THIN BEDDED FACIES ANALYSIS OF THE UPPER MANCOS SHALE, RIO ARRIBA COUNTRY, NEW MEXICO

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Introduction and Background Literature

Even though fine-grained sedimentary rocks dominate most of the sedimentary record, they are relatively misunderstood (Schieber et al., 2007; Lazar et al., 2015). These rocks have traditionally been described as "homogeneous" and misinterpreted to be dominantly deposited by suspension setting in quiet, low energy environments (Schieber, 2011; Plint et al., 2012). However, examination of these rocks in outcrop, core, and thin section has shown that they are in fact heterogeneous over a wide range of scales, and form as a result of a variety of depositional processes (Schieber et al., 2007; Bhattacharya & MacEachern, 2009). Known processes that transport mud to distal environments include tempestites, ignitive turbidites, and hyperpycnites. Depositional processes can be inferred by examining sedimentary structures preserved within the rock record, as these processes produce distinct sequences of sedimentary structure (Bhattacharya & MacEachern, 2009; Li et al., 2015). For instance, turbidity currents produce turbidites and can be recognized by a complete or partial Bouma Sequence (Figure 1) within the rock record (Lamb et al., 2008).

These processes are commonly produced by sediment gravity flows (Lamb et al., 2008; Plint et al., 2012). However, in order for these depositional processes to occur, a significant slope is required to maintain sediment movement (Bhattacharya & MacEachern, 2009; Schieber, 2016). It has been shown that ancient epicontinental seas, such as the Western Interior Seaway during the Cretaceous, had large lateral extents and only relatively small bottoms slopes in the range of 0.001- 0.005 degrees (Schieber, 2016). With minimal slopes, gravity induced depositional process can only deliver sediment a limited distance offshore (Figure 2). Due to the relatively flat nature of these epicontinental seas, it is unlikely that current and widely accepted mechanisms of distant offshore transport of fine-grained sediments were responsible for the deposition of sediment into waters far offshore. It has been proposed that bottom currents that carried silts and flocculated mud in bedload were responsible for the transport of fine-grained sediment into the interiors of epicontinental seas (Schieber, 2016). Tidal currents and seasonal winds likely drove circulation that produced these bottom currents and contributed to the distribution of sediment (Schieber, 2016). Tidal currents would be strong enough to transport flocculated muds in bedload (Schieber et al., 2007). In conjunction with tidal circulation, seasonal winds would have also been able to move fine-grained sediments into distal waters as a result of seasonal winds interacting with large extents of the sea surface (Schieber, 2011).

Interest in the sedimentology and stratigraphy of thin-bedded deposits has become greater in recent years as a result of unconventional hydrocarbon reserves being found and successfully exploited. However, fluid flow parameters in these unconventional reservoirs are difficult to understand because of the complex vertical and lateral variability in thin-bedded fine-grained rocks (Passey et al., 2010). Clarifying the dominant mechanisms and the possible influence of tides in the deposition of mudstones would greatly benefit petroleum exploration, as it would help provide a better understanding of these fine-grained rocks as seals and reservoirs of resources as well as their distribution (Lazar et al., 2015). Having a better understanding of deep-water mudstones would also provide information that would benefit the fields of hydrogeology and engineering in coastal areas (Schieber et al., 2007). Even with an increased understanding of distal fine-grained sediments over the last decade there is still uncertainty surrounding the processes responsible for deposition of muddy sediment in the most distal extent of epicontinental seas.

