Available online at www.sciencedirect.com
ScienceDirect
Sedimentary Geology 198 (2007) 125–145
Sedimentary Geology
www.elsevier.com/locate/sedgeo

Patterns of early post-depositional and burial cementation in distal shallow-marine sandstones: Upper Cretaceous Kenilworth Member, Book Cliffs, Utah, USA

Philip G. Machent [a,*], Kevin G. Taylor [a], Joe H.S. Macquaker [b], Jim D. Marshall [c]

[a] Department of Environmental and Geographical Sciences, Manchester Metropolitan University, Chester Street, Manchester M1 5GD, UK
[b] School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Oxford Road, Manchester M13 9PL, UK
[c] Department of Earth Sciences, University of Liverpool, PO Box 147, Liverpool L69 3BX, UK

Received 13 February 2006; received in revised form 13 November 2006; accepted 7 December 2006

Abstract

There is a limited understanding of the spatial linkage between cementation processes in shoreface/coastal plain successions and those operating in distal offshore successions. To address this, an integrated sedimentological, sequence stratigraphic and diagenetic study was undertaken on a distal shallow-marine succession, the Upper Cretaceous Kenilworth Member Book, Cliffs, Utah, USA. Laterally extensive carbonate cement is the most volumetrically significant diagenetic feature. It constitutes up to 55 vol.% of the distal lower-shoreface sandstone and sandy siltstone units beneath major flooding surfaces. During rising relative sea-level major flooding events resulted in low sedimentation, which extended residence time of sediments in early diagenