# Lateral Continuity and Thinning Ratios, an Analysis of Thin Beds Within a Storm Dominated Prodelta: Cretaceous Ferron Sandstone, Utah

RESEARCH PROPOSAL

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Introduction:

Many modern oil and gas plays are trapped within thin-bedded heterolithic strata, which are generated in a variety of offshore marine environments. The importance of understanding the intricacies of these thin bedded heterolithic deposits has never been more critical. The primary physical processes that cause for the majority of deposition and preservation of thin beds within the sedimentary record are hyperpycnites, ignitive turbidites, and tempesites (Seepersad, 2012). Hyperpycnal flows occur due to river floods, when the suspended sediment load is extremely high and the density of the river water becomes greater then that of the sea upon which it is entering. The typical or ideal hyperpycnite will have two periods of deposition marked by different energy processes. The first occurs while the hyperpycnite flow is increasing in energy, called it's waxing period, where it will deposit an upward coarsening unit. The second occurs as the hyperpycnal flow is losing energy, this is called the waning period, and is marked by a normally graded fining upward unit (figure 1) (Mulder et al., 2003; Soyinka & Slatt, 2008). Ignitive turbidity currents entrain sediment from underlying bed and self-accelerate, thus giving to the name ignitive (Fukushima, Parker & Pantin, 1984). Ignitive turbidity currents will start as a sub-marine slide, but will scour and erode, picking up sediment along the way adding to their gravitational pull, ultimately increasing their downslope energy (Fukushima, Parker & Pantin, 1984; Soyinka & Slatt, 2008). The turbidity current bedding sequence was first documented by Bouma and can be seen in figure 2. It is important to note that the primary difference between an ignitive turbidity current and a hyperpycnite is that hyperpycnites originate from fresh water systems and ignitive turbidity currents do not (Mulder et al., 2003). Tempesites (storm deposits) often form in wave dominated systems and are preserved within the sedimentilogical record below fair weather wave base and above storm weather wave base (Myrow & Southard, 1996).

They are commonly characterized by hummocky cross stratified beds that have an erosive base, and can form under combined flow regimes (Dott & Bourgeois, 1982; Long, 2007). This erosive base is often seen in the form of gutter casts that can be filled with a variety of sedimentary facies including hummocky cross stratification (Myrow, 1990). Dott & Bourgeois (1982) documented a common sedimentary bedding sequence of hummocky dominated tempesite deposits (figure 3). Hyperpycnites, ignitive turbidites, and tempesites while all being deposited within the same environment can create very complex sedimentilogical and depositional interactions. It has been documented throughout the literature for each one of these depositional processes that they can have erosive bases (Dott & Bourgeois, 1982; Parker & Pantin, 1984; Mulder et al., 2003). With constant deposition and erosion in a given environment, it become difficult to understand how the final sedimentary sequence will be preserved, specifically for each bed what the thinning ratios are and what the lateral continuity is.

Objectives:

The objectives of this study are to first test the methods to be presented in the methods section regarding the drone, 3D model, and resolution of the model. These need to be tested in conjunction with the measured sections taken for this study and the measured sections previously documented by Seeprasad (2012) in the same area. The following objective is to measure the thinning ratios and lateral continuity of each bed to the highest accurate resolution possible for the entire documented outcrop.

Background Information:

**Geological Setting:**

The Ferron Sandstone is a member of the Mancos shale formation, and was deposited within the western interior seaway during the late cretaceous (Turonian) (Garrison & van de

Bergh, 2004; Zhu, 2010). The western interior seaway extended from modern day California to Ontario (figure 4), and contained three clastic wedges that developed during the Turonian (DeCelles & Giles, 1996; Ryer & Anderson, 2004; Zhu, 2010). Zhu (2012) documented high resolution sequence stratigraphic framework of the Ferron Natom deltaic complex. He found that this complex consist of 6 depositional sequences, 18 parasequence sets, and 43 parasequences. Seeprasad (2012) followed Zhu (2010) and Li (2010) by completing a high resolution facies analysis of prodelataic parasequence sets 5, 6, 11, and parasequence 16a. Through this analysis Seeprasad (2012) documented parasequence 5a as “highly wave dominated, with 96% of the known facies being wave-dominated, and 4% being fluvial-dominated”, and parasequence 5b as “less wave-dominated than parasequence 5a, with 71% of the known facies being wave-dominated, 29% being fluvial-dominated”. Documented measured sections for parasequence 5a and 5b can be seen in figure 5 and figure 6 respectively. Associated facies percentages plotted on tripartite diagram is seen in figure 7.

**Thin Beds and Lateral Continuity of Thin Beds:**

The literature regarding thin beds is somewhat situational. Thin beds as documented by Campbell (1967), are beds between the size of 3cm and 10cm, with very thin beds between 0cm and 3cm (Figure 8). This viewpoint is one of sedimentilogical background. The geophysical literature defines thin beds as the smallest bed resolvable by seismic data (Zeng, 2008). The petrophysical literature defines a thin bed as a shaly sand that can be thinner than the resolution of the logging tools (Passey et al., 2006b). For the purposes of this study the classification defined by Campbell (1967) will be used, as it is well defined.

