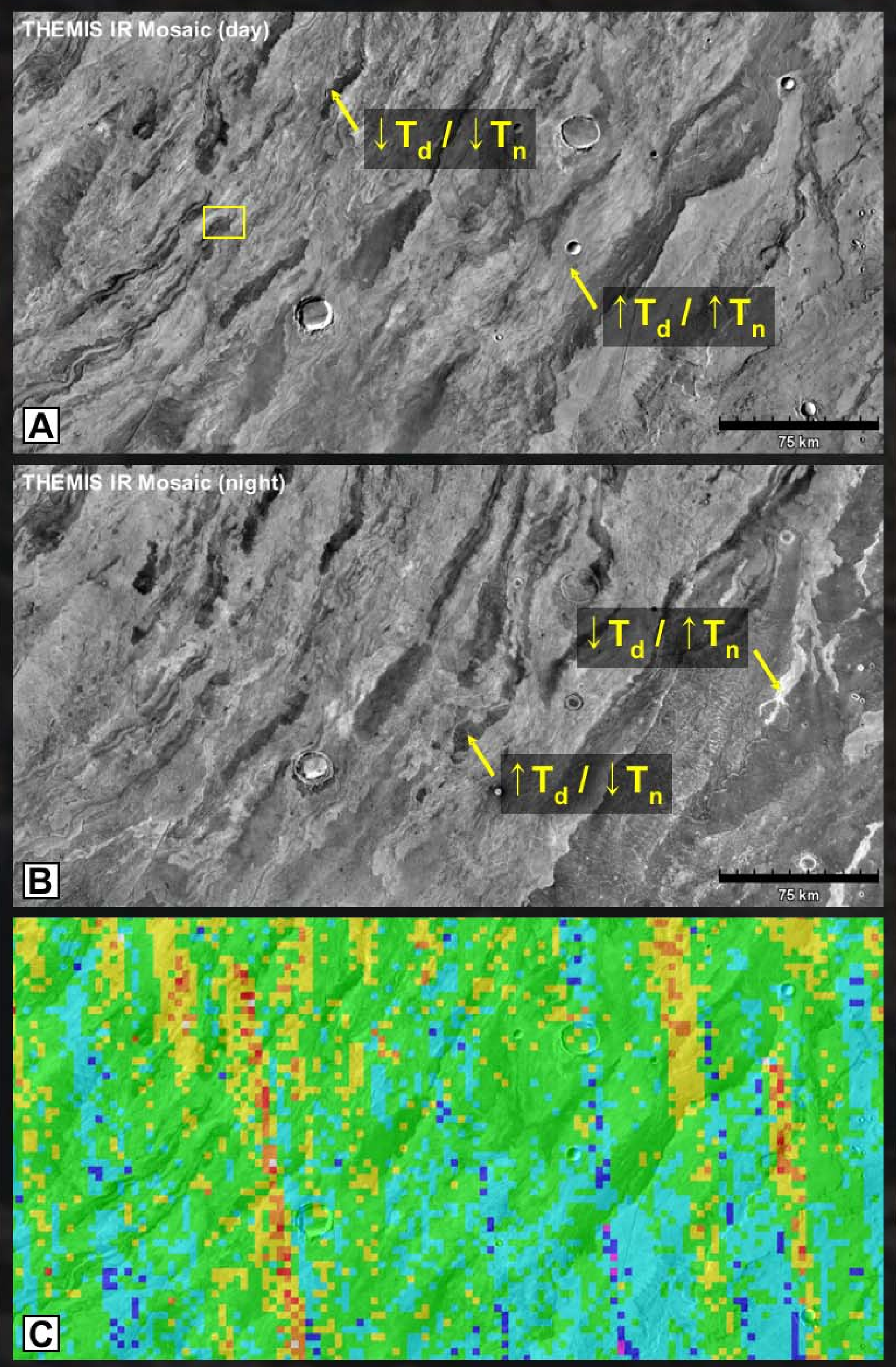

Figure 1: THEMIS infrared (IR) data mosaic of the southern Arsia Mons flow field showing distinct thermophysical variations. (A) Daytime IR mosaic. (B) Nighttime IR mosaic. Note that certain flows exhibit significant changes in thermal radiance between day and night, whereas others do not. (C) TES-derived dust cover index (DCI) of the region. The colors represent a variation of between 0.95-0.97 and the TES-derived albedo for the region varies between 0.24-0.26. Small yellow box in (A) shows the area covered in Figure 2A.

