STRATIGRAPHIC ARCHITECTURE OF COMPOUND CHANNEL-FILLING DEPOSITS IN THE CEDAR MOUNTAIN AND MORRISON FORMATIONS, UTAH: STRATIGRAPHIC ANALOGS TO MARTIAN SINUOUS RIDGES.

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Introduction: Topographically-inverted fluvial deposits, presented as sinuous ridges, are located across the surface of Mars and have been interpreted in a number of different ways which have led to significant variations in paleo-environmental interpretations [1-9] The linchpin of each paleo-environmental interpretation has repeatedly been the stratigraphic interpretation of the sinuous ridges; however, the way in which the surface topography of the ridges is controlled (or not) by the stratigraphy of the ridge has never been fully addressed.

Interpretation of the stratigraphy contained within these features on Mars benefits from detailed study of similar features on Earth. Here we present initial results from an analog field study at eastern Utah. Both formations contain fluvial deposits that have been topographically inverted via selective erosion of surrounding material [10,11]. The goals of this analog field study are: (1) to characterize and compare the stratigraphic architecture presented within both formations; (2) understand the connection between the deposits and the channels they filled; and (3) to correlate stratigraphy with visible and topographic expressions observed with remote sensing data, with the goal of aiding future interpretations of sinuous ridges on the surface of Mars.

Geologic Context: The Jurassic Morrison and Cretaceous Cedar Mountain formations of eastern Utah both feature outcrop of channel-filling deposits that are well-exposed through a process of topographic inversion. Topographic inversion of a channel-filling deposit requires burial and cementation, followed by exhumation via erosion that favors the removal of fine-grained floodplain strata relative to well-cemented, coarser-grained channel fills [10-11]. The results of this process are ridges over 30 m high in the Cedar Mountain Formation, and outcrop up to 17 m above the surrounding terrain in the Morrison Formation. In both formations, the deposits are predominantly composed of sandstone and conglomerate.

Methods: Fieldwork in the Morrison Fm. and Cedar Mountain Fm. focused on field mapping of a large compound channel outcrop and two ridges defining compound channel-fills. We collected the following datasets using a Phantom Vision 2+ UAV with 20-30 ground control points per deposit: (1) 5-cm resolution aerial ortho-images; (2) 20-cm resolution digital elevation models derived photogrammetrically from these aerial photos (Fig. 1). Maps were made from these data and brought into the field to: (1) map the location and size of ~1500 sets of cross-strata along the top surface of the outcrops, including measurements of paleoflow direction and sediment composition; (2) map the location and dip directions of the lateral accretion surfaces and slip faces of interpreted point bars and free bars; and (3) map the contacts between stacked channel-deposits. Stratigraphic sections were measured roughly every 100 m around the perimeters of both Cedar Mountain ridges.

Results: Bar forms are preserved within the channel-filling deposits. Bar type and orientation have been interpreted using stacked sets of cross-strata that preserve dune migration directions that were partially forced by the larger-scale bar topography. Dune migration directions are observed to diverge and converge around exhumed bar forms that exist as local topographic highs on the top surfaces of sinuous ridges. The preservation of ancient bar-form topography in the rock record is hypothesized to be the result of a rapid channel avulsion, which quickly diverted the water and sediment transport to another location. This "shutting off" of channel transport is interpreted to allow for preservation of the channel-bottom topography present at the time of avulsion.

In the Cedar Mountain Fm., fine-grained intervals separating sandy and gravelly channel-fills are interpreted as erosional remnants of floodplain deposits based on grain size and evidence of pedogenesis. These relatively thin intervals document periods of inactivity within a channel following avulsion and during which the channel is transferred to the floodplain environment and filled with fines. Overlying coarser-grained channel-filling deposits mark the re-occupation of an underfilled channel, a diagnostic stratigraphic property of these net-aggrading, avulsive paleo-environments. The imperfect stacking of successive channel-filling deposits produces discrete topographic benches along the surface of an inverted ridge. By identifying these surfaces, we have found that not only are there are multiple stacked channels preserved within a single ridge, but there are frequently multiple channels exposed along the top surface of a ridge. These ridges are compound stratigraphic features representing multiple episodes of channel reoccupation. Evidence that ridges are compound features on Mars has been used to constrain paleo-environment in previous studies [1].

