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## STRATIGRAPHY AND STRUCTURE OF THE MARGIN UNIT, JEZERO CRATER: IMPLICATIONS FOR FORMATION SETTING.

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**Introduction:** The Mars 2020 *Perseverance* rover is currently exploring the *Margin Unit*, a geologic unit stratigraphically underlying the Jezero Western fan, and which has been identified as part of one of the most carbonate-rich regions of Mars, making it a compelling astrobiological target [1-3]. Its origin, however, is uncertain. Before exploration by the rover, one hypothesis was that the unit is part of a regionally extensive, olivine- and carbonate- bearing altered pyroclastic or igneous deposit [4]. Alternatively, the unit's distribution within a narrow elevation range along the inner margin of the western crater rim, coupled with its strong orbital carbonate signature has led to a lake beach interpretation [2]. Aeolian and fluvio-deltaic interpretations have also been considered during the ongoing exploration of the unit [3]. Here, we report on the lithology, stratigraphy and structure of the *Margin Unit* explored by the Science Team between sols 910 – 1130, aiming to constrain its potential origins.

**Methods:** Mastcam-Z and SuperCam Remote-Micro-Imager images were analyzed to identify distinct lithologies of the *Margin Unit*. Orbital HiRISE images were used to further map the distribution of these lithologies. 3D data generated by the Planetary Robotics processing and viewing tools PRoViP and PRo3D were used for structural mapping of outcrop features [5].

**Observations:** Mastcam-Z landscape images indicate that the *Margin Unit* largely consists of discontinuous blocky- and paver-like outcrops making lithologic correlations challenging. However, two distinct sub-units can be distinguished:

*Eastern Margin Unit (Sols 911 – 1003):* The Eastern Margin Unit (EMU) comprises variably exposed, plane-parallel stratified beds, sub-horizontal or gently inclined either east (basinwards) or west (rimwards). Basinward inclined layers are the dominant outcrop type in the EMU, and comprise planar to gently sigmoidal layers, in places overlapping against underlying sub-horizontal strata (Fig 1a). Layering appears laterally continuous with a mean orientation of 11/075. Low-angle undulate stratification and local cross bedding are present in some outcrops around Turquoise Bay but are poorly exposed (Fig 1b). Rimwards inclined layers also display shallow dip angles but have a contrasting dip direction towards the west (mean = 12/273). Candidate rimwards-inclined cross strata foresets display steeper dips (~20 – 25°) and asymptotic bases (Fig 1c). Rimwards inclined layers truncate and overlie basinwards inclined layers along a N-S trending surface at ~ – 2405 m elevation, which can be mapped striking parallel to the crater rim for > 700 m (Fig 1d, Fig 2). PIXL and SHERLOC WATSON analyses of the Bill's Bay and Amherst Point abrasion patches indicate that the EMU comprises moderately- to well-sorted, medium to coarse sandstones dominated by sub-angular to well-rounded grains of olivine and carbonate [6-7].

*Western Margin Unit (Sols 1003 – 1130):* The Western Margin Unit (WMU) comprises wind-blasted blocky exposures which appear largely structureless at outcrop (Fig 1e), punctuated by intervals with moderately- to well-exposed planar layering, ~1 – 20 cm thick (Fig 1f), inclined north-east (mean 12/061).

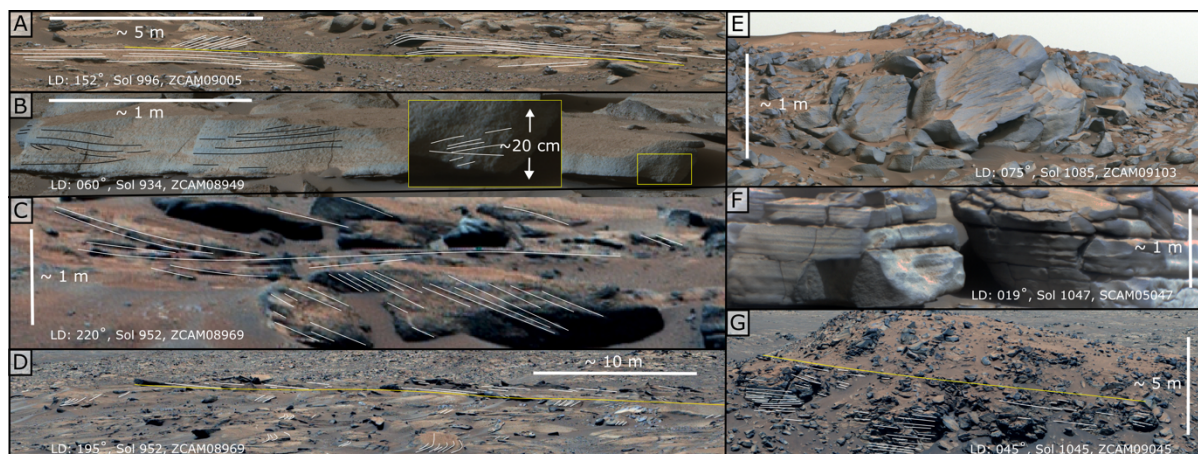


Fig 1: Annotated outcrop images showing outcrop-scale lithologic characteristics of (a-d) the *Eastern Margin Unit* and (e-g) the *Western Margin Unit*. Locations of images are annotated on Fig 2. LD = Looking direction.

