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Going the distance: A basinwide, high-frequency allostratigraphic framework for the Upper Cretaceous Colorado Group, Western Canada Foreland Basin

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Summary

The Upper Cretaceous Colorado Group is a mudstone-dominated sequence in the Western Canada Foreland Basin. A high-resolution allostratigraphic framework analysis of the succession showed allomembers present in the foredeep condensing toward the forebulge region. Several of the major allostratigraphic surfaces are discontinuous and do not extend into the backbulge. The foredeep and forebulge successions are mudstone-dominated. Backbulge successions become carbonate-rich and bentonite beds increase in frequency relative to the foredeep. The lithologic differences and discontinuous nature of allostratigraphic surfaces observed between the WCFB segments suggests forebulge dynamism played a significant role in stratigraphic preservation and depositional differentiation of the Colorado Group.

Introduction

The Colorado Group is a mudstone-dominated sequence that spans the foredeep, forebulge, and backbulge segments of the Cretaceous Western Canada Foreland Basin (WCFB). This basinwide succession records the depositional response to time-variant and paleographically diverse tectonic, eustatic and climatic controls (Schröder-Adams, et al., 2001; Tyagi et al., 2007; Varban and Plint, 2008; Hu and Plint, 2009). This dynamic interplay is reflected in stratigraphic discontinuities in the Colorado Group between the Alberta foredeep succession and the Saskatchewan backbulge succession.

A key component to understanding the relationship between the foredeep and backbulge stratal packages is determining how flexural dynamics of the putative forebulge affected regional stratigraphic continuity. Correlation of high-frequency allostratigraphic surfaces establishes the time relationships of stratal packages across the basin. Previous work demonstrates the utility of high-frequency allostratigraphic frameworks for elucidating the spatial and temporal relationship between flexural loads, forebulge response and the resulting stratal packaging in Colorado Group units of the WCFB foredeep (e.g.: Plint et al., 2012). This technique can be used to define the geographical, stratigraphic and temporal limits of discrete petroleum systems in the carbonaceous mudstones of the Colorado Group.

The initial phase of our research investigated implications for stratigraphic and spatial distribution of organic matter in the WCFB when integrating allostratigraphy with organic geochemistry. This study focuses on the high-frequency allostratigraphic framework phase of our work, which is being developed for subsequent regional burial history and petroleum system modeling.

Method

Three forebulge-related stratigraphic model options were considered in this study: a) forebulge is not active and produces a ‘tapering’ geometric pattern of regionally discontinuous, onlapping strata, b) forebulge is active, producing regionally continuous stratal packages that thin (condense) across the

forebulge, but major surfaces can be correlated on both sides of forebulge, or c) forebulge is active, but surfaces are discontinuous due to onlap on either side.

Twenty cores were examined across the basin. Nine are located in Alberta and the remaining eleven are located in Saskatchewan. The core interval focused on the Second White Specks through to Base of Fish Scales interval (and their allostratigraphic equivalents). Major allostratigraphic bounding surfaces observed in core were correlated from the foredeep and into the backbulge using geophysical log data. Surfaces established in the allostratigraphic framework of Tyagi et al. (2007) that were incorporated in this study include the regional Bighorn (Red) and 'X' bentonites, K1 disconformity, flooding surfaces 'X' and 'AX-3', and the downlap surface of Fish Scales Upper (FSU).

Examples

In general, cores from the foredeep and forebulge-region (along Alberta-Saskatchewan border) are mudstone-dominated with localized, very finely laminated, interbedded silty mud and very fine sandstone. Lithology in the backbulge shifts to calcareous mudstones with interbedded bioclastic limestone, and an increased frequency of bentonite beds. Transgressive surfaces are marked by abrupt to gradual increases in mud content, locally associated with 1 to 5 cm thick coarse sand lags with fish bone debris. Figure 1 is a graphic log of core from the forebulge region, showing a mud-dominated succession with intermittent coarsening-upwards cycles. The frequent episodes of lag deposits and bentonite beds suggest a high degree of condensation. Figure 2 depicts a core from the backbulge region of the WCFB. Like the previous example, there are cycles of mudstone-rich intervals with varying amount of very fine sand interbeds, and frequent bentonite beds, but thick calcareous mudstones are more evident.

The allomembers noted by Tyagi et al., (2007) in the foredeep are continuous until the western flank of the forebulge region. Within the forebulge region, allomembers become condensed as they onlap onto the FSU surface. Several major allostratigraphic surfaces do not correlate across the forebulge into the backbulge succession. The condensation of allomembers from the foredeep to the forebulge region, and the allostratigraphic discontinuities into the backbulge segment suggest that episodic forebulge movement influenced depositional continuity in the basin.