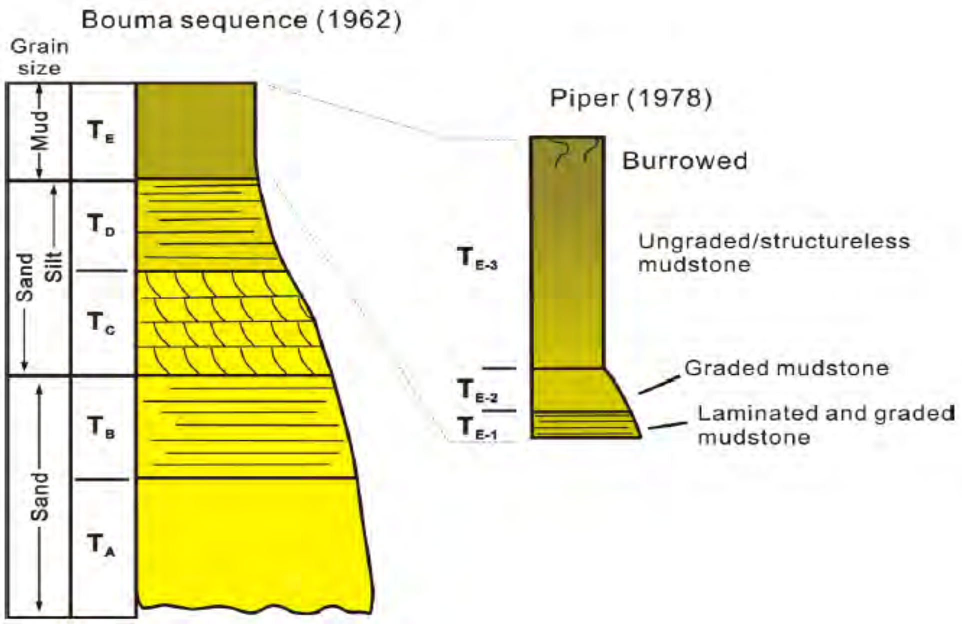

Figure 1: Bouma Sequence exhibiting normal grading and distinct subdivisions. A further division of the T_E subdivision as proposed by Piper (1978) is illustrated. Taken from Li et al., 2015.

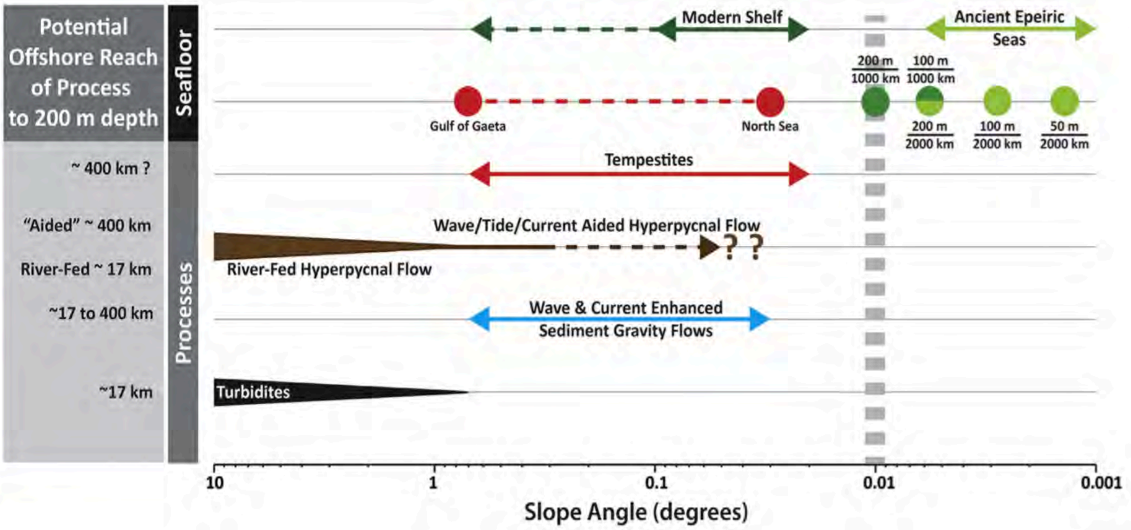

Figure 2: Potential offshore transport distance of sediment for depositional processes including tempestites, wave/ tide/ current aided hyperpycnal flow, wave and current enhanced sediment gravity flows, and turbidites. Taken from Schieber, 2016.

Objectives

The main objective of this project is to investigate the possible influence of tides on the transportation and deposition of muddy sediments during the formation of the Upper Mancos Shale in the Western Interior Seaway. The goal of this study is to also examine strata using existing conceptual models to interpret facies successions. This can be used to determine if gravity driven depositional processes also contributed to the transportation of mud into distal waters and the production of the Upper Mancos Shale Formation. This will be done by conducing a detailed thin-bedded facies analysis of the Upper Mancos from a core extracted in the San Juan Basin of Rio Arrriba Country, New Mexico and examining heterolithic units for tidal bundles.

Geologic Setting

The Mancos Shale in the San Juan Basin was deposited in the Western Interior Seaway, a marine foreland depositional basin that extended from the Gulf of Mexico to the Arctic Ocean. The Western Interior Seaway basin was created as a result of tectonic activity in the Sevier Thrust Belt, and was subsequently flooded as a result of load-induced subsidence and techno-eustatic sea level changes (Sageman & Arthur, 1994). During the Turonian, sea level reached its highstand for the Cretaceous and the Western Interior Seaway attained its greatest extent (Figure 3) (Sageman & Arthur, 1994). Multiple sea level fluctuations within the San Juan Basin caused the deposition of interbedded terrestrial and marine lithofacies (Mack et al., 2016).

In the San Juan Basin, the Mancos Shale is subdivided into the Upper and Lower Mancos Shale Formations, which are separated by an unconformity (Lamb, 1973;

Ridgley et al., 2013). The Upper Mancos Shale Formation is commonly characterized by dark grey marine shale, which is interbedded with marine siltstone and very fine-grained sandstones (Broadhead, 2015). A recent study by Broadhead further divides the Upper Mancos into three parts, the Mancos A, B, and C, (Figure 4) based on distinct differences in the sand, clay, and carbonate content of the shale as observed from gamma-ray and resistivity logs (2015). This study examines the Upper Mancos by conducting detailed facies analysis on a core taken from this formation.

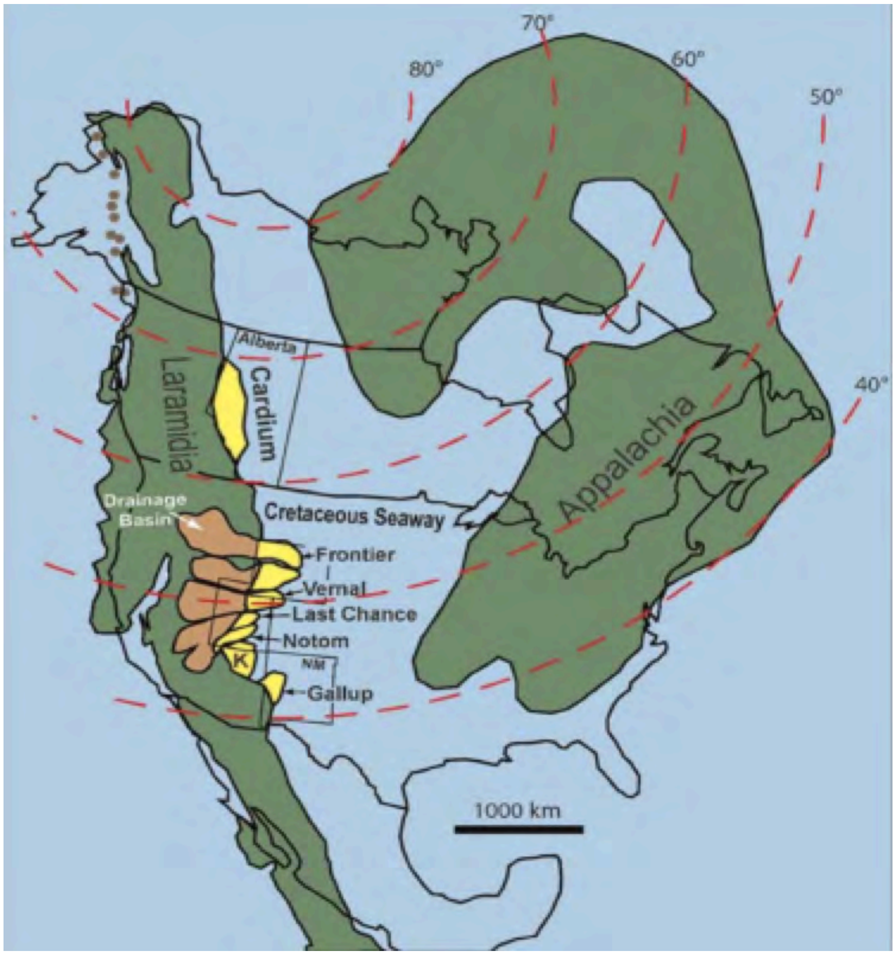

Figure 3: The Cretaceous Western Interior Seaway showing the delta complexes Cardium, Frontier, Vernal, Last Chance, Notom, Kairparowits (K) formed during the Turonian. Taken from Bhattacharya & MacEachern, 2009.

