INSIGHT FROM GLACIO-FLUVIAL DELTAS AT PATAGONIAN LAKE GENERAL CARRERA FOR MARTIAN DELTAS R. M. E. Williams[1] and B. M. Hynek[2], [1]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719, williams@psi.edu, [2]University of Colorado Boulder.

Introduction: Increasingly, the role of ice meltwater as well as rainfall has been hypothesized to be important during past aqueous periods on Mars. However, we have limited Earth analogs in cold climates. We studied the morphological and sedimentological attributes of deltas at Patagonian Lake General Carrera (LGC). Our work constrains delta growth rates as a function of water source, with important implications on formation timescales and climate conditions for martian deltas.

Site Description: Located near the 46.5° S parallel, the elongated (130 km across and 20 km at widest) Lake General Carrera (LGC) extends into Argentina (where it is called Lake Buenos Aires). The LGC deltas are an excellent natural laboratory because the site has considerable variation in topography and micro-climate. The Andes Mountains encircle the western half of the lake and are the natural cause of significant differences in annual precipitation [1, 2] and catchment size. Within this geographic setting, the stepped deltas developed during a series of lake lowering events [3, 4] since the breakup of the Patagonian Ice Field ~15 ka [5].

LGC Deltas: We studied 15 deltas on the Chilean LGC [6]. As expected, the delta size is correlated with the catchment size, with the ratio of fan area to drainage basin area between 0.01 and 0.14 (Fig. 1A). The LGC deltas follow the trend of other arid fans on a fan-to-catchment area plot, and their large scale fills a knowledge gap (Fig. 1B).

Surprisingly, the pronounced longitudinal precipitation gradient across the study region (0.2 to >2 m/yr [1, 7]) is anti-correlated with the observed variations in delta size. The largest deltas are located on the eastern side of the basin in a semi-arid steppe setting. However, we identified an association between delta size and the time-dependent ice distribution. Ice reconstruction maps from [5] are used to identify catchments with continuous glacier presence since the last glacial maximum (defined here as X=1), versus those with catchment glaciers at some time in the past (X=0.5) or never present (X=0). Drainage basins with sustained glacier presence are associated with larger deltas (blue triangles Fig. 1A).

This association between delta size and catchment water storage is also manifested in the exposed topset deposits of ancient, perched deltas that record short- and long-term flood variability. Using available streamflow [2, 7] and deposit age [8] constraints, we estimate the range of development rates that encompass the multiple variables influencing delta formation. The exposed sedimentary record in the older deltaic deposits [3,4] reveal details of the frequency and magnitude of delta constructional events. The bulk of the delta volume is cobble-rich, and could be deposited during seasonal floods (~100-200 m^3/s). In some deltas, the occurrence of meter-size boulders in individual topset layers is consistent with rare (decadal or longer intervals), high magnitude (>600 m^3/s) flood events that we attribute to ice meltwater release. In addition, the modern average progradation rate (length/age) is two-fold higher for deltas with ice in their catchments relative to those with no or minimal ice (0.32 vs 0.14 m/yr).

The intermittency factor (I_f) is the proportion of total time needed to transport sediment load assuming the case where only continuous bankfull flows occurred [9]. For the youngest LGC deltas, we estimate the plausible range in the I_f, a dimensionless measure of the frequency of floods, is 1×10^{-2} to 4×10^{-5}, significantly below I_f values reported in [10] (Fig. 1C). LGC deltas with sustained glaciers in their catchment have approximately an order of magnitude higher average intermittency factor than those with ice-free catchments.

This study quantified the effects of seasonal floods alone versus additional input from glacial meltwater on LGC delta development. The added contribution of rare ice meltwater release events is speculated as the differential driver to enhance delta growth.

Implications for Mars Deltas: Coarse grained deposits were predicted in Jezero delta based on thermal inertia [11]. Ground truth images confirm boulder-bearing units [12]. Preliminary analysis of THEMIS data shows additional deltas with an afternoon thermal gradient similar to the Jezero delta (Fig. 2). (As a check, comparison was made to a second morphological class of fans, defined by [14, 15]. These had a distinctly lower thermal slope, confirming the late afternoon cooling rate differs for the two fan classes.) The thermophysical properties of these deltas could be consistent with coarse-grained deposits and raises the possibility of high-energy floods at more locations than previously recognized. The glacio-fluvial LGC deltas are a model that should be considered for reconstruction of select Mars fans, with ramifications on flood triggering mechanisms, formation timescales and associated climate conditions.

