HIGH RESOLUTION ANALYSIS OF UNIT BAR ACCRECTION PATTERNS OF THE FERRON SANDSTONE MEMBER OF THE MACHOS SHALE, UTAH

Research Proposal

By

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Introduction

Point bars, the key indicators of modern meandering rivers (Durkin et al.2015)，have been extensively studied in modern fluvial systems (Walker and Cant 1984, Musial et al.2012). Understanding bar accretion patterns and channel migration patterns are critical for reservoir-characterization studies of oil and gas accumulation (Pranter et al.2007, Nardin et al.2013, Hubbard et al.2011); however, the study of ancient meandering-fluvial deposits is limited by scattered and incomplete plan view exposures.

In order to understand point bars, the concept of unit bars is important as a building block for compound bars. Point bars and braid bars in the early literature were implied to be fundamental bar units in river systems. However, newer studies suggest that these compound features built out of unit bars and add other sandy units, but the identification of unit bars in meandering belts is not well studied (Wang and Bhattacharya 2018, Moody and Meade 2014, Bridge 2003).

Point bars accumulate in response to channel-bend expansion and downstream migration processes (Bridge et al., 1995). In addition, scroll bars are considered as ridges of sand bodies that build into the complex formation of point bars in a downstream migration pattern (Figure 1.2B). Overall, unit bars can be superimposed by smaller-scale bedforms (Figure 2) or may consist of single sets of large-scale inclined cross strata, (Ex. lateral accretion surfaces) (Wang and Bhattacharya,2018). In some situations, the channel belt can also be deposited in a simple form called unit bars (Lunt and Bridge, 2004; Wout et al., 2010). Compound braid bars are often developed in the middle of a river channel where a compound point bar is formed at the edges of the channels (Figure 1).

This proposal focuses on a pair of Cretaceous meandering channel belts in the Ferron Sandstone Member of the Mancos Shale Formation in Utah (Figure 3), USA, that have perfect plan view exposures. Sediments within the formation were derived from the Cordilleran highlands adjacent to the foreland basin, which deposited as three delta complexes at the western edges of the seaway (Hill, 1982; Garrison and Van den Bergh 2004 ;). The Ferron Sandstone has been divided into three fluvial fed delta wedges (Figure 4), including the younger Last Chance delta, the older Notom delta, and the Vernal delta (Zhu et al.,2012, Bhattacharya and Tye 2004, Garrison and Van den Bergh 2004).

This study is focused on the Notom delta, which developed after 91.25 Ma (Zhu et al.,2012). 6 sequences, 18 parasequence sets, and 43 parasequences were identified (Zhu et al. 2012, Li et al., 2011). The study area is located on a series of fluvial sand deposits that are lying above the valley-fill bodies in sequence 1(figure 5). Two major sand bodies in the region will be studied, one is North of Neilson Wash near Hanksville,Utah (Figure 3,6B), about 1 km from the Coalmine Wash Road, and the other was located further to the East (Figure 6A). Several studies reconstructing paleo-hydraulic parameter, channel migration patterns and specific architectural elements from the same outcrop have been down using various methods (Wang and Bhattacharya 2018, Wu et al.2015, and Bhattacharyya and Bhattacharya 2015).

Previous Research:

In early study, Smith (1974) first introduced the term of “unit bars” as active bars with simple histories and predominantly depositional morphologies whose form depends on variables of local current and channel geometry. In his interpretation, unit bars tend to fine downstream if their long axis is parallel to flow. However, bars can become modified by erosion and subsequent depositional events such that they may lose their identity and no longer have simple sediment size distribution or structures. In this case, the depositional record of whole unit bars would rarely be preserved in ancient river systems. Cant and Walker (1978) also identified unit bars from their research on bar morphology from a braided sandy river. In their interpretation, the "horn" shaped sandy unit, form additional units to which other bars and dunes attach, forming more extensive sheet sandstones (Ex. compound bars), which matches Smith (1974)'s interpretation(Figure 8A).

In previous research, point bars and braid bars are considered as fundamental bar units that build up the channel belts. However, modern studies suggest that point bars and braid bars from by the accretion and complex growth of unit bars and other sandy element (Wang and Bhattacharya 2018, Moody and Meade 2014, Bridge 2003).

Few studies are done on reconstructing the patterns of smaller scale unit bars in ancient fluvial system. Ielpi and Ghinnassi (2014) studied point bar migration patterns from Jurassic meander belts of the Scalby Formation, however, they didn't observe any unit bars. Hartley et al. (2015) studied an upper Jurassic point bar complex of unit bars. They interpreted that the development of bank-attached bars with trough cross-strata represent unit bars.

Previously Wu et al. (2015) and Wang and Bhattacharya (2018) worked on areas A and B（Figure 6）, respectively and interpreted the river as low sinuosity in both areas. The discharge of channel, calculated by Wang and Bhattacharya (2018), falls within the same range of the data interpreted by Wu et al. (2015). Therefore, the scale of the channels and channel belts in these two areas are assumed to be similar.

Wu et al. (2015) interpreted Area A as a point bar sand body built in a scroll bar complex. Numerous paleocurrents were marked on the map (Figure 7) by analyzing the closely spaced rib and furrow structures. In addition, grain size pattern and rib width pattern were also illustrated (Figure 7). The rib widths decreased, and the grain sizes coarsened from north to south (Figure 7). In addition, inclined large-scale foresets are interpreted as indications of unit bars.

Previously, Wang and Bhattacharya (2018) indicated that the bar complexes are developed by the migration of a compound bar and superimposed unit bars in low-sinuosity rivers (Figure 1.2). The unit bars are interpreted as the core for the amalgamation and growth of attached dune sets that laterally accreted on the unit bar (Figure 2).

Unit bars were identified by cross-beds that are thicker than 0. 5 meters and by foreset ribs wider than 3 meters in plan-view (Figure 2). Numerous paleocurrents were identified using rib and furrow structures to distinguish basic elements from the compound sand bodies. However, the bar distribution map illustrated by Bhattacharyya and Bhattacharya. (2015), revealed different bar positions compared to Wang and Bhattacharya (2018) (Figure 8). As the figure indicated, Wang and Bhattacharya (2018) distinguished unit bars mainly at the upstream portion and within the cut-bank side of the channel, whereas, Bhattacharyya and Bhattacharya. (2015) identified unit-bars along the inner bank as well.

The reason for this difference is the clarity of the images, for example, the satellite images used by Wang and Bhattacharya (2018) have lower resolution compared with hill shade images analyzed by Bhattacharyya and Bhattacharya. (2015). Therefore, detailed maps of rib and furrow structures are critical for this research of investigating exact unit bar positions.

Dunes are one of the most common bedforms in the fluvial depositional environment and make up a large portion of sandy river deposits (Leclair and Bridge, 2001; Best, 2005). Study of dune characteristics is also critical for investigating the bar morphology.

