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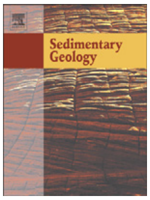

Preservation of primary lake signatures in alkaline earth carbonates of the Eocene Green River Wilkins Peak-Laney Member transition zone

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ABSTRACT

Significant changes in carbonate mineralogy, texture, and stable isotope composition occur at the transition from the Wilkins Peak Member to the Laney Member in the Eocene Green River Formation, Bridger Basin, Wyoming, which reflect evolution of inflow waters, lake waters, and paleoenvironments.

The top of the Wilkins Peak Member contains heterogeneous laminae of calcite and dolomite. Evaporites associated with these layers suggest deposition in hypersaline lakes. Diagenetic carbonate mineral textures include euhedral cement overgrowths and interlocking mosaics of calcite and dolomite crystals, 20–70 μm in size. Electron microprobe analyses indicate diagenetic overgrowth of Fe-rich dolomite on cloudy Fe-poor cores. $\delta^{18}O$ values of carbonate laminae in the upper Wilkins Peak Member vary by ~6‰ with no depth dependent or mineralogic trends, which also suggests diagenetic overprinting.

Alternating organic-rich and primary aragonite, calcite, and dolomite laminae were identified from the lower Laney Member. Primary lacustrine aragonite consists of well sorted, prismatic crystals 5–10 μm in length, with micro-lamination defined by crystal size variation. Primary precipitated calcite and dolomite laminae are monomineralic, with well sorted polyhedral crystals, ~10 μm in size. Primary mineralogy of the lower Laney Member changes from calcite to aragonite and dolomite stratigraphically upward. Along the same 15 m thick stratigraphic interval, $\delta^{18}O$ values decrease upward by ~3‰, all of which suggests (1) lake waters underwent evaporative concentration, which together with calcite precipitation increased the lake water Mg/Ca ratios and led to formation of aragonite and dolomite, (2) source waters became lower in $\delta^{18}O$, possibly as inflow changed to higher altitude foreland rivers.

The results from this study show that understanding the primary lacustrine versus diagenetic origin of Green River carbonate minerals is essential for paleoenvironmental and paleoclimate interpretations.

1. Introduction

Carbonate minerals deposited in lacustrine settings potentially preserve information about tectonic setting, paleoaltimetry, paleoenvironments, variations in lake water conditions (evaporative concentration, source waters, temperature) and biological activity (Kelts and Hsü, 1978; Eugster and Kelts, 1983; Gierlowski-Kordesch, 2010; Renaut and Gierlowski-Kordesch, 2010; Last and Last, 2012). Lacustrine carbonates form as: (1) primary precipitates in the water column, (2) biologically produced skeletons or microbialites, and (3) transported detrital grains. All of these carbonates can be affected by diagenetic processes. Precipitation of carbonates in lacustrine settings is triggered by many factors, including: evaporative concentration, temperature changes, degassing, and mixing of lake waters with groundwater, spring water, or surface water inflows (Kelts and Hsü, 1978). Carbonate detritus is added to lake basins through river systems which drain surrounding higher elevation topographies. Carbonates can also enter lakes as airborne dust (Leng et al., 2010). Diagenetic alteration of lacustrine carbonates could make interpretation of depositional conditions difficult because mineral dissolution and precipitation can reset primary geochemical lake signatures (Morrill and Koch, 2002).

Most fresh water lakes precipitate low-Mg calcite (LMC). However, at higher salinities high-Mg calcite (HMC), aragonite, and dolomite can form as the primary precipitated phase (Müller et al., 1972; Kelts and Hsü, 1978; Eugster and Kelts, 1983; Demicco and Hardie, 1994). Primary carbonate precipitates (calcite, aragonite, or dolomite) are typically very fine-grained and form layers that commonly alternate with layers rich in detrital and organic matter and/or cyanobacteria (Gierlowski-Kordesch, 2010). Clay minerals and silt-sized terrigenous quartz are brought into lakes in the suspended load of rivers or as windblown dust (Flügel, 2010).

Detrital carbonates are problematic when interpreting carbon and oxygen stable isotope data. For example, the sediments of Lake Gölhisar Gölü, Turkey, and Lake Pamvotis (Greece), contain both *in*

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situ precipitated and detrital carbonates. Such a mixed source greatly complicates stable isotope interpretations (Leng et al., 2010).

Primary precipitated, detrital, and diagenetic carbonates are well-preserved in the Eocene Green River Formation of Colorado, Wyoming, and Utah (Fig. 1). Previous studies have not fully constrained the origins of these carbonates (e.g. Eugster and Hardie, 1975; Lundell and Surdam, 1975; Surdam and Stanley, 1979; Smith et al., 2008). Several studies of stable isotopes in carbonates of the Green River Formation used bulk rock samples to document changes in lake state (hydrologically open vs. closed) and changing source waters (e.g. Norris et al., 1996; Pitman, 1996; Carroll et al., 2008; Doebbert et al., 2010). Although care was taken, these bulk sampling approaches could not fully consider the origin or diagenetic alteration of the carbonates. Norris et al. (1996), for example, interpreted low $\delta^{18}O$ values from Green River carbonates to reflect snowmelt-derived inflow waters, depleted in $\delta^{18}O$, but no assessment was made of diagenetic overprints of the microbial carbonates studied. Morrill and Koch (2002) questioned this interpretation; they analyzed primary aragonite bivalve shells and altered calcite bivalve shells and found that unaltered samples do not support the snowmelt hypothesis.

