PHOTOGRAMMETRIC MODELING OF THE SÉÍTAH TOE-DIP AREA FOR STRATIGRAPHIC ANALYSIS OF JEZERO CRATER, MARS

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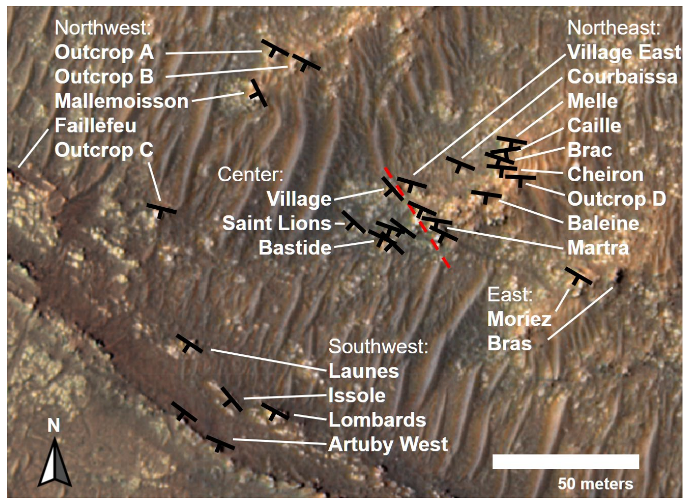
Introduction: Quantitative analysis of rock outcrop geometry is crucial to reconstructing the stratigraphic organization of rock units and their emplacement mechanisms. Since landing, the Perseverance rover has been investigating rocks on the Jezero crater floor. Here we analyze the orientations of the layered outcrops observed in the Séítah toe-dip region of Jezero crater, Mars where the Perseverance Rover performed both near-field and long-distance measurements. Studying this region with its stratigraphic older relationship to neighboring units is key to clarifying the compositional and morphological uniqueness of Séítah [1].

We use the stereo images from the Mastcam-Zs [2] and enhanced engineering cameras [3] on Perseverance to model several representative outcrops throughout this region. Best-fit planes fit through the exposed bedding layers show a consistent dip to the SSW. The dip angles, however, change significantly for outcrops deeper into Séítah with the steepest layers on the Artuby West ridge that borders the Cf-fr unit.

Data: The Mars 2020 rover carries a variety of stereo cameras that can be used for precise photogrammetric reconstruction. The Mastcam-Zs [2] and engineering cameras [3] work in tandem to provide high-resolution detail and wide-angle context of the outcrops studied here. The navigation and hazard avoidance cameras (Navcams and Hazcams) are fish-eye color imagers that supply the 360-degree terrain context for each end-of-drive location. These surveys are enhanced with targeted Mastcam-Z mosaics that add greater resolution in areas of interest. The Mastcam-Z instrument has two zoomable cameras with an iFOV ranging from 68 to 283 microradians (horizontal FOV from 6.2 to 25.5 degrees) and is mounted at a 24 cm baseline. Navcams by contrast have a 96-degree horizontal FOV and is 42 cm baseline. The Front and



Rear Hazcams supply additional parallax on the surrounding terrain.

Figure 1: Map of the Séítah toe-dip area in the floor of Jezero Crater. The dip bars show the average azimuth of each outcrop measured in this study.

Methodology: For short drive distances and ample imaging at each location, a collection of Mastcam-Z, Navcam, and Hazcam images are suitable for

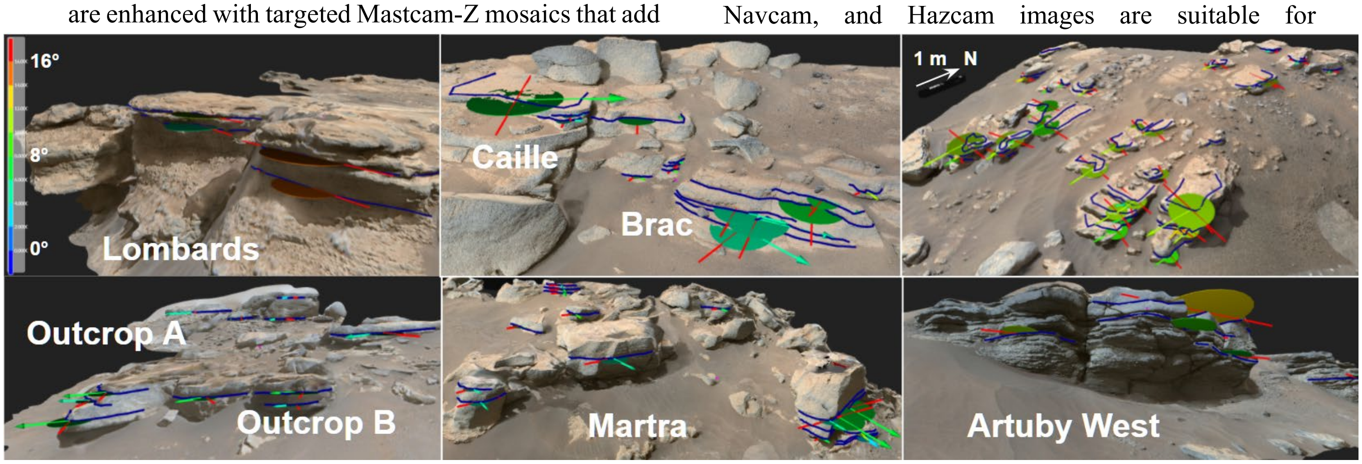


Figure 2: Several representative outcrops in Séítah with plane-fit annotations that show the dip orientations (arrows) and magnitudes (dip angles). The arrows all point approximately southwest. These frames are rendered with Pro3D [6]

photogrammetric reconstruction methods such as structure from motion [4,5]. This study uses semi-global stereo reconstruction implemented by the commercially available software Agisoft Metashape.

