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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1. Introduction

-Erosionally-generated topography south of Green River, Utah is the result of the topographic inversion of amalgamated fluvial channel-belts of the Cedar Mountain and Morrison Fms. (Fig. 1).

-The 3-D nature of the outcrops allows for a detailed study of the amalgamated channel-belts

-Characterization of the deposit architecture at several spatial scales will improve our understanding of the sedimentology of channel-belts, including bar form and bedform stratigraphy

2. Methods

Several datasets gathered during a field campaign:

(1) 5-cm resolution aerial orthoimages collected via drone (Fig. 1)

(2) 20-cm resolution DEMs derived photogrammetrically from these aerial photos (Fig. 2)

(3) maps showing location and size of ~1500 sets of cross-strata along the top surface of the outcrops, including measurements of paleoflow direction and sediment composition (Figs. 3-5)

(4) maps showing the location and dip directions of the lateral accretion surfaces of point bars and free bars (Figs. 3,5)

(5) maps defining contacts between stacked channel-deposits (Fig. 6)

(6) stratigraphic sections measured every 100 m around the perimeters of both Cedar Mountain ridges.

3. Results

-Channel fills are composed of both point bars and free bars [alternate bars] (Fig. 3)

-Fine-grained intervals between sandstone and conglomerate channel-fills document periods of inactivity within a channel following avulsion and help define reoccupation of older channel by younger flow (Fig. 6). Eastward flow not represented in ridge slope (Figs. 2,6).

-Residuals between paleoflow direction from sets and nearest centerline trend normally-distributed around near zero (Fig. 7)

-In one ridge, stratigraphically-highest channel-belt shows free bar-like topography and increasing spread in paleoflow directions with higher topographic position. This is not observed in lower channel-fills (Figs. 8-9)

4. Discussion

-Ridges are compound, composed of several stacked channel-fills (Fig. 6,8). Erosional surface of ridge not equal to paleo-channel slope (Fig. 8), so erosional ridge surfaces cannot necessarily be used to measure paleo-flow direction

-Paleocurrent directions recorded in cross-strata of the highest of the stacked channel-fills steered by bar topography (Fig. 8-9)

-This indicates preservation of channel-bed morphology following a rapid shutting-off of transport (Fig. 8-9)

-Channel-bed morphology is not observed in lower fills (Fig. 9). Hypothesized to be eroded during channel re-occupation

-Overall, planform patch of continually re-occupied channel preserved in sinuous ridge form (Fig. 7), of interest to planform-geometry related paleoflow direction measurement (Cardenas et al., 2016, LPSC 47)

Hypothesis: Dimensions, aspect ratios, grain size of sets tied to the styles of bar growth & translation

Hypothesis: Morrison Fm. more laterally-stacked; may better preserve bed morphology, but not planform geometry

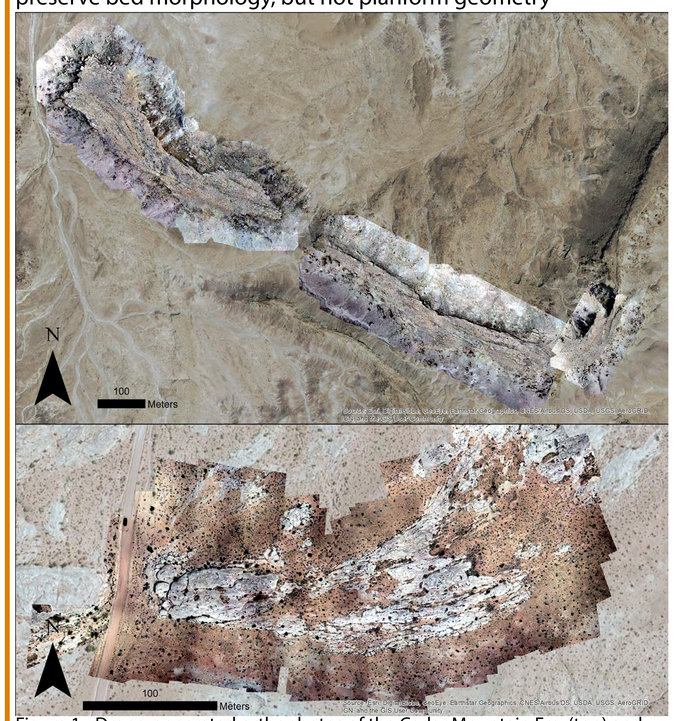


Figure 1 - Drone-generated orthophotos of the Cedar Mountain Fm. (top) and Morrison Fm. (bottom) outcrops.

