NEW PARADIGM FOR EMPIRICAL RELATIONSHIPS IN MARTIAN PALEOHYDRAULICS: INSIGHTS FROM ANALYSES OF A TERRESTRIAL ANALOG CHANNEL.

R. E. Jacobsen[1] and D. M. Burr[1], [1]University of Tennessee, Knoxville, TN USA 37996 (RJacobse@vols.utk.edu and dburr1@utk.edu).

Introduction: Paleodischarge estimates are used in Martian sedimentary and landscape evolution models that have important implications for ancient climates [e.g., 1,2]. Estimates of paleodischarge also have been used to characterize habitability of ancient environments at candidate rover landing sites [3-5]. Thus, estimating paleodischarge represents a critical analysis for addressing important questions in Mars science.

Martian paleodischarge magnitudes are commonly estimated through the use of one or more bivariate empirical relationships. These relationships are derived from data of, e.g., discharge, channel width, wavelength, radius of curvature, of active channels on Earth [e.g., 6-8]. Analysis of the Quinn River, NV, a Martian-terrestrial analog channel [9], suggests that width-discharge empirical relationships from hydraulic geometry are more accurate than the most commonly used empirical relationship from the Missouri River Basin [10]. Applying the more accurate hydraulic geometry relationships to a suite of Martian fluvial features yields new paleodischarges that magnify the hydrologic contrast between early (3.7 Ga) and late (3.0 Ga) episodes of climatically-driven hydrologic activity [10]. Thus, analyses of terrestrial analog channels refine techniques for estimating paleodischarge and thereby improve our understanding of the Martian hydrologic timeline.

Here, we summarize another analysis of the Quinn River that evaluates an empirical relationship between point bar radius of curvature and channel width, which may then be used to estimate paleodischarge [7,11]. Results of this analysis yield important insight about confounding variables of terrestrial-based empirical relationships, uncertainty associated with Martian paleochannel dimensions and estimating of paleodischarge from morphometry [11].

Background: Candidate landing sites of the Mars 2020 rover include diverse paleochannels and stacked fluvial deposits [5 and refs. therein]. Changes in fluvial feature morphology with stratigraphy have been interpreted to indicate changing paleohydraulics and paleoclimate evolution [3,4]. Although not a candidate landing site, the Aeolis Dorsa (AD) region includes numerous stacked fluvial deposits that are well exposed, commonly in positive relief (i.e., topographically inverted), and have been interpreted as evidence of decreasing magnitude and frequency of formative discharges, and localization of fluvial activity through time [e.g., 8,12,13]. Stacked fluvial deposits include a lower unit of relatively broad (~1 km) meandering fluvial deposits and a upper unit of thin (~10's m) sinuous channel fills [12]. We hypothesize that the decrease in deposit width from the lower to the upper unit represents a decrease in the paleodischarge that formed the channels and concomitant deposits.

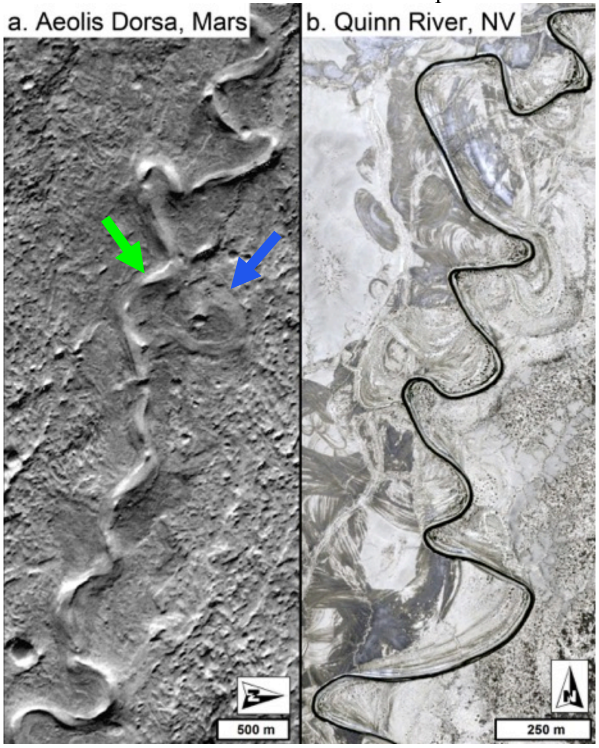

Figure 1:* *(a) *Stacked fluvial deposits of the AD include a lower unit meandering fluvial deposits (blue arrow) and a upper unit of channel fill (green arrow). (b) The Quinn River, NV, forms morphologically similar planview meander patterns deposits in a nearly vegetationless environment.*

Methods: Based on published terrestrial relationships [6,7], we used width as a proxy for paleodischarge [10,13] and test the hypothesis by comparing the average widths of the lower unit and the average widths of the upper unit. However, strata in the AD region preserve disparate fluvial units, i.e., channel fills and meandering floodplain deposits. Widths of the upper channel fills may be readily measured, whereas paleochannel widths for the lower meandering fluvial unit are not exposed. To estimate bankfull widths (W_b) of the paleochannels of the lower unit, we coupled the radii of curvature (R_c) of the meander fluvial deposits with a terrestrial-based empirical relationship (W_b=0.71*$R_c^{0.89}$, SE=40%) [7]. Radii measurements were repeated four times to calculate the standard deviation of the mean (SDOM).