Lateral continuity and thinning ratios of thin beds deposited by processes previously discussed in the introduction are poorly defined. Hyperpycnal flows have been documented to “maintain a near-constant thick- ness for long distances (e.g. thin from 3 m to 2 m across 2 to 3 km lateral distance), then pinch-out abruptly in a few hundred metres” (Soyinka & Slatt, 2008). Hyperpycnal flows are also capable of having a large amount of variation in preserved beds, which is dependent on the physical process that caused for the initiation of the hyperpycnite within the river system (Soyinka & Slatt, 2008). Ignitive tempesites thin as they reach more distal setting and are thicker in a more proximal setting, with along dip facies changes occurring within the same depositional event (Walker, 1967). Sand rich turbidites have been documented within channel fills in the Permian to be laterally continuous for at least 6km (Grecula, Flint, Wickens, & Johnson, 2003). Tempesites primarily consisting of hummocky cross stratified layers are 0.5 to >3.0m thick and can typically be traced for hundreds of metres (Long, 2007). Gutter casts that form due to erosion while tempesites are being deposited can be centimetres to metres in width (Myrow, 1990). It is important to note that all of the documented thinning ratios just mentioned were estimated by walking out the beds and visually inspecting the lateral continuity, with the exception of the gutter casts. Snyder et al, (2016) looked at thinning ratios of thin beds within heterolithic strata of fluvial dominated wave influenced parasequence 6 within the Ferron Sandstone. Hyperspectral terrain data was collected for this study and used in conjunction with a measured section. Bedding in plan view is lobate to elongate, anisotropic relative to dip and strike, and will be laterally continuous for a ratio of <10,000 (i.e. a 10cm bed will extend for >1km)(Snyder et al., 2016).

Methods and Analysis:

Sedimentilogical and stratigraphic data was obtained from the Coalmine Wash field site. The location of the field site can be seen in figure 9, and 10. To give three-dimensional control, two measured sections were taken repelling on ropes, one on the North West face of the outcrop and one on the North East face of the outcrop. One measured section was taken as a composite, walking up talus slopes along the outcrop exposure to obtain the entirety of the vertical extent. All measured sections were taken at centimeter scale resolution. The data obtained from these outcrops consisted of sedimentary structures, grain size, bed thickness, paleocurrents, ichnofacies, and lithofacies. The tools used in the field included a Silva compass, measuring tape, rock hammer, hand lens, and grain size chart. A drone scan of the outcrop was completed by David Kynaston using the DGI Phantom 4 Pro+ quad-copter with 20-megapixel camera. All measured sections will be digitized using Adobe Illustrator, and a 3D model of the entire outcrop will be generated using Pix4D. The measured sections taken for this study as well as Seeprasad (2012) measured sections (figure 8), which were taken in the same area will be converted to object files using Sketch Up, and brought into the Pix4D interface so they can be used for measured ground control of the outcrop. Once all information has been compiled and projected within the Pix4D software each bed will be traced and correlated, then analyzed to give thinning ratios and lateral continuity for all resolvable beds within parasequence 5a and 5b. Samples that were taken at marked locations within the measured sections will be analyzed in this section to provide supplementary high resolution sedimentilogical data on grain size, grain size variability, and net to gross ratios. High resolution photographs taken throughout measured sections will be analyzed in millimeter scale resolution and incorporated into digitized measured sections where possible. Grain size distribution charts and pie charts of proportions of sedimentary structures will be created for measured sections to match Seeprasad (2012) data being incorporated within this study.

Hypothesis and Expected Outcomes:

The methodology presented will be capable of resolving beds with a higher degree of certainty relating sedimentilogical process to bed thinning ratios and lateral continuity, then has been accomplished in the past. From the information gathered throughout this study the relationship of hydrocarbon production in wave dominated storm influenced prodeltaic facies in relation to lateral continuity and thinning ratios both in stratigraphic strike and dip will be better understood.

Timeline:

The tentative timeline for the research being proposed is outlined in table 1. The primary data collection for this project has already been completed, as a field assistant working for David Kynaston who was doing research in the same area I was able to collect my own data for this project. The literature review will be completed for November 3rd 2017. All measured sections being used for this study will be compiled into the Pix4D format as outlined in the methods section by December 1st 2017. All subsequent analysis including any statistical work, and analysis of thin sections to be used as supplementary information will be completed by January 26th 2018. The first draft of the final thesis will be submitted by March 2nd 2018, the final edited draft will be submitted by April 6th 2018, and the thesis presentation will be presented on April 10th of 2018.

| Task | Due Date |
|---|---|
| Data Collection | June 1st 2017 – July 1st 2017 |
| Research Proposal | October 6th 2017 |
| Literature Review | November 3rd 2017 |
| All measured sections compiled in Pix4D | December 1st 2017 |
| Completion of all analysis required for Thesis | January 26th 2018 |
| Draft Thesis | March 2nd 2018 |
| Written Thesis | April 6th 2018 |
| Paper Presentation | April 10th 2018 |

Table 1. Timeline for project from start to completion.

