GEOMORPHIC AND RESOURCE ANALYSIS OF THE VIPER LANDING SITE OF THE ARTEMIS PROGRAM.

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Introduction: A robotic component of NASA's Artemis Plan [1] is the Volatiles Investigating Polar Exploration Rover (VIPER). The VIPER mission seeks to analyze polar regolith and potential volatiles in the lunar south polar region [2]. VIPER will land at Artemis Site 102, near Nobile crater, and notionally traverse up to 20 km over at least 90 days on a massif informally known as Mons Leibnitz β [2,3]. Leibnitz β is the highest elevation summit of the south polar region, with illumination averaging greater than 50% and has line-of-sight of Earth. The region is heavily cratered with topographic lows that often host permanently shadowed regions (PSRs). The PSRs are potential reservoirs of water- and dry-ice (e.g., [4,5]) and are, thus, volatile targets for VIPER and *in situ* resource utilization (ISRU).

Geologic background. The Leibnitz β massif was uplifted by the South Pole-Aitken (SPA) basin impact event (4.25 to 4.35 Ga [6-8]), exposing a vertical cross-section of south polar crust in the flanks of the massif. The massif may have been covered with SPA ejecta that excavated material from the upper mantle and lower crust of the lunar farside [9,10]. Ejecta from younger nearby craters, such as Nobile (3.8 Ga [11]), may have also blanketed the massif. Surface samples at the VIPER landing site (site 102) are speculated to include fragments of the underlying massif and, thus, signatures of a potential magma ocean, in addition to ejecta that can be used to enhance lunar crater chronologies.

Data Processing and Methods: This study investigates geologic and ISRU attributes within a 20 km radial exploration zone of the VIPER landing site, along with traversability of the region. Hillshade, slope, and NAC imagery data were used to assess rock exposures and produce a geomorphic map with 5 m horizontal resolution. Illumination, PSR, temperature, and hydrogen abundance datasets were implemented for ISRU analysis, producing a map of potential seasonal water- and dry-ice thermal stability. Analyses and maps are processed using the ArcGIS Pro 2.6.0. software.

Digital elevation models. DEMs [12] are calibrated in a 100-step model to correct for geolocation errors horizontally (10 to 20 cm) and vertically (2 to 4 cm), producing 5 m resolution slope and hillshade maps.

Narrow angle camera imagery. A 0.5 to 1.0 m/pixel NAC mosaic of the VIPER landing site was assembled using Lunar Rocnnaissance Orbiter Camera (LROC) data from the Planetary Data System (PDS). The Experimental Data Record (EDR) products of NAC images were processed using the Integrated Software for Images and Spectrometers 3 (ISIS3) software package. Processed ISIS level 2 cube images were merged using GDAL python to create a seamless mosaic over the study site.

ISRU a*nalysis*. PSRs and average illumination are mapped at 120 m/pixel resolution, derived from Lunar Orbiter Laser Altimeter (LOLA) data [13]. Hydrogen abundance, derived from the Lunar Prospector Neutron Spectrometer (LPNS) from PDS, was mapped at a spatial resolution of 0.5° by 0.5°/pixel bin size [14]. Hydrogen abundance incorporated the orbital identification of surficial water-ice derived from Moon Mineralogy Mapper (M^3) data (280 m/pixel) [15]. Maximum seasonal (summer and winter) bolometric temperatures were derived from Diviner data (240 m/pixel) [16]. Potential areas of water- and dry-ice are estimated by modeling maximum temperatures of ice stability in a vacuum below 110 K and 55 K, respectively [17].

Results: Our results (Fig. 1) show the VIPER landing site atop a massif is traversable on slopes <15° and provides access to ISRU-relevant material in a terrain shaped by an interesting geologic history. We examine the terrain within 2, 10, and 20 km radial exploration zones suitable for different human exploration scenarios, which also encompass the maximum exploration distance anticipated for VIPER.

Geomorphic analysis. Elevations change dramatically between the summit of the massif and the floors of adjacent Nobile and Stose craters. The 2, 10, and 20 km radial exploration zones have topography that varies by 0.23, 2.07, and 3.47 km, respectively. The mapping units are heavily cratered ridges and heavily cratered floor regions (Fig. 1A) with highly traversable surrounding areas (slopes <15° [18]). Over 12,000 craters were mapped within the region, with diameters ranging from 0.01 to 4.1 km. A major trough formed by a chain of secondary craters (Fig. 1A) near the VIPER site contains ample boulders (1.5 to 18 m diameter) ideal for sampling the lunar crust, along with rock exposures up to 40 m in diameter. The cratered terrain likely reworked crustal components in the underlying massif, ejecta from Nobile, which cross-cuts the massif, and ejecta from other nearby large craters

ISRU analysis. Two, 10, and 20 km radial exploration zones around the VIPER landing site contain potentially stable regions for water-ice (Fig. 1B). Three large PSRs east and west of the VIPER site are accessible (with slopes less than for 15°) for ISRU. At the scale of our analysis (240 m resolution), no PSRs are thermally stable for water-ice throughout the winter and summer months within 2 km of the VIPER landing site. However, up to 3.39 km^2 (1.08%) and 3.93 km^2 (0.31%) of the area within the 10 and 20 km zones, respectively, may remain thermally stable for water-ice throughout the lunar year.

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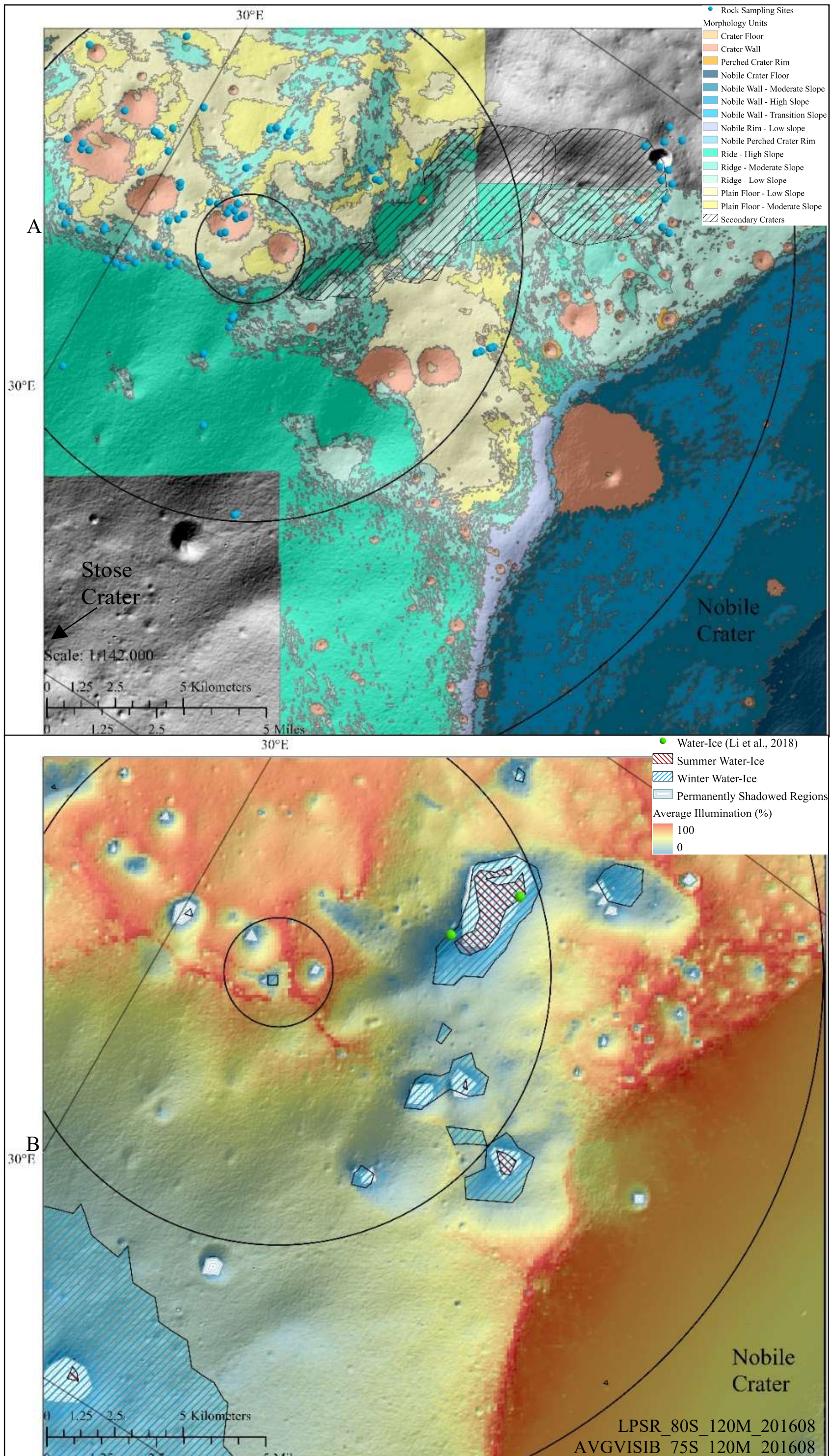

Figure 1. : Geomorphic and ISRU analytical maps of Artemis Site 102, VIPER landing are in lunar polar stereographic projection. Radial exploration zones of 2 km, 10 km, and 20 km are exhibited by the black circles. (A) Geomorphic map of western Nobile crater, including locations of rock or boulder exposures for potential sampling and the prominent secondary crater train. (B) Volatile resource map of the VIPER landing site, showcasing the illumination, PSRs, regions with temperatures for water-ice (Maximum 110 K) during lunar summer and winter, and M^3 water-ice identified points in [15] of the VIPER landing site.