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PS Controlling Factors and Mechanisms in the Formation of a Muddy-Normal Point Bar: A 3D Architectural-Element Analysis of a Heterolithic Point Bar in Dinosaur Provincial Park, Alberta, Canada*

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Search and Discovery Article #51326 (2016)**
Posted November 14, 2016

*Adapted from poster presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 16-22, 2016

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Abstract

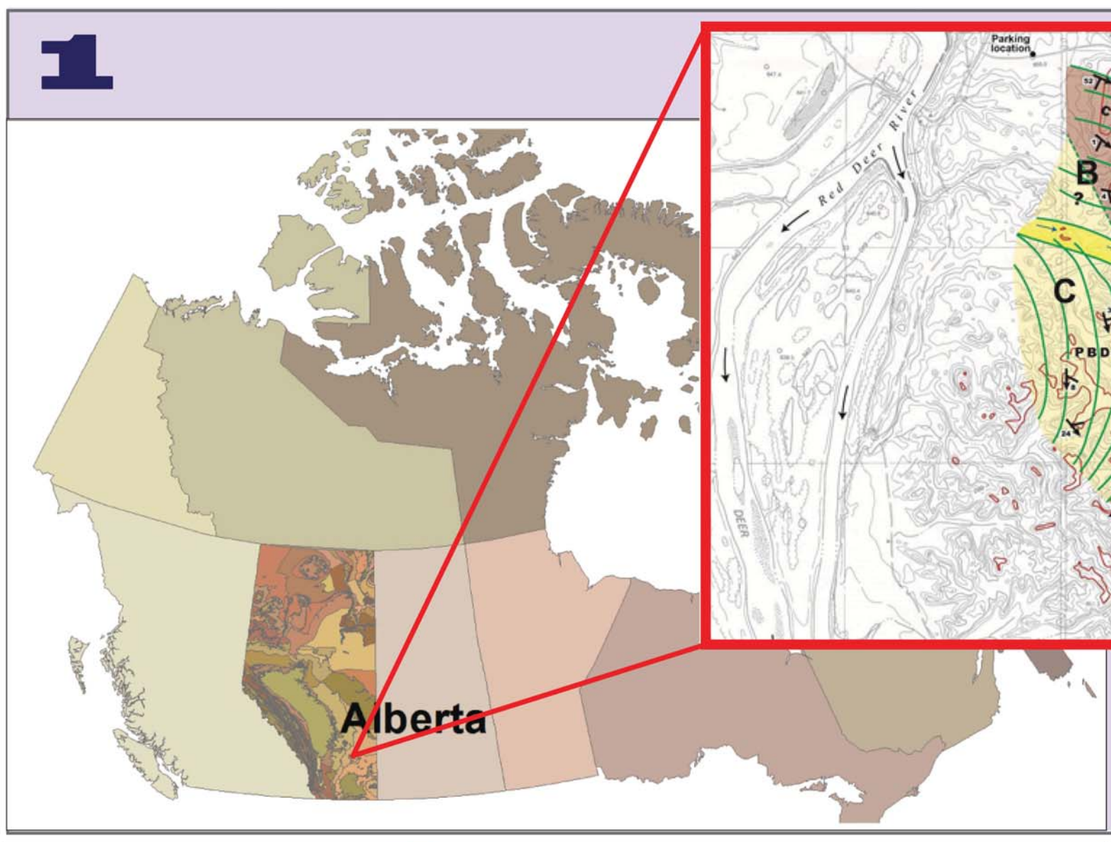
Mud-dominant point bars are common features showing deposition by either tidal influence, bar tails, or counter point bars. Less understood are mud-dominant point bars that lack these depositional characteristics. These “muddy-normal” point bars are common in hydrocarbon reservoirs. Better understanding a muddy-normal point bar’s impact on reservoir quality and how they form will assist in establishing predictive relationships that will aid in production and exploration. Upper Cretaceous fluvial strata of the Dinosaur Park Formation in the Steveville badlands of Dinosaur Provincial Park, Alberta, are targeted to address this issue. The goal of this study was to determine processes by which normal-muddy point bars form from LIDAR renderings to develop a 3D model of the bar volume. Strikes and dips, paleocurrents, and stratigraphic columns were collected to determine accretion trajectories and lithologic trends. Surfaces were also mapped according to the rules of architectural-element analysis in 3D form. This point bar had altering layers of sand and mud, mud comprising over 50%. Mud layers within this point bar have current ripples, suggesting that the mud layers were deposited by active accretion events. This point bar also consists of accretion packages with differing orientations. The sand and mud packages are present throughout the point bar and do not appear to reflect location within the bar. These data suggest that the muddy deposits of the muddy-normal point bar reflect changes in trajectory of the bar and sudden and temporary adoption of accretion orientations not conducive to sand deposition, and do not record either late stages of growth in the overall bar formation process, deviations from fully fluvial drivers, or counter point bar patterns.