Martin and Bhattacharya (2015) investigated the scaling relationships between channel width, bar width and dune width. In their study, the dune furrow widths were interpreted to be equal to the cross-flow wavelength of the sinuous crest of a hither-to unnamed 'dune-row' (Figure 9). They also found that the dunes can form atop of the bar bodies (Figure 10).

Research Objectives

There are three main components to this research objectives. Firstly, to study bar accretion patterns, for example, to distinguish unit bars in the bar complex in area A (Figure 6). This can be investigated by high-resolution mapping of the numerous rib and furrow structures from the imported aerial images and differentiating/dividing them according to their width to distinguish unit bars from the compound sand bodies. In addition, paleocurrents will also be identified and plotted on the pre-existing paleocurrent distribution map that was done by Wu et al., 2015 (Figure 7). In this case, new data will be superimposed to help correlate the bedding directions of the individual bars and dunes.

The second objective is to test whether the rib and furrow structures can be used to verify the location of unit bars in Area B that were mapped by Wang, 2018, and Bhattacharyya,2015, (Figure 9). This can be further investigated by measuring paleocurrents of unit bars using mapped rib and furrow structures. The last component will be to determine if the drone images present better resolution in assessing the details in the sedimentary structures and the development of the bar complex. This question will be answered during the investigation of the first two objectives.

This study will have applications in the geologic field and have potential economic values including the reservoir study of oil and gas accumulation.

Working Hypothesis

The hypothesis will be to test how paleocurrents and scales of rib and furrow structures can be useful in distinguishing unit bars from the high-resolution aerial map. The interpretation that "dune furrow widths are equal to the cross-flow wavelength" from Martin and Bhattacharya (2015) and the method from Wang and Bhattacharya (2018) of distinguishing unit bars from erosional bar contacts will be used to identify unit bars from the classic scrollbar in area A and the meander loop in area B.

Method and Analysis

To study this ancient meandering river, high-resolution aerial drone images were taken from three locations within the study region. Locating unit bars from the plan view images from Areas A and B will be done by detailed tracking and measuring of numerous rib and furrow structures. This process will be done using Pix4D and LIME software. In addition, the associated paleocurrents will also be measured using rib and furrows, to further distinguish the unit bar margins.

The aerial drone images for this thesis were collected during 5 days of fieldwork in Utah, from May 15th to 20th by Rachel Nelson (Master's student at McMaster University), including 3 areas, each with 4 datasets and overall approximately 6000 photos. The photos were taken at 15 meters elevation off from the ground. The goal of this research is to study the two areas within the research period.

The research will be initiated by distinguishing medium to large-scale trough cross-bedding in area A (Figure 11), which will possibly indicate unit bars. As discussed earlier, the furrow width can be used as a well-preserved record of cross-flow-width of ancient dunes (Martin and Bhattacharya 2015). Therefore, measuring the furrow width can help to distinguish dune bedforms from the unit bars. To do that, numerous rib and furrow structures, formed by the exposure of migration of dunes in the study field, must be accurately measured and traced. Then, the mapped dune scale rib and furrow structures will determine the position of unit bars from scrollbars. To make the data analyzable, the drone data with high-quality images will be imported from Pix4D into a complete zoomable aerial image in LIME.

In LIME, individual rib and furrow structures can be mapped in detail. During this process, a pattern of the size change of rib width can be identified and this may help to further outline the unit bar margins. In addition, closely-spaced rib and furrow structures can provide information about paleocurrent directions of bedsets, which can help to further distinguish bar positions. Detailed paleocurrent directions will be measured in area A and the result will be correlated with Wu et al. (2015) by superimposing the new data onto his pre-existing map (Figure 7).

In area B, similar methods will be used to identify exact unit bar locations on the aerial map. This process will also be done using the LIME software. The goal of this specific study is to calibrate previous unit bar distributions from the maps drawn by Wang and Bhattacharya

(2018) and Bhattacharyya and Bhattacharya. (2015) (Figure 8), using the high-resolution images.

Timeline

The proposed research project is expected to be completed by April 2019.Drone images were taken in May 2018. This research proposal was written for submission on October 5^{th} ,2018. A literature review will follow on November 2^{nd} ,2018. By March 1^{st},2019, a completed thesis draft will be submitted. The final thesis paper will be done by April 9^{th} ,2019 and follow a research presentation on the next day (April 10^{th},2019).

