DECIPHERING THE PALEOENVIRONMENTAL ARCHIVES OF JEZERO CRATER THROUGH PHYSICAL SEDIMENTOLOGY: ORBITER-BASED PREDICTIONS.

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Introduction: After landing in Jezero crater next year, the Mars 2020 rover is bound to investigate the remnants of an ancient river delta near the western rim of the crater [1]. The exposed fluvio-deltaic stratigraphy will offer a unique window into the depositional environments and climate of early Mars. One key question that remains to be answered is that of timing and duration of delta formation. Specifically, resolving the duration and intermittency of flow events within Jezero crater bears significant implications for understanding Mars' habitability at the time of delta formation, as well as the astrobiological potential of the fluvio-deltaic deposits. Here, we constrain the duration and intermittency of delta-forming flow events from orbiter-based imagery. Our results have direct implications for the Mars 2020 rover's exploration of the delta deposits.

Methods: Although fluvial and lacustrine deposits have been observed and investigated before by the Curiosity rover at Gale crater [2-4], the fluvio-deltaic deposits of Jezero crater are unique in terms of their clear preservation of planform morphology. In particular, channel-body deposits indicate that single-thread channels meandered over the delta top. The morphodynamics of rivers that meander in the absence of land vegetation are poorly understood [5]. Here, we build on a new compilation of the lateral migration rate of unvegetated meandering rivers on Earth [6], and scale it for martian gravity in order to infer the lateral migration rate of ancient martian meandering rivers. Combined with morphometric measurements of channel deposits [7] and a conceptual model for the avulsion timescale of rivers [8], we constrain the vertical aggradation rate of the ancient riverbed. We then calculate the integrated duration of delta forming events, $T_{\min}$, from the inferred thickness of fluvial deposits [7,9-10] for different stratigraphic-completeness scenarios [11-12].

In addition to the integrated duration of delta-forming events, we estimate the total duration of delta formation, including dry spells (T_{tot}). To do this, we utilize the technique of [13] applied to the delta-feeding valley upstream of the delta, reconstructed for paleotopography, using independently constrained erosion rates [14-17]. We then calculate the intermittency of delta-building events as $I = T_{\min}/T_{\text{tot}}$.

Finally, measurements of the delta-deposits volume combined with our estimate of $T_{\min}$ allow us to constrain the average sediment fluxes (bedload and suspended load) that constructed the deposits, and to make predictions of fine-scale sedimentary features such as grain size of the bed, banks, and bed configuration [17-20].

Results: Our best estimates suggest that $T_{\min}$ = 19–37 years and T_{tot} = 375,000 years. The uncertainty in T_{tot} is large due to significant uncertainty in the paleotopographic reconstruction of the feeder valley. Our corresponding best estimate delta-formation intermittency is of 1 sol/ 15–30 MY (martian years). These intermittencies reflect the frequency of bankful flows that significantly contributed to delta building. Baseflow not capable of producing significant geomorphic work could have been more frequent. Instantaneous bed aggradation rate is estimated to be ~1.5 cm/sol, with significant sediment transport in suspension (<1% bedload). Full uncertainties as well as predictions of bed configuration and grain sizes will be presented at the conference.

Discussion:

Implications for the climate of Early Mars. Our estimated duration are quantitatively consistent with a recent climate model [21] under which a few percent-level emissions of CH_4 in the early martian atmosphere would maintain a mixed CO_2-CH_4-H_2 atmospheric composition capable of raising the mean annual surface temperature by tens of degrees over a timescale of a few 10^5 years. Our estimated sediment concentrations are modest, such that they do not require the accumulation and rapid release of large volumes of fine sediments into the channels.

Implications for the landing site's astrobiological potential and the Mars 2020 rover. Although our inferred aggradation rates only strictly apply to the channel deposits, our predicted average bedload flux only represents a small fraction of the total sediment load, such that burial rate of putative organics by fines in the distal part of the delta was likely rapid, promoting quick compaction and the formation of a closed chemical environment with low permeability that would have inhibited diffusion and supported rapid remineralization [22-23]. Furthermore, clays like those detected from orbit [24] were shown to absorb organics into their mineral lattice. Together with mineralogy, rapid burial strongly supports the preservation potential of the Jezero deposits. Based on the relationships between channel width, migration rates, aggradation rates, and frequency of avulsions, we make predictions of areas with rapid burial, providing a clear strategy for sampling of the Jezero fluviodeltaic deposits.

Finally, as future rover observations either corroborate or contradict different aspects of our predictions, arising discrepancies will help refine our assumptions. For example, in situ observations of channel bedforms will directly inform us about bed stresses, which combined with channel width estimates, may help us constrain bank strength, and determine whether riverbanks were permeated with ground ice, providing additional insights into the paleoenvironments of Jezero crater.

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