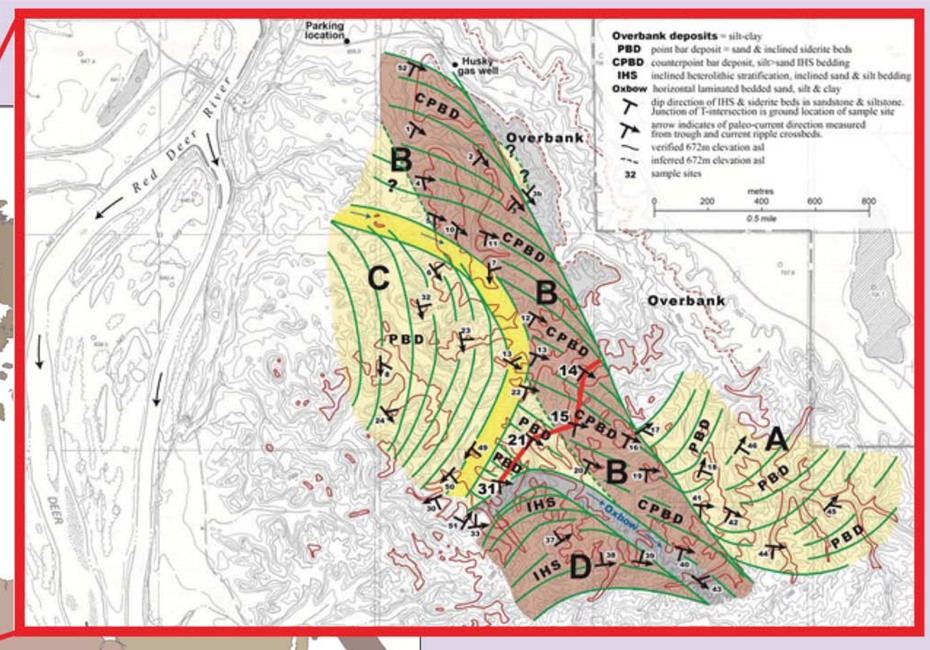
Abstract

Mud-dominant point bars are common features showing deposition by either tidal influence, bar tails, or counter point bars. Less understood are mud-dominant point bars that lack these depositional characteristics. These "muddy-normal" point bars are common in hydrocarbon reservoirs. Better understanding a muddy-normal point bar's impact on reservoir quality and how they form will assist in establishing predictive relationships that will aid in production and exploration. Upper Cretaceous fluvial strata of the Dinosaur Park Formation in the Steveville badlands of Dinosaur Provincial Park, Alberta, are targeted to address this issue. The goal of this study was to determine processes by which normal-muddy point bars form from LIDAR renderings to develop a 3D model of the bar volume. Strikes and dips, paleocurrents, and stratigraphic columns were collected to determine accretion trajectories and lithologic trends. Surfaces were also mapped according to the rules of architectural-element analysis in 3D form. This point bar had altering layers of sand and mud, mud comprising over 50%. Mud layers within this point bar have current ripples, suggesting that the mud layers were deposited by active accretion events. This point bar also consists of accretion packages with differing orientations. The sand and mud packages are present throughout the point bar and do not appear to reflect location within the bar. These data suggest that the muddy deposits of the muddy-normal point bar reflect changes in trajectory of the bar and sudden and temporary adoption of accretion orientations not conducive to sand deposition, and do not record either late stages of growth in the overall bar formation process, deviations from fully fluvial drivers, or counter point bar patterns.