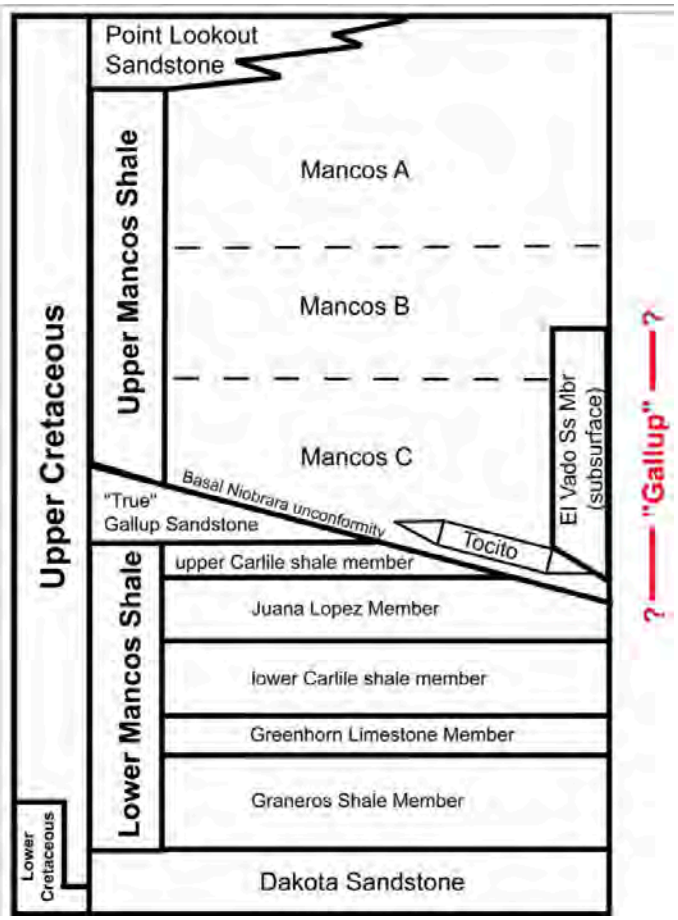

Figure 4: Stratigraphy of the Mancos Shale in the San Juan Basin with subdivisions of the Upper Mancos Shale. Taken from Broadhead, 2015

Methodology

A total of 17 boxes of slabbed core from the Upper Mancos Shale Formation, were measured and logged in a field notebook. The slabbed core was then cleaned and photographed with the use of a copy stand. Sedimentological data collected includes lithology, grain-size, ichnofacies, degree of bioturbation, fossils, type and quantity of sedimentary structures, and thickness of facies units. A measuring tape was used to measure bed thickness and the length of the core. A hand lens with a x10 magnification and a grain sized card were also used in order to determine grain size measurements according to the Wentworth classification. Since a hand lens could not be use to determine the clay content of the mudstone, a combination of two techniques, chewing and colour differences, were used to estimate the clay content of the core. Chewing samples of the core can be used to differentiate between the amounts of clay verses silt within a mudstone, as clay will have a smooth texture when chewed whereas silt feels gritty. Differences in colour can also be used to determine the clay content of a mudstone because clays are commonly darker in colour than silt grains. Therefore, if a mudstone is a light grey in colour it likely has a higher silt content, and if it is very dark then it would commonly be composed of a greater percentage of clay.

A general measured log of the core will be created in Adobe Illustrator from the photographs taken and the initial notebook log in order to show the general trends within the core at a meter scale. Specific portions of the core will be selected based on trends observed in well-log gamma and resistivity. These subsections of the core will then be logged at a millimetre scale in high-resolution in order for thin bed facies analysis to be conducted. Specifically, heterolithic units of the core will be examined for possible tidal bundle sequences, which will be delineated by rhythmic patterns of thickening and thinning lamina. Examining these lamina can help develop a better understanding of the depositional processes that created these units in the Cretaceous Western Interior Seaway and the possible influence of tides on the deposition of fine-grained sediment far offshore in past epicontinental seas. The high-resolution logged sections of the core will also be used to examine the influence of known processes including tempestites, ignitive turbidites and hyperpycnites in the transport of mud offshore. These processes are known to deposit unique facies sequences that can be used to infer the dominant formative process (Bhattacharya & MacEachern, 2009; Li et al., 2015).

