Architectural and Chronostratigraphic Analysis of a Modern Point Bar: Powder River, Montana, USA

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Abstract

Due to the logistical challenges and the dynamic nature of fluvial systems, studying modern point bar deposits over formative time periods is difficult. Seasonal and annual changes in precipitation can greatly influence the rate at which deposition is recorded. The lack of accurate sediment-package dating makes it difficult to compare sedimentation rates to actual chronostratigraphic events such as floods. This study combines photogrammetry, mapped surface migration, a survey of sediment elevation change, a trench, and water discharge rates to develop a more complete understanding of how a point bar forms on an annual scale. The Powder River, Montana, USA, which has little influence from engineering, offers a unique opportunity to study a seasonally exposed point bar and how its internal architecture and surface features form through time.

The study area is along the Powder River between Moorhead, Montana, USA, and Broadus, Montana, USA. The Powder River is a northward flowing, meandering river that is sourced from the Bighorn Mountains in northeast Wyoming, USA and is a tributary to the Yellowstone River. Point bar PR141A, the focus of this study, is the result of the neck cut-off of point bar PR141 during a 50 year flood in 1978. The sediment elevation survey is conducted annually, with a few exceptions, at centimeter scale to determine sediment elevation change and the building and erosion of the point bar. The survey is applied to the architectural-element analysis of the sediment packages within the point bar to compare time with sediment deposition.

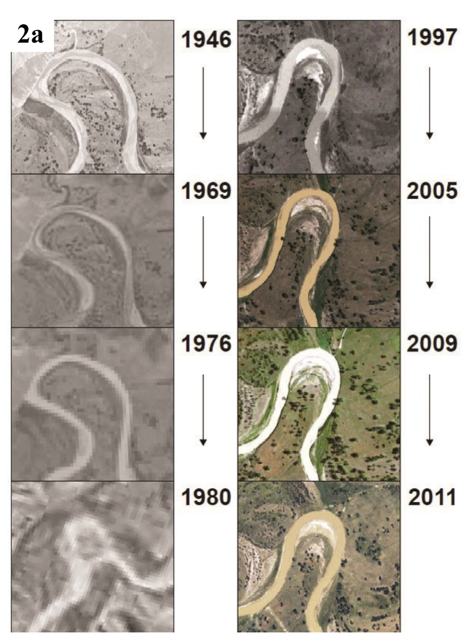
This study reconstructs the growth of point bar PR141A, its discrete accretionary architecture at the scale of years, and determines the inter-relationship between annual flooding events and bar accretion. The sediment survey timeline shows that on average the river builds one accretionary body per yearly flood cycle. On occasion, the river builds multiple bodies during the year or can take several years to build one accretion set. The change in the accretion set building period is attributed to changes in river flow. The continual change of deposit direction, grain size distribution, erosion, and reshaping of the bar surface between accretion events leads to fragmentation of the point bar body, vastly different from the textbook model of a point bar. The detailed study of how a modern point bar forms lends insight into the fragmentation of fluvial hydrocarbon reservoir bodies.

Introduction

1

Although the internal architecture of a point bar has been studied, relationships between specific discharge events and specific bar architecture is not established. The purpose is to reconstruct the growth of the point bar and discrete accretionary architecture at the scale of years in order to determine the relationship between annual flooding events and bar accretion processes. The timeline of events such as high precipitation months, floods, and effects of snow melt to the sediment deposition and internal geometries of the point bar will be compared. The history of the bar surface depositional features will be analyzed in order to assess and interpret the processes by which they were formed and modified. Relationships between bar-surface migration, accretionary bodies, accretion sets, and changes in river discharge rates are expected.

