GEOLOGIC MAPPING IN THE SOUTHERN UTOPIA BASIN: 2019 STATUS REPORT. C. H. Okubo, US Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001, cokubo@usgs.gov.

Introduction: Geologic mapping is being undertaken to investigate the geologic history of an area within the southern Utopia basin. This work will produce a 1:150,000 scale map published as a USGS Scientific Investigations Map. This presentation will discuss the investigation's background, motivation and current results.

Background: Numerous studies have presented interpretations of widespread subsurface sediment mobilization and mud volcanism on Mars based on studies of landforms in areas such as the northern lowlands [e.g., 1, 2], impact craters [e.g., 3], and Valles Marineris [4]. These findings paint a fascinating picture of a Late Hesperian to Early Amazonian Mars characterized by widespread "sedimentary volcanism" (i.e., subsurface sediment mobilization and mud volcanism), with concomitant circulation of water and other fluids between the subsurface, surface and atmosphere, and associated habitable environments–a "muddy Mars".

Interpretations of sedimentary volcanism on Mars is contentious however, and alternate interpretations of these landforms as products of igneous volcanism [e.g., 5, 6] and periglacial processes [7] have also been proposed.

In 2016, Okubo et al. [8] analyzed MRO HiRISE images of a small area containing pitted cones and rifts in southwestern Utopia Planitia (Figure 1). They showed that stratigraphic, cross-cutting and superposition relationships indicated that the pitted cones and rifts formed contemporaneously through sedimentary volcanism, rather than by the alternative mechanisms of igneous volcanism or periglacial processes.

Motivation: Motivated by the results of Okubo et al. [8], the overarching goal of the present work is to investigate and document the stratigraphic, cross-cutting and superposition relationships of landforms in a wide area around the Okubo et al. [8] study area in southwestern Utopia Planitia (Figure 1). The present work aims to gather novel mapping-based observations to provide either refutation of or support for the hypothesis that sedimentary volcanism was widespread in the region and therefore many of the associated landforms are potential water-related, geologic and astrobiologic resources.

The significance of sedimentary volcanism on Mars is best conveyed by considering studies of their terrestrial counterparts. In terrestrial sedimentary basins, the mobilization of subsurface sediments is recognized as a common and significant process that acts to enhance, impede or otherwise alter local patterns of fluid migration and storage within the subsurface. These mobilized sediments often have a higher porosity and permeability than the host rock and therefore increases the volume of subsurface fluid reservoirs, improves hydraulic communication between these reservoirs, and facilitates the release of subsurface fluids into the aboveground environment [10], including gasses of biogenic origin [e.g., 11].

Such sediments are mobilized as slurries within the subsurface. The solid phase predominantly comprises sand, silt and clay-sized sediment, with minor amounts of pebble and cobble-sized clasts. The fluid phase typically consists of water, hydrocarbons, carbon dioxide and hydrogen sulfide. A variety of processes have been identified as triggers for the mobilization of subsurface sediments including, seismicity, tectonic compression,

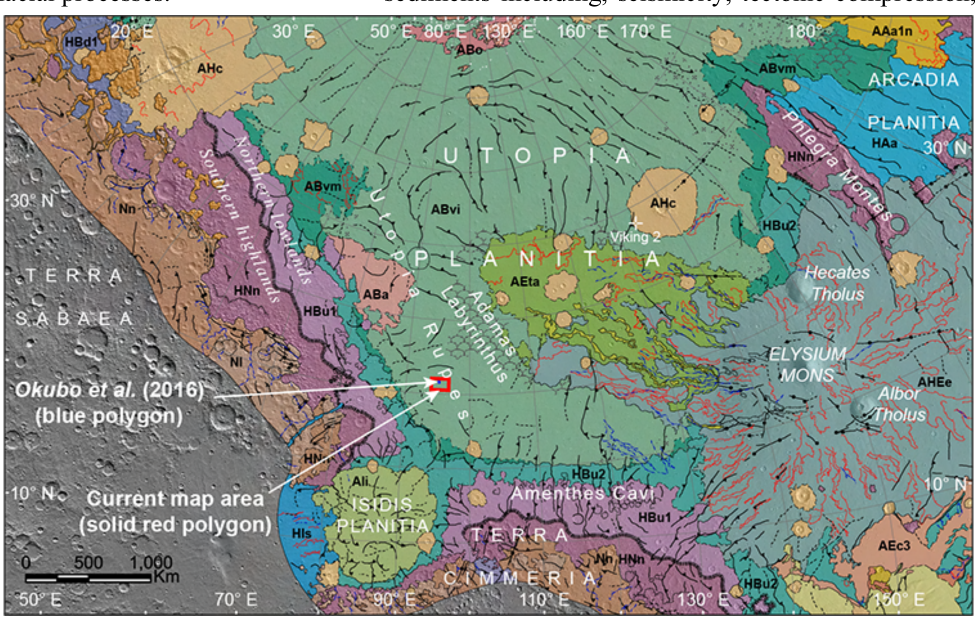

Figure 1. Location of the map area in southwestern Utopia Planitia. Mapped geology in the northern plains region is taken from [9], wherein ABvm (dark green) and ABvi (light green) are the Vastitas Borealis marginal and Vastitas Borealis interior units respectively. Basemap is MOLA shaded relief.

gravity-driven compaction, hydrocarbon generation, dehydration of clay minerals, hydrothermal activity and sediment diapirism.

