PLANFORM ARCHITECTURE OF FLUVIAL CROSS STRATA WITHIN THE CEDAR MOUNTAIN FORMATION, UTAH WITH APPLICATIONS TO MARS K. Stacey[1] and B.T. Cardenas[1], [1] Dept. of Geosciences, The Pennsylvania State University, University Park, PA 16802 Email: kns5750@psu.edu

Introduction: Preserved sedimentary structures within lithified fluvial deposits, in particular cross bedding (or cross strata), can provide a wealth of information about formative depositional settings and the history of surface water. A cross set is defined as a set of cross stratified layers contained by an upper and lower erosional bounding surface [1] with the strata within the set recording the position of the migrating dune's lee face. Cross set thicknesses, which are some proportion of the original bedform height, are ultimately controlled by aggradation rates, flow conditions, and trough depth [e.g., 2, 3].

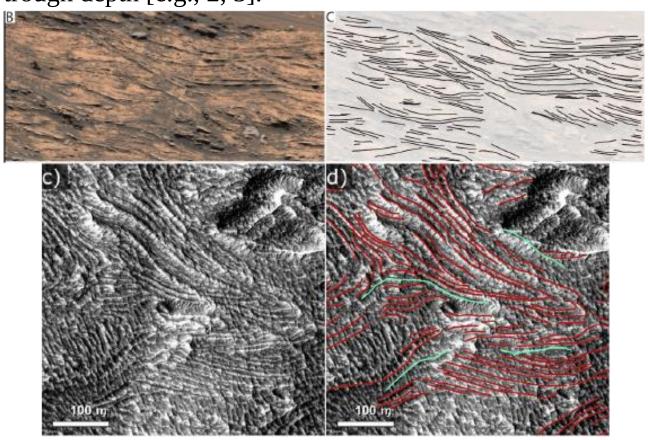

Fig. 1: Examples of cross bedding on Mars in plan-view. Top images are from the Carolyn Shoemaker Fm. in Gale Crater [4] and bottom images are from Aeolis Mons in Gale Crater [5].

With the rise of drone and satellite imagery being used in geomorphological and sedimentological analyses, there is an abundance of planform views of cross strata in sedimentary surfaces at locations where thicknesses cannot be measured (Fig. 1). However, there is also a dearth of quantitative tools for investigating cross strata architecture of sedimentary deposits in plan-view. One way to investigate the relationship between cross set geometry in cross sectional and planform views is to compare cross set widths and thicknesses within 3D exposed fluvial deposits. This new method could begin to fill our knowledge gap surrounding fluvial dune architecture and could aid in reconstructing paleo topography and paleo hydraulic conditions from exposed rock and imagery in plan-view.

Since the variability in scour depth defines erosional bounding surface locations and set thickness, we expect the same is true for plan view exposures where the cross set widths are similarly set by erosional bounding surfaces. We hypothesize that within a depositional unit, the distribution of cross set widths should be similar to the distribution of cross set thicknesses since they record the same information about the formative bedforms and flow conditions.

Background: The exhumed fluvial channel belts in the Ruby Ranch Member of the Cedar Mountain Formation in Utah are one such example of excellently preserved fluvial deposits that provide these 3D exposures, displaying cross bedding in plan-view along the top of the channel belt exposures that cross set widths can be measured from. These ridges are comprised of stacked channel belt deposits as a result of multiple episodes of channel abandonment and reoccupation, that became high standing relative to the surrounding topography due to differential erosion and exhumation of the coarser sandstone bodies [6,7,8]. These fluvial ridges are often used as a terrestrial analog to the numerous sinuous ridges on Mars, thought also to be of a fluvial origin [7].

Methodology: Field work was done to collect cross set widths from cross strata exposed in plan-view along an exposed ridge of the Ruby Ranch channel deposits within the Cedar Mountain Formation , which had a previously published dataset of 350 measured cross set thicknesses [6]. We sought to match this number of measurements. At six locations along the ridge top, we measured cross set widths along transects spaced 1 m apart and oriented perpendicular to paleoflow direction. In determining cross set width, we identified bounding surfaces by looking for evidence of truncation of cross strata and measured their position along a measuring tape to derive the widths (Fig. 2). In order to compare the cross set widths and thicknesses, we normalized each distribution by its mean and used a two sample Kolmogorov-Smirnov test (KS test) [9].

Results: The distributions of the two datasets (thickness and width) are shown in Fig. 3, where mean thickness is 13.9 cm with a standard deviation of 10.5 cm, and mean width is 129.4 cm with a standard deviation of 108.3 cm (Fig. 3). The mean width was 9.3 times the mean thickness and the standard deviation of the widths was 10.3 times the standard deviation of the thicknesses.

At a significance level of α=.05 the KS test failed to reject the similarity of the mean-normalized distributions (p=.12) meaning there is no statistically significant difference in the distributions.