Figures

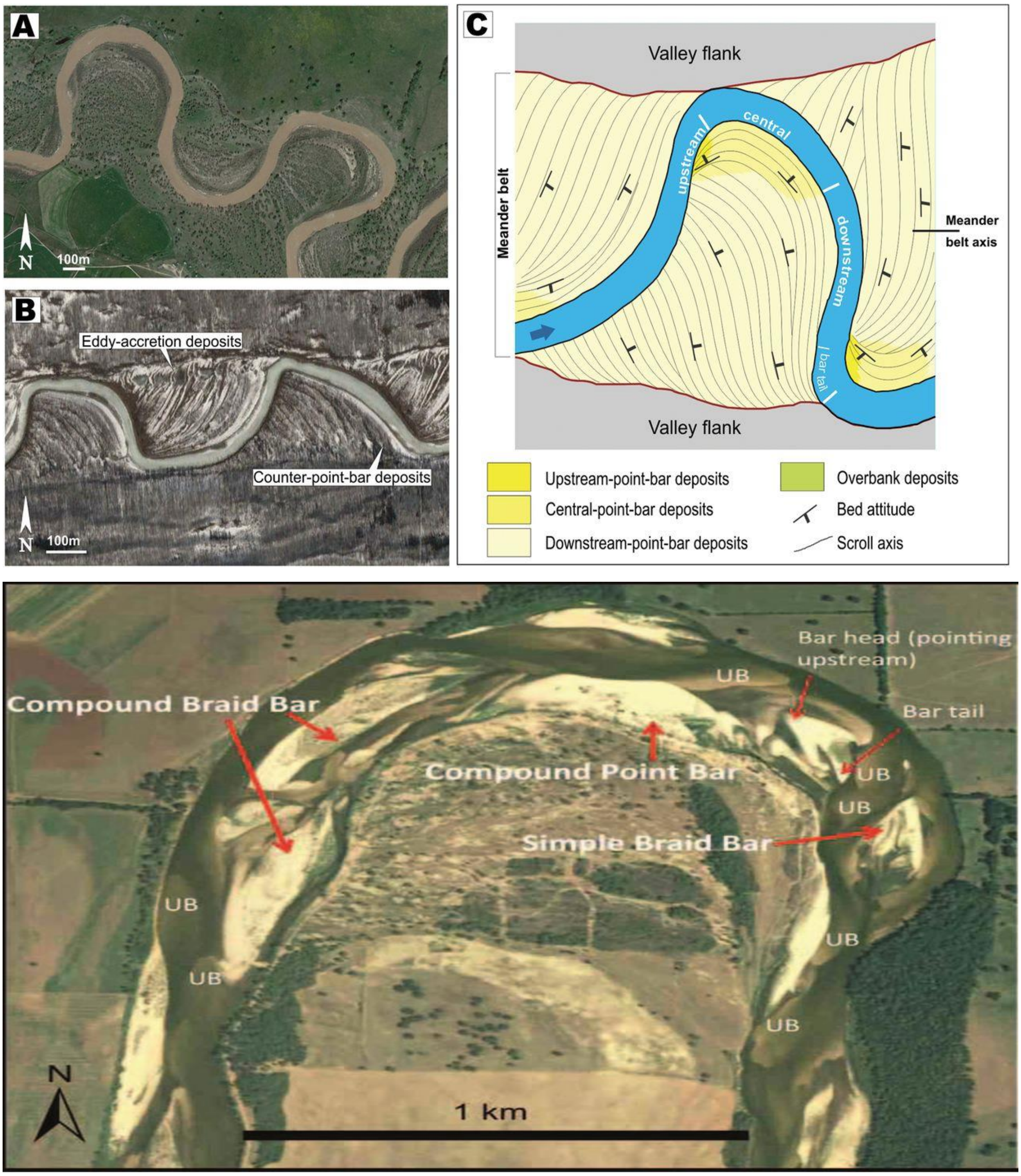

Figure 1: The top three images shows plan-view of Powder River of Montana (A), and Beaver River (B) downstream migration of Meander bends with obvious meander bend expansion. C shows a terminology for this study for studying the Meander belt deposits (Bridge et al., 1995, Ghinassi and Ielpi, 2015). The bottom image shows basic channel belt components in the Red River (Wang and Bhattacharya, 2018).

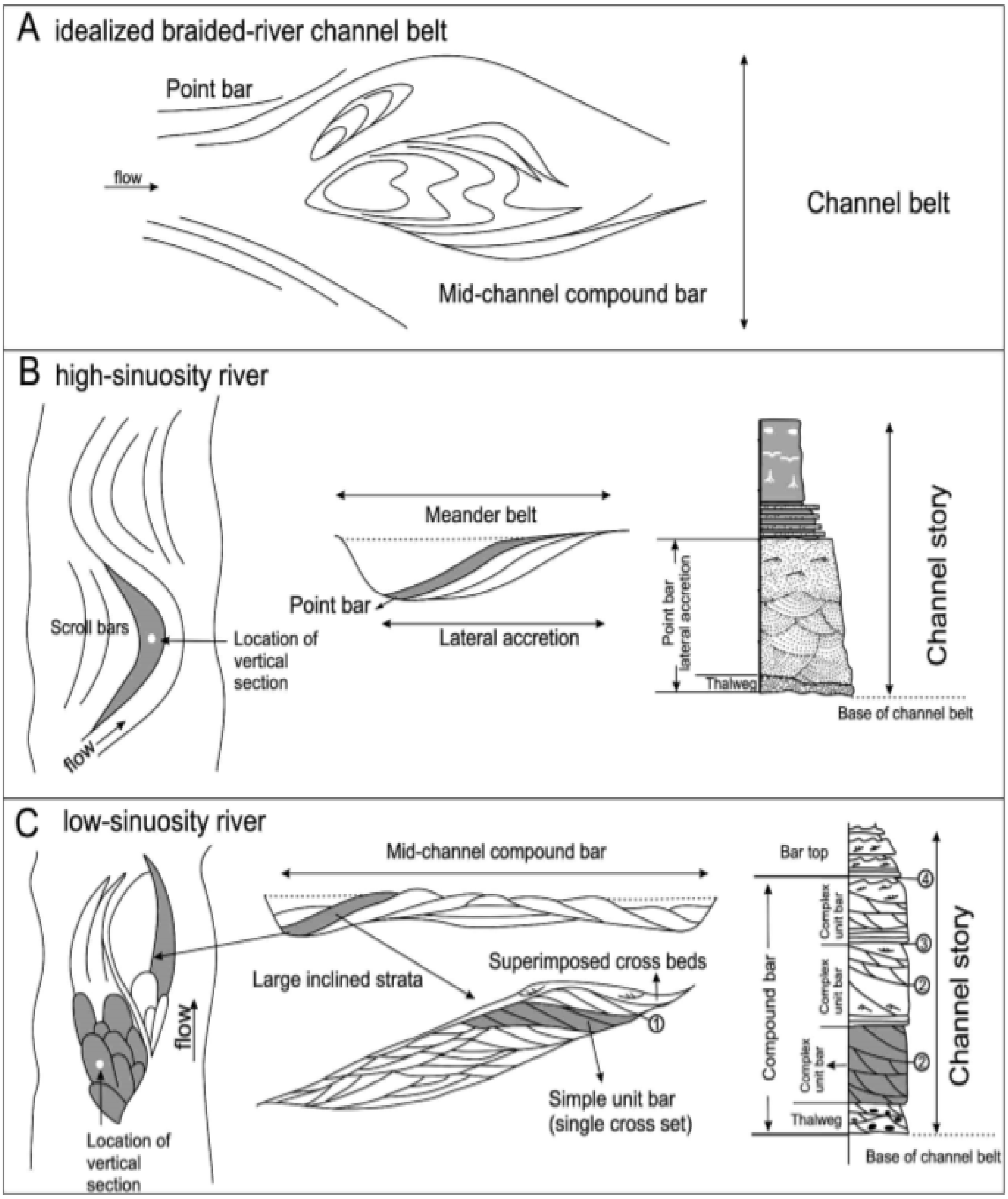

Figure 1.2: Fluvial-hierarchy diagrams modified and enhanced from Bridge (2006), Bridge and Lunt (2006), and figure 8Donselaar and Overseem (2008). Wang and Bhattacharya (2018) indicated that the bar complexes are developed by the migration of a compound bar and superimposed unit bars in low-sinuosity Rivers.