LOCATIONS:

Arsia Mons (9.5°S, 239.5°E) is the southernmost Tharsis shield volcano, rising more than 11 km above the surrounding plains and having a well-developed summit caldera [6,7]. Two large lava flow aprons extend from alcoves on the NE and SW flanks and postdate the main shield. The SW apron has an average slope of 0.6° with flows that exhibit a wide range of morphologies, surfaces, textures, and degrees of eolian mantling [7,8]. A series of lava flows on the SW apron (near 22.5°S, 238.0°E) have unusual thermophysical characteristics and new findings show that these flows are relative young (~100 My) [9]. This is also the same region of Mars with some of the largest meter-scale roughness on the planet [10].

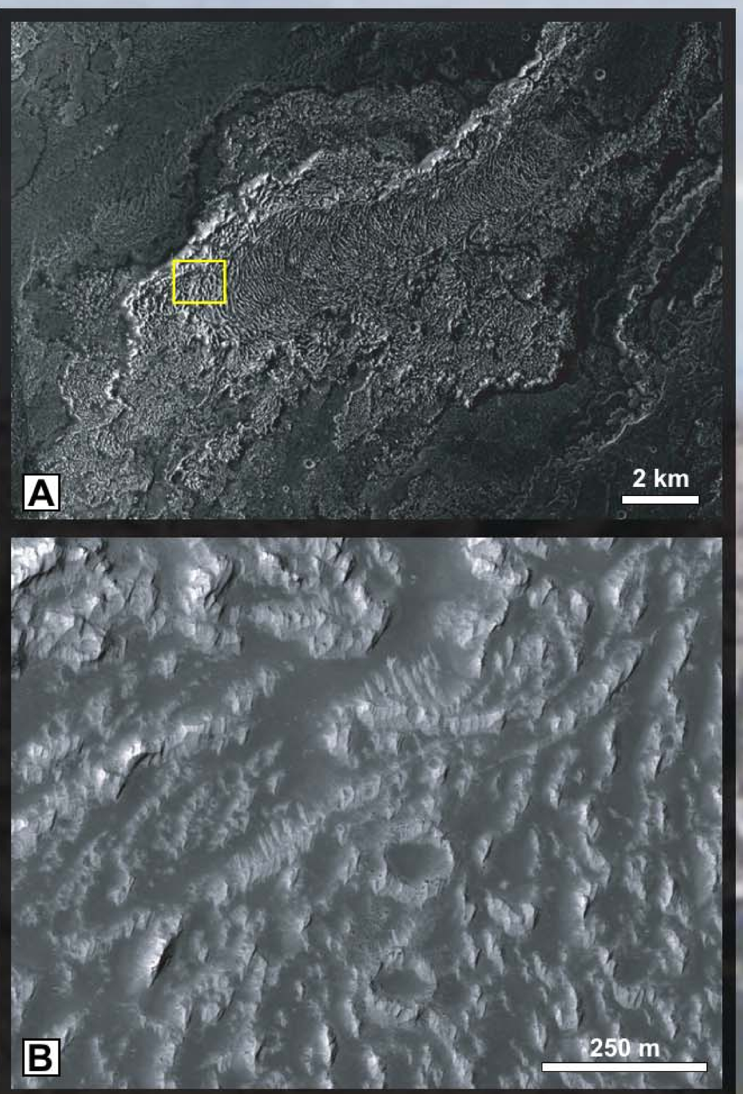

Figure 2: High spatial resolution data of the Arsia Mons flow field centered at 121.50°W, 22.13°S showing the complex flow relationships [e.g., 7] and different flow morphologies (i.e., bright/rugged and dark/smooth). (A) CTX data mosaic with yellow box indicating the area shown in (B). (B) HiRISE image (PSP_006614_1580) showing the lower albedo mantling of the higher albedo lava flow surface. This mantling material covers ~ 50% of the flow surface [6].

The recent silicic flow and domes of the Mono Craters/Domes (MCD) in east-central CA formed within the last 1,000 years. Some are mantled in places by fine-grained pyroclastic airfall deposits of similar composition due to younger explosive activity [11]. These surfaces provide an excellent process-analog for the Arsia flows. Fundamental to the formational process and geologic history is the underlying composition of the lava as well as the block size distribution, which has been shown to reflect the balance between lava emplacement (extrusion rate) and cooling-derived deformation [12]. It is also representative of the lava type/composition. Extracting these parameters is difficult in cases where the flow surfaces are mantled.

Figure 3: The Mono Craters/Domes (MCD) field located in central east CA. The arcuate chain generally trends from older to younger (S to N) mantled varying amounts of pyroclastic material. Also seen in the image: Mono Lake, recent fire scars and pumice plains to the SE of the domes.

RESEARCH FOCUS:

The general objective of our ongoing terrestrial research is to more accurately quantify blocky, mantled, and eroded lava surfaces using a combination of field measurements and remotely-acquired datasets. Most important is understanding how eolian overprinting of lava surfaces can be spectrally removed in order to more accurately map the underlying composition, morphology, and extent of the flows. This knowledge will then be adapted for improved interpretations of planetary flow surfaces.

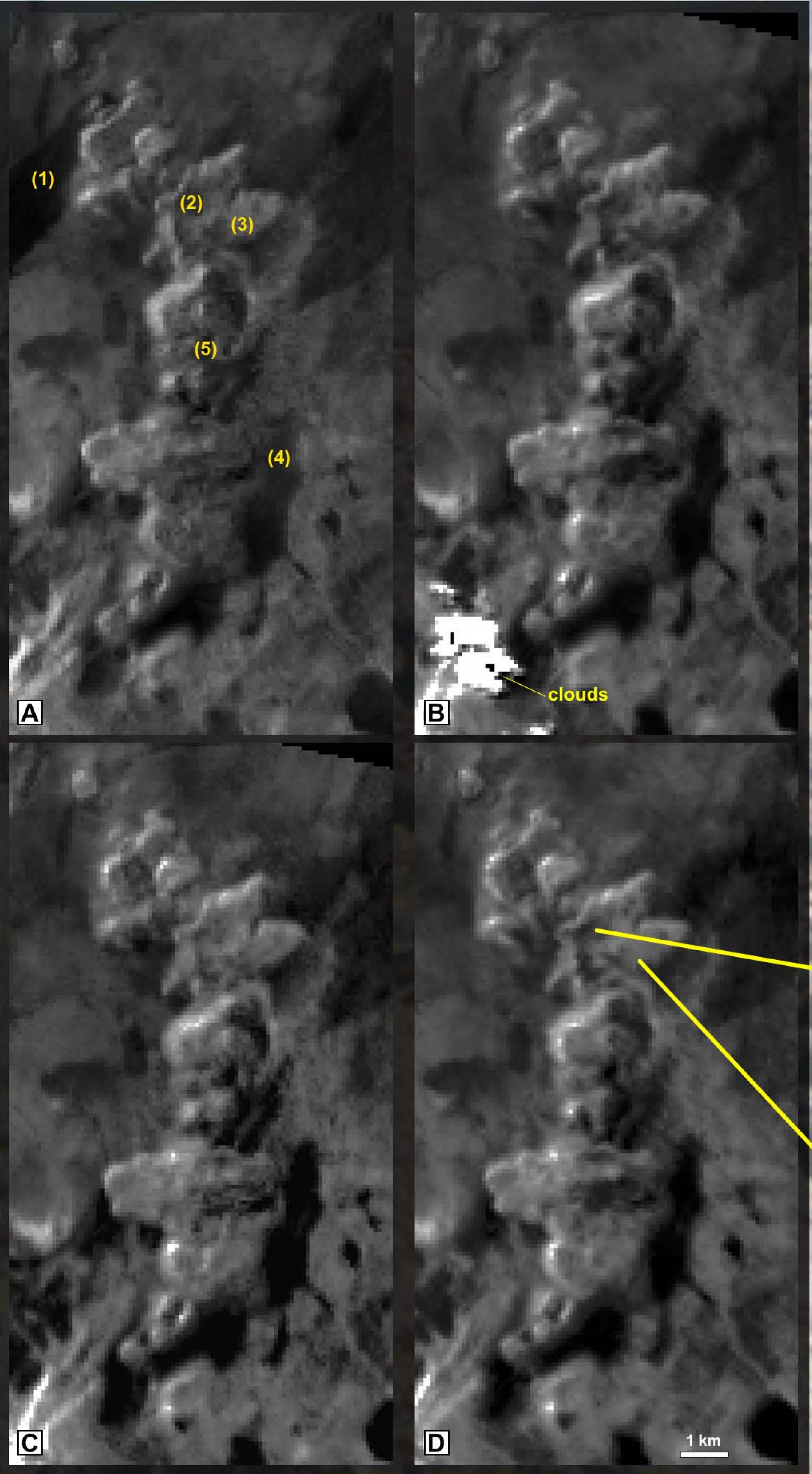

Figure 4: Apparent thermal inertia (ATI) time series derived from ASTER thermal infrared (TIR) day/night temperature and visible/short-wave infrared (VSWIR) albedo data using: ATI = (DT / 1- albedo). ATI varies little over time on the domes, but changes to the surrounding plains are apparent, including the appearance of a fire scar and an increase on the SE pumice plain. Numbers (1) to (5) denote areas plotted in Figure 5. (A) JUL 2011. (B) AUG 2009. (C) AUG 2008. (D) JUL 2009.