Introduction

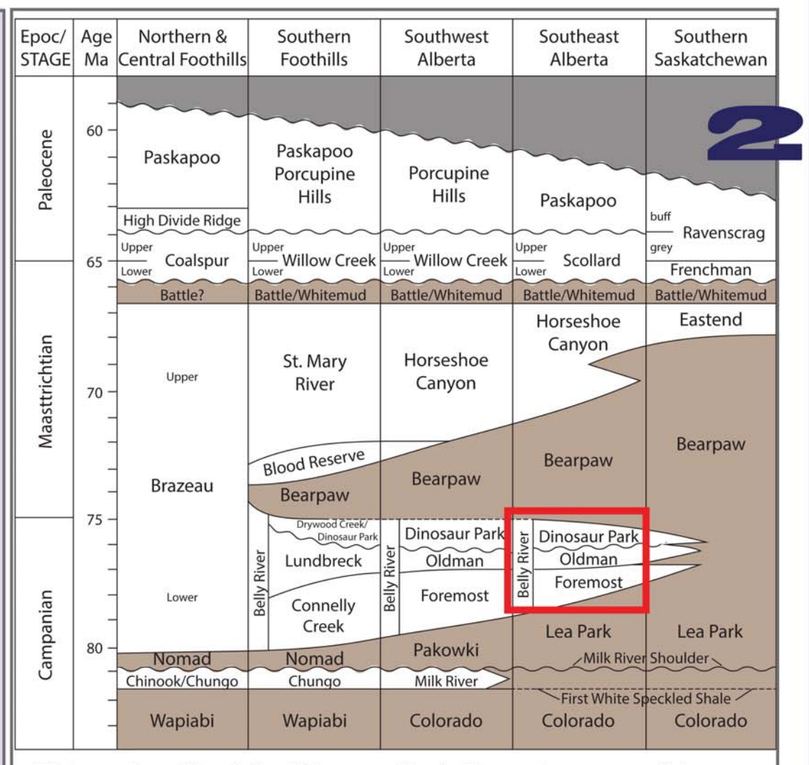
1





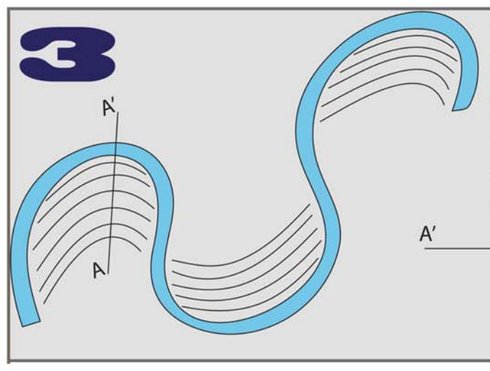
This study examined the internal architecture of a heterolithic point bar deposit within the Cretaceous Belly River Group of Dinosaur Provincial Park, Canada, more specifically the Steveville Area, that lacked evidence of tidal or counter-point-bar features. (Modified from Smith's reconstructed paleo-meander belt)

2

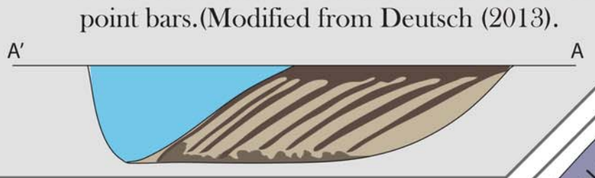


This study utilized the Dinosaur Park Formation, part of the Belly River Formation, due to excellent three-dimensional outcrops. These outcrops allowed for an extensive lithostratigraphic study of the architecture of the point bar, which aided in better understanding the formation of this study's point bar. (Modified from Hamblin (1997a))

3



To better understand this study, it is first important to have a basic understanding of heterolithic properties. Heterolithic properties are the result of inclined heterolithic stratification (IHS) deposits and are typical in counter point bars and tidally influenced point bars.(Modified from Deutsch (2013).



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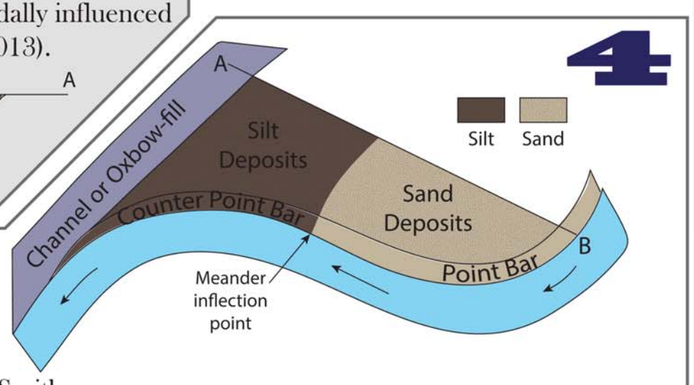


The heterolithic point bar in this study differs from typical heterolithic point bars because it was neither formed, nor influenced by counter or tidal processes, yet it shares similar features to a typical heterolithic point bar. This study's point bar has thicker mud deposits, like that of a counter point bar, and alternating beds of sand and mud, as in IHS, but it is neither. (Modified from Smith et al. (2009))

5

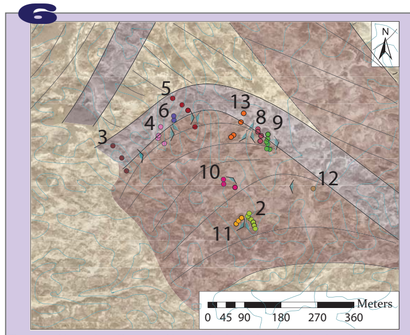
Here we see images from across this study's point bar. As seen from these images, the point bar looks like a "normal" point bar, except for the fact that it is about 50% mud instead of predominantly sand. We know this "muddy-normal" bar was neither the result of tidal influences nor counter point bar processes, it is something entirely new. We do not see such things as mud clast breccias at the base, thick clay layers in the uppermost portion, or completely diminishing and fining of sand interbeds. The goal of this study was to determine the process though which mud-dominant point bars form.