We assessed the uncertainty of our results in three ways. First, we calculated wavelength-width ratios for the upper unit of fluvial channel fills. Terrestrial channels, in general, have wavelength-width ratios between 10 and 14 [7], and paleochannel deposits with ratios >14 may suggest deposits thinned by erosion [e.g., 8]. Second, we examined the relationship between point bar radius of curvature and channel width along the Quinn River to identify any confounding variables that may need to be considered when interpreting results from analysis of the AD. Third, we are assessing the uncertainty associated with measuring radii of curvature from channel point bars through the use of an automated GIS algorithm.

Results: *AD:* Average radii of curvature for the lower unit of meandering fluvial deposits range from 72 to 214 m (SDOM of 38 to 294). These radii yield paleochannel widths from 32 m (±12) to 84 m (±120) (Fig. 2a). These derived paleochannel widths of the lower unit are larger than the measured upper unit widths, which range from 13 m to 50 m (SDOM of 1.2 to 13) (Fig. 2a). Wavelength-width ratios for the upper unit of fluvial channel fills range from 12 to 56, but all but one fluvial channel fills have ratios >14.

Quinn River: Meander point bars along the Quinn River have average radii of curvatures of 21 to 114 m (SDOM of 1.5 to 43) and average widths range from 13 to 21 m (SDOM of 0.24 and 2.4). One-third of the paired radii and widths data plot above the interval for the standard error of the estimate for the terrestrial relationship derived from vegetated channels [6,7].

Discussion: With paleochannel width as a proxy for paleodischarge, the greater derived paleochannel widths in the lower unit compared to smaller measured widths for the upper unit implies a decrease in paleodischarge from the lower to upper strata. These results support the hypothesis and are consistent with the overall hydrologic history of Mars and with stratigraphic columns throughout the AD region [10,12-14].

High wavelength-width ratios suggest erosion of fluvial channel fills. As a result, paleochannel widths in the upper unit have likely been underestimed and, therefore, erroneously exaggerate the paleodischarge contrast between the upper and lower units (Fig. 2b).

Results from the Quinn River also increase the uncertainty associated with results from the Aeolis Dorsa. Well-lithified paleo-lacustrine clays and silts along the Quinn River promote meandering in the near absence of rooted plants [9]. Examination of the meander bends along the Quinn suggests that it migrates readily in reworked fluvial sediments, but that cut banks of well-lithified paleolacustrine clays limit lateral migration and promote translation of the downstream limb. Enhanced downstream translation expands the bend radius of curvature without a corresponding increase in channel width and suggest bank lithification to be a confounding factor. Stable channel banks have been inferred in AD in order to promote meandering in the absence of vegetation [9]. Thus, widths in the lower unit may be overestimated through the use of the radii-width empirical relationship and exaggerate the paleohydraulic contrast between the two units (Fig. 2b).

Conclusions & Future Work: Analyses of terrestrial analogs, such as the Quinn River, refine the use of empirical relationships by providing insights about confounding factors that may lead to overestimates of paleochannel dimensions and erroneous interpretations of paleohydraulic evolution. A final analysis will focus of quantifying the uncertainy associated with measuring radii of curvature of meander point bars.

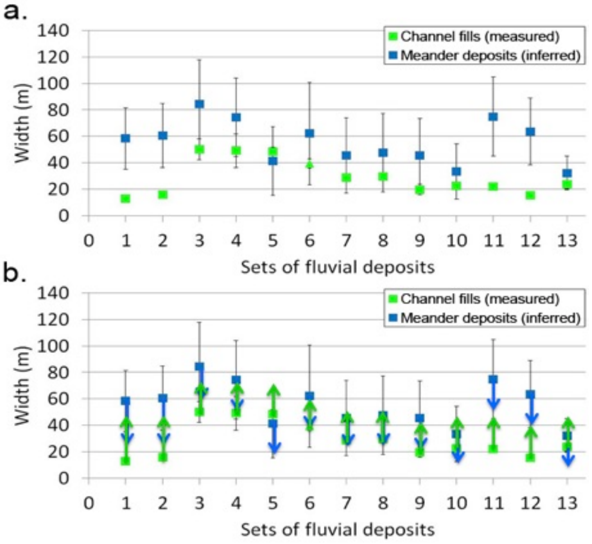

Figure 2: ***(a)*** *Derived paleochannel widths for the lower unit of meander deposits are, in general, larger than measured widths of channel fills in the upper unit, suggesting a inter-strata decrease in paleodischarge.* ***(b)*** *Arrows represent uncertainty of underestimation of channel fill widths and overestimation of meandering channel widths and decreases the paleohydraulic contrast between the two units.*

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