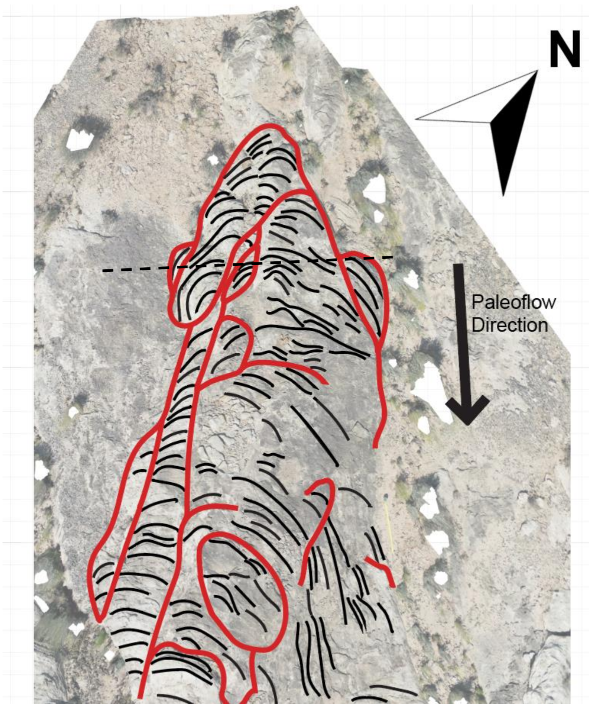

Fig. 2: Drone mosaic of a plan-view exposure of cross sets. Red lines represent bounding surfaces and black lines represent bedding planes. Dashed line is an example of a transect. Image is approximately 10 meters across.

Discussion: Our results indicate that the distribution of cross set widths has the same shape as the distribution of cross set thicknesses, with a scaling relationship of width to thickness distributions being approximately 10:1. This suggests that a distribution of cross set widths records the same information regarding bedform migration, aggradation, and geometry that a distribution of thickness records [e.g., 2,3]. This relationship should also apply to cross set widths measured at in-transport exposures [1].

This quantitative relationship between cross set width and thickness increases the number of suitable outcrops for sedimentological and paleohydraulic analyses. This is certainly useful with the rise in drone imaging on Earth, but is particularly important for planetary missions where time constraints may not allow for the slow exploration of an area for the most suitable outcrops for a particular type of analysis. For example, fluvial strata in Gale crater exposed at the outcrop Mont Mercou (Carolyn Shoemaker fm.) had plan-view exposures but no clear vertical exposures (Fig. 1)[4]. At the Jezero delta, both Perseverance and the helicopter Ingenuity may also observe plan-view cross strata.

We are currently testing whether a similar scaling relationship exists for aeolian cross sets. Wide swaths of mostly plan-view exposed Stimson fm. could be quantitatively analyzed. Plan-view exposures of aeolian cross sets have also been observed stratigraphically between the younger Stimson fm. and older, fluvial Carolyn Shoemaker fm., potentially recording the shrinking of Gale's ancient lake [10]. Given the large size of some aeolian cross sets, a relationship between aeolian cross set width, thickness, and kinematics could be applied to aeolian strata observed across the planet in HiRISE images (Fig. 1)[5].

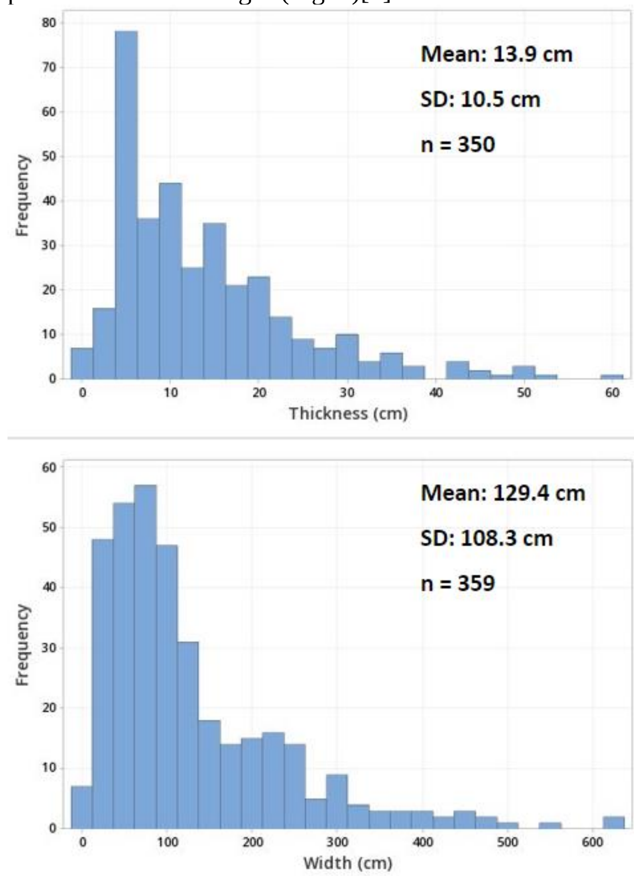

Fig. 3: Histograms of cross set thickness and width.

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