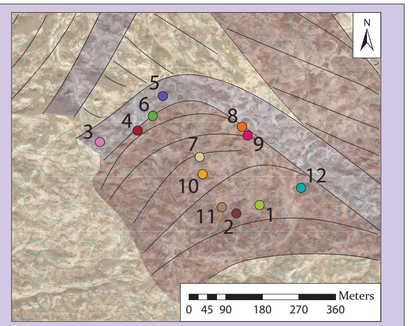
Controlling Factors and Mechanisms in the Formation of a Muddy-Normal Point Bar: A 3D Architectural-Element Analysis of a Heterolithic Point Bar in Dinosaur Provincial Park, Alberta, Canada

Holbrook, J., Johnston, S., & Warwick, B. | School of Geology, Energy, and the Environment, Texas Christian University | AAPG ACE Calgary 2016

Methods

6





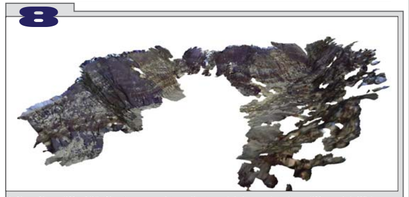
To answer this question of how a muddy-normal point bar forms, we began by going to the field to collect data. This study intended to determine the formation process of a muddy-normal point bar through a means of completing descriptions of point bar lithologies, utilizing photographs to depict important bar characteristics, analyzing strikes and dips of accretion surfaces, and generating a 3D model with a complete architectural-element analysis . Here are the locations from which data was retrieved. The image on the left shows the locations of all the photographs taken and the one on the right shows the location of all the stratigraphic sections. We completed detailed descriptions of point bar lithologies for locations 1, 2, and 7. For the other stratigraphic locations we took unit measurements, noted mud to sand ratios, and took measurements of the major accretion surfaces - no detailed lithologic descriptions were made.

7

Section	Surface	Strike	Dip	Section	Surface	Strike	Dip	Section	Surface	Strike	Dip
1	1	296	2 N	5	1	269	4 N	10	1	246	2 N
	2	296	2 N		2	253	9 N		2	137	2 W
	3	334	11 E		3	260	10 N		3	133	2 W
	4	5	16 E		4	66	10 S		4	214	12 W
	5	184	5 W		5	79	4 S		5	184	7 W
	6	184	5 W		6	246	4 N		6	209	11 W
	7	281	7 N	6	1	84	10 S		7	137	6 W
	8	184	5 W		2	129	11 S	11	1	278	14 N
2	1	253	11 N		3	99	8 S		2	254	11 N
	2	250	16 N		4	74	11 S		3	224	8 W
	3	250	16 N		5	81	13 S		4	224	1 W
	4	276	11 N	8	1	359	2 E		5	59	7 S
	5	276	11 N		2	59	9 S		6	59	7 S
	6	281	13 N		3	207	11 W		7	240	14 N
	7	257	10 N		4	119	11 S	12	1	59	2 S
	8	324	10 E		5	259	12 N		2		
	9	288	3 N	9	1	44	2 E		3	37	8 S
	10	314	12 N		2	189	4 W		4	57	8 S
	11	319	12 E		3	224	2 W		5	91	7 S
3	1	289	11 N		4	229	8 N		6	94	7 S
	2	266	10 N		5	226	9 W		7	69	11 S
	3	286	12 N		6	227	9 N		8	274	11 N
	4	285	7 N		7	252	8 N		9	59	5 S
	5	255	9 N		8	256	12 N	13	1	294	11 N
	6	264	5 N		9	255	11 N		2	81	12 S
	7	249	3 N		10				3	109	17 S
4	1	309	12 N		11						
	2	319	7 E		12	252	8 N				
	3	334	8 E								
	4	209	14 W								
	5	104	14 S								

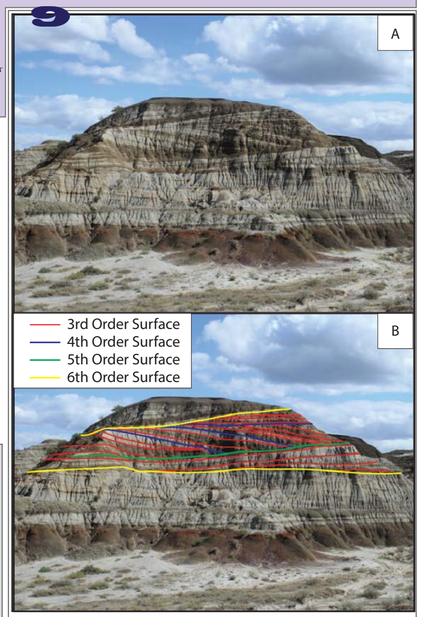
Strike and dip data of major accretion surfaces taken from every photograph location. This table divides major accretion surface strikes and dips by stratigraphic section and then by surfaces within the section.

