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Surface-compositional properties of the Malea Planum region of the Circum-Hellas Volcanic Province, Mars

David A. Williams [a,*], Ronald Greeley [a], Leon Manfredi [a], Robin L. Fergason [b], Jean-Phillipe Combe [c], François Poulet [d], Patrick Pinet [e], Christine Rosemberg [e], Harold Clenet [e], Thomas B. McCord [c], Jouko Raitala [f], Gerhard Neukum [g]
and the HRSC Co-Investigator Team

[a] School of Earth and Space Exploration, Arizona State University, Box 871404, Tempe AZ 85287-1404, USA
[b] Astrogeology Science Center, United States Geological Survey, 2255 N. Gemini Drive, Flagstaff AZ 86001, USA
[c] The Bear Fight Center, 22 Fiddler's Rd., Box 667, Winthrop WA 98862-667, USA
[d] Institut d'Astrophysique Spatiale, Bâtiment 121, Université Paris-Sud, 91405 Orsay Cedex, France
[e] Observatoire Midi-Pyrénées, Laboratoire Dynamique Terrestre et Planétaire, UMR 5562, CNRS, Université Paul-Sabatier, 14, Avenue Edouard Belin, 31 400 Toulouse, France
[f] Astronomy Division, Department of Physical Sciences, University of Oulu, Oulu, Finland
[g] Freie Universitaet Berlin, Department of Earth Sciences, Institute of Geosciences, Planetary Sciences and Remote Sensing, Malteserstr. 74-100, Building D, D-12249 Berlin, Germany

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ABSTRACT

We used Thermal Emission Spectrometer (TES), Thermal Emission Imaging System (THEMIS), High-Resolution Stereo Camera (HRSC), and Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA) data to assess the physical and compositional properties of the Malea Planum portion of the Circum-Hellas Volcanic Province (CHVP). Our analysis of surface materials shows that the thermal inertia decreases from north to south, and that there is greater dust cover on the flanks of the CHVP volcanoes than in their putative calderas. Local variations in thermal inertia in Malea Planum are likely due to variations in surface material caused by aeolian and periglacial/permafrost processes, whereas regional variations are likely due to seasonal deposition and sublimation of ice at higher latitudes. Spectral analysis of OMEGA data indicates the widespread presence of pyroxenes and/or olivine, particularly in the rims of craters that likely excavated volcanic materials. Dark materials occur throughout the CHVP, but are concentrated in topographic lows such as crater and caldera floors. Derivation of modal mineralogies from OMEGA data show a variation in composition of dark materials across Malea Planum: eastern dark deposits have higher olivine and low-calcium pyroxene contents, lower high-calcium pyroxene contents, and higher ratios of low-calcium to total pyroxene, relative to western dark deposits. Correlation with cratering-model age estimates suggests that the western deposits are associated with older features (3.8 Ga) than the eastern deposits (3.6 Ga), but these age differences are within uncertainties. Nevertheless, these results suggest a potential change in composition of volcanic materials in the Malea Planum portion of the CHVP with space, and possibly time.

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1. Introduction

The surface of Mars is dominated by volcanic materials. Low-albedo, dark deposits observed on the surface in the visible-to-thermal-infrared spectrum have long been recognized to be composed of basaltic minerals (e.g., McCord et al., 1982; Bandfield et al., 2000; McCord et al., 2007). Recently Greeley et al. (2007) and Williams et al. (2009) defined a third major volcanic province on Mars, the Circum-Hellas Volcanic Province (CHVP), composed of volcanoes and flow fields long recognized in *Mariner 9* and *Viking* data (McCauley et al., 1972; Carr, 1973; Carr et al., 1973; Potter, 1976; Carr et al., 1977; Peterson, 1977, 1978; Scott and Carr, 1978; Plescia and Saunders, 1979; Greeley and Spudis, 1981; Tanaka and Scott, 1987), and thought to have had a potential genetic relationship to the formation of the Hellas impact basin (3.99 Ga: Werner and Neukum, 2003; Werner, 2005). Williams et al. (2009) identified several dark deposits within CHVP volcanoes, and they performed initial analyses using multispectral data from the Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA: Bibring et al., 2004) to assess the modal mineralogy (i.e., volume % of component minerals) of one of these dark deposits. In this paper we use color images from the High-Resolution Stereo Camera (HRSC: Neukum et al., 2004) to map

* Corresponding author. Tel.: +1 480 965 7029; fax: +1 480 965 8102.
E-mail address: David.Williams@asu.edu (D.A. Williams).

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the distribution and abundance of dark deposits in the Malea Planum portion of the CHVP, and then use OMEGA data to gain further insight into the compositions of additional dark deposits in this region. Additionally, we use infrared (IR) data from the Thermal Emission Spectrometer (TES: Christensen et al., 1992) and Thermal Emission Imaging System (THEMIS) to assess the physical properties of surfaces in Malea Planum.