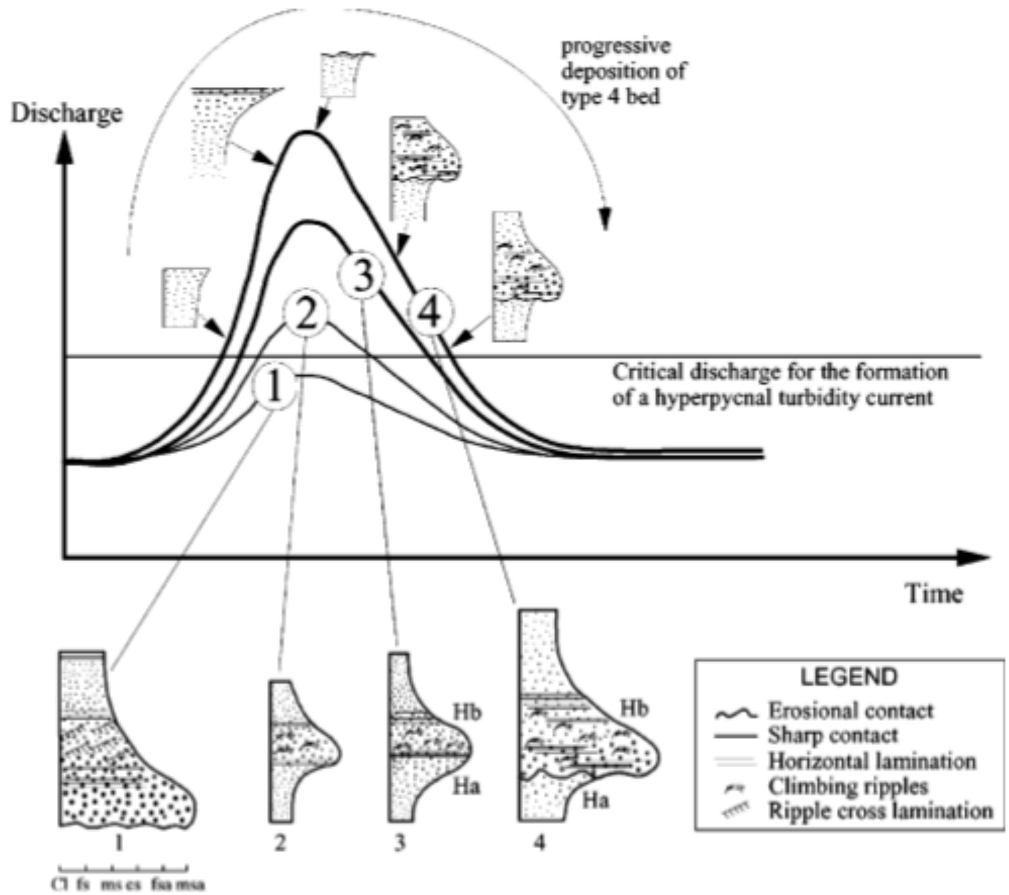


Fig.1. Facies and sequences deposited as a function of the magnitude of the flood at the river mouth. (1) low magnitude flood. (4) High-magnitude flood, erosional surface exists between Ha and Hb. Ha may have been completely eroded during peak flood conditions (Taken from Mulder et al., 2003).

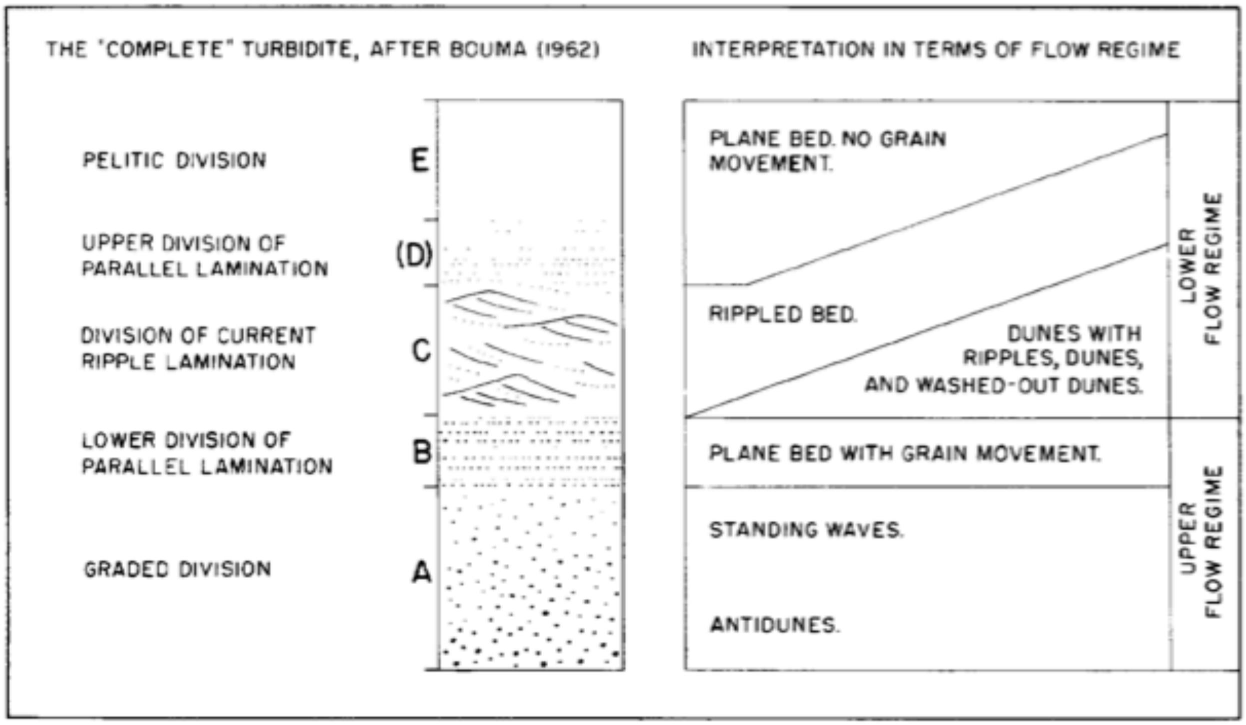


Fig.2. Bouma's complete turbidite and its interpretation by analogy with the flow regimes of Simons and others (1965). (Taken from Walker, 1967).