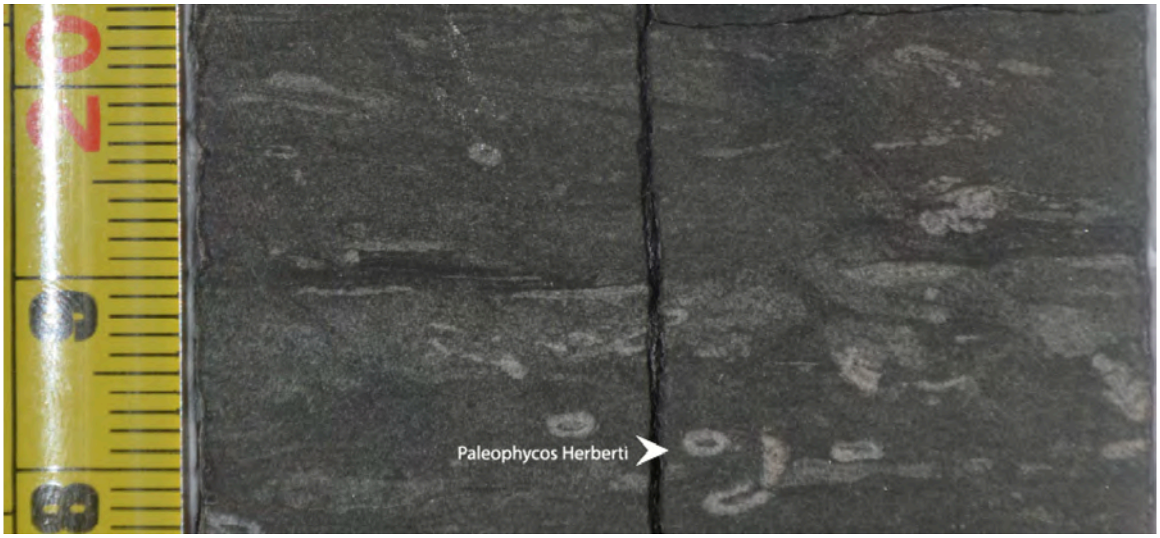

Figure 5: Paleophycos Herberti trace fossil in the core examined from the Upper Mancos. Scale is in centimeters.

Analysis

A general examination of the core shows that it is a laminated and ripple bedded siliceous mudstone with numerous trace fossils including Planolities, Chondrites, Paleophycos Herberti (Figure 5), Schaubcylindrichnus, Zoophycus, Bergaueria, and Cylindrichnus. Laminations and ripple beds are comprised of silt to very fine-grained sediments. Some continuous ripple beds are present in the core, but the majority of laminations and beds are discontinuous. The degree of bioturbation varies through the core, however it is relatively high throughout. Inoceramus fragments are also present in the core in varying concentrations.

Further research beyond basic examination of the core still needs to be conducted, including high-resolution facies analysis. An examination of heterolithic units for tidal bundles by counting lamina and measuring lamina thickness also needs to be conducted. Reading further literature will also assist in the interpretation of depositional processes and the influence of tides on bottom current deposition in the Upper Mancos.

Timeline for Future Research

Research for this project began in June of 2016 and data collection was completed during the summer of 2016 in Socorro, New Mexico at the New Mexico Bureau of Geology and Mineral Resources located on the New Mexico Institute of Mining and Technology campus. A literature review will be conducted and completed by early November 2016. A general measured log of the core and select portions of the core logged in high-resolution will be created from detailed photographs and field notes using Adobe Illustrator. These digitized logs will be completed no later than the beginning of February 2016. A draft thesis will then be completed by the end of February 2016 and will undergo a process of review and editing. The final written thesis including all recommended changes will be completed and submitted by April 6th, 2017.

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