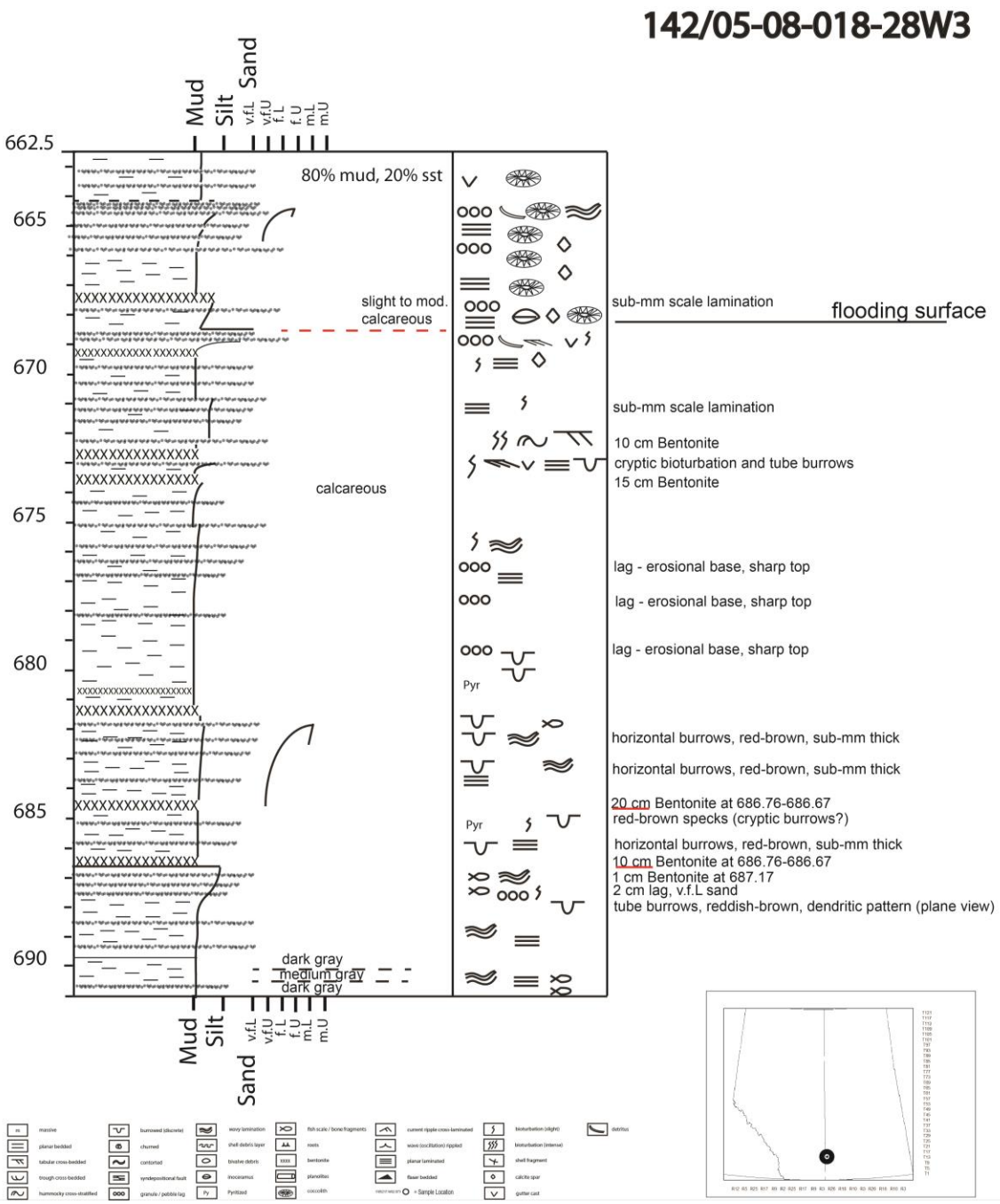

Figure 1. A stratigraphic log of a forebulge region well (142/05-08-018-28W3), cored within the Second White Specks and Fish Scales Formations. The high frequency of lag deposits and bentonites are evidence of condensation of the stratigraphic succession at this location.