2a



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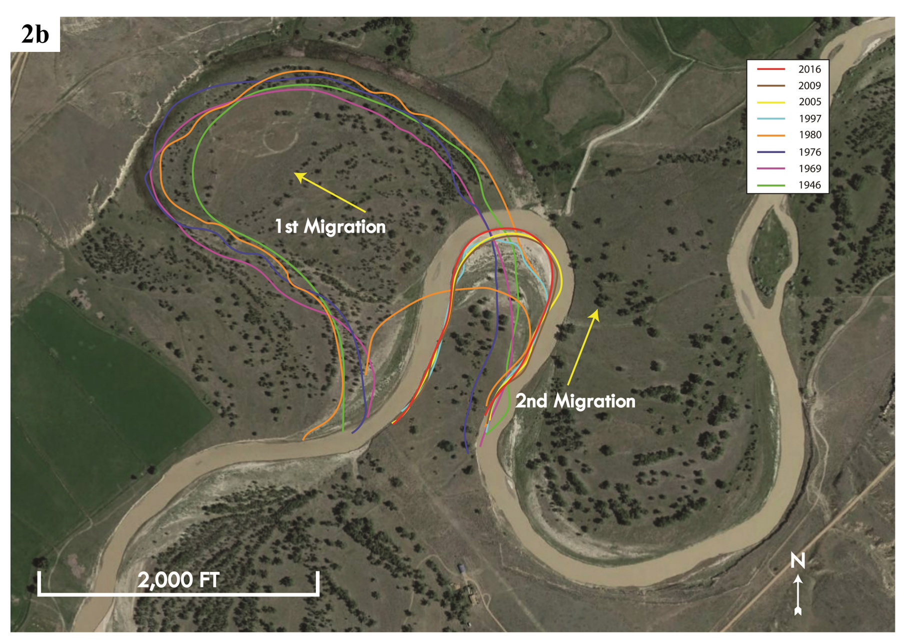


Fig 1: Research trench to the left of the USGS survey line, flow right to left, channel behind prospective

Fig 2a: Satellite and aerial photos showing point bar migration through time

Fig 2b: Mapped channel migration through time

Location

3a

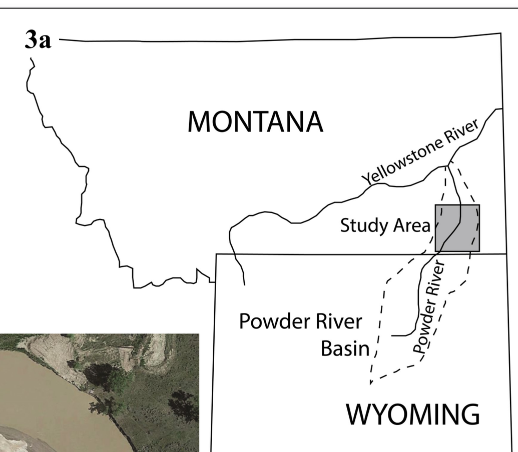
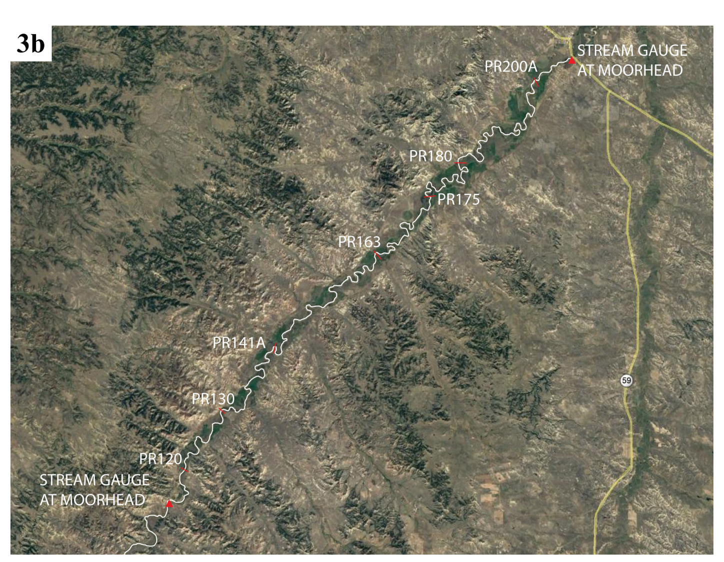


Fig 3a: Map of the states that contain Powder River Basin and the study area

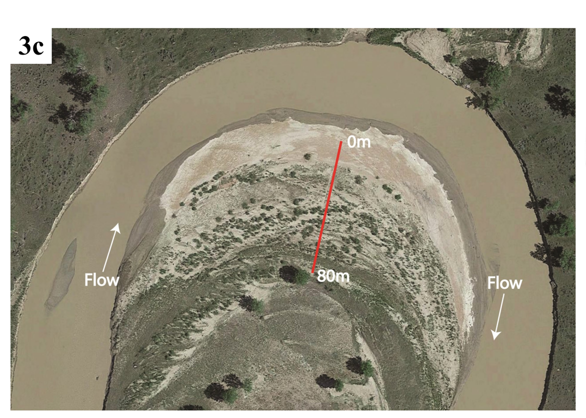
Fig 3b: USGS Powder River Study Area showing some of the surveyed point bar locations