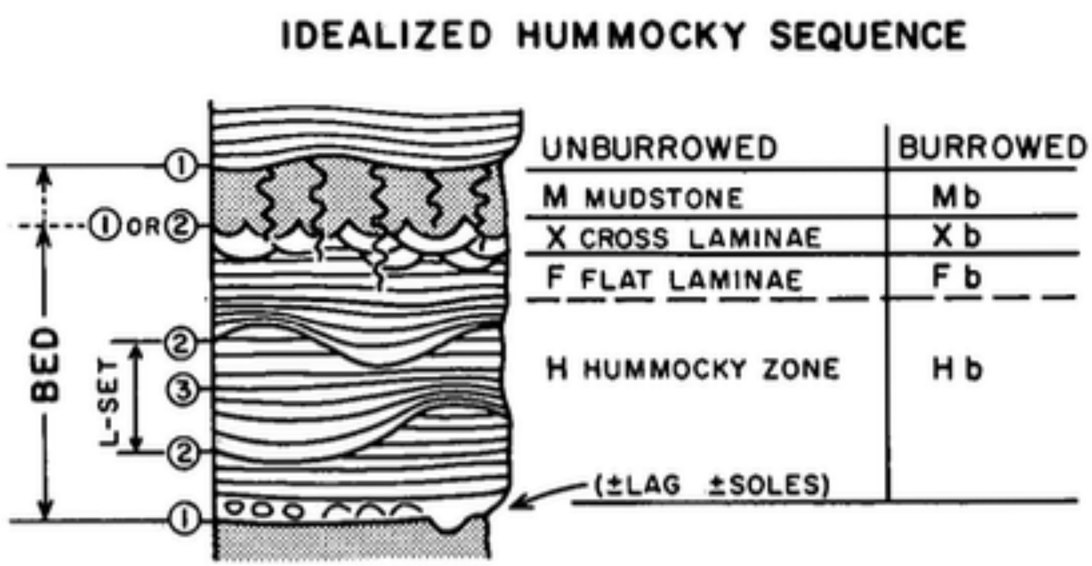


Fig. 3. Figure 3. The idealized hummocky sequence, burrowing may overprint the top or even the entire sequence. (After Dott and Bourgeois, 1979, 1980.) (Taken from Dott & Bourgeois, 1982)