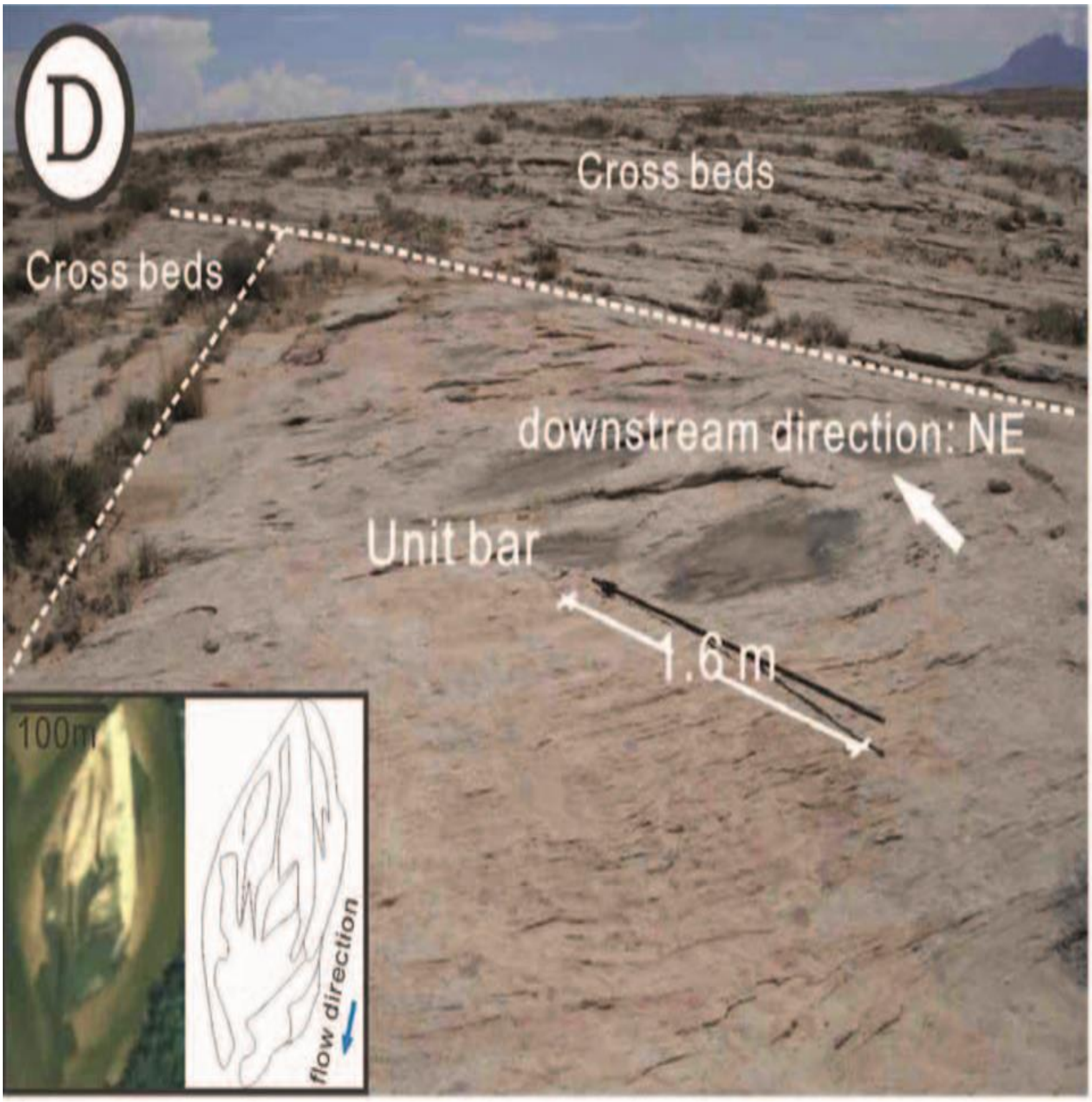

Figure 2: Taken by Wang and Bhattacharya (2018). The unit bars are interpreted as the core for the amalgamation and growth by attached dune sets that were laterally accreted. Unit bars were identified by cross beds that are thicker than 0. 5 meters and by foreset ribs wider than 3 meters in plan-view

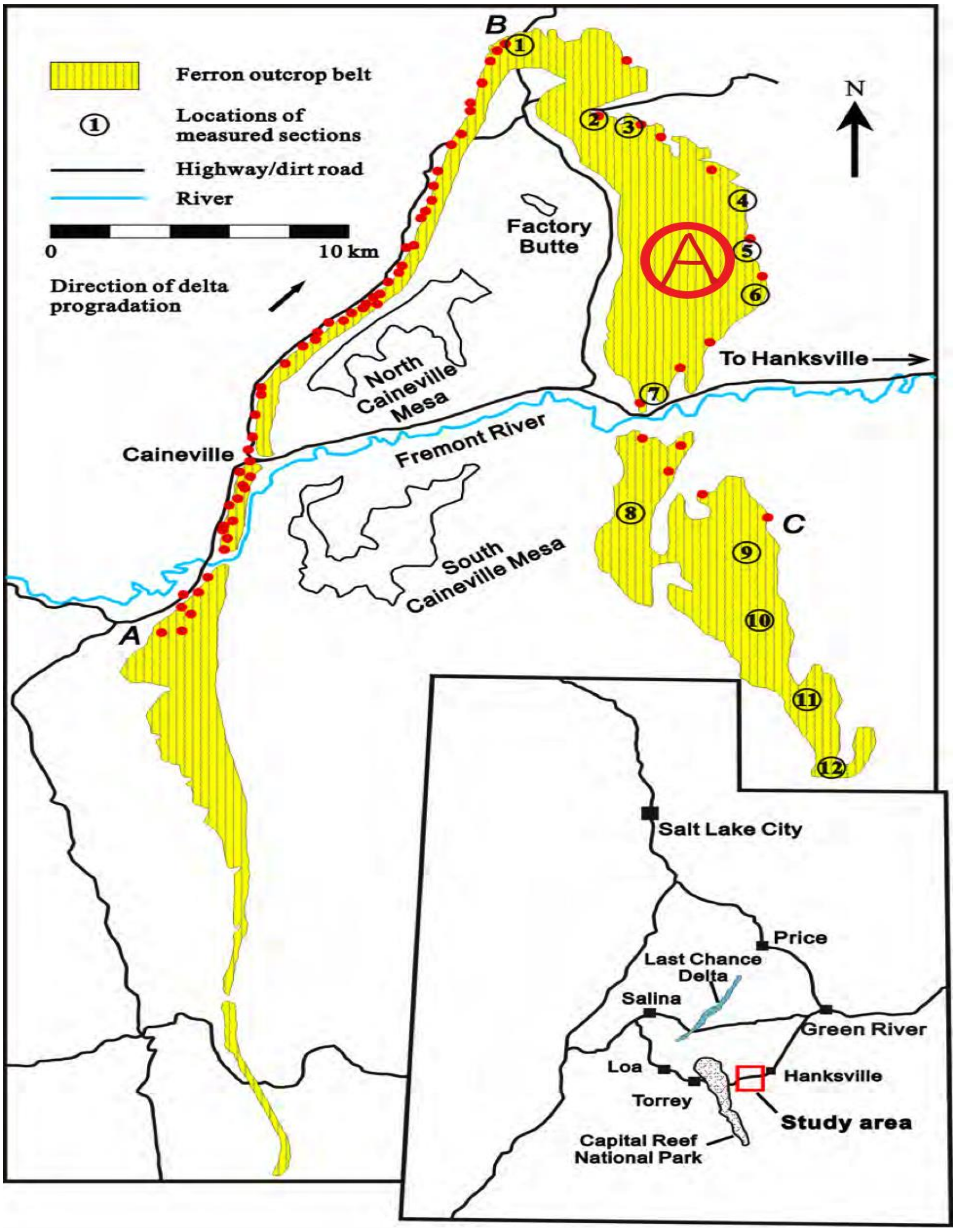

Figure 3: Overall area of the Notom Delta. The red circle indicates the current study area.

The image was taken from Li et al. (2015).