2. Background

The CHVP (area >4.86×10^6 km^2, Fig. 1; see Williams et al., 2010-this issue) is defined as the region containing the major volcanic edifices and surrounding wrinkle-ridged plains located on the margins of the Hellas basin. These include (on the basin's NE margin) Tyrrhena Patera, the surrounding Hesperia Planum, and Hadriaca Paterae (e.g., Greeley and Crown, 1990; Crown et al., 1992; Crown and Greeley, 1993; Wilson and Head, 1994; Gregg et al., 1998; Gregg and Farley, 2006; Crown and Greeley, 2007; Williams et al., 2007, 2008), as well as the volcanoes and ridged plains located in Malea Planum south of the Hellas basin (including Amphitrites, Peneus, Malea, and Pityusa Paterae: Greeley and Guest, 1987; Tanaka and Scott, 1987; Tanaka and Leonard, 1995; Head and Pratt, 2001; Tanaka et al., 2002; Plescia, 2003, 2004; Larson, 2007; Kolb and Tanaka, in review), the (very degraded) ridged plains in western Promethei Terra (Raitala et al., 2007; Ivanov et al., 2010), and the ridged plains in the eastern Hellas basin floor (Williams et al., 2010-this issue). The cratering-model formation ages of the CHVP range from 3.4 to 3.8 Ga (Williams et al., 2009, 2010-this issue), during which both flood volcanism and central vent volcanism occurred contemporaneously. The CHVP volcanoes have two morphologies: shield-like edifices (Tyrrhena, Hadriaca, Amphitrites Paterae) and caldera-like depressions (Peneus, Malea, Pityusa Paterae), the latter of which may have been Martian equivalents to terrestrial large calderas that produced ignimbrite deposits (Williams et al., 2009). The exposed surfaces of these volcanoes have been heavily modified by fluvial, aeolian, and/or periglacial/permafrost processes. Dark materials are exposed on the floors of craters and other locations, whose spectral signatures are consistent with terrestrial basaltic material (McCord et al., 1982, 2007). It is unclear at present whether this dark material differs in mineralogy across the CHVP, and whether this material is derived from local deposits exposed by deflation or aeolian winnowing, or has been transported from elsewhere on Mars.

3. Methodology

3.1. Thermophysical surface properties

We used TES and THEMIS thermal-IR data to assess the physical properties of the surfaces of the CHVP volcanoes located in Malea Planum via derived thermal inertia and particle-size estimates (Fig. 2).

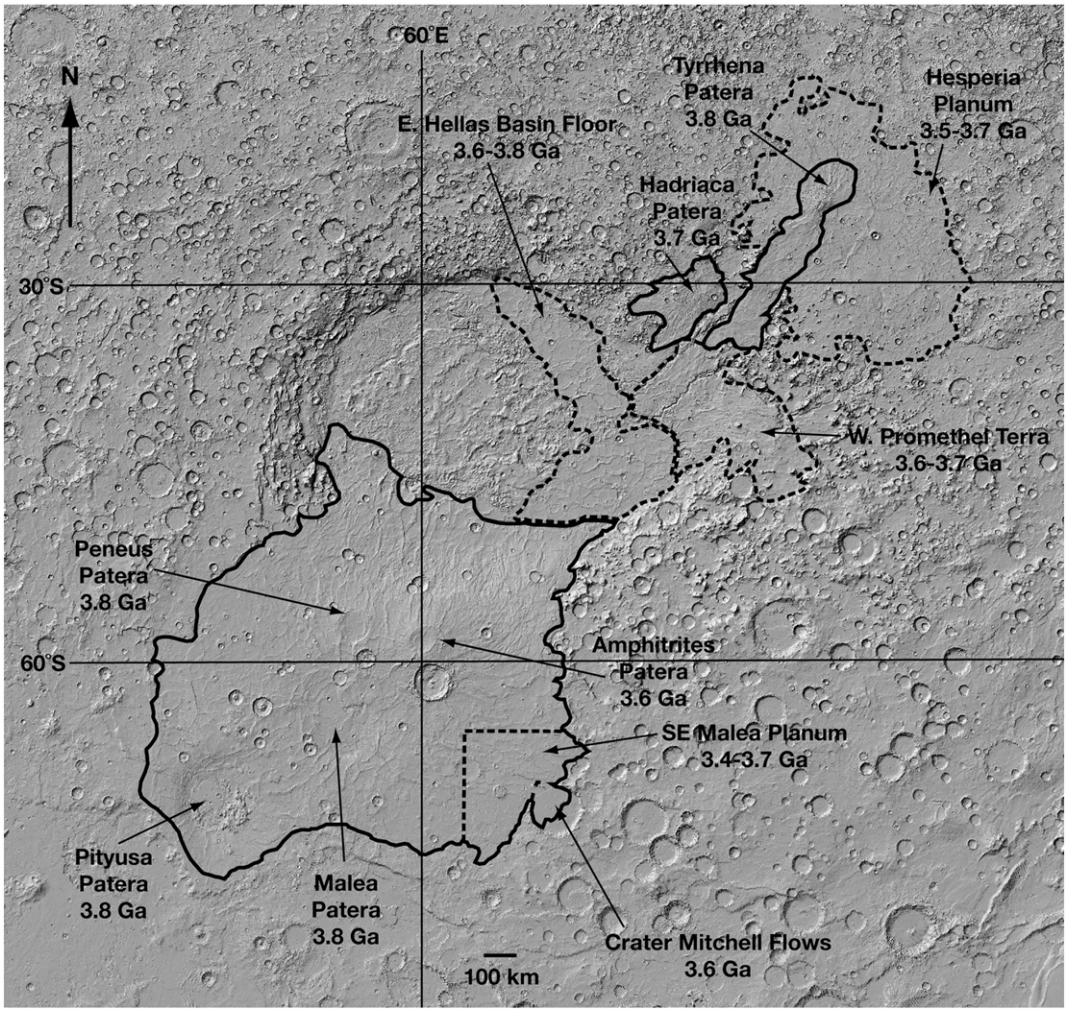

Fig. 1. MOLA shaded-relief map of the Circum-Hellas Volcanic Province (CHVP). The regions outlined in solid black mark the original bounds of the CHVP as defined in Williams et al. (2009), including cratering-model ages of prominent volcanoes. The areas outlined in dashed black are additional regions of wrinkle-ridged plains that were suggested to be part of the CHVP, which were assessed with crater counts (see Williams et al., 2010-this issue).

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