ICHNOLOGY OF THE BRIDGE CREEK LIMESTONE: EVIDENCE FOR TEMPORAL AND SPATIAL VARIATIONS IN PALEO-OXYGENATION IN THE WESTERN INTERIOR SEAWAY

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ABSTRACT: The Upper Cretaceous (Cenomanian-Turonian) Bridge Creek Limestone is characterized by decimeter-scale alternation of pelagic limestones and marly shales that were deposited under variably oxygenated waters. Vertical stacking patterns of laminities and four oxygen-related ichnocoenoses in the Bridge Creek in two cores—USGS #1 Portland from east-central Colorado and Amoco #1 Rebecca K. Bounds from western Kansas—provide a record of both temporal and spatial changes in benthic oxygenation within the distal offshore parts of the Western Interior Seaway.

Paleo-oxygenation histories reconstructed for the Portland core reflect (1) a broad trend towards decreased benthic oxygenation through the entire Bridge Creek interval; (2) a high-amplitude redox cyclicity that corresponds to limestone/marly shale couplets; and (3) a higher-frequency, lower-amplitude redox cyclicity expressed within the marly shale intervals.

Trends (1) and (2) are well expressed in the Bounds core. However, bioturbated horizons in marly shale intervals are less common, thinner, of lower ichnocoenosis rank, or absent altogether. This pattern indicates that paleo-oxygenation levels were lower at the Bounds locality, at least during clastic-dominated phases of depositional cycles, and may reflect higher productivity and oxygen demand in the eastern part of the basin.

INTRODUCTION

The rhythmically bedded Bridge Creek Limestone Member of the Greenhorn Formation represents one of two Upper Cretaceous intervals targeted for detailed study as part of the Cretaceous Western Interior Seaway Drilling Project. Among many other objectives (Dean and Arthur, this volume), this multidisciplinary research program was undertaken to better establish the mechanisms responsible for depositional cyclicity and to determine controls on accumulation rate, character, and preservational state of organic matter in the Western Interior basin. Attainment of these and related goals depends, in part, on our ability to evaluate how benthic oxygenation levels varied through time and space.

Benthic oxygenation is an important oceanographic parameter that may reflect aspects of oceanic circulation, some of which may be mediated by climate (e.g., upwelling intensity, degree of thermohaline density stratification, etc.), and exerts significant control over the quantity and preservational state of organic matter in marine deposits. Oxygenation is also one of the most crucial factors influencing the character and activities of benthic organisms in quiet marine settings. Fortunately, the response of bioturbating infauna to variations in benthic oxygenation are preserved and reflected by ichnological parameters. Hence, by serving as proxy indicators of paleo-redox conditions, ichnofabrics of hemipelagic and pelagic strata can play a significant role in paleoceanographic reconstructions and source-rock studies.

With this as incentive, I analyzed ichnofabrics and component ichnofossils at the centimeter scale throughout the Bridge Creek interval of two cores: USGS #1 Portland in east-central Colorado and Amoco #1 Rebecca K. Bounds in western Kansas (Dean and Arthur, this volume). The objectives of this paper are to (1) summarize the ichnologic data collected during these studies and (2) discuss their general implications for both temporal patterns (long-term trends and higher-frequency cycles) and spatial variations in benthic oxygenation in the offshore part of the Western Interior Seaway.

BRIDGE CREEK LIMESTONE

General Framework

The Cenomanian-Turonian Bridge Creek Limestone Member of the Greenhorn Formation records deposition in distal offshore settings of the Western Interior Seaway during a major transgressive episode (Elder and Kirkland, 1985; Elder et al., 1994). The Bridge Creek Limestone, which is approximately 15 m thick on average (Eicher and Diner, 1989), overlies the Hartland Shale Member of the Greenhorn Formation and is overlain by the Fairport Member of the Carlile Shale (Elder and Kirkland, 1985; Hattin, 1985). In Colorado, the Bridge Creek Limestone is subdivided into three units (lower, middle, and upper Bridge Creek; Pratt, 1984; Elder and Kirkland, 1985), which are generally equivalent to the upper Hartland, Jetmore, and Pfiester Members of the Greenhorn Limestone as defined in Kansas (Hattin, 1985). Delineation of these units is based primarily upon bedding characteristics and minor lithological variability (see Elder and Kirkland, 1985).

As a whole, the Bridge Creek is characterized by well-defined, decimeter-scale rhythmic alternation of highly bioturbated, organic-poor, micritic limestones and laminated to bioturbated, organic-rich marlstones and marly shales (Pratt et al., 1985; Elder and Kirkland, 1985; Arthur and Dean, 1991; Pratt et al., 1993). Subordinate lithological components include numerous bentonites, derived from the volcanic arc to the west, and calcarenites of variable thickness (Pratt, 1984; Elder, 1985). Bentonites, as well as prominent limestone beds, can be traced over a large area of the Western Interior and define lithostratigraphic units within which spatial changes in sedimentation patterns can be assessed (Hattin, 1985; Elder and Kirkland, 1985; Elder et al., 1994). Calcarenites, which are attributed to bottom-current winnowing, are relatively minor components of the lower and middle units, but are extremely abundant in and diagnostic of the upper Bridge Creek (Pratt, 1984).

Carbonate Cyclicity

Decimeter-scale rhythmicity in the Bridge Creek traditionally has been interpreted to be the product of orbitally driven climate cycles (Gilbert, 1895; Hattin, 1975; Kaufman, 1977; Fischer, 1980; Barron et al., 1985). However, there is considerable disagreement regarding the primary paleoceanographic mechanisms responsible for these carbonate rhythms. Bridge Creek carbonate oscillations are attributed to combined productivity/redox cycles that may be linked to climate-driven changes in density stratification of the Tethys to the south (Eicher and Diner, 1989, 1991; Ricken, 1991, 1994). Alternatively, carbonate rhythms may record combined dilution-redox cycles associ-