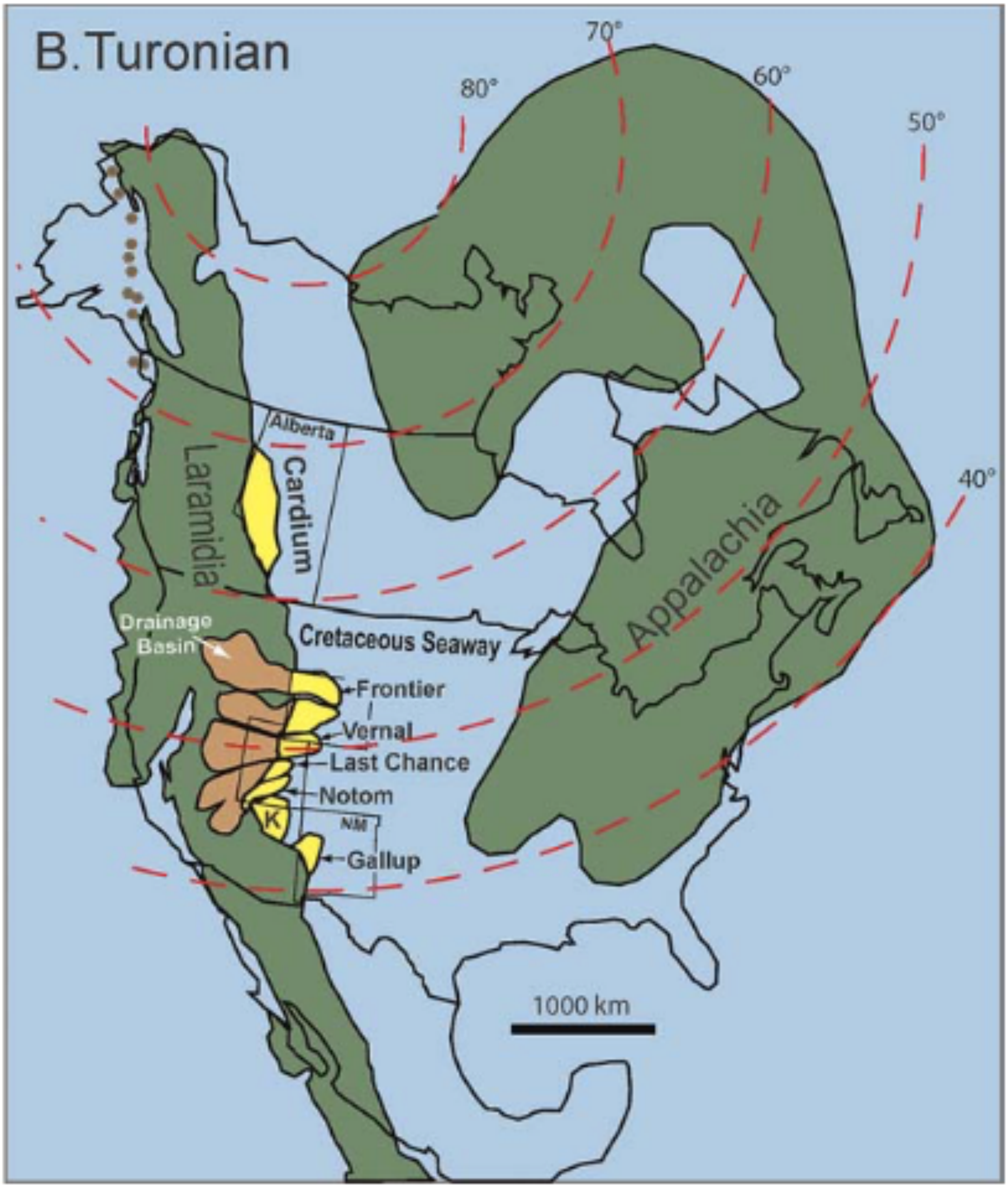


Fig. 4. Cretaceous Western Interior Seaway showing the Ferron Delta complex (taken from Bhattacharya & MacEachern, 2009)

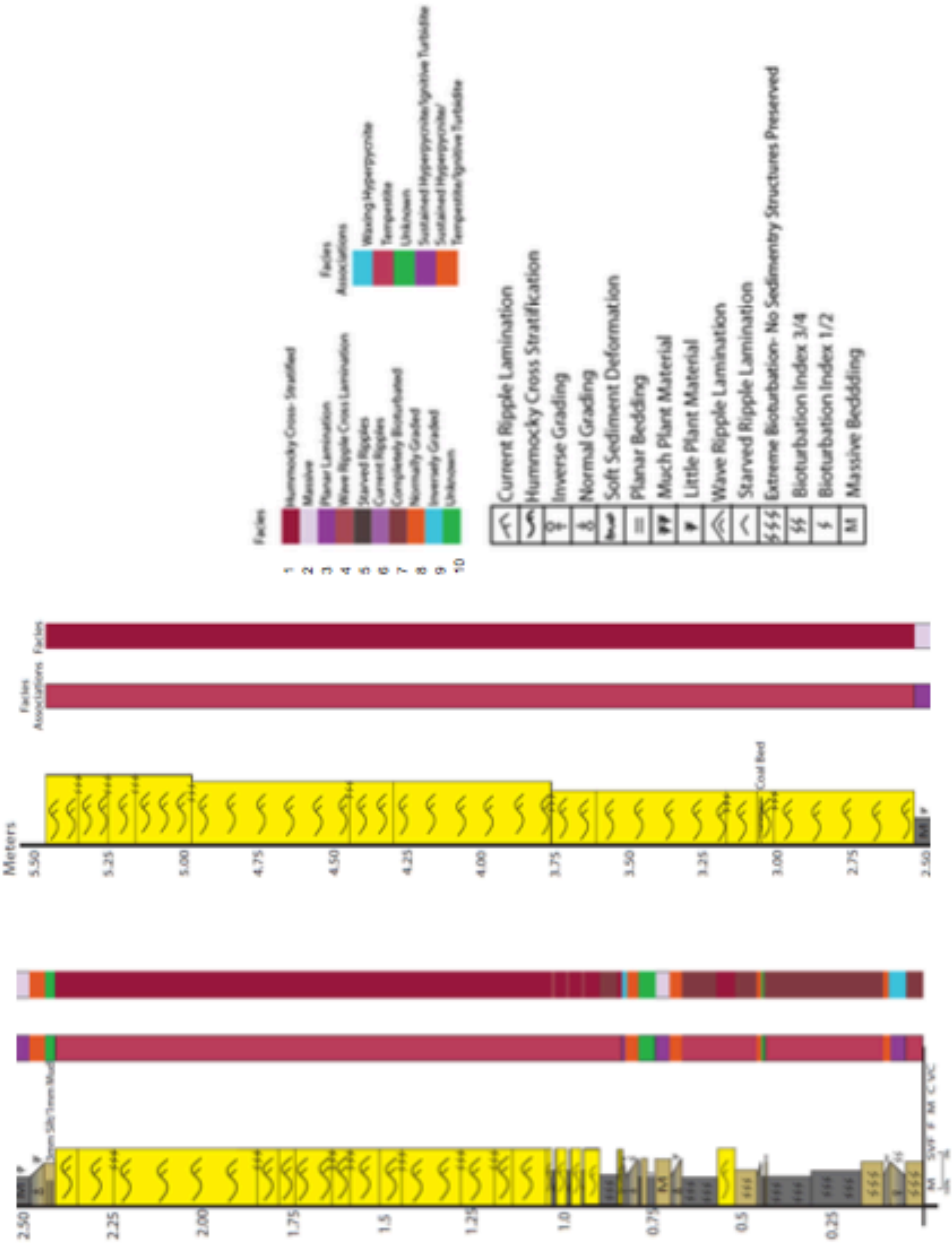


Fig. 5. Measured section of parasequence 5a digitized in adobe illustrator (taken from Seeprasad, 2012)