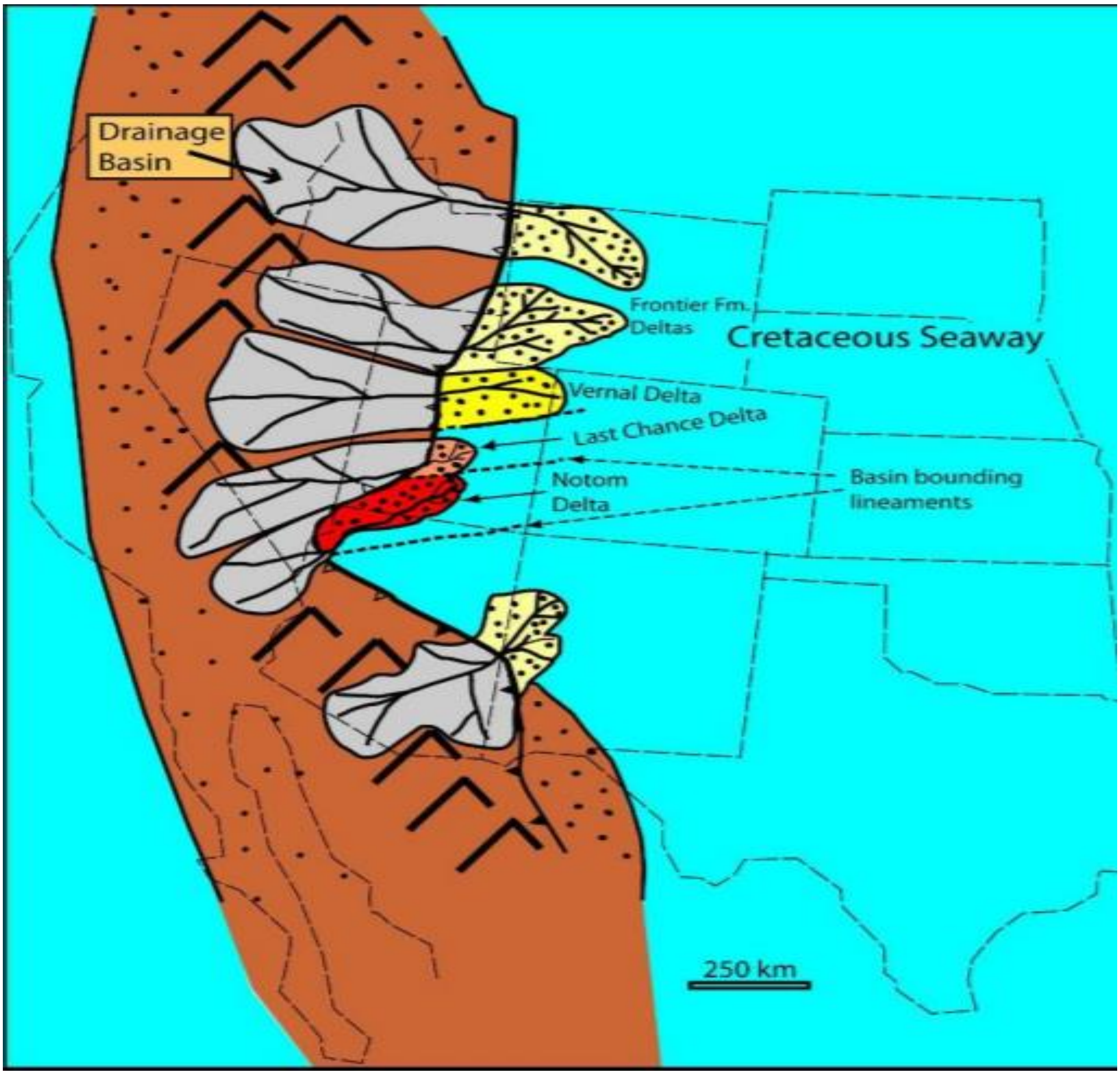

Figure 4: Paleo-reconstructed Western Interior Seaway. Delta complexes of the Ferron sandstone are shown above. The study area is within the red delta complex. (Modified from Bhattacharya and Tye, 2004)

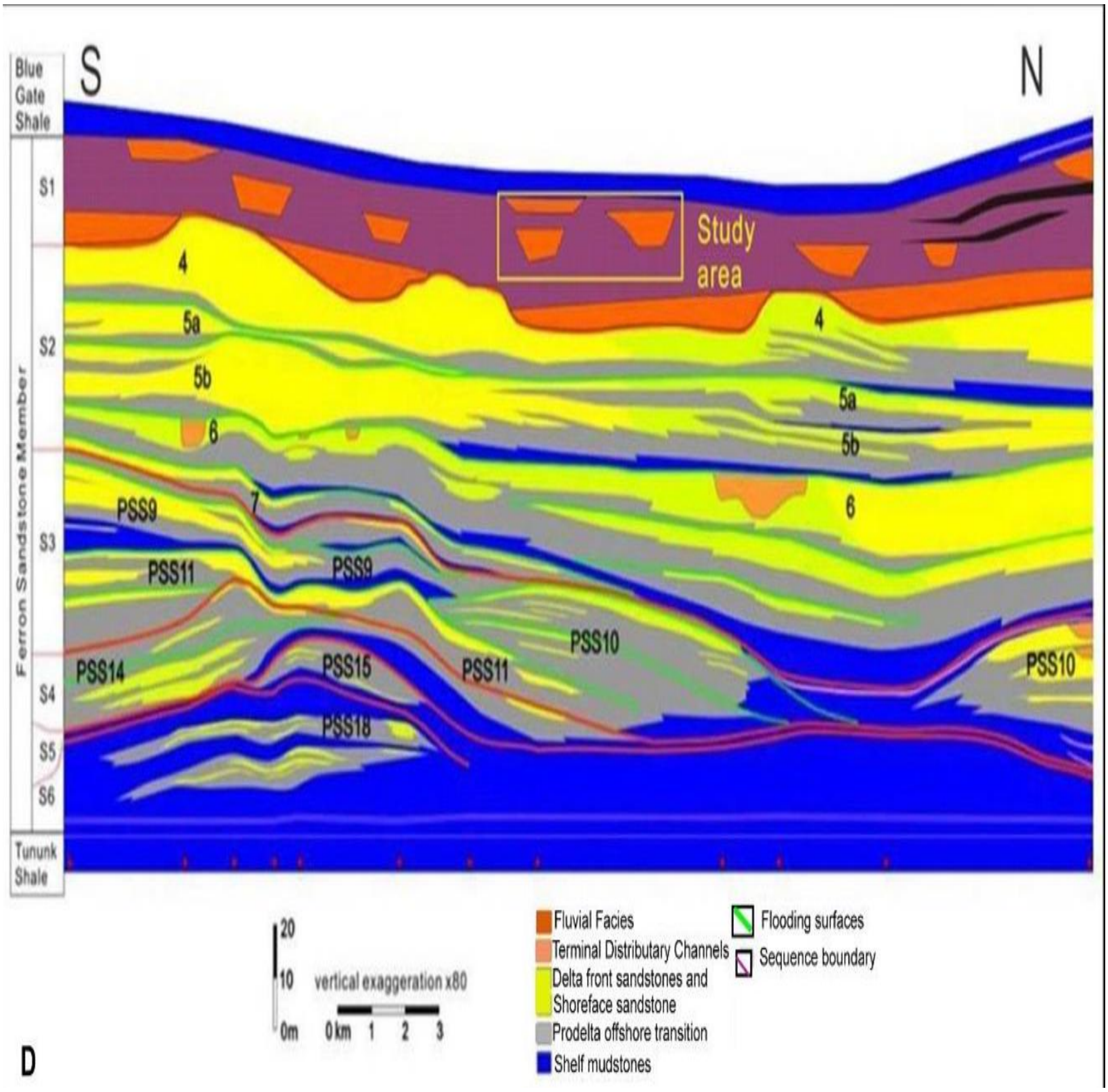

Figure 5: Regional stratigraphy of Ferron Notom Delta (Li et al. 2011). The yellow box marked the study area, which on top of the valley-fill deposits in sequence 1.