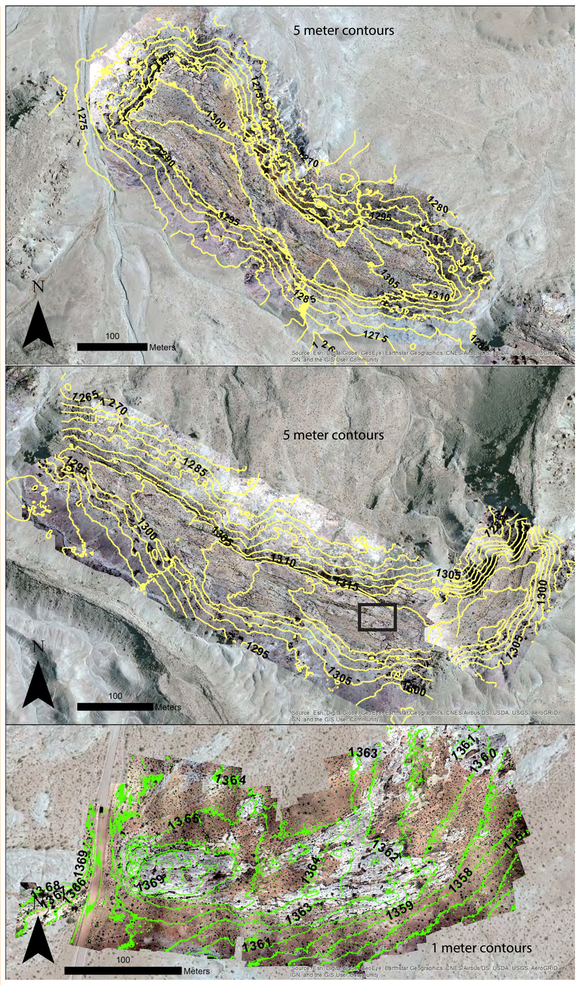


Figure 2 - Contours generated from stereo pair-derived DEMs. Top: western ridge of Cedar Mountain Fm. (5 m contours); Middle: eastern ridge of Cedar Mountain Fm (5 m contours). Box shows location of Fig. 5; Bottom: Morrison Fm. (1 m contours). Note that exhumation of the Morrison Fm. does not form ridges as prominent as the Cedar Mountain Fm.

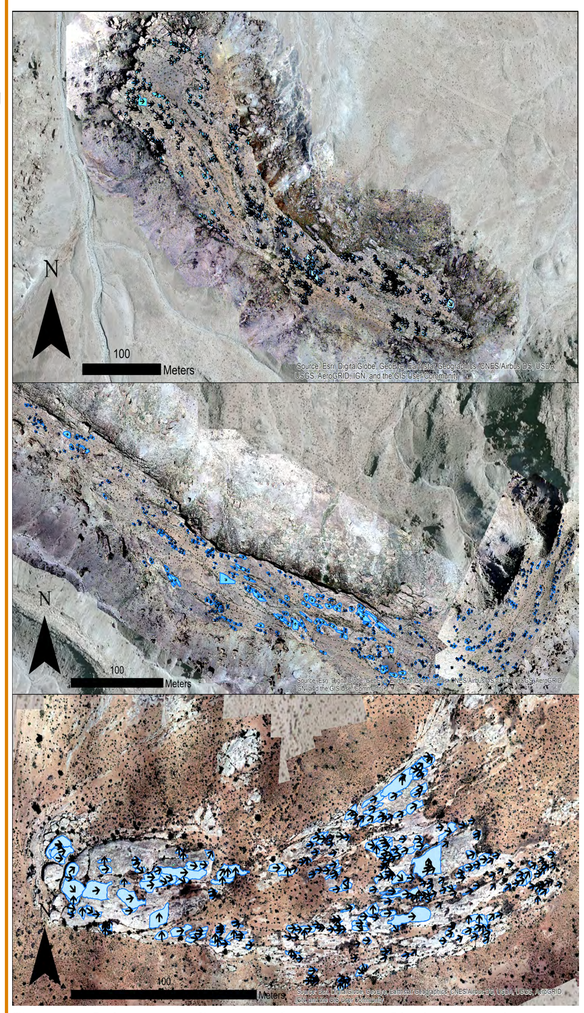
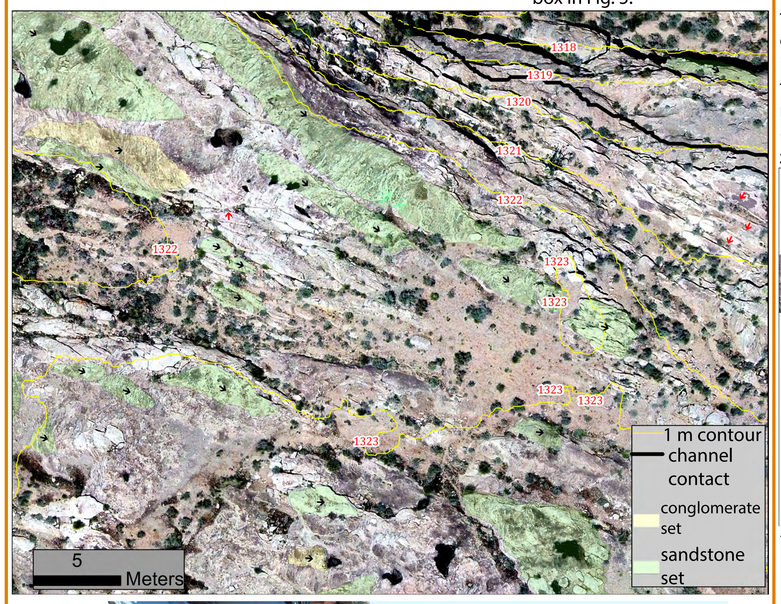