Fig 3c: Thesis study point bar and trench location

3b



3c



Methods

•A trench was dug along the axis of point bar PR141A (Fig 3c). The trench dimensions are 80m long, 1m deep, and a 1/2m wide. The limiting factor on depth was the water table. The location of the trench was 1m downstream of the Moody and Meade survey line. The slightly downstream location was chosen to minimize the influence on the surface features used by the survey.

•To create a 3D model we took thousands of photos with roughly 60% overlap in the horizontal and vertical directions. We used Agisoft Photoscanner 3D software to stitch the photographs together. The software uses photogrammetry to determine depth and connectivity of images to render a 3D model of the trench face.

•We field mapped the current surface features, to include ridges and swells, scroll bars, and coffin bars. Aerial LIDAR data was collected the width of the river channel from the Moorhead stream gauge to the Broadus stream gauge. The LIDAR data will be used by other studies in the area, but for this study it was used to create a digital elevation model (DEM) of PR141A. Aerial and satellite photos were collected to map the migration of point bar PR141A as a whole, and to track the evolution of the surface features of the bar.

4a

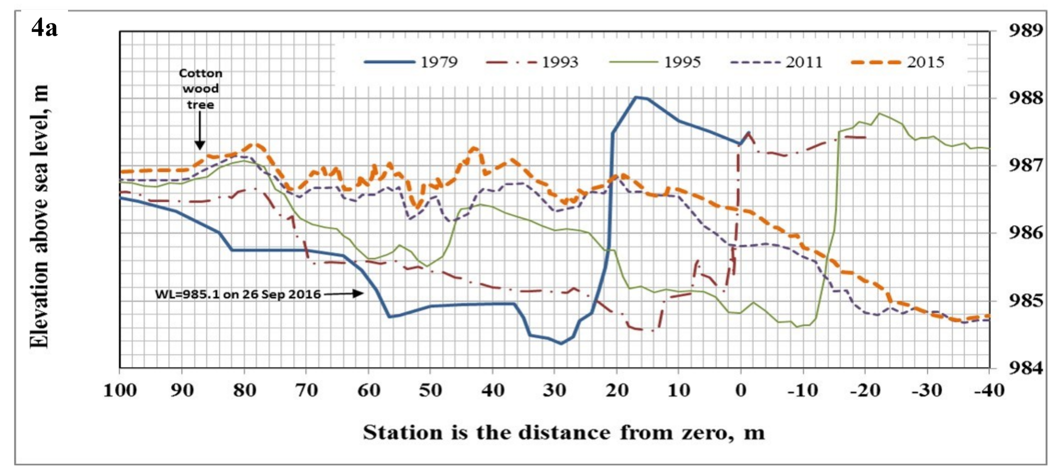


Fig 4a: Surface elevations derived from the USGS survey showing the migration of the channel through time

4b

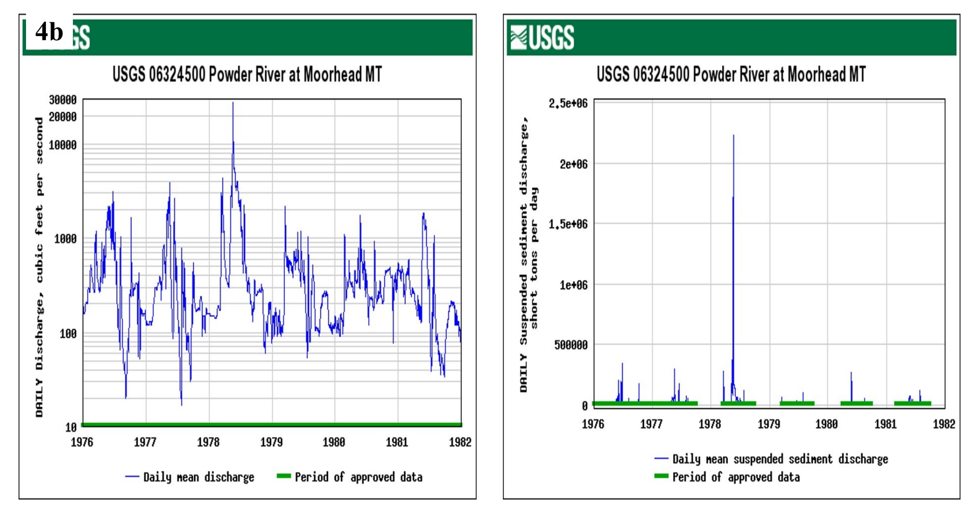
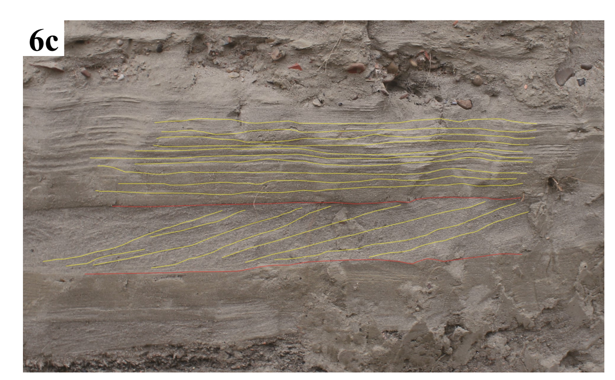