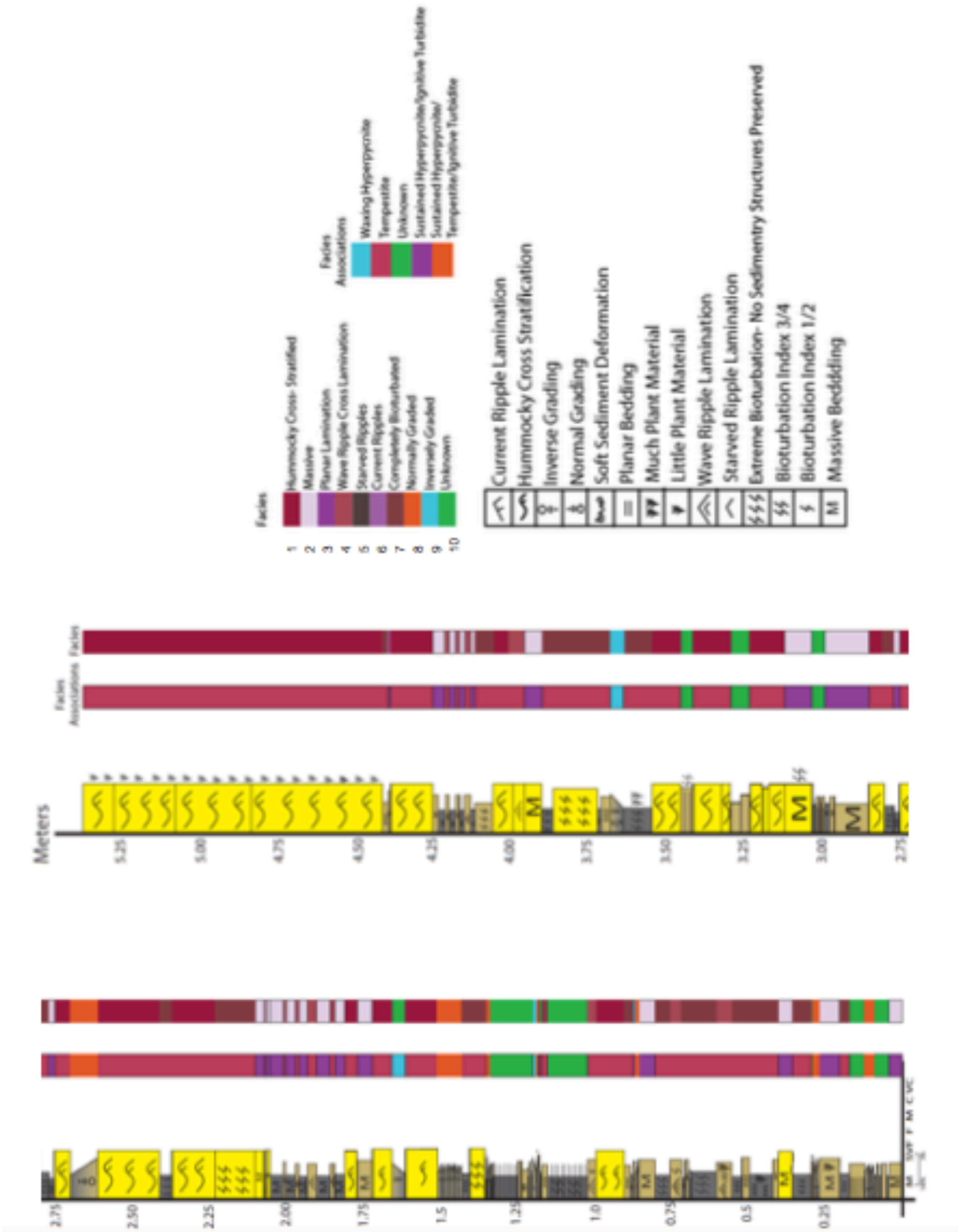


Fig. 6. Measured section of parasequence 5b digitized in adobe illustrator (taken from Seeprasad, 2012)

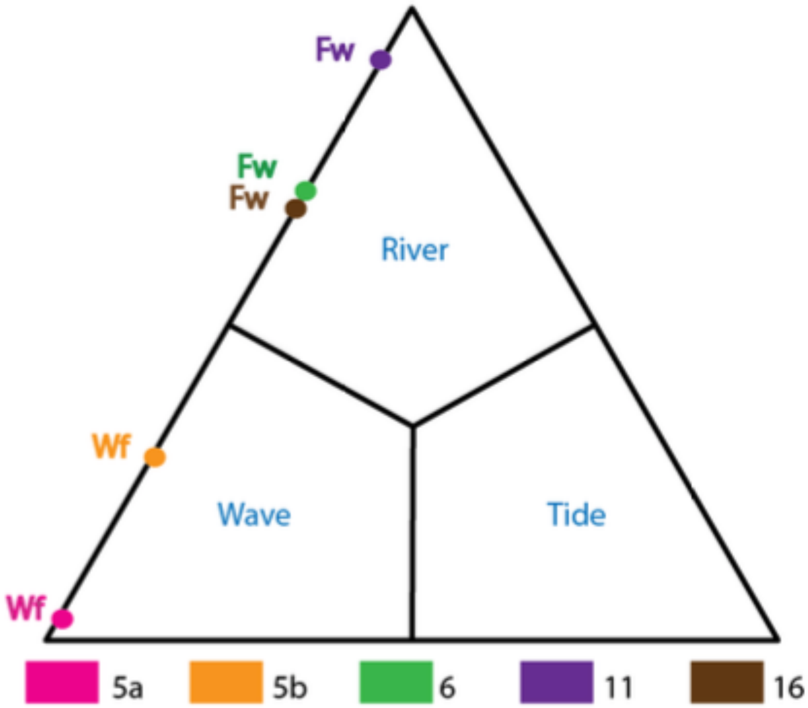


Fig. 7. Tripartite diagram showing the relative proportions of wave, fluvial and tidal influence within each parasequence. (taken from Seeprasad, 2012)