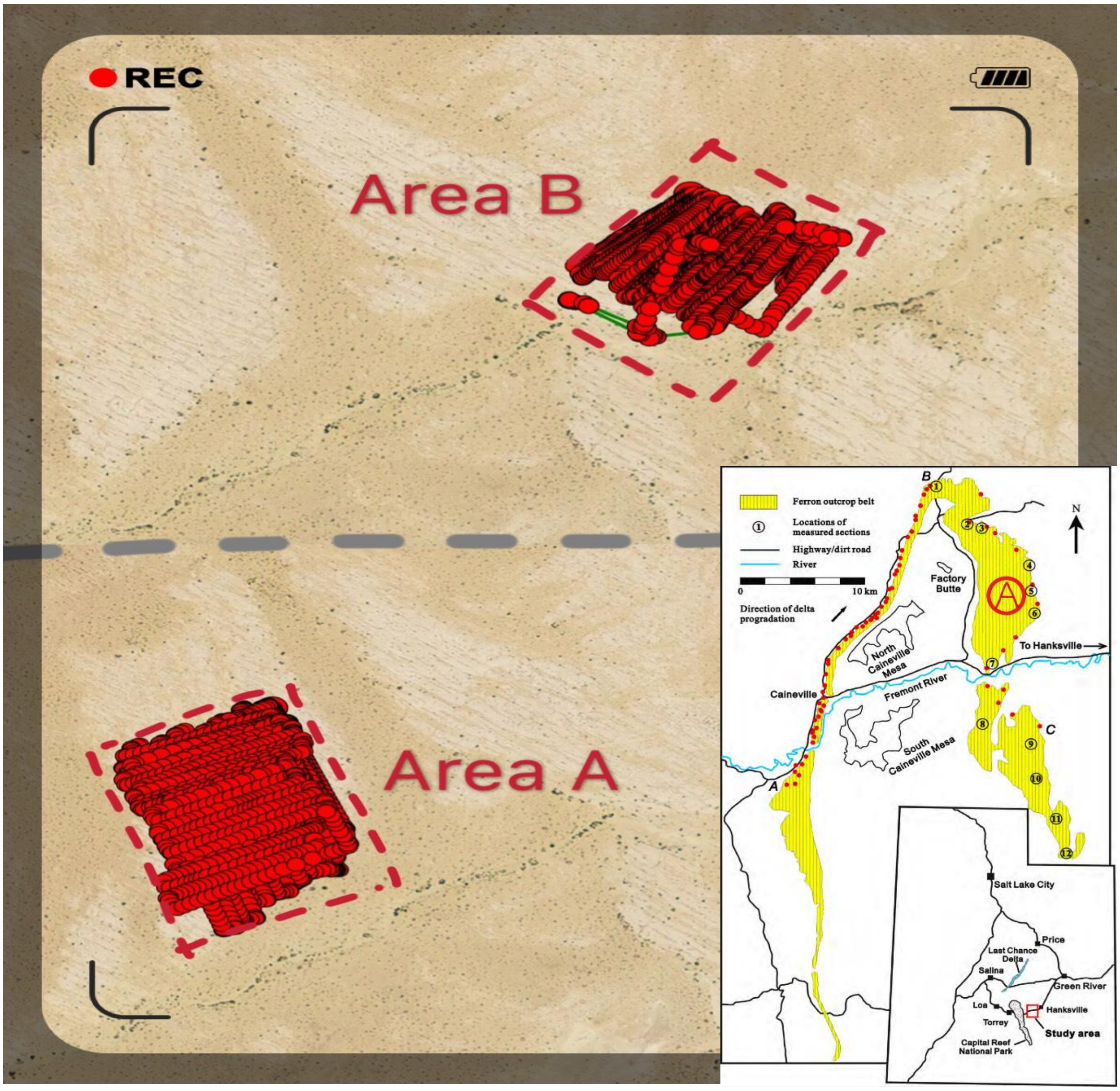

Figure 6: Current study area A and B. The gathered red dotted points are image collection point. Area A is located at the North of Neilson Wash in Hanksville, which is about 2 km from the Coalmine Wash Road. Area B is at the center of the region, close to area A. Both areas A and B are indicated from the red circle marked A in the overall Notom Delta image shown at bottom of the right.

