DETERMINING PALEOFLOW DIRECTION OF MARTIAN CHANNEL BELTS USING PRESERVED CHANNEL-BEND ASYMMETRY: CASE STUDY AT AEOLIS DORSA, MARS

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Introduction: Well-preserved, topographically-inverted fluvial deposits at Aeolis Dorsa, Mars, are indicative of a warmer, wetter period of martian history [1-3]. Deltaic deposits and exposed valley-fills suggest that, during this period, Aeolis Dorsa was a coastal region [4-6]. Currently, the regional slope at Aeolis Dorsa is towards the north. This has led to the hypothesis that paleoflow was also towards the north [2,7]. However, closer studies of sedimentary deposits (including deltas and incised valley fills) indicate paleoflow was towards the east-southeast [4,5], and that the regional slope is the result of differential stratal erosion rather than representing a preserved surface that dates back to the wetter period. Correctly interpreting the paleoflow direction at Aeolis Dorsa is vital for an accurate paleo-environmental reconstruction, including accurate interpretations of coastline position and fluctuations of it. However, a consensus has yet to be reached.

Previous workers observed an asymmetry in the bends of actively migrating rivers on Earth's surface that is a function of flow direction [8]. Here, we use this observation as a tool to determine the paleoflow direction of topographically-inverted valley-filling channel belts at Aeolis Dorsa, Mars, described by [5]. This method provides evidence of a southeastern paleoflow direction at Aeolis Dorsa, and will be useful for future work on any planetary surfaces where the flow or paleoflow direction of a channelized feature must be determined from remote observations.

Methods: [8] mapped river centerlines and identified the locations of maximums of channel curvature and inflection points along those centerlines. They defined the portion of centerline between two maximums of curvature as a traverse. By definition, two adjacent maximums of curvature must be separated by an inflection point, so each traverse contains one inflection point. [8] observed that the inflection points between maximums of curvature tend to be closer to the downstream maximum of curvature (termed a delayed inflection point, Fig. 1A). This observation is quantified using the asymmetry value (z):

$$z = 100 * u/(u*d),$$

where u is the length of the upstream concave portion of the traverse, and d is the length of the downstream concave portion of the traverse. By this definition, z can range from 0 to 100. Values of z that are greater than 55 indicate the inflection point is closer to the downstream maximum of curvature, values from 45-55 indicate the inflection point is about equidistant to both maximums of curvature, and values less than 45 indicate the inflection point is closer to the upstream maximum of curvature.

In this study, a series of closely spaced X,Y points along the centerlines of active terrestrial rivers and martian channel belts were imported into Matlab, and the curvature of the centerline was measured at each point using the geometric method described by [9]. Inflection points and maximums of curvature were automatically identified (Fig. 1B), and the lengths of the upstream and downstream concave sections of each traverse were measured as shown in Fig. 1. Values of z were then calculated for each traverse.

To estimate the paleoflow direction of fluvial deposits on Mars, we identify the direction producing a similar distribution of delayed inflection points as those observed in terrestrial rivers [8].

Results: Fig. 1C is a histogram of asymmetry values from active rivers on Earth's surface. The 451 traverses measured are a combination of new measurements from the Mississippi, Strickland, and Fly rivers, (n=174) and results from [8] (portions of the Beatton, Pembina, Iowa, Neuse, Big Sioux, Savannah, Sabine, Au Sable, Lumber, Rum, Rough, Blacks Fork, and Animas rivers, n=277). The larger dataset is consistent with observations made by [8]: there is a greater tendency for inflection points to be skewed towards the downstream maximum in curvature of a traverse (i.e., asymmetry values are more likely to be >55, and less likely to be <45.)

When paleoflow is assumed to be towards the southeast at Aeolis Dorsa, the same skewness in the distribution of asymmetry values is observed (Fig. 1D). Thus, a southeastern paleoflow direction at Aeolis Dorsa is interpreted to be correct.

Discussion: We provide evidence here that paleoflow at Aeolis Dorsa is generally towards the southeast. This conclusion is consistent with stratigraphic analyses of exhumed deltaic deposits in the region [4,6], which makes the hypothesis more compelling. In addition, we have developed a method of determing paleoflow direction of other relict channel belts on Mars, and anywhere else where observations must be made remotely.

Ongoing work includes improving the automation of this process, and fully exploring how the inherent asymmetry of rivers is preserved in channel belts, which record all lateral channel migration over the lifetime of a river.