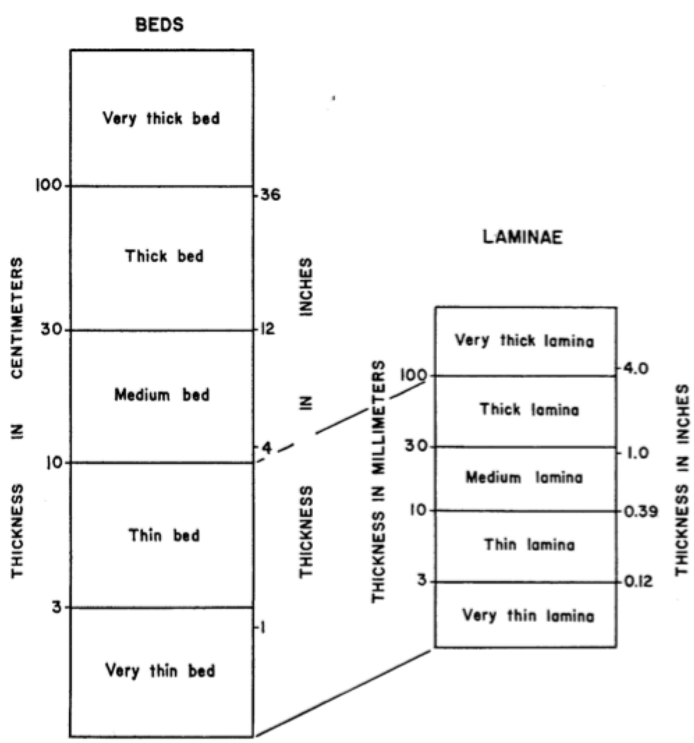


Fig. 8. Classification of thisckness of beds and laminae. (taken from Campbell, 1967)

