EPSC Abstracts
Vol. 17, EPSC2024-748, 2024, updated on 25 Mar 2025
https://doi.org/10.5194/epsc2024-748
Europlanet Science Congress 2024

Water and Sediment Transport Processes in Jezero Crater

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Introduction: The current NASA's Mars 2020 mission is exploring the Jezero crater that was once filled with water. Since it is widely acknowledged that access to liquid water is essential for life, studying the fluvial activity in Jezero can aid in the crater's habitability assessment. We examined ten water-related processes using water and sediment transport models by [3]: 1) the western inlet valley carving, 2) the northern inlet valley carving, 3) crater flooding by only northern inlet, 4) by both northern and western inlets, 5) erosion of the western rim by the western inlet, 6) erosion of the eastern rim due to the outlet, 7) water outflow from the crater, 8) outlet valley carving, 9) western delta deposition, 10) northern delta deposition. The goal of our study was to calculate the minimum timescales for each event and estimate the minimum volume of water provided/released during each event. Relative comparison of timescales and of water amount which we calculated based on new geomorphological observations introduces a deeper understanding of the water history in Jezero.

Data: Measurements of channel sizes, valleys, deltas, eroded rims, and outflowed water volumes were based on Mars 2020 Science Investigation CTX DEM Mosaic [5] and HRSC Mars Chart (HMC) DTM and corresponding orthomosaics [2].

Geomorphological observations: The northern inlet was most likely involved in the crater flooding because it has terraces at the same height as the breaching terraces in the eastern rim (breaching happened in 3 phases, as shown in [7]). The western inlet, in contrast, has no terraces at the breaching heights. This implies that either it was not involved in crater flooding, or its terraces were eroded.

Mapping: Both deltas were mapped using three potential extents: minimum, medium, and maximum. Valleys were mapped based on two morphological features: 1) initial valley, borders of which are not visible on HMC ortho-mosaics and could only be recognized on slope and profile curvature rasters, calculated from HMC DTM; 2) last incision valley, which was mapped on HMC ortho-rectified image mosaic.

Measurements: Dimensions of the channels were derived from longitudinal and cross-sectional profiles on CTX DTM. Water volume to fill the crater before breaching and the amount of sediments, transported from valleys and deposited in deltas were estimated using ArcGIS Tools „Surface Volume‟ and „CutFill‟.

Methodology: Flow discharge and sediment transport models [3] are used to calculate water and sediment transport timescales under constant bank-full discharge when most of erosion occurs. The models do not include the climate and non-bank-full conditions to constrain minimum timescales. Main input parameters include: Median Grain Size, Channel depth, width and slope, Sediment porosity, Shields criterion for incipient motion, Sediment density, Martian gravity, and Water density. Data from the Perseverance rover [1] were taken for the Median Grain Size estimation. Sediment porosity, Sediment density, and Shields criterion for incipient motion were taken based on previous research [3], [4], [6]. Several scenarios were modeled with varying values of input parameters in the most expectable ranges. Eastern and western rim breechings were modelled both in a catastrophic scenario and in a long-term erosion under constant flow scenario.

Results: A comparison of the timescales of the last incised valleys carving and delta depositions showed that deltas were deposited during the last incision of the corresponding valleys. For the northern delta, the medium extent is the most probable; for the western delta, the maximum extent is the most probable.

Most modelled cases, in both long-term and catastrophic scenarios of the rim breaching, showed that the outlet valley carving lasted longer than the eastern rim erosion. Therefore, Jezero was an open-basin lake after breaching.

The eastern rim erosion and water outflow during breaching showed different results depending on the scenario. In the long-term scenario, the eastern rim erosion lasted longer than the outflow of water which was stored in the crater before breaching. That means, that this amount of water (236 km^3) was not enough to carve the breach. In the catastrophic scenario there are overlapping timescales, therefore, the eastern rim breaching, and water outflow could happen simultaneously.

Multiplying the timescales by corresponding discharges allows us to calculate the minimum water volume provided/released during each event. Dividing the minimum water volume by the volume of the crater before breaching (446 km^3) shows that the northern inlet as well as the western inlet could alone flood the crater (last column in Table 1).

A comparison of the minimum amount of water discharged after the breach (236 km^3) with the amount of water needed to carve the whole outlet valley (1000 – 14800 km^3, Table 1) confirms that Jezero must have been an open-basin lake after the breaching.

Table 1. Minimum water volume provided/released during the carving of the valleys. Timescales presented for the total valley carving (initial valley and last incised valley together).

	Timescale, Earth years	**Discharge, km^3/day**	**Minimum volume of provided/released water, km^3**	**How many times Jezero could be filled before breaching (basin volume = 446 km^3)**
Northern Valley Total	70 – 632	~0.2	4600 – 42000	10 – 94
Western Valley Total	505 – 3792	~0.2	33500 – 253000	75 – 567
Outlet Valley Total	1.4 – 21.2	~1.9	1000 – 14800	–

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