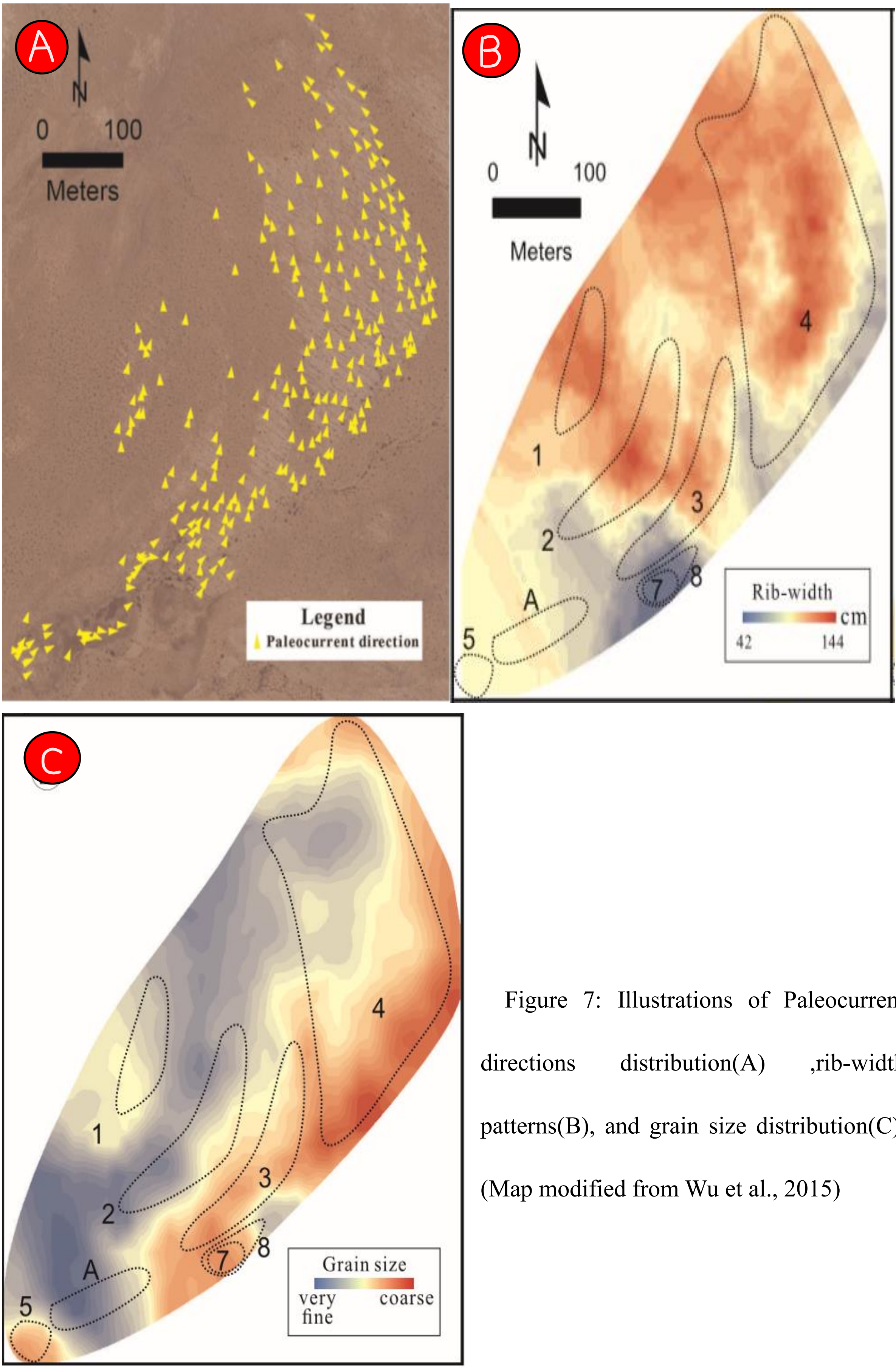

Figure 7: Illustrations of Paleocurrent directions distribution(A) ,rib-width patterns(B), and grain size distribution(C). (Map modified from Wu et al., 2015)

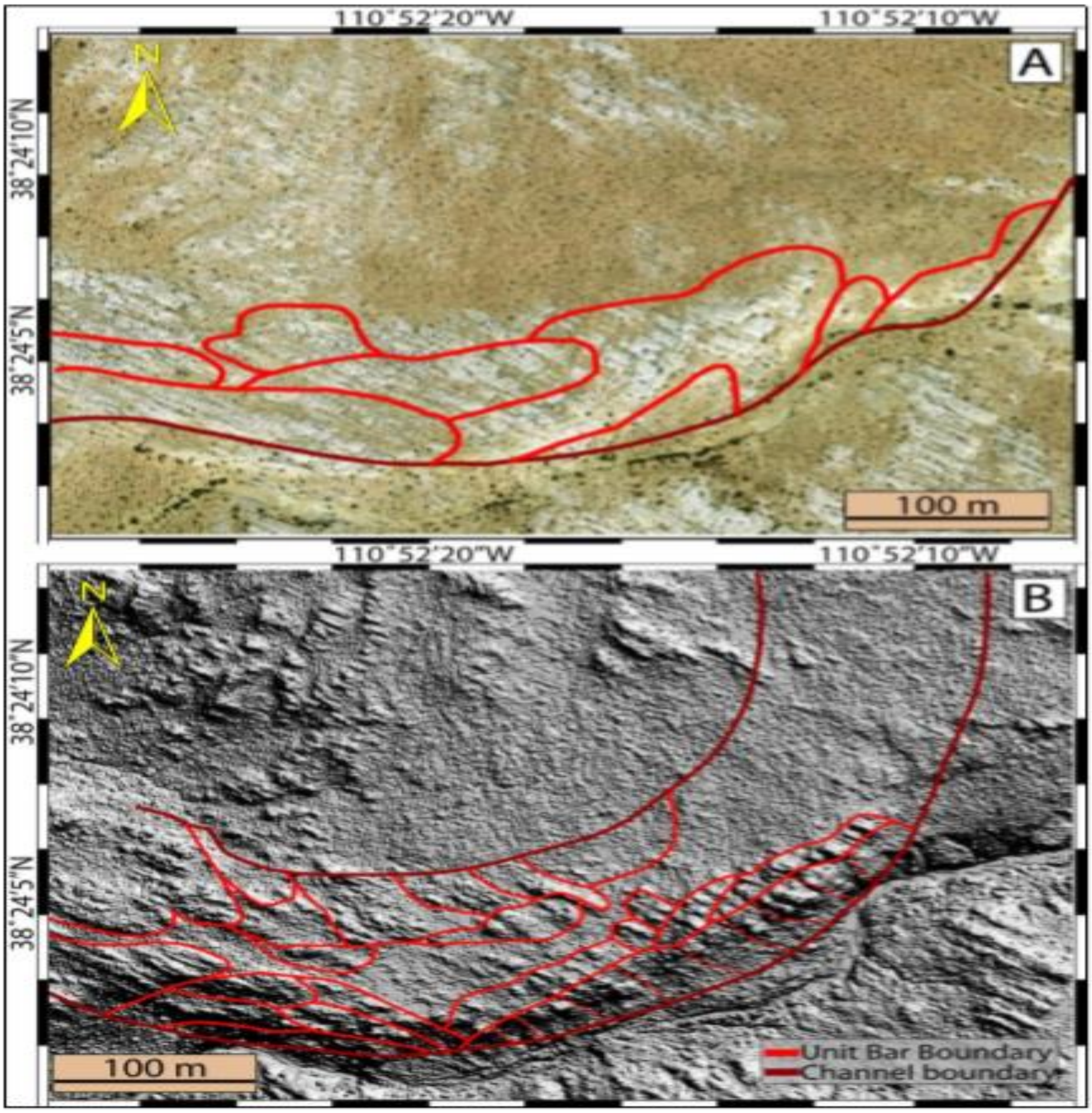

Figure 8: This figure shows a comparison between the inferred bar map as proposed by Wang and Bhattacharya (2018) (A) and the hill shade image drawn by Bhattacharyya and Bhattacharya. (2015).