Fig 4b: Graphs of Powder River water discharge levels used to find floods and compare to sedimentation packages

Architectures

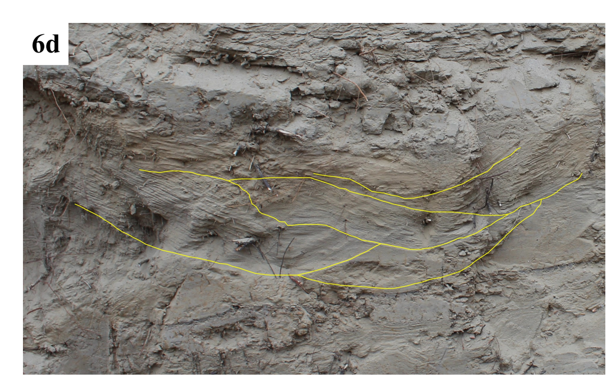
6a

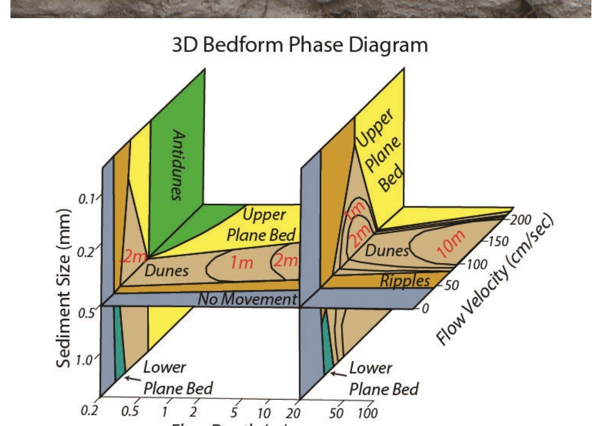
6c

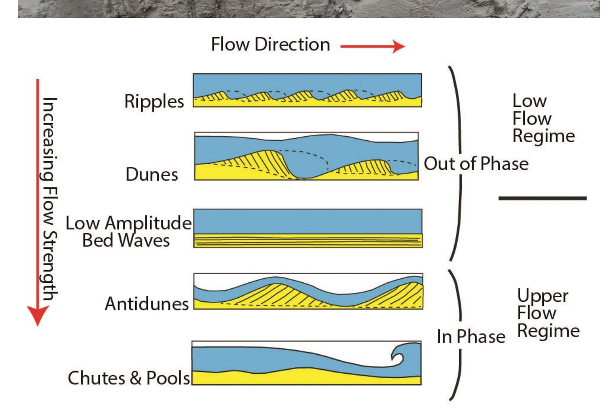


6b

6d







Figures 6a through 6d are examples of architectures or geometries that are found in the study point bar and are as follows:

Fig 6a: Scours surfaces showing the result of erosion. Fig 6b: climbing ripples. Fig 6c: planar cross bedding, and planar laminae. Fig 6d: trough cross bedding.

