THE STANISLAUS TABLE MOUNTAIN: OBSERVATIONS OF A LAVA-CAPPED INVERTED PALEOCHANNEL FOR INTERPRETATION OF INVERTED PALEOCHANNELS ON MARS.

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Introduction: Topographic inversion is the process by which a feature becomes more resistant to erosion than the surrounding, higher-standing terrain; regional erosion of the surrounding terrain leaves the previously lower but more resistant feature in positive relief above the eroded surroundings (e.g., [1]). Inversion is often, though not necessariy, associated with exhumation. Inverted fluvial features, many of which have been exhumed, have been documented in a number of locations and settings on Mars [e.g., 1-8]. These paleoflow features expand our view of the hydrological, climatic, and sediment transport processes that have operated on that planet by extending the paleohydrologic record in both time and space.

Correct interpretation of the paleoflow conditions from inverted forms requires: 1) a knowledge of the inversion mechanism that created the form and 2) the relationship between the inverted form dimensions and the paleoflow parameters (e.g., how well does the current form reflect the paleoflow width?) Recent work [9] has documented the morphology and discharge-form relationships of a set of inverted channels in Utah formed through chemical cementation. On-going work is expanding such investigations to include lava-capped inverted channels. Here we provide an overview of this on-going work, including discussion of 1) paleochannel morphology for identification of inversion mechanisms, and 2) paleoflow width preservation for use in discharge calculations.

Terrestrial inversion processes: On Earth, fluvial features commonly become more resistant to erosion than the surrounding terrain through: 1) lava infill [10], 2) chemical cementation [11,12], or 3) deposition of a coarse-grained lag [13]. Subsequent erosion of the surrounding terrain is usually caused by base-level drop that increases river capacity and competence [1].

Cemented inverted channels in Utah: A set of exhumed, inverted channels in central Utah, which provide an example of inversion through chemical cementation, conform to this general sequence of events (see summary by [14]). The fluvial sediments comprising the beds of these channels were laid down during the early Cretaceous and buried by marine sediments during the late Cretaceous. Groundwater flow through the more porous fluvial sediments preferentially to the finer-grained overbank deposits cemented the channel bed with calcium and quartz cements. Following base level lowering, the cemented paleochannels were exhumed within the last 650,000 years. The morphology of the inverted channels preserves much flow sedimentology, including cross-bedding and point bars [9].

Stanislaus Table Mountain: An inverted paleochannel in northern California provides an example of inversion through lava infill (Fig. 1). The Stanislaus (or Tuolumne) Table Mountain (STM) in the western Sierra Nevada, with the best exposures between Columbia and Knights Ferry, California, stretches discontinuously over 100 km southwestward proximal to the present-day Stansilaus River [15,16]. The lava that filled the paleo-Stanislaus River was erupted from the Little Walker Caldera. The more headward reaches of the network either were never inverted, may have not been preserved, or are buried. However, at least 16 flow junctions are preserved in inverted relief [16]. The lava either may have flowed down the tributaries or may have backed up the tributaries at these junctions; the point-location of the source vent and the short length of the paleotributaries suggests the latter mechanism. At the distal end, the STM is buried beneath the Mehrten Formation. The fluvial sediments stratigraphically beneath the STM are cliff formers and therefore difficult to distinguish remotely from lava.

Morphology and surface texture: The STM indicates that lava-capped paleochannels can be distinguished remotely from cemented inverted paleochannels in several ways on the basis of morphology. The lava is columnarly jointed, a morphology that may be observed with high-resolution images of Mars [cf. 17]. The columnar joints provide planes of weakness along which the lava is collapsing, creating wide lateral rubble piles that often bury the contact of the lava with the underly fluvial sediments. The lava is also collapsing along planes of weakness parallel to the flow direction. Collapse along these longitudinal fissures contributes large, intact blocks of lava to the basal rubble.

The surface texture also provides an indication of formation by lava capping. A series of straight lineations are orientated across the STM, and change azimuth at STM bends, thereby maintaining a flow-transverse orientation. This behavior is consistent with compression and buckling of cool lava surface as it flowed around channel bends. Another set of relatively straight, transverse lineations is ascribed to regional tectonism [15]. Isolated, slightly sinuous lineations decrease in elevation either downflow or towards the edges of the Stanislaus Table Mountain, suggesting their formation as runoff gullies. Although the precise causes of the lineations remain to be tested, the lineations are dissimilar from the arcuate, semi-concentric lineations visible on scrolled floodplains.

Flow width: Hydrologic information can be inferred through empirical form-discharge relationships using various form parameters [18]. Of these parameters, width is one of the easiest to obtain in an erosive environment with only limited feature preservation.

The STM varies signficantly in width, by up to an order of magnitude in some locations. At the northern end of Tulloch Dam Road, minimum STM plan view width is a few hundred meters. The side view provided by lateral erosion by the present-day Stanislaus River, shows that in this narrower upstream reach, the columnar jointing is vertical, indicating horizontal cooling surfaces, i.e., the channel floor and the atmosphere. In comparison, at the southern end of Knights Ferry Road, the planview lava width increases to ~2 km and thickens due to a significant drop in elevation of the contact between the lava and the underlying unit. In this location of wider and thicker lava, the columnar jointing is curved or angled, indicating cooling against an angled surface such as the valley wall. These observations suggest ponding and cooling of the lava at a broad, local depression within the paleovalley.

Aerial views show multiple locations of lava ponding, connected by reaches where the STM is thinner in plan view. The thinner reaches (~150 m) are interpreted as more accurately representing the paleochannel flow, as the consistent lava width indicates that the lava did not overflow the channel banks. In general, the distal reaches are wider than the headward reaches.

Conclusions: These observations indicate that: 1) lava-capped inverted channels may be distinguished from other types of inverted channels through the presence of columnar jointing, basal rubble piles, and straight or semi-straight surface lineations. 2) Paleoflow width preservation is variable. Sites of ponding likely exceed paleoflow width, whereas narrow reaches (probably paleoflow constrictions) likely preserve flow width, although collapse may reduce observed width below paleoflow width. Thus, careful examination of landform margins is necessary to correctly determine paleoflow width. Comparison with lava-capped channels in southern Utah [19] will allow testing of these observations.

Application to Martian inverted fluvial features. Based on morphological/field-based observations of both the cemented inverted channels in Utah and the lava-capped STM, Mars shows examples of both lava-capped and cemented inverted fluvial features. The STM was previously suggested as an analog for a broad, flat-topped, sinuous ridge in Mangala Valles [20]. The linear surface texture and variable width support this interpretation, although the feature lacks significant basal rubble. Inverted channels and floodplains in the Aeolis/Zephyria Plana (AZP) region show steep sides and concentric, curved lineations, interpreted as scroll bars on a meander belt [7]. As lava infill would have obscured this texture, these features are inferred to have been indurated by chemical cementation.

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Figure 1: Oblique aerial view of the Stanislaus Table Mountain, showing collapse, longitudinal fissuring (both on the right), and lineations (e.g., left foreground). Buildings on left suggest scale.