A HUMAN EXPLORATION ZONE IN THE PROTONILUS MENSAE REGION OF MARS.

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Introduction: The exploration zone concept for the human exploration of Mars provides the opportunity to consider many new scientifically compelling areas for future human missions. These exploration zones (EZ) offer a wide variety of scientific value from astrobiology to geochronology and direct new attention at the potential for resources, including access to useful materials and H_2O in the form of ice or mineralogically bound H_2O.

Astrobiology investigations may answer some of humanity's deepest scientific and philosophical questions. Currently, one of NASA's highest priorities is understanding if life ever arose, or even still exists, on Mars. Identifying areas with geomorphologic and/or chemical potential for preservation of biosignatures is central to the scientific goals for the EZ concept. A qualifying EZ will also provide outcrops that lead to understanding Mars' past and present. Observations can lead to inferences about the regional climate, and past environments for the planet as a whole.

Establishing a semi-permanent base for reoccurring missions to Mars requires *in situ* resource utilization (ISRU). Possibly the most important commodity for a Mars missions will be H_2O. Too heavy to transport from Earth, most water used by the astronauts for feedstock and civil engineering purposes must be locally derived. Silicon and metals (Fe, Al, Ti, Mg, etc.) will need also be mined on site.

Landing Site (Figure 1): The proposed EZ (48.062E, 42.187N) is in the Protonilus Mensae region of Mars, located just to the east of Moreux Crater and situated on the planetary dichotomy boundary.

Figure 1a. Regional context for the proposed EZ. Figure 1b outlined in Red with EZ outlined in white.

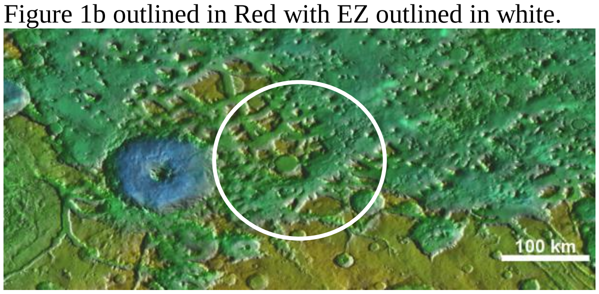

Figure 1b. EZ outlined in white.

Geologic units [1]. The oldest unit in the EZ is the Middle Noachian highland unit (mNh - brown). This unit is characterized by rolling topography and high relief outcrops of undifferentiated impact and volcanic material. The next oldest unit is the Hesperian and Noachian transition unit (HNt - tan). The unit comprises knobs and mesas of Noachian age and intervening aprons of Hesperian age. The Early Hesperian transition unit is (eHt - light brown) is at the very northeast edge of the EZ. It comprises small, degraded knobs and mesas separated by extensive plains. The Amazonian and Hesperian impact unit (AHi - yellow) is also represented within the EZ. The youngest unit is an Amazonian and Noachian apron unit (ANa - dark yellow); the unit comprises mesa forming primitive Noachian crustal remnants (fretted terrain), most likely mNh, draped by ice-rich Amazonian materials.

Figure 2. Geologic context in the EZ region. EZ outlined in white.

Other features. Moreux Crater (~138 km) is the largest crater in the vicinity of the EZ. Observations have shown intense glacial modification in the past, evidence for large amounts of H_2O ice [2]. An unnamed crater (~33 km) near the center of the EZ appears to have been host to glacial processes and a crater lake as there is an outflow channel cutting through the eastern rim. Another unnamed crater (~42 km) in the southeast quadrant of the EZ will also be available for investigating.

There are four large, unnamed outflow channels within the EZ. Two of the channels originate from the mNh unit while the other two are breaches in the rims of Moreux crater and the unnamed crater near the EZ center. All four channels are accessible for exploration.

This EZ is located in an area of remnant magnetism as seen in MAG/ER data. Investigations of magnetic fields within samples may shed light on the issue of Mars' past magnetic field history and interior. The nearest patches of positive magnetism would require unmanned, base-controlled rovers for sampling return.

Mission Requirements: The proposed EZ lies at ~42°N, within the ±50° latitudinal constraints set for the mission. The maximum altitude in the EZ is also well below the +2 km limit. Low thermal inertia and high albedo in the EZ signifies a relative lack of thick, fine grained dust deposits.