The bases of structureless WMU sub-units are resistant, planar surfaces at outcrop, oriented parallel to underlying layered exposures (Fig. 1g), and potentially correspond to strong subsurface radar reflectors [8]. Both the structureless and planar layered varieties of the WMU explored so far appear to lack internal sedimentary lamination or structure, and show a high degree of textural variability, which may be a result of varying degrees of alteration and weathering [9]. PIXL and WATSON analyses of a structureless WMU exposure at *Bunsen Peak* imply it comprises uniform-in-size, mm-scale angular to sub-rounded carbonate and carbonated olivine masses, locally lined with serpentine-group minerals (80% vol. rock), encased in a silica matrix (20% vol. rock) [10].

**Structural relationships:** Orbital- and rover-based geologic mapping (Fig 2) suggest the EMU is present as a thin, NS-striking veneer, thickening to the east and overlying structureless WMU material.

**Interpretation:** The lithologic and structural variability of the *Margin Unit* documented here suggests it is a complex, altered unit likely formed by several geologic processes. One possible interpretation we propose is that the EMU may preserve a lake beach-bar type deposit, overlying and potentially partly derived from older WMU bedrock. In lake settings on Earth, wave action can generate bars parallel to the coastline (in this case parallel to the crater rim), with internal layering dipping in alternating lakewards and landwards directions. Planar to sigmoidal basinwards dipping beds such as those seen in the study area are formed in fairweather conditions as the shoreface progrades into the basin [11]. Raised lake levels or onshore winds can transport sediment over the bar crest and deposit it on the landwards-facing side as washover fans or sheets [12], which may be consistent with the rimwards dipping layers in the EMU. Low-angle undulate stratification and cross bedding can also be found in terrestrial beach-bar deposits [13]. This

hypothesis would be consistent with textural interpretations of aqueous emplacement [6] and previous orbital work which places the Jezero outlet channel and potential sustained palaeoshoreline at -2395 m elevation [14]. The structures reported here in the EMU occur ~10 m below this elevation, consistent with a predicted near shore paleo-environment.

Due to the limited structure of the WMU seen in Mastcam-Z and Supercam imagery, interpretation of its formation setting is ongoing. The chemical and textural composition of the WMU could be consistent with an altered sedimentary, pyroclastic, or crystalline igneous rock, or a complex interbedded sequence of these where olivine has been partially to completely carbonated [14]. Structureless and planar layered lithologies lacking sedimentary structures and inclined away from the crater rim may be generated by an eruptive volcanic sequence, via repeated, low-viscosity lava flows, crystal settling in an intrusive body, or via pyroclastic density currents or airfall entering the crater [16-18]. Additionally, the potentially extensive alteration and reported high textural variability [10] suggests that although sedimentary indicators have not yet been observed at outcrop, a clastic component to the WMU cannot be discounted at this stage. Upcoming investigation of the *Margin Unit*, including its relationship to the crater rim, will be critical in developing a complete model for its origin.

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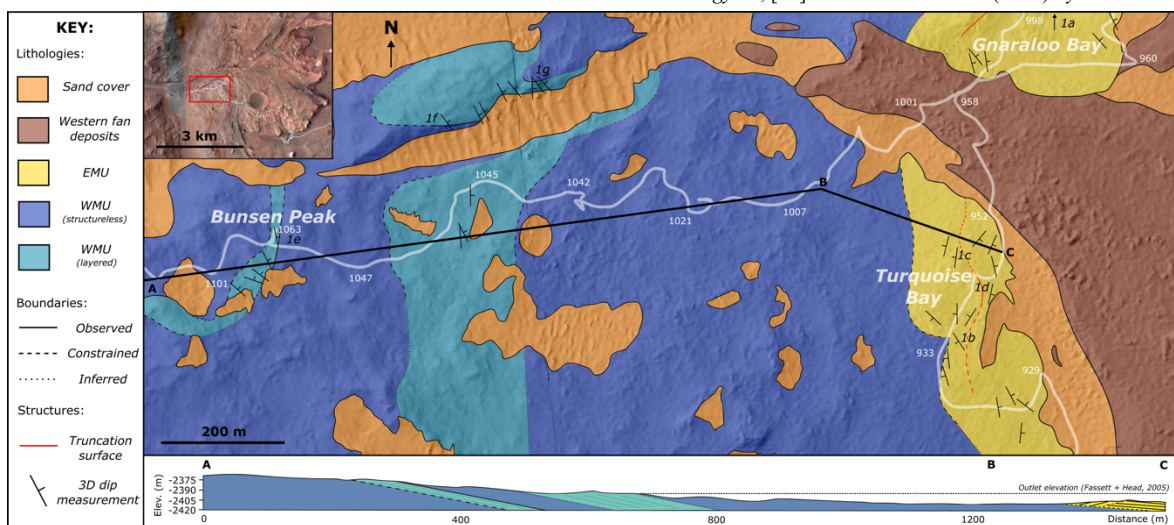


Fig 2: Geologic map and preliminary cross section of the *Margin Unit* explored by Perseverance, with traverse and sol numbers annotated. Cross section is taken along line ABC. Locations of the images in Fig. 1 are also shown.