Figure 3 - Polygons outline sets of cross-strata. Black arrows show dip directions of cross-strata and lateral accretion surfaces along outcrop surfaces. Top: western ridge of Cedar Mountain Fm. Note the curvature in the spatial distribution of sets is similar to the curvature of a point bar. Lateral accretion surfaces dipping away from the center of curvature support the point bar hypothesis. Middle: eastern ridge of Cedar Mountain Fm. Bottom: Morrison Fm.

Fig. 4 (left) - Two examples of cross-strata along the upper surface of Cedar Mountain Fm. ridges mapped and measured for paleo-transport direction. Tim's legs for scale.

Fig. 5 (below) - Example of zoomed in drone orthophoto with sets of cross-strata mapped in green and yellow based on facies. Black arrows represent paleo-transport direction measured from dune cross-strata. Red arrows represent dip directions of bar lateral accretion strata. Location shown by black box in Fig. 5.



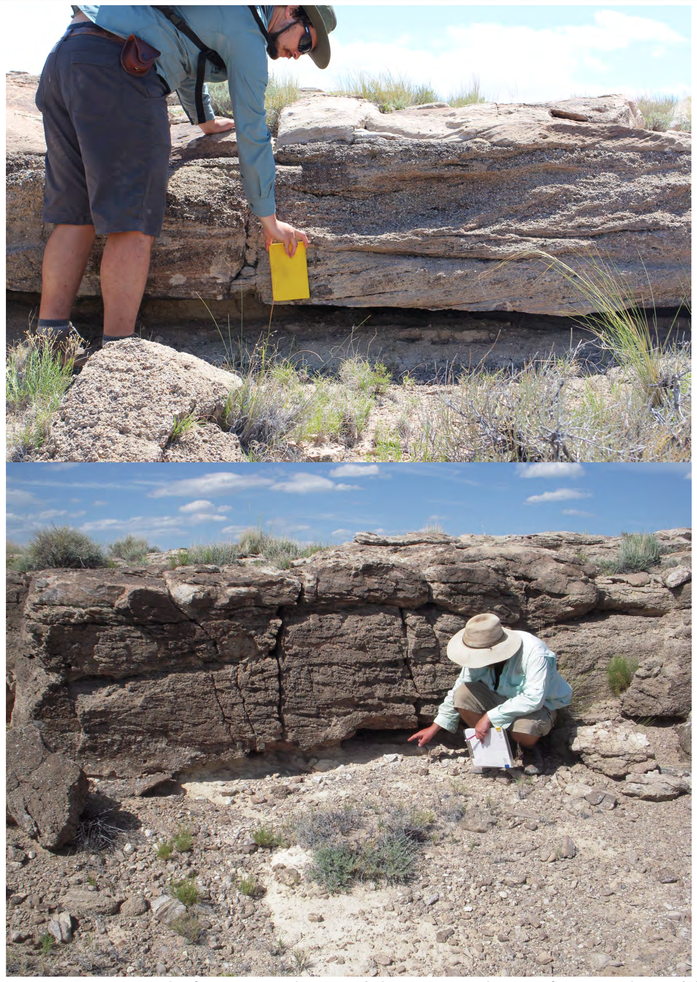


Figure 6 - Fine grained, often recessed, intervals between packages of coarser channel-fill represent periods of inactivity in the channel and contacts between stacked channel-fills.