The process of creating the models starts from radiance calibrated images and rover frame to site frame localizations at the end of each drive. The image localizations set the scale, location, and orientation of the model, which can then be measured in physical units of length and orientations relative to the directions of North and Up. These models can give precise estimates of layer thickness, strike, and dip. These measurements are made with an open-source tool Pro3D [6] that uses the PCA-based method proposed by [5].

The models used in this study are viewable and downloadable here. This is a series of models starting with a low-resolution base model that shows the contextual terrain between the most notable outcrops, which are each modeled in high resolution.

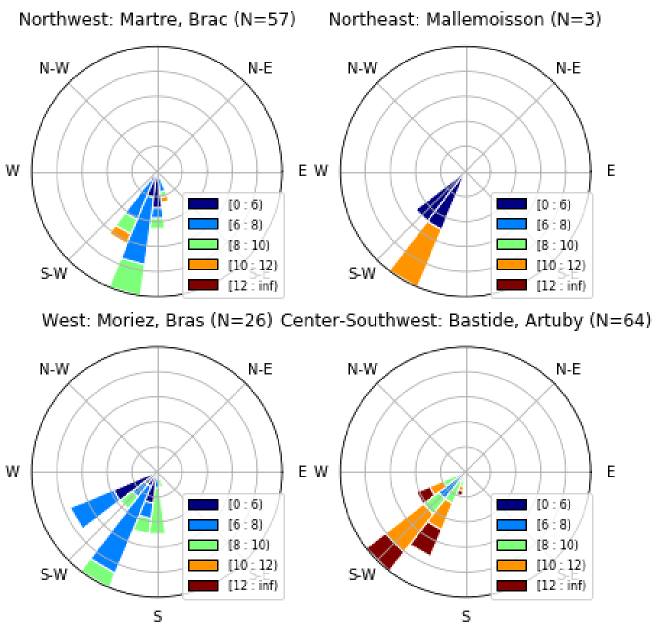


Figure 3: Windrose of the strike and dip measurements in the Séitah toe-dip area. The radial direction shows the probability distribution function with azimuth, and the color legend shows dip angles in degrees. Note that all outcrops dip towards to southwest and that the center and southwest outcrops have significantly greater dip angles.

Results: The rocks in Séitah toe-dip area show low angle layering. The measurements of N=150 in-place outcrop layers from the area have a mean dip angle of 8.5 ±2.5 degrees and mean azimuth 209 ± 30 degrees clockwise from North. The dip azimuths are normally distributed, while the dip angles have a significant bimodal distribution with values at 7.0 ± 1 degrees for layers north and east of the red dashed line in Figure 1 and 10.3 ± 1 degrees for layers south and west of the red dashed line. This means that Artuby West, Bastide, and the SW part of Village have higher dip angles with azimuths that trend more to the west, while the opposite is true for most other outcrops. While these two populations are distinct in both dip angle and dip azimuth, the azimuthal difference is likely not statistically significant.

These higher dip angles from Artuby West to Bastide are consistent with the RIMFAX subsurface measurements made along that route [7].

Orbital mosaics of this area show a curvilinear feature running approximately through this divide between the two layering populations SE from Village. Orbital mosaics of this area show a curvilinear fracture running approximately through this divide between the two layering populations southeast from Village. If this feature is a simple mode 1 crack, then it could result in a rotation of ~3 degrees to the northeast. If true, then outcrops further into Séitah would resume at the 10.3 degrees dipping angles.

Alternatively, the shallower dipping angles of 7.0 degrees could extend further into Séitah making the higher angles measured from Artuby to Bastide related in some way to its border with the Cf-fr unit. If this difference is due to a local fracture, then outcrops further into Séitah would resume at larger dipping angles. The future work of measuring dip angles at Dani dit ihi and Brac can elucidate this hypothesis.

Summary: The cracks in Séitah show a consistent dip direction toward the southwest pedicular to the boundary of the Séitah and Cf-fr units. The dip angles appear to decrease as the layers extend further into Séitah, and the steepest layers are found on the Artuby West ridge.

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References: [1] Núñez, J. et al (2022) *LPSC LIII abstract*. [2] Hayes, A. et al. (2021) *Space Sci. Rev.* [3] Maki, J. et al. (2021) *Space Sci. Rev.* [4] Caravaca, G. et al. (2021) *Remote Sens, 13*, 4068 [5] Quinn D. and Elaman B. (2019), *Earth and Space Science, 6, 1378–1408.* [6] Barns et al. (2018) *Earth and Space Science, 5(7), 285-307*. [7] Russel, P. et al (2022) *LPSC LIII abstract*. [8] Kanine M. et al. (2022) *LPSC LIII abstract.*