The ASTER instrument acquires data at 90 m/pixel resolution in 5 TIR bands and 15m/pixel resolution in 3 VSWIR bands, making it a good proxy for THEMIS IR and VIS data. Four summer day/night image pairs separated anywhere from 30 hours up to several days were selected from the ASTER archive. ATI was calculated and changes over time were analyzed (see Figure 4). Mantled areas of the larger flows were easily detected (Figures 5 and 6) as well as changes on the surrounding plains (e.g., fire scars and pumice plains). Of interest is whether this approach together with the spectral variation derived from the application of super-resolution techniques can be used to extract the mantling extent and thickness. Initial examination appears to support this approach; however, more analysis and field-validation are required before applying it to THEMIS data of the Arsia flow field.

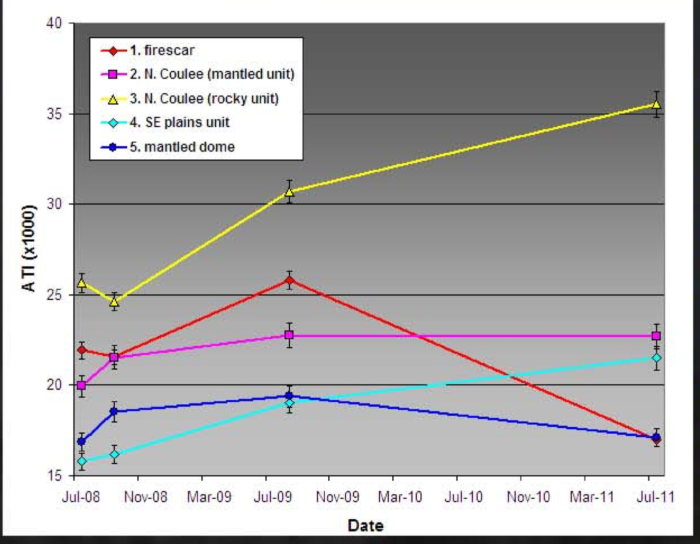

Figure 5: ATI over time for selected units (locations shown on Figure 4). Heavily mantled dome units show little change in thermal inertia. A large drop in ATI occurs with the appearance of a fire scar in 2010. Slight increases in ATI occurred over the SE pumice plain due perhaps to induration and the rocky unit of the north coulee due perhaps to removal of fines.