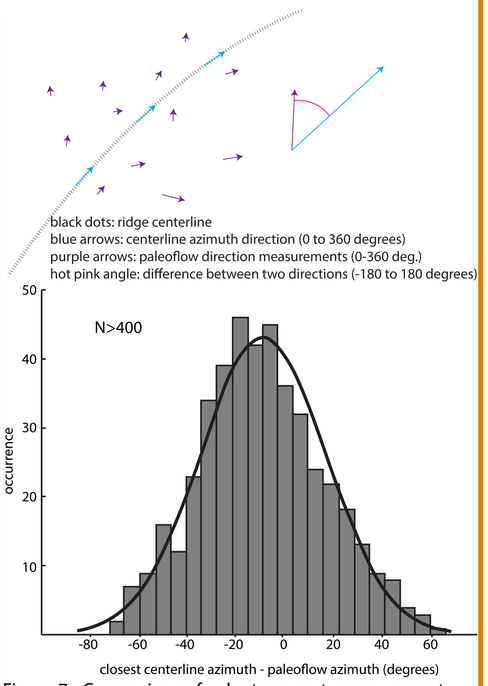


Figure 7 - Comparison of paleotransport measurements from dune cross-strata to the trend of the nearest ridge centerline point. Top: Diagram explaining measurement. Bottom: Histogram of these measurements with normal fit around mean. Kalmogorov-Smirnov test does not reject normality around mean at 95% confidence (-8.8 degrees, <.5 st. dev from zero.) KS test rejects normality around zero. Measurements only from Fig. 8 location.

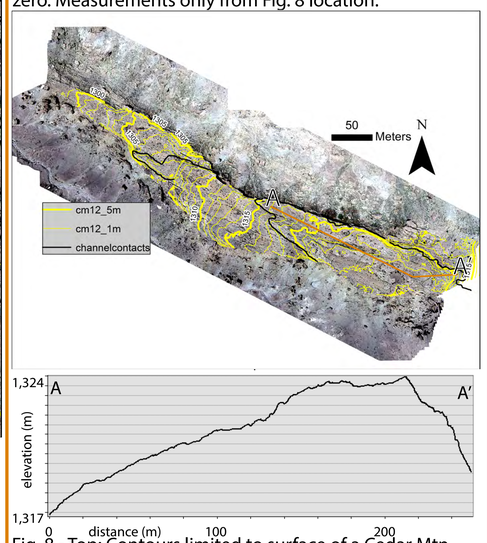


Fig. 8 - Top: Contours limited to surface of a Cedar Mtn. ridge. Note surface dips towards west, while paleo-transport was towards east (Figs. 3,5). Black lines mark stacked channel-fill contacts (Fig. 6). Profile A-A' shown in bottom part of figure. Bottom: Topographic profile A-A' is similar to that of a bar migrating towards east, with west-dipping bar stoss slope and east-dipping bar lee slope. Measurements in Fig. 9A taken from this location.

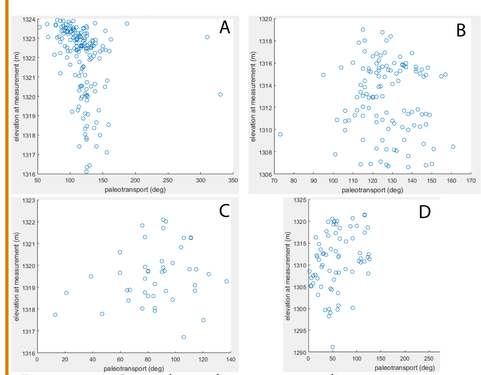


Figure 9 - A: Spread in paleo-transport directions increases with increasing elevation. Interpreted as steering by bar topography and preservation of a complete bar form. These measurements taken from the top channel-fill in a ridge composed of many channel fills (Fig. 8). This channel-fill also preserves a bar-like morphology (Fig. 8).

B-D: Measurements from stratigrapically-lower channel-fills do not display the same trend.

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