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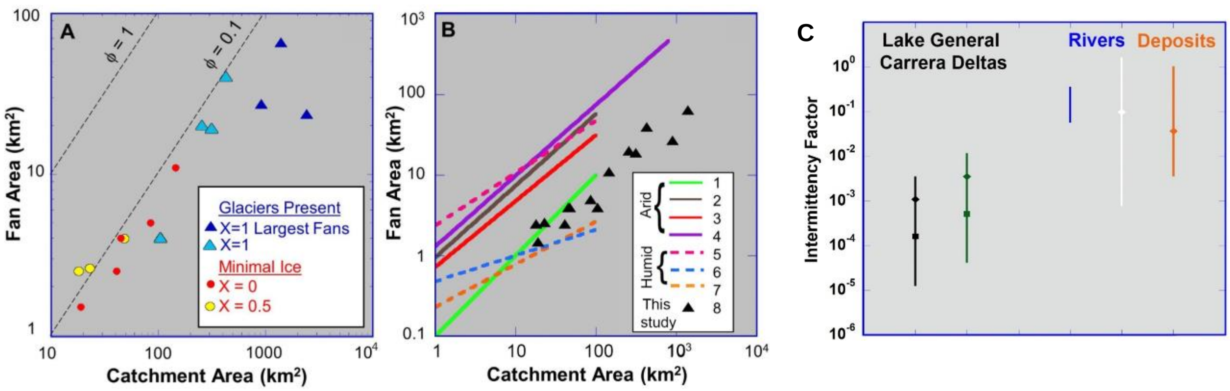

Figure 1: A) Largest deltas have glaciers in catchment (blue triangles). **B)** On fan-to-catchment area plot, LGC deltas (triangles) have a similar slope to arid fan sites. Data for solid lines is reported in [13] for numbered locations: 1 east side of Death Valley, CA and NV; 2 west side of Death Valley, CA; 3 Almeria, Spain; 4 Fresno, CA; 5 Aklavik, Canada; 6 Banff, Canada; 7 Dellwood, CA. **C)** The average intermittency factor (I_f) of LGC deltas are higher for catchments with glaciers (diamond) than ice-free catchments (square). Computed intermittency factor based on exposed LGC delta volume (black line) and extrapolated volume (green line) is lower than published values reported in [10]: measured I_f for rivers (dark blue line), computed I_f from stream gauge data (white line) and sedimentary deposits (orange line). Diamonds mark the median I_f of modern rivers (0.10 white) and sedimentary deposits (0.04 orange) [10].

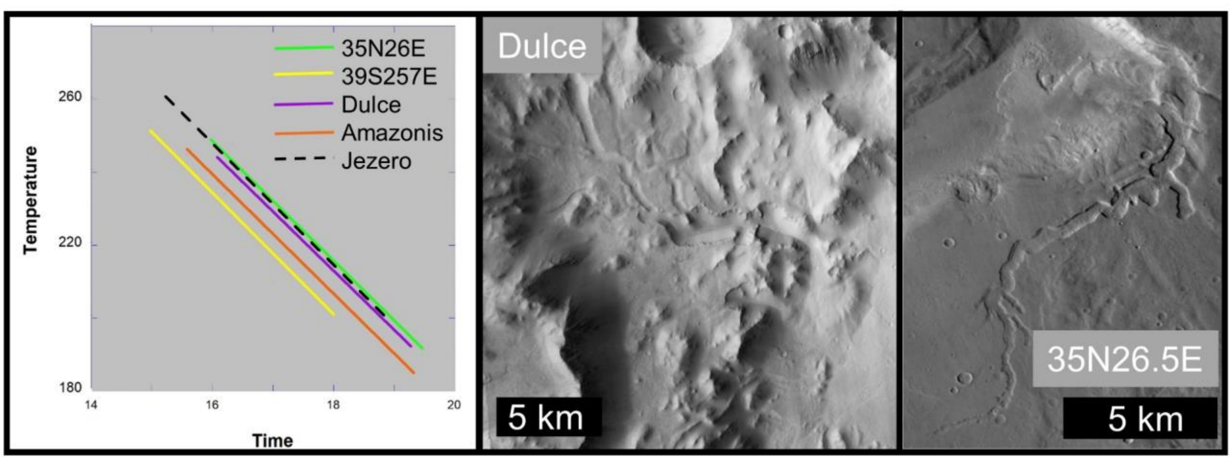

Figure 2: Left side: Late afternoon thermal response of candidate martian deltas that match the Jezero delta. **Right side:** CTX subscenes of two candidate deltas, at the termination of Dulce Vallis in western Gale Crater and an unnamed stepped fan deposit near 35° N, 26.5° E.