In the subsurface, these mobilized sediments form deposits often referred to as injectites [e.g., 11]. The slurry can also rise to and discharge on the surface and sometimes recede back to depth, forming a variety of positive and negative relief landforms such as mud volcanoes and mud calderas [e.g., 11].

The patterns of fluid flow established by injectite and mud volcano systems can be areally extensive and persist for millions of years [e.g., 11] and therefore can have a substantive impact on hydrologic, geologic and biologic processes on the surface and in the subsurface environments. Due to their sustained flux of fluids, subaerial mud volcanoes on Earth are oases for bacterial and archaeal communities [e.g., 12, 13]. Therefore, mud volcano systems are important sites for investigating the geologic processes that could have supported past habitable environments on Mars and for seeking evidence of past life in the form of fossils and other preserved biomarkers.

Methods: Mapping will begin by tracing contacts between landforms in the map area. Anticipated landform types that will be mapped are pitted cones, low-relief shields, wide rifts, rift-filling lobate deposits, low-standing mesas, fracture-bounded mesas, impact craters, and impact ejecta. Geologic units will be defined by the contacts between landforms. Areas that are not attributable as a specific landform, i.e., terrain surrounding the landforms, will be classified as a regional plains unit.

MOLA and THEMIS base maps available through the PDS will aid in the preliminary recognition of landforms, and the precise boundaries of those landforms will be identified and mapped using CTX. Rather than creating a single CTX mosaic, individual CTX images will be controlled with SPICE, map projected, and displayed in a virtual mosaic within the GIS project. Previous experience has shown that this technique produces a mapping base that is adequately georeferenced for the proposed map scale, while eliminating the cost of producing a controlled image mosaic.

Where available, non-stereo and stereo HiRISE observations and stereo CTX observations will be used to supplement interpretations of cross-cutting and superposition relationships and landform boundaries made using the (non-stereo) CTX mapping base.

Interpretations of the nature and origin of each map unit will be developed based on previous investigations of the regional geologic setting of the map area (as reported by others in smaller scale maps, topical papers, etc.) and observations made in the present study of landform morphology, cross-cutting and superposition relationships, all the while revising previous interpretations where my new observations warrant. Through the course of this analysis, similar map units will be merged to make the map easier to read and help convey the salient spatial and temporal relationships between units.

Discussion: A fundamental aspect of this work is to assess the hypothesis that sedimentary volcanism was responsible for creating many of the landforms of southwestern Utopia Planitia. A primary test of this hypothesis builds upon the work of Okubo et al. [8] and entails evaluating for the presence of discontinuities (such as a lobate margin) between the rift-filling material and surrounding lowland plains. Such discontinuities could represent a stratigraphic boundary, admitting the possibility that the rift-filling material has a different origin than surrounding plains (e.g., the rift-filling material could be lava flows). Conversely, if discontinuities are not observed between rift-filling material and surrounding plains, this would support the interpretation that the rift-filling material consists of the same material as the surrounding plains, i.e., the sediments of the Vastitas Borealis Formation (VBF). A sedimentary origin for the rift-filling material can then be linked to the origin of adjacent landforms in the following way. If the rift-filling material comprises the sediments of the VBF, and cross-cutting and superposition relationships indicate that the pitted cones formed contemporaneous with emplacement of the rift-filling material, then the simplest and most logical conclusion is that the pitted cones also comprise the sediments of the VBF. Thus, the pitted cones would be mud volcanoes driven by subsurface sediment mobilization within the VBF. In this way, analyses of discontinuities, cross-cutting and superposition relationships will be used to evaluate the possibility that those landforms are the result of sedimentary volcanism.

References: [1] Brož P. et al. (2019) *JGR, in press*. [2] Komatsu G. et al. (2016) *Icarus, 268*, 56-75. [3] Hemmi R. and Miyamoto H. (2017) *Earth Planet. Sci. 4*, 26. [4] Okubo C. H. (2016) *Icarus, 269*, 23–37. [5] Brož P. et al. (2015) *JGR, 120*, 1512–1527. [6] Brož P. and Hauber E. (2013) *JGR, 118*, 1656–1675. [7] de Pablo M. and Komatsu G. (2009) *Icarus, 199*, 49–74. [8] Okubo C. H. et al. (2016) *LPS XLVII* Abstract #1334. [9] Tanaka K. L. et al. (2005) *USGS SIM* 2888. [10] Milkov A. V. (2003) *GRL, 30*, 1037. [11] Huuse M. et al. (2010) *Basin Res., 22*, 342–360. [12] Lazar C. S. et al. (2011) *Env. Microbiology, 13*, 2078–2091. [13] Pachiadaki M. et al. (2011) *Microbial Ecology, 62*, 655–668.