Conclusions: The Cedar Mountain and Morrison Fms. of eastern Utah demonstrate that there is potential for a complex, time-integrated history of fluvial activity to be stratigraphically preserved within sinuous ridges on Mars, and that ridges should not be simply thought of as 'frozen' individual channel forms. Channel-stacking, which is indicative of a net-depositional paleo-environment where avulsions and channel-reoccupations are common [12], can be identified topographically at HiRISE resolutions, although observations at this scale most realistically provide minimums for the number of channel-reoccupations preserved within a ridge. Work concerning architectural differences between the two formations, and between the aggrading vs. pre-avulsion channel fills, is ongoing. Such stratigraphic and sedimentologic differences that are associated with the modern erosional form of the outcrops will certainly be useful for interpreting similar features on Mars.

References: [1] Cardenas B. T. et al. (in review) [2] Kite E. S. et al. (2015) *Icarus, 253,* 223-242. [3] DiBiase R. A. et al. (2013) *JGR: Planets*, *118*, 1285-1302. [4] Burr D. M. (2009) *Icarus*, *200,* 52-76. [5] Williams R. M. E. et al. (2013) *Icarus*, *225,* 308-324. [6] Davis J. M. et al. (2016) *Geology*, *44*, 847-850. [7] Lefort A. et al. (2012) *JGR: Planets*, *117,* E3. [8] Lefort A. et al. (2015) *Geomorphology*, *240*, 232-136. [9] Matsubara Y. et al. (2015) *Geomorphology*, *240*, 102-120. [10] Williams R. M. E. et al. (2011) *GSA Special Papers*, *483*, 483-505. [11] Nuse B. R. (2015) *MS Thesis, Colorado School of Mines.* [12] Mohrig D. et al. (2000) *GSA Bulletin, 112,* 1787-1803.

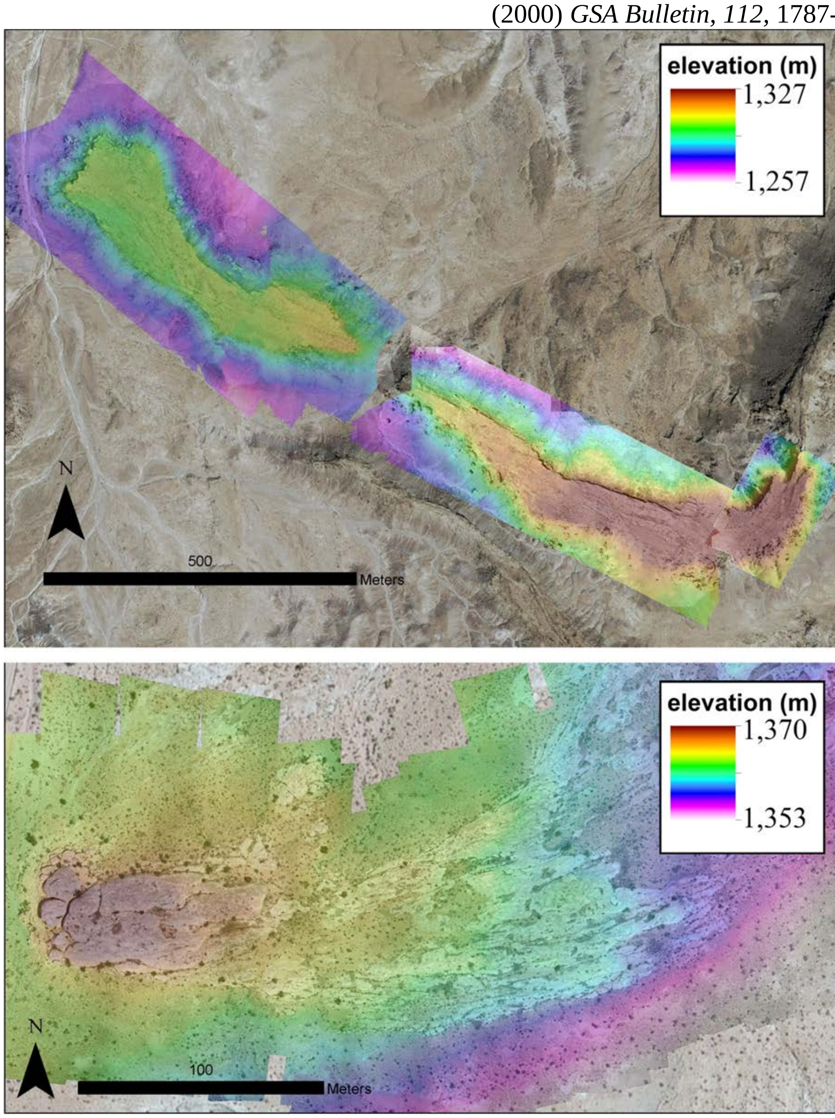

Figure 1 – Digital elevation models of the topographically-inverted channel-filling deposits of the Cedar Mountain Fm. (top) and Morrison Fm. (bottom). The models are derived from stereo-pair images collected by overhead drone surveys.