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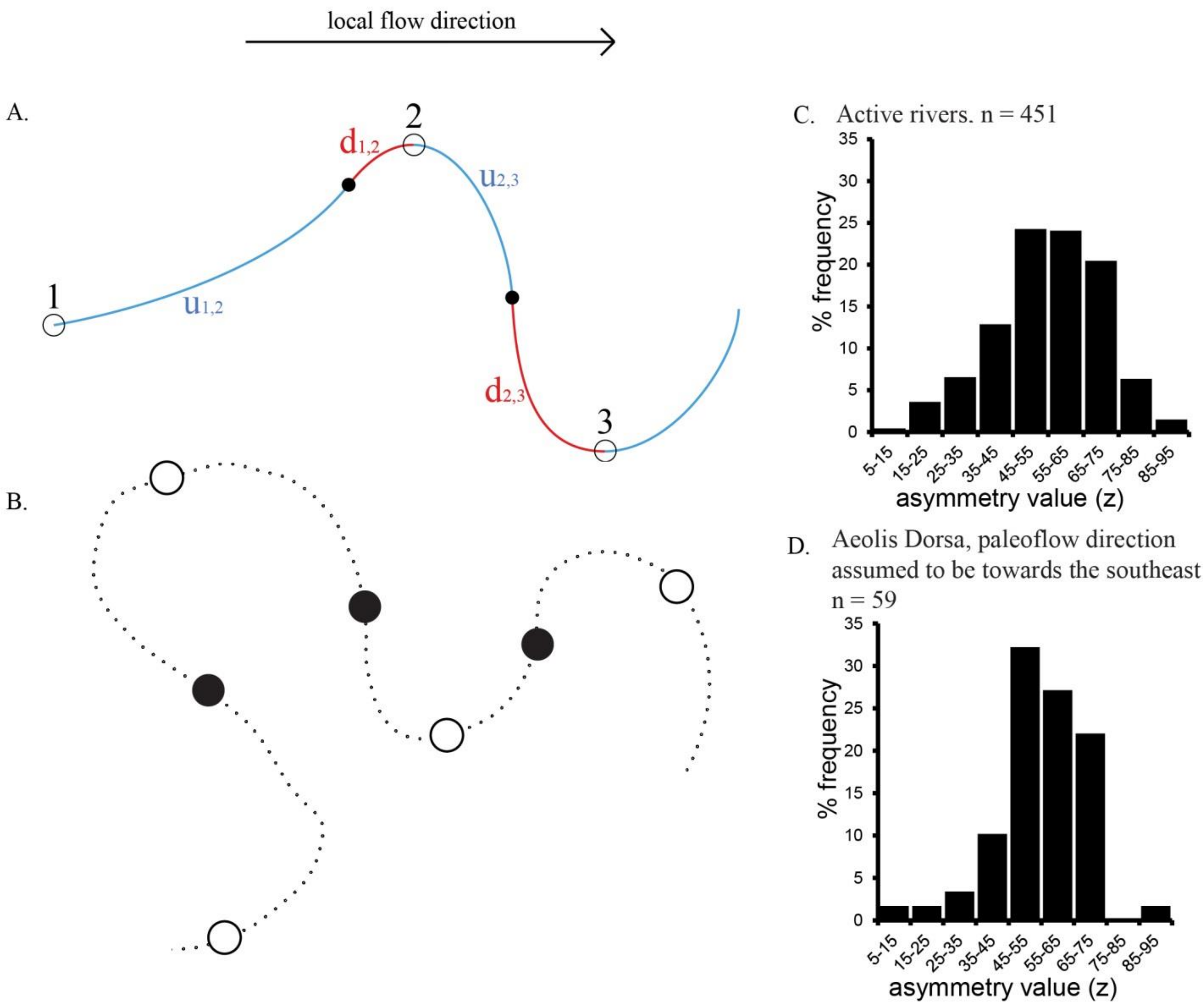

Figure 1 – A: Components of the bend asymmetry analysis. The unfilled circles 1, 2, and 3 mark maximums in curvature. Traverses are the lengths of centerline between maximums of curvature. Black dots mark inflection points. Overall flow direction is shown by the arrow. Upstream and downstream portions of each traverse are shown in blue and red. In traverse 1-2, the inflection point is closer to the downstream maximum of curvature (delayed). In traverse 2-3, the inflection point is roughly equidistant from either maximum of curvature. B: A portion of centerline from the Fly River, Papau New Guinea. Flow direction and symbology from panel A still apply.. C: Histogram of asymmetry values from active rivers measured in this study and by [8]. Note the greater number of asymmetry values greater than 55 as opposed to those less than 45. D: Histogram of asymmetry values from valley-filling fluvial deposits at Aeolis Dorsa described by [5]. The distribution shape of asymmetry values is similar to panel C if a southeastern paleoflow direction is assumed, as it was here.