8



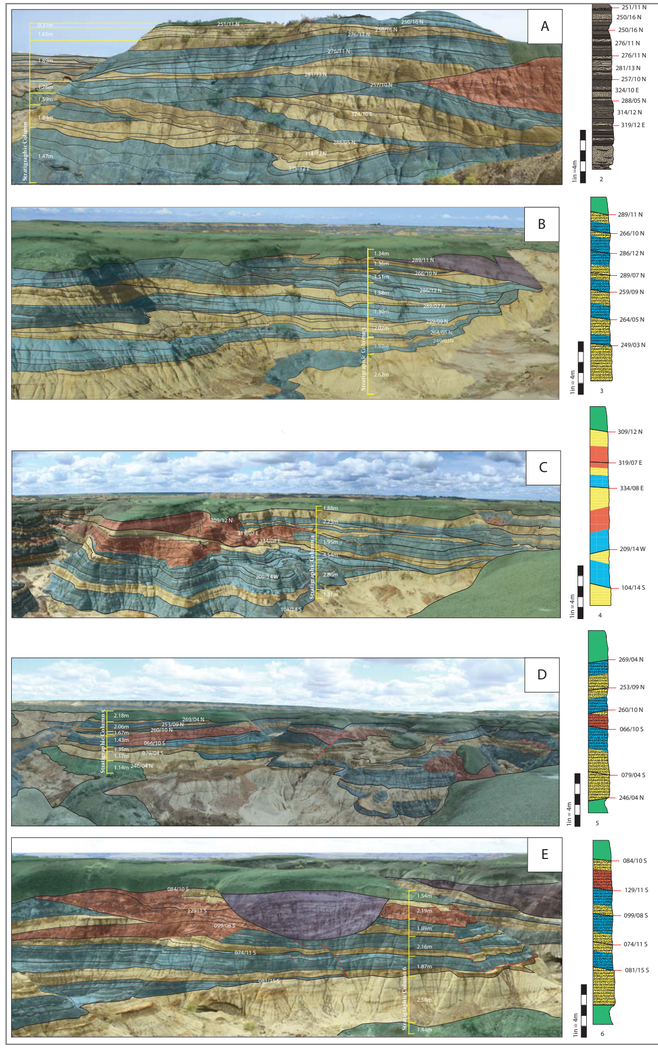
A Faro Focus3Dx 130 (Faro) was used to collect spatial data points for a 3D model. This model was taken at the location of Section 1. The Faro provided photo-realistic 3D topographic data based on spatial data points. A total of 28 scans were collected at a ratio of ½ and a quality of 4x. Data points collected through this process were given to Echo3D to generate a 3D model.

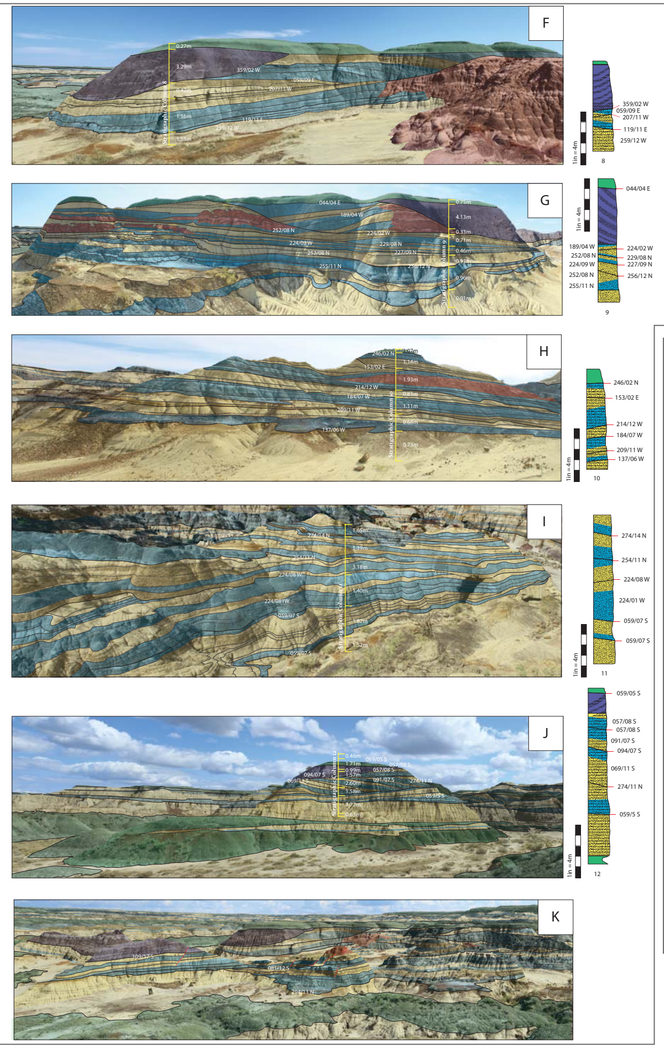
9



We applied the process and principles laid out by Miall (1985, 1986, 1996) and Holbrook (2001) for an architectural-element analysis of the photographs obtained from the field. This process will also be used on the 3D model, once it is complete. A. Raw image of stratigraphic section 12. B. Image interpreted using architectural-element analysis. In this interpretation, a 6th order surface is the highest order with a 3rd order being the lowest. (Modified from Holbrook (2015))