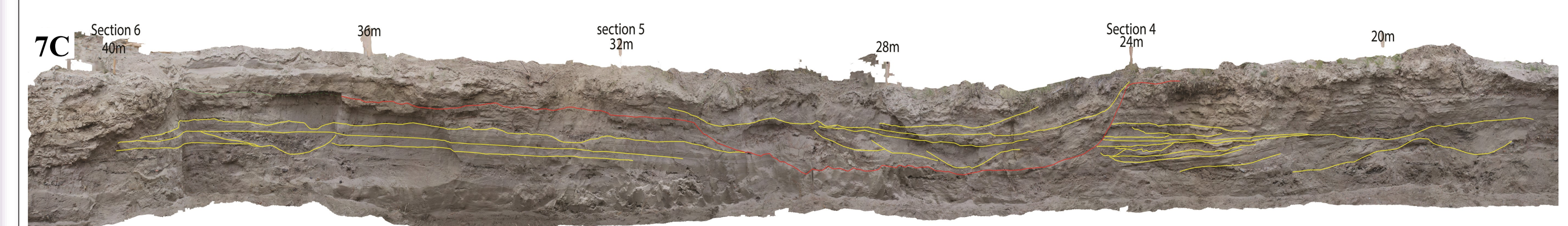
The graphs below depict what type of bedforms will form under different flow volumes and velocities.

Results

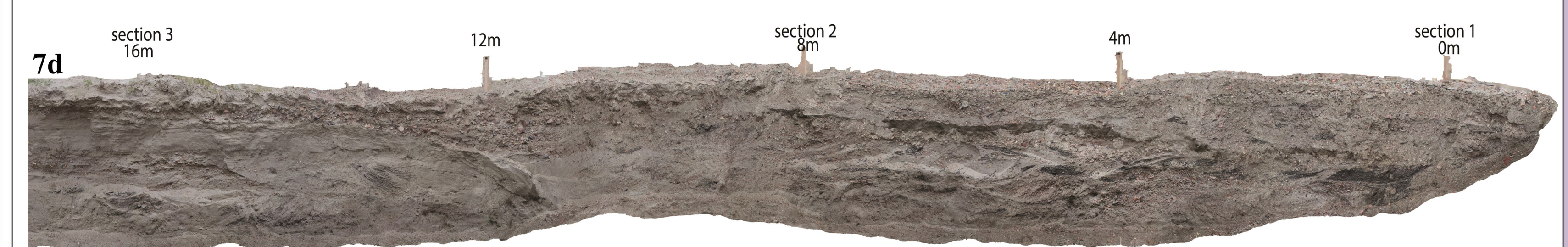
7a

7b

7C



7d



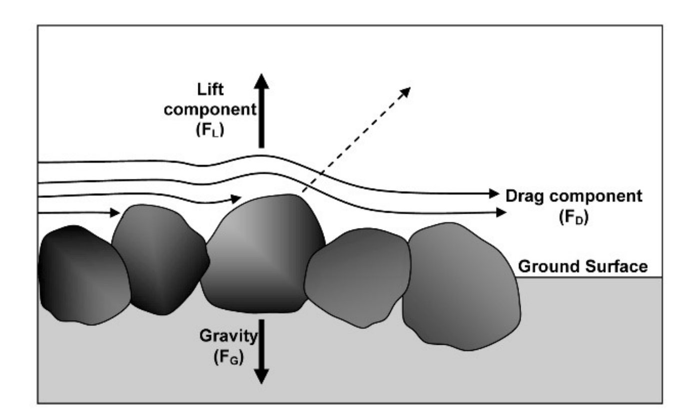
- Figures 7a through 7d are panels of the 3d models of the trench made using photogrammetry and Agisoft Photoscanner
- The trenches will be interpreted and individual sediment packages delineated and compared to the USGS survey and stream gauge data

Conclusions

- On average, one accretionary body is formed per yearly flood cycle
- Fragmented bars are caused from pole deviation of accretion sets caused by randomized composite constructional surfaces formed by selective and local stacking of multiple unit bars
- Surveys that do not match 3rd order surfaces are the result of accretionary sets developing in either less than one per year or more than one per year

Future

- Hydraulic equivalence will be determined comparing the mass of different grain types such as gravel, sand, or coal fragments.
- This relationship can help determine the type of sediment based of the flow, helping predict sediment volumes from different sized floods



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Aerial photos from: Aerial Photo Single Frames, NAIP GEOTIFF< NAIP JPG2000, NAPP, NHAP, GoogleEarth

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