ARABIA TERRA LAYERED DEPOSIT STRATIGRAPHY AND MINERALOGY IS CONSISTENT WITH EARLY MARTIAN EXPLOSIVE VOLCANISM

P.L. Whelley1,2, A. Matiella Novak3, J. Richardson2, and J.A. Bleacher2, 1. University of Maryland, College Park, Department of Astronomy, 2. NASA Goddard Space Flight Center (patrick.l.whelley@nasa.gov), 3. Johns Hopkins University/Applied Physics Laboratory

Introduction: Volcanism is a fundamental process involved throughout Mars’ history and in nearly every aspect of Mars’ evolution [1]. Our understanding of explosive volcanism (i.e., violent expulsions of ash, pumice and rock fragments) on Mars continues to evolve as numerous, small (10s km diameter) and dispersed volcanic centers are recognized throughout the Tharsis region [2] and degraded, ancient volcanic centers are recognized in the southern highlands [3-6]. While volcanic deposits have been suggested to exist in Arabia Terra [e.g., 7], few vents are identified in the region. The fretted terrain is a landform type within Arabia Terra defined as smooth low-lying plains separated from complex plateaus by steep uniform cliffs [8] forming a polygonal network of slot canyons [Fig. 2]. It is an enigmatic geological unit composed of altered, fine-grained, layered, clay- and sulfate-bearing sediments suggested to be eroded ancient explosive volcanic deposits [e.g., 7, 9, 10]. Michalski and Bleacher [12] proposed that several large and irregularly shaped depressions in Arabia Terra [Fig. 2] are calderas that produced colossal explosive eruptions (i.e., supereruptions) that could have been the largest to ever occur on Mars. Consistent with past mapping [13], if these features are indeed explosive calderas, ash dispersion modeling [e.g., 14; 11] suggests extensive ash deposits, carried by ancient westerlies, should be common throughout the region. The km-deep canyon walls within the fretted terrain should therefore expose evidence for Noachian-Hesperian era volcanic deposits.

This work is cataloging the layered deposits exposed in these canyon walls to study their mineralogy using CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) data, morphology using HiRISE (High Resolution Imaging Science Experiment) and CTX (Context Camera) data, thermal inertia using THEMIS (Thermal Emissions imaging system) data and distribution using a GIS (geographic information system). We have so far identified many hundreds of meters of exposed strata that contain jarosite, smectite, and zeolites at distances of 500-3000 km from the paterae. We interpret these minerals to be altered products of volcanic ash. Through this work we are assessing if Arabia Terra could have been the site of early martian supereruptions. Understanding the geologic history of this area is also important for future exploration. The Mars 2020 Rover landing site (Jezero) is within the potential ash dispersion reach of the suggested calderas [Fig. 2], giving this work the potential to comment directly on the geology of the selected landing site.

Methods:

GIS Survey: Our team is performing a regional survey to identify the subset of image, spectral and topographic data that 1) are not dust covered, 2) contain canyon walls, and 3) overlap each other. Identified data will be used in detailed analyses of clay mineralogy, layer morphology, and distribution models [Fig. 1].

Clay Mineralogy: Our team is investigating the variety of minerals exposed in Arabia Terra Canyon walls. Altered volcanic ash produces a unique suite of minerals (e.g., jarosite, smectite, and zeolite) now observable in CRISM data. We are identifying their abundance.

Layer Morphology: Our team is investigating layer thickness, block abundance, competence and spatial distribution in image and topography data. Explosive eruptions produce deposits with unique morphologies (e.g., thinning from source, proximal resistant layers with blocks, distal friable layers, that conform to topography) now identifiable in cross-

Figure 1: Field Photo (A) and Map View (B) of deposits from supereruptions on Earth and layers we suggest are consistent with 500 m thick packages of altered volcanic ash on Mars (C and D) visualized using CRISM image: FRT-94F6 HYS draped over a CTX DEM. Our team will identify more locations in Arabia Terra with analogous packages of deposits and use their distribution to study the volcanic history of the region.

Clay Mineralogy: Our team is investigating the variety of minerals exposed in Arabia Terra Canyon walls. Altered volcanic ash produces a unique suite of minerals (e.g., jarosite, smectite, and zeolite) now observable in CRISM data. We are identifying their abundance.

Layer Morphology: Our team is investigating layer thickness, block abundance, competence and spatial distribution in image and topography data. Explosive eruptions produce deposits with unique morphologies (e.g., thinning from source, proximal resistant layers with blocks, distal friable layers, that conform to topography) now identifiable in cross-
section with HiRISE and CTX data. We are identifying the spatial trends and morphology of layered deposits.

**Spatial Distribution**: Alone, neither the mineralogical nor the morphological study can definitively distinguish volcanic layers from other types of rock. Our team is also assessing layer spatial variability. Using these three aspects together our team is evaluating the hypothesis of calderas in Arabia Terra.

In preliminary work we have observed layering in Arabia Terra with CRISM data. The diversity of spectral bands, which correspond to layering in the targeted features, suggests the presence of phyllosilicates, sulfates and hydrated silica species. These are good candidates for further analysis to determine the presence of minerals that are indicative of altered volcanic deposits.

**Conclusions**: This project is testing a provocative hypothesis that calderas in Arabia Terra produced widespread ash deposits, which could suggest that an early phase of explosive volcanism accounts for the disconnect between modeled magmatism and the observed volcanic record. In addition, this work has implications beyond martian volcanology. This work could be used to constrain future climate models as ash dispersion patterns could be used to constrain ancient atmospheric pressure. Furthermore, as volcanic eruptions produce gasses as well as ash, this work contributes to the discussions regarding the composition of Mars’ atmosphere. We will also illuminate weathering products and the distribution of clay minerals in Arabia Terra.

**References**:

**Acknowledgements**: This work is funded by NASA’s Mars Data Analysis Program Grant #: 80NSSC19K0044.

**Figure 2**: A Mars Orbiting Laser Altimeter (MOLA) color hillshade of Arabia Terra with suggested calderas [19] filled in with red. The black line shows the outline of the Arabia friable layered deposit, a suggested ash fall unit [after 18]. The canyons that dissect the northern boundary of this unit make up the fretted terrain. White arcs indicate the distance from the calderas. The selected landing sites for the Mars 2020 rover is indicated with a white star adjacent to the study area. We are investigating chemical and morphological evidence for volcanic deposits in cliff walls at different distances from the potential calderas. The white circles indicate locations of completed mineralogical analysis of possible altered volcanic ash deposits (e.g. jarosites, smectites and hydrated silica).