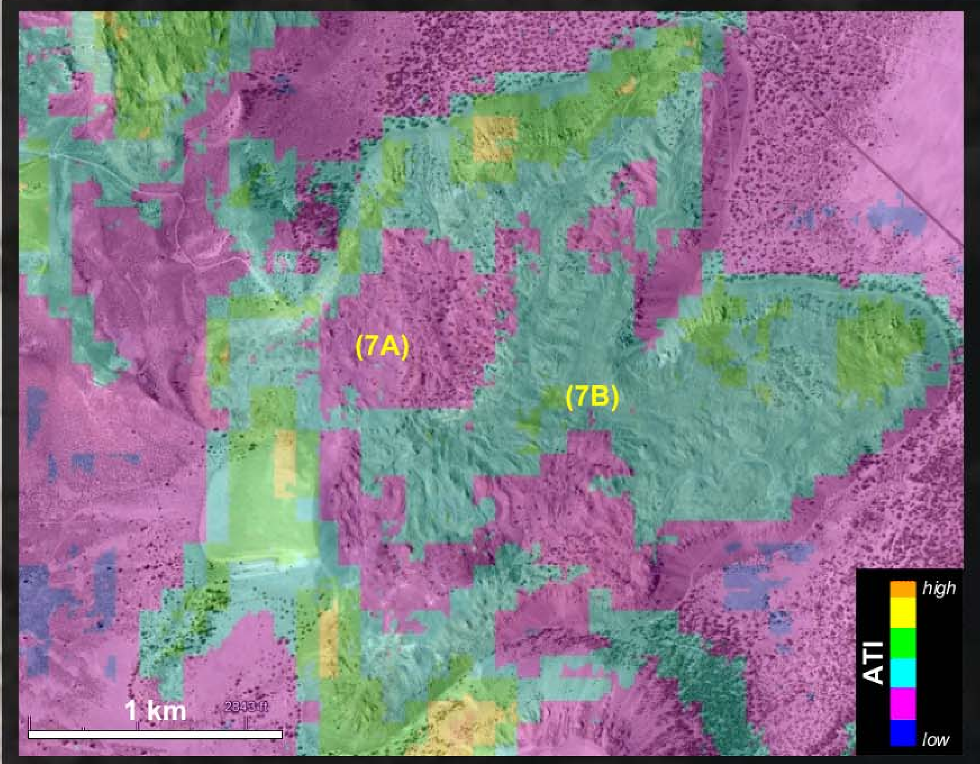

Figure 6: ASTER-derived apparent thermal inertia (ATI) image of the North Coulee flow in the MCD chain. The data were overlain on a Google Earth high resolution visible image. Areas of low to moderate ATI values (magenta) correspond to regions of the greatest pyroclastic mantling (see Figure 7A).

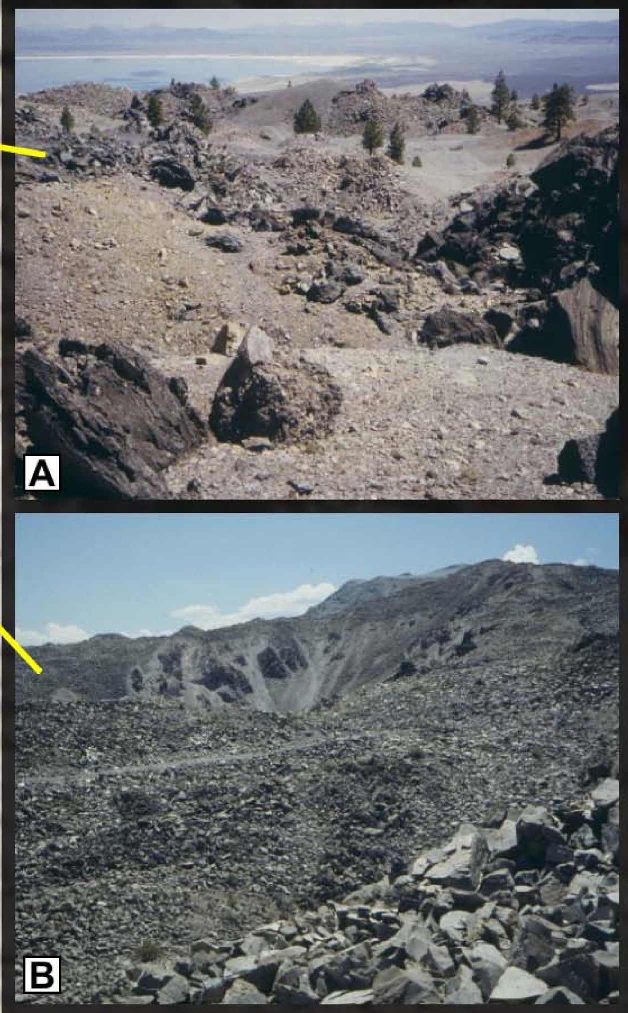

Figure 7. Field images of the North Coulee lava surfaces. The rhyolite flow is partially mantled with pyroclastic airfall from the eruptions of north dome. Mantling can vary from zero to meters thick with the thicker deposits occurring on the western portion of the dome and detectable with the ATI data (see Figures 4 and 6). (A) Heavily mantled western region. (B) Unmantled summit region.

REFERENCES:

[1] Malin, M.C. and K.S. Edgett (2001), *J. Geophys. Res., 106*, 23,429-23,570.
[2] Edgett, K.S. and N. Lancaster (1993), *J. Arid Environ., 25*, 271-297.
[3] Ruff, S.W. and P.R. Christensen (2002), *J. Geophys. Res., 107*, 5127.
[4] Ramsey, M.S. and D.A. Crown (2010), *Lunar Planet. Sci. Conf. XLI, abs. 1111.*
[5] Ramsey, M.S. and D.A. Crown (2011), *AGU Abst. P42C-06.*
[6] Crumpler, L.S. et al. (1996), *Geol. Soc. Spec. Publ., 110*, 307-348.
[7] Plescia, J.B. (2004), *J. Geophys. Res., 109*, E03003, doi:10.1029/ 2002JE002031.
[8] Crown, D.A. et al. (2009), *LPSC XL*, abs. 1488.
[9] Crown, D.A. et al. (2011), *AGU Abst. V31A-2514.*
[10] Bandfield, J.L. (2009), *Icarus, 202*, 414-428.
[11] Sieh, K. and M. Bursik (1986), *J. Geophys. Res., 91*, 12,539-12,571.
[12] Anderson, S.W. et al. (1998), *Geol. Soc. Amer. Bull., 110*, 1258-1267.