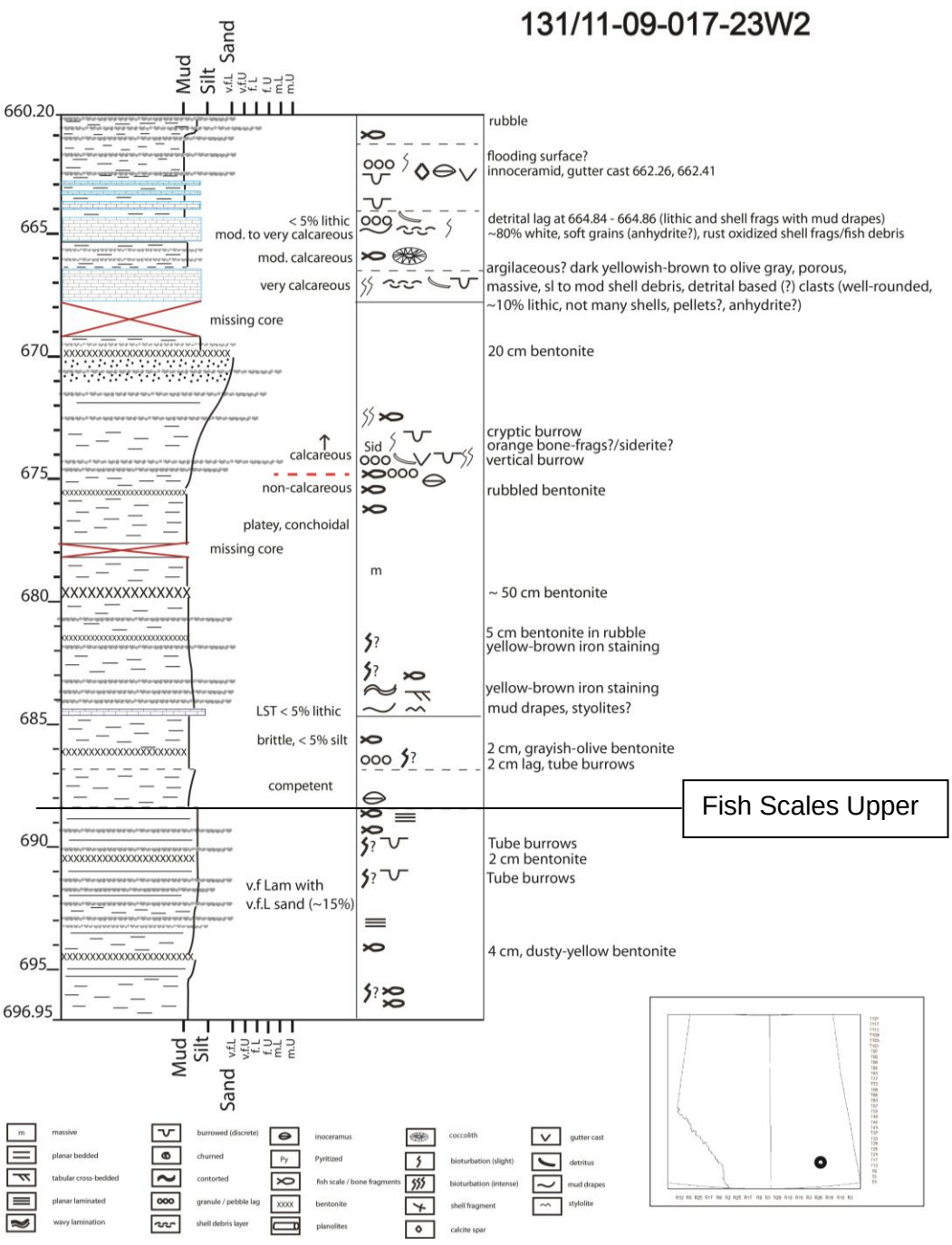

Figure 2. A stratigraphic log of a backbulge well (131/11-09-017-23W2), cored through the Second White Specks, Belle Fourche, and Fish Scales Formations. Note the increased abundance of calcareous strata relative to the example in Figure 1.

Conclusions

Using an allostratigraphic approach to correlate Upper Cretaceous Colorado Group successions has permitted recognition of the relationship between foredeep and backbulge stratal packages, and the conditions under which they were deposited. The discontinuous nature of time-related surfaces and the variability in stratigraphic successions from the foredeep to backbulge suggest an active forebulge at

time of deposition. It appears that transgressive boundaries can be correlated into the forebulge region of the WCFB, but then become obscured within the carbonate-rich interbeds of the backbulge. Future work will investigate the correlation of major bentonites observed in core across the basin and use them to refine the temporal relationship between forebulge and backbulge stratigraphy.

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