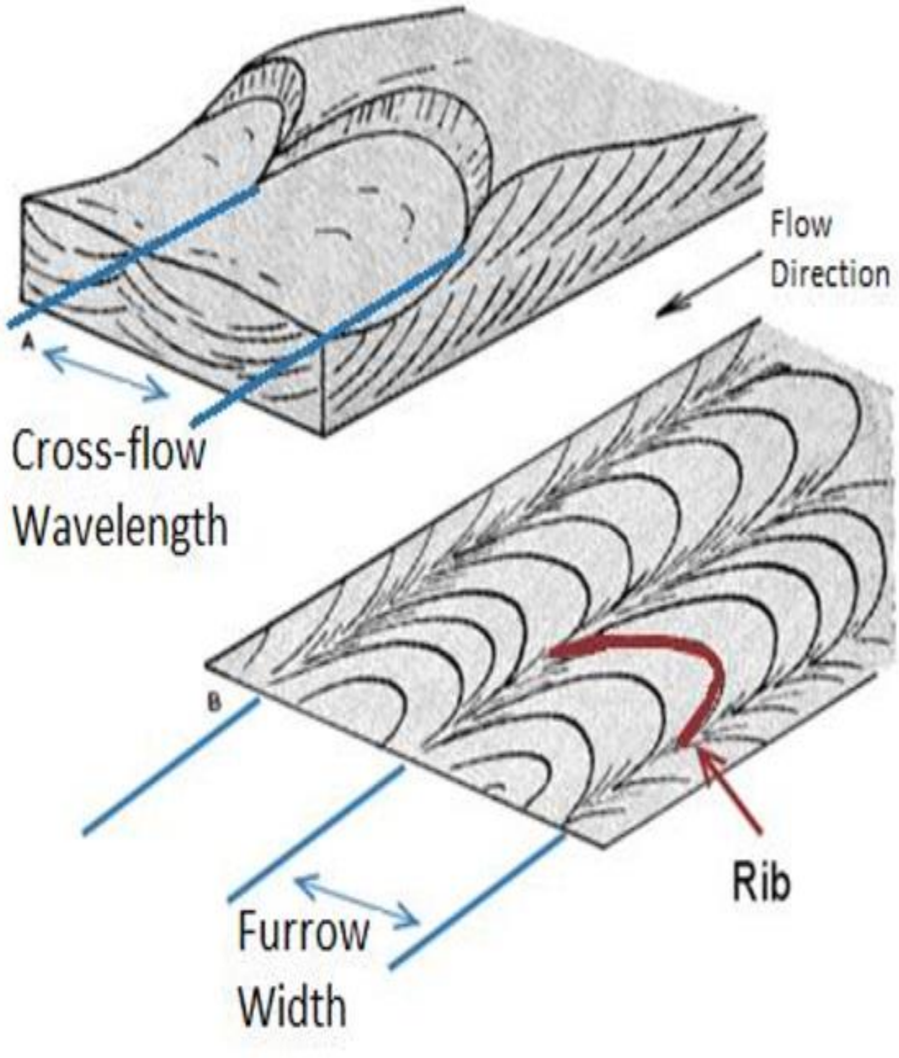

Figure 9: Illustration image of Duneforms and their corresponding preserved rib-and-furrow structures. The cross-flow wavelength shown in A corresponds to the furrow width seen in B (Taken from Martin H and Bhattacharya,2015, adapted from Dzulynski and Walton, 1965).

Figure 10: A bar form found in the Sewa River, Sierra Leone from Martin H and Bhattacharya, 2015. Duneforms can be seen growing on the bar, the interpreted crests of which have been outlined in blue in the lower picture.

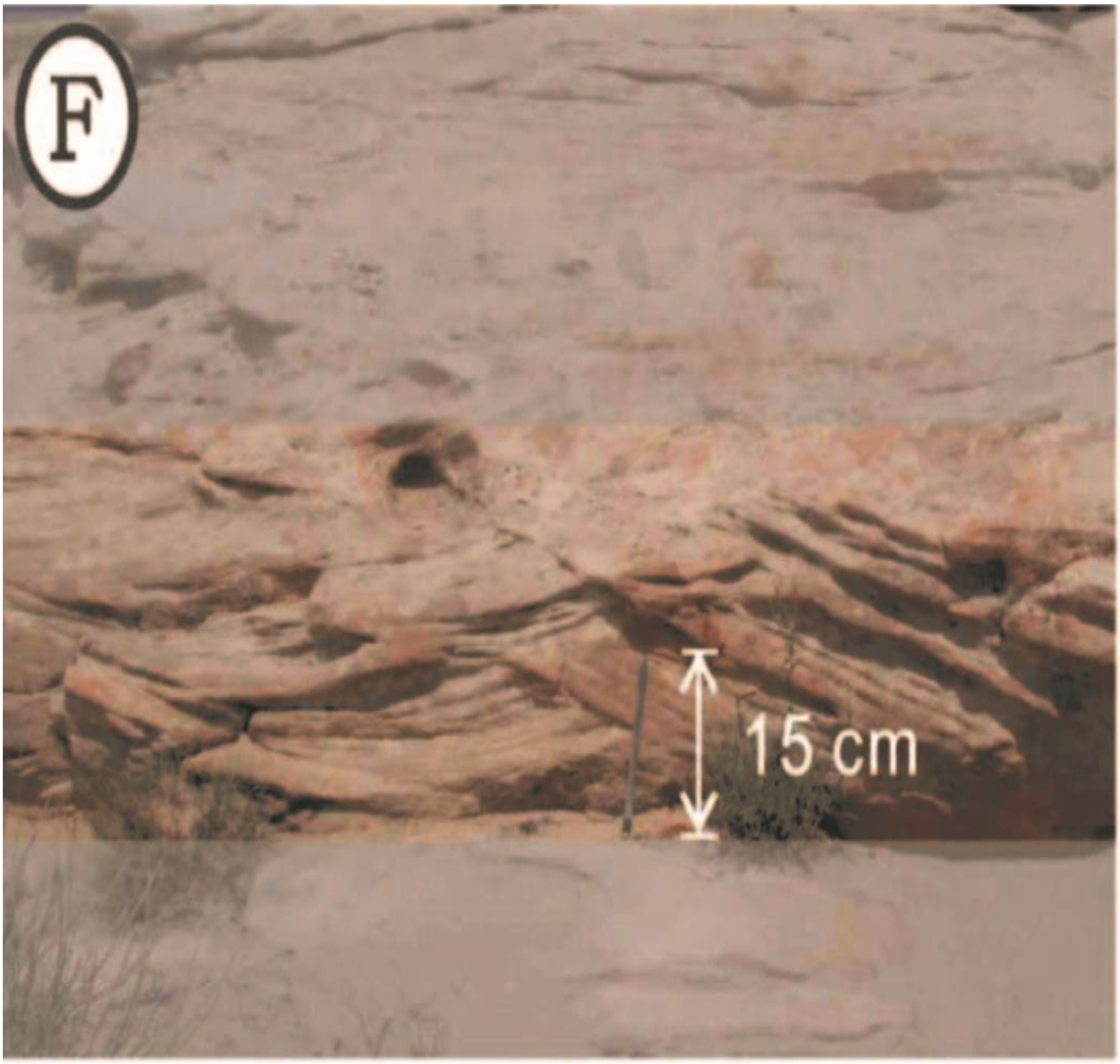

Figure 11: A typical medium-scaled trough cross bedding illustrated by Wang and Bhattacharya, (2018).

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