In another study, Carroll et al. (2008) used stable isotope data from carbonates of the Wilkins Peak Member (WPM) and the Laney Member (LM) in the Washakie Basin to interpret river capture and source water origin. They found a decrease of 6‰ in calcite $\delta^{18}O$ across a “fill-to-spill” surface, which they attributed to capture of lower $\delta^{18}O$ source waters from a high elevation foreland river. Although macroscopically obvious diagenetic phases were excluded from consideration, Carroll et al. (2008) did not sample at the sedimentation unit scale.

This study examines the mineralogy, petrography, and stable isotopes ($\delta^{18}O$) of Green River Formation carbonates at the sedimentation unit (i.e. laminae) scale. Aragonite, calcite, and dolomite occur at the transition from the Wilkins Peak Member to the Laney Member in the Bridger Basin, WY. Evidence for preservation of primary lake and detrital carbonates is presented along with evidence for diagenetic alteration. The origins of the carbonate are constrained by petrographic criteria obtained from transmitted light and scanning electron microscopy (SEM). Changing lake conditions are inferred from sedimentologic and mineralogical changes across the transition zone and trends in stable isotope composition. This study focuses on the carbonates in the ERDA 1 Blacks Fork core from the Bridger Basin where the stratigraphy and sedimentology of the WPM are well documented (Surdam and Stanley, 1980; Smoot, 1983; Dickinson et al., 1988; Roehler, 1992a,b; Smith et al., 2003; Pietras and Carroll, 2006; Smith et al., 2008, 2010).

2. Geologic setting

The Green River Formation of Wyoming, Colorado, and Utah was deposited in two large lakes, Lake Gosiute and Lake Uinta, in basins east of the Cordilleran fold and thrust belt (Smith et al., 2008; Fig. 1). Lake Uinta filled the Uinta and Piceance Creek Basins in Utah and

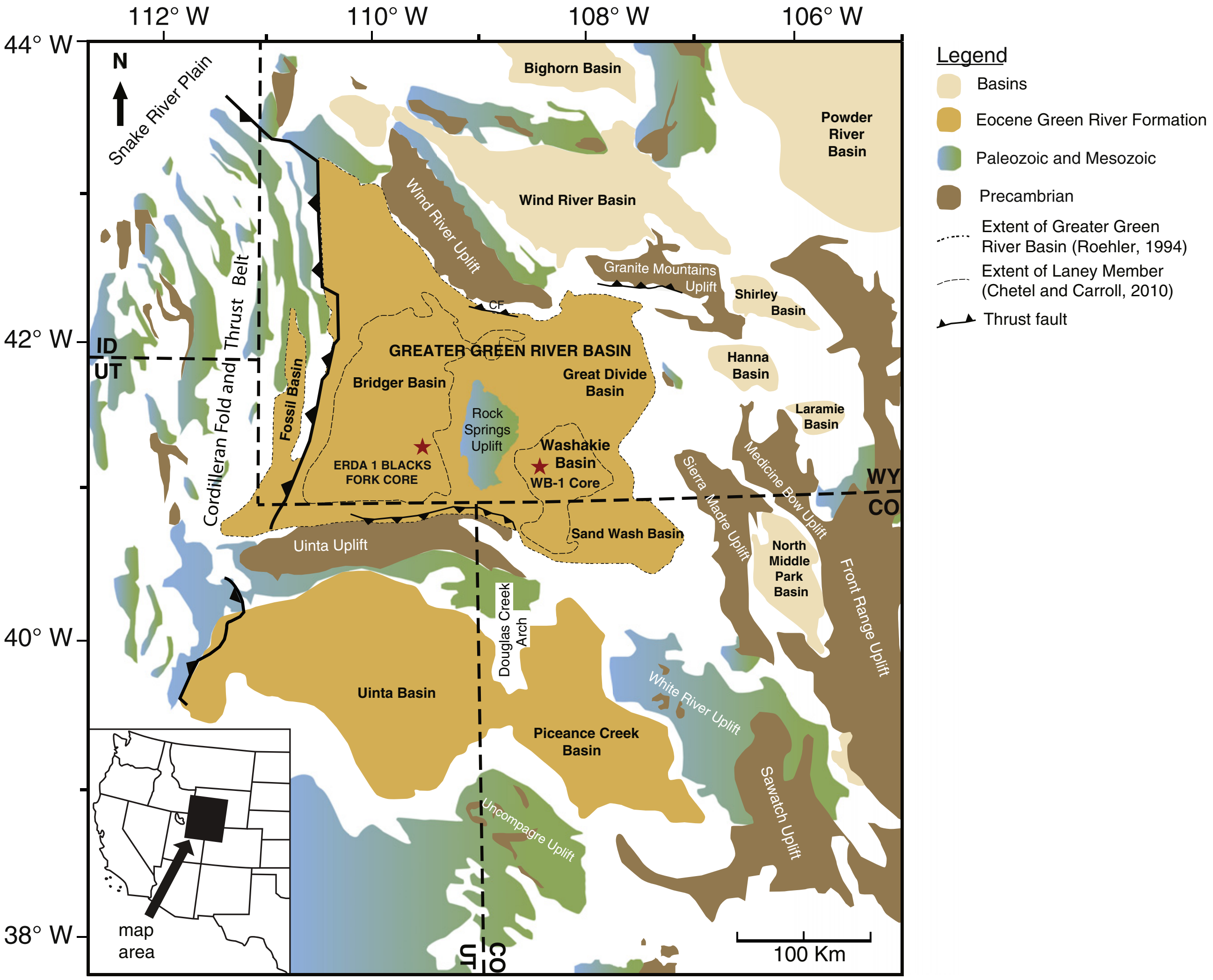

Fig. 1. Simplified geologic map showing the location of the Greater Green River Basin, the ERDA 1 Blacks Fork core (this study), and the Arco Oil and Gas WB-1 core (Carroll et al., 2008) (modified from Roehler, 1992a, 1992b; Smith et al., 2008; Jagniecki et al., 2013).