Landing site (LS). A moderately large crater (~25 km^2), dubbed LS crater, to the east of the EZ center has been chosen as a reoccurring LS. The area appears to be adequate for EDL constraints, however no HIRISE observations are available within the LS.

Habitation zone (HZ). At the center of the EZ lies the HZ, where the base of operations will be established. The HZ is located just outside LS crater in the outflow channel that resulted from the breach of the crater rim. A pair of HIRISE observations is available in the HZ.

Regions of Interest: The initial stages of site selection for human missions rely on the identification of regions of interest (ROI). An ROI must be within 100 km of the HZ; however, unmanned, base-driven rovers may be able to traverse farther and retrieve samples. ROIs qualify an EZ on the basis of science and/or resource value. There are many potential ROIs in this EZ (**Figure 3**).

Science ROIs. This is a compelling site for astrobiology studies. The ANa unit (ROI 1), the multiple valley networks (ROI 2), and Moreux Crater (ROI 3) will be investigated for past and present signs of life. ANa may be a current refugium for life, as the thick ice deposits may create pressures conducive for liquid H_2O, and possibly life. The valley networks are evidence for large amounts of past water flow and current H_2O ice. Whether they were long lived enough to preserve, or even harbor, life is still to be determined. Moreux Crater offers a look at past atmospheric gasses trapped within its impact glass; impact glass is also a potential medium for biopreservation. Large impacts like Moreux Crater can create long-lived hydrothermal systems capable of supporting life; hydrothermal systems have yet to be confirmed in or near the EZ.

This site is also intriguing geologically. Units in the area range in age from Noachian to Amazonian, providing a large variety of rocks and environments to study. Noachian age highlands material (RIO 4), Hesperian and Noachian transition units (ROI 5), and Hesperian transition units (ROI 6) will provide a glimpse into an environmentally dynamic period on Mars. The outflow channel networks (ROI 2) are of interest for the processes that accompany large amounts of water flow. The networks incise the units through which they flow, exposing thick sequences of outcrops and depositing altered materials.

Resource ROIs. The fretted terrain of the ANa unit (ROI 1) contains large supplies of H_2O ice [3]. The lineated valley fill features in the area (ROI 2) are a geomorphologic indication for large supplies of H_2O ice. The older Noachian and Hesperian aged units (ROI 4, ROI 5, ROI 6) are high in Fe and other metals, which will be useful for civil engineering purposes.

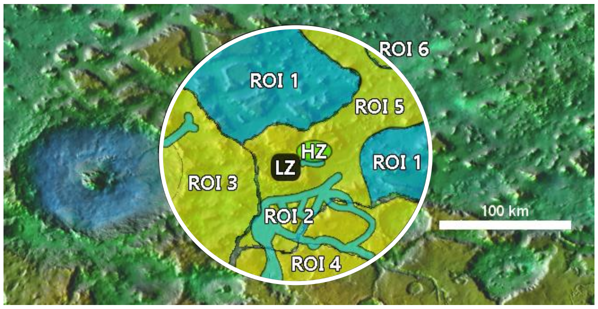

Figure 3. Science ROIs: yellow. ISRU ROIs: blue.

HIRISE, CRISM, and Future Datasets: There are abundant HIRISE and CRISM observations in all the units of the EZ (**Figure 4**). More complete coverage will be needed in LS crater as well as in the HZ. Current and future orbiting missions should target this area to enable future lander, rover, and human missions.

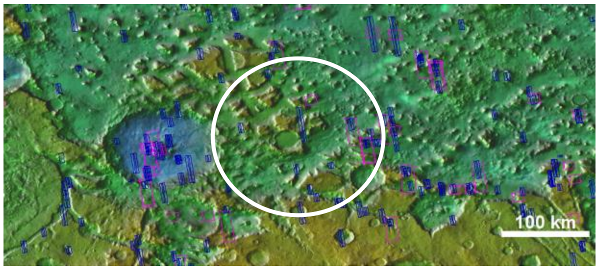

Figure 4. HIRISE (blue) and CRISM (magenta) coverage in the EZ region.

Conclusions: The proposed EZ in the Protonilus Mensae region offers a new, scientifically exciting area with abundant resources for future human missions to Mars.

References: [1] Tanaka K. L. *et al*. (2014) USGS, Scientific Investigations Map 3292. [2] Merchant D. R. *et al.* (2006) *LPSC XXXVII*. [3] Dickson J. L. *et al.* (2008) *Geology* 36(5):411.