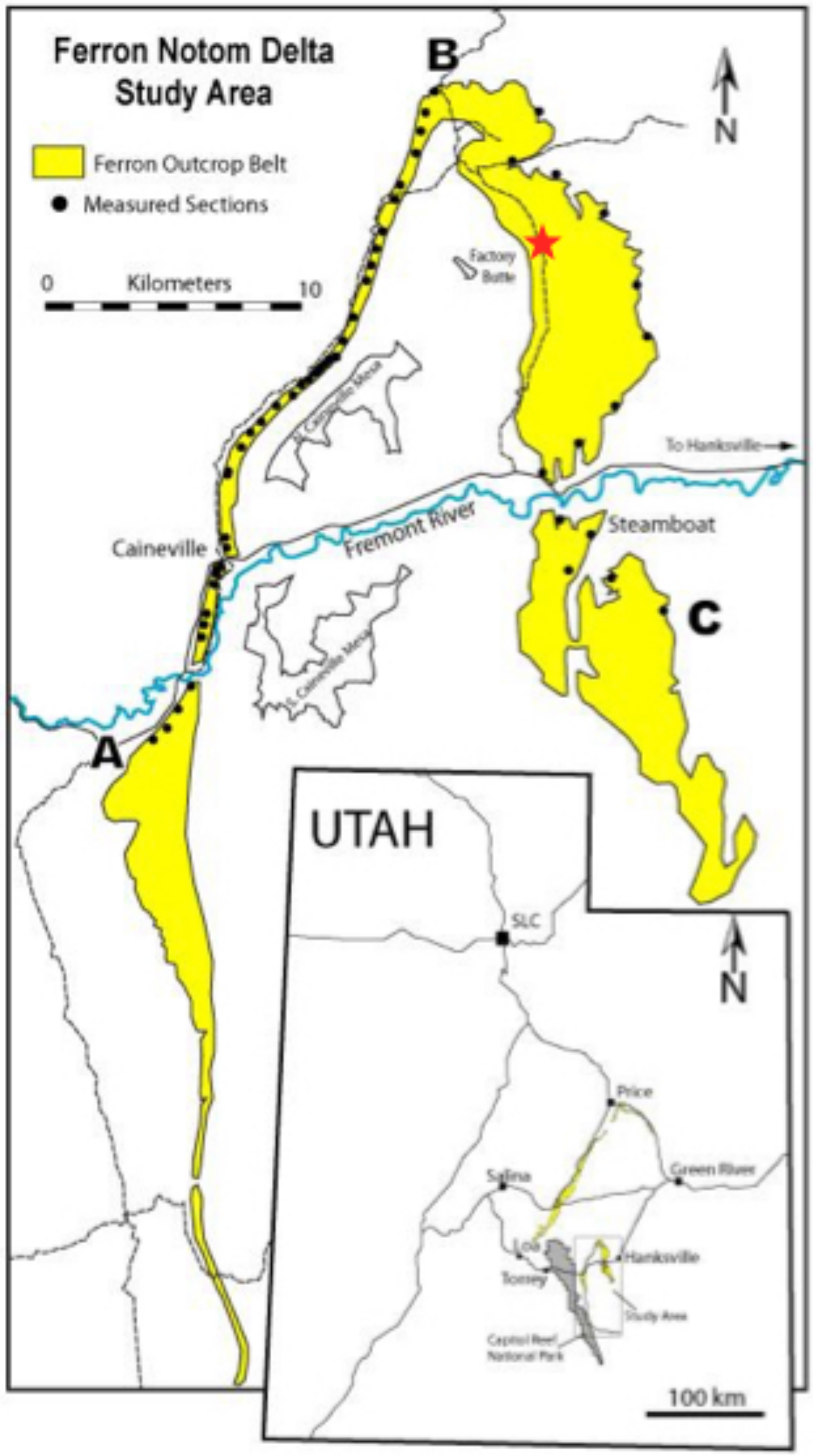


Fig. 9. Location of the Ferron Outcrop Belt between Hanksville and Cainville (taken from Zhu et al., 2012). Black dots between A and B represent the locations of all dip sections (Zhu et al., 2012). Black dots between B and C represent locations of all strike sections (Li, 2009). Red star represents the measured section taken for this project.

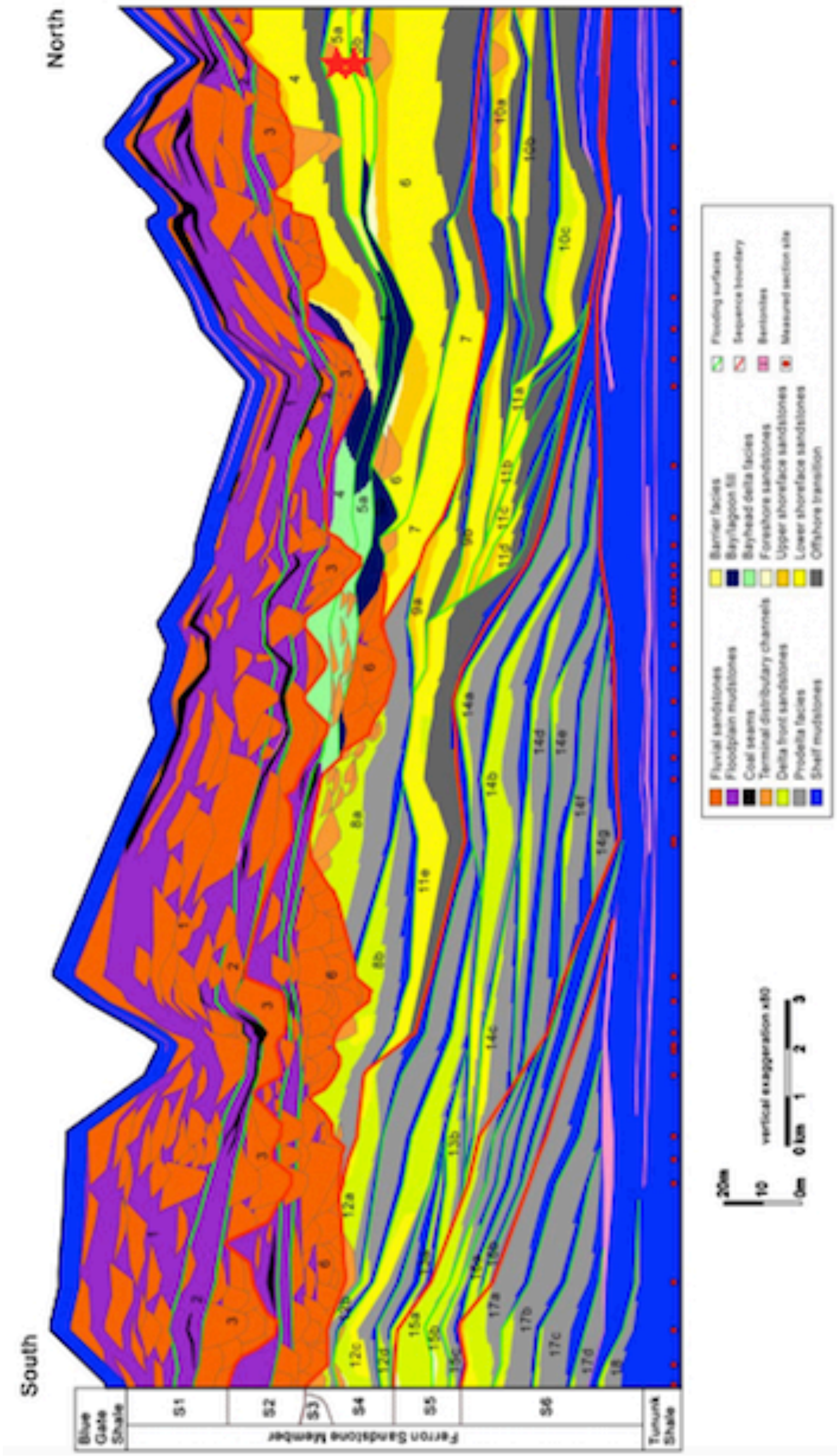


Fig. 10. Stratigraphic dip section, with 43 parasequences, 18 parasequence sets, and 6 depositional sequences illustrated. Location of measured sections related to this study marked by red stars. (taken from Zhu, 2010)

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