Results



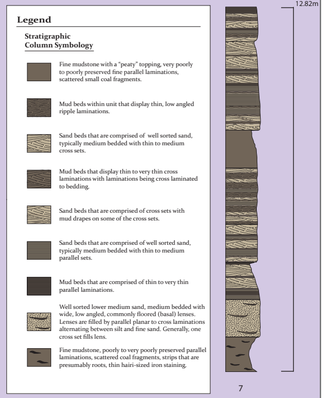


10

Mud | Sand | Flood Plain | Channel Fill | Lithification

Interpretations of the photographs taken from the field revealed four main facie types - mud (blue), sand (yellow), flood plain (green), and channel fill (dark purple-blue). Also identified, are zones of lithification (red). Interpreted photographs also show locations of stratigraphic sections, major accretion surfaces, minor accretion surfaces, and strikes and dips of major accretion surfaces. Next to each interpreted photograph is its associated stratigraphic column - one detailed and nine "quick" stratigraphic sections. The detailed and quick stratigraphic columns, as well as the photograph interpretations, revealed that mud does indeed comprise 50% of this point bar and that this percentage of mud is across the entire bar.

11



This detailed stratigraphic column of Section 7 shows the complete point bar - from flood plain deposit to flood plain deposit. The muddy-normal point bar is the lower portion of this column and directly above is the first two units of the overlying sandier point bar. Seeing the sandier "normal" point bar directly above this study's point bar just reemphasizes the point that this study's point bar is indeed different. It is muddy and the muddy deposits are not just mud drapes, but actual beds - we see sedimentary structures, such as ripples.

Discussion

12

2			
Unit	Percentage	Facie	Lapping Relation
9		Flood Plain	N/A
	0.50	Mud	
8	0.75	Sand	On
	0.50	Sand	
7	0.75	Mud	Top
	0.75	Mud	
	0.50	Sand	
6	0.75	Mud	On + Top
		Lithification	
	0.75	Mud	
	0.50	Sand	
	0.75	Mud	
	0.50	Sand	
5	0.75	Mud	Top
	0.75	Mud	
4	0.75	Sand	Top
3	0.75	Mud	Top
2		Thalweg	N/A
1		Flood Plain	N/A

3			
Unit	Percentage	Facie	Lapping Relation
9		Flood Plain	N/A
8		Channel Fill	N/A
	0.50	Sand	
7	0.75	Mud	Top
	0.75	Sand	
6	0.50	Mud	Top
	0.50	Mud	
5	0.75	Sand	Top
	0.75	Sand	
4	0.50	Mud	Top
	0.75	Sand	
3	0.50	Mud	Top
	0.75	Sand	
2	0.75	Mud	Top
1		Thalweg	N/A

4			
Unit	Percentage	Facie	Lapping Relation
6		Flood Plain	N/A
	1.00	Sand	
	0.75	Mud	
	0.75	Sand	
	0.75	Mud	
	0.75	Sand	
5	0.75	Mud	On
	0.50	Sand	
	0.75	Mud	
	0.50	Sand	
4	0.75	Mud	On + Top
	0.75	Sand	
		Lithification	
3	0.50	Mud	Top
	0.75	Sand	
	0.75	Mud	
	0.50	Sand	
2	0.75	Mud	Top
1		Thalweg	N/A

5			
Unit	Percentage	Facie	Lapping Relation
7		Flood Plain	N/A
	1.00	Sand	
	0.75	Mud	
6	0.50	Sand	Top
	1.00	Sand	
5	0.50	Mud	Top
	1.00	Sand	
4	0.75	Mud	On + Top
	0.75	Mud	
	0.50	Sand	
3	0.75	Mud	Top
2		Thalweg	N/A
1		Flood Plain	N/A

6			
Unit	Percentage	Facie	Lapping Relation
7		Flood Plain	N/A
	0.75	Sand	
6		Lithification	On + Top
	0.75	Mud	
5	0.50	Sand	On + Top
	0.75	Mud	
4	0.50	Sand	Top
	0.50	Sand	
	0.75	Mud	
	0.50	Sand	
3	0.75	Mud	Top
2		Thalweg	N/A
1		Flood Plain	N/A

8			
Unit	Percentage	Facie	Lapping Relation
5		Flood Plain	N/A
4		Channel Fill	N/A
	0.50	Sand	
	0.75	Mud	
3	0.50	Sand	Top
	0.50	Sand	
2	0.75	Mud	Top
1	0.75	Sand	Top

9			
Unit	Percentage	Facie	Lapping Relation
8		Flood Plain	N/A
7		Channel Fill	N/A
	0.75	Mud	
	0.50	Sand	
	0.75	Mud	
	0.50	Sand	
	0.75	Mud	
6	0.50	Sand	Top
	0.75	Sand	
	0.75	Mud	
	0.50	Sand	
	0.75	Mud	
	0.50	Sand	
5	0.75	Mud	Top
	0.75	Sand	
	0.75	Mud	
	0.50	Sand	
	0.75	Mud	
	0.50	Sand	
4	0.75	Mud	Top
3	0.75	Sand	Top
	0.75	Mud	
	1.00	Sand	
	0.75	Mud	
	0.75	Sand	
2	0.75	Mud	Top
1		Thalweg	N/A

10			
Unit	Percentage	Facie	Lapping Relation
7		Flood Plain	N/A
	0.75	Mud	
6	0.50	Sand	On
	0.50	Sand	
5	0.75	Mud	Top
4	1.00	Sand	Top
	0.75	Mud	
3	0.75	Sand	Top
	1.00	Sand	
2	0.75	Mud	Top
1		Thalweg	N/A

11			
Unit	Percentage	Facie	Lapping Relation
	0.50	Sand	
	0.75	Mud	
6	0.75	Sand	N/A
	0.75	Mud	
	0.50	Sand	
	1.00	Mud	
	0.50	Sand	
5	0.75	Mud	N/A
	0.50	Sand	
	0.75	Mud	
4	0.50	Sand	Top
	0.75	Sand	
	0.75	Mud	
	1.00	Sand	
	0.50	Mud	
	0.75	Sand	
3	0.75	Mud	Top
	0.75	Mud	
	0.75	Sand	
2	0.50	Mud	Top
1		Thalweg	N/A

12			
Unit	Percentage	Facie	Lapping Relation
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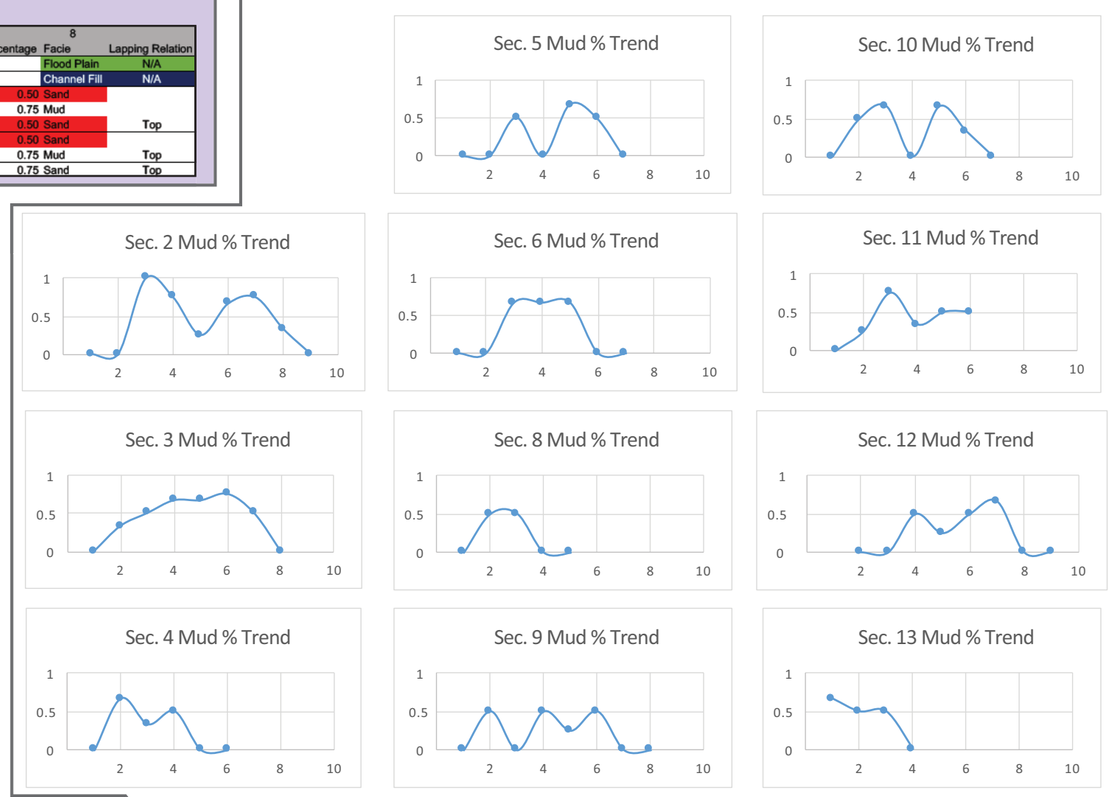
	0.75	Sand	
7	0.50	Mud	Top
	0.50	Sand	
	0.75	Mud	
	0.75	Sand	
6	0.75	Mud	Top
	1.00	Sand	
	0.75	Mud	
5	0.75	Sand	Top
	0.75	Sand	
	0.75	Mud	
4	0.50	Sand	Top
	0.50	Mud	
	0.75	Sand	
	0.75	Mud	
	0.50	Sand	
3	0.50	Mud	Top
2	1.00		N/A
1		Flood Plain	N/A

13			
Unit	Percentage	Facie	Lapping Relation
5		Channel Fill	N/A
	1.00	Sand	
	0.75	Mud	
	0.75	Sand	
4	0.50	Mud	Top
		Lithification	
	0.75	Sand	
	0.75	Mud	
3	0.75	Sand	Top
	0.75	Mud	
	0.50	Sand	
2	0.75	Mud	Top
1		Thalweg	N/A

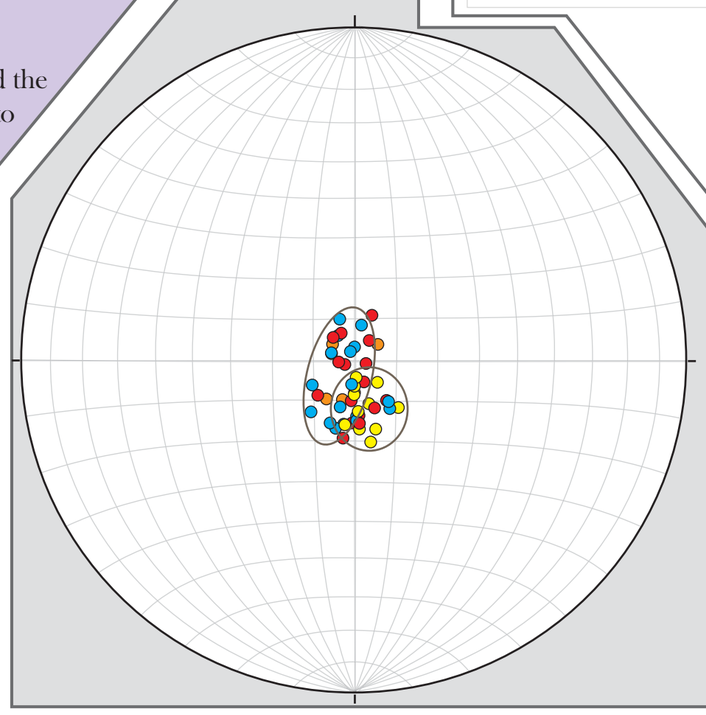
Using the interpreted photographs and stratigraphic columns, we identified the percentage of mud and sand. For these tables, each section was divided into units and then each unit was further divided into mud and sand layers, as designated by the appropriate interpreted photograph. We also disinguished what layers were 50% mud and 50% sand (50/50) - as seen in red. These tables allowed us to quantifiably see how much mud is actually contained within this study's point bar. Out of 152 layers, 60 are mud, 42 are sand, 46 are 50/50, and 4 were uncounted due to lithification. These tables further support that this is a muddy point bar. Also noted in these tables is the type of lapping relation of each unit - as divided by major accretion surfaces. We were looking to see if there was any pattern between lapping surface type and the type of sediment deposited. As can be seen from these tables, there was no notable correlation between the two.

13



Here we graphed mud percentages against units for each section - mud percentage is on the y-axis and unit number is on the x-axis. We used these graphs to see if there was a trend associated with the formation of muddy-normal point bars. From these graphs we determined that there was no trend.

14



We plotted strikes and dips of major accretion surfaces using Rick Allmendinger's Stereonet 9. We then transfered the stereographs manually to Illustrator to distinguish surfaces between mud (blue), sand (yellow), and 50/50 (red). We were looking to see if there was a correlation between orientation and what was deposited. Through this process we found a fairly strong correlation with orientation and sand deposits and a slight correlation with orientation and mud deposits. In this stereonet we have not corrected for position in the point bar, but are currently working on a new stereonet that will account for position. We believe, that once position is accounted for, both mud and sand deposits will show a correlation with orientation.

Conclusion

This point bar was typically between 8 to 10 meters thick with altering layers of sand and mud, with mud being the predominant sediment and comprising over 50% of the point bar. Flood plain deposits stratigraphically confined the point bar, allowing for the determination that it was a single complete point bar. Within the point bar, grain size had an upward fining trend for both the mud and sand layers. Typically, the mud layers are silty mudstones and the sand layers started as medium-grained at the base of the point bar and then fined up to layers of lower fine sand at the top of the point bar. Mud layers and sand layers varied between thin- to medium-bedded. Mud layers within this point bar are thick-bedded and have current ripples indicative of deposition by transport. This suggests that the mud layers were deposited by active accretion events and are not simple drapes. This point bar also consists of accretion packages with differing orientations. Accretion packages commonly are between 3 to 4 meters thick and 10 to 15 meters long. Sand content shifts between packages, and alternating packages have sand contents more consistent with typical sandy point bars. Both the sand-rich and mud-rich packages also contain surfaces with alternating orientations, but at a smaller scale. The sand and mud packages are present throughout the point bar and do not appear to reflect location within the bar. These data suggest that the muddy deposits of the muddy-normal point bar reflect changes in trajectory of the bar, and sudden and temporary adoption of accretion orientations are not conducive to sand deposition and do not record either late stages of growth in the overall bar formation process, deviations from fully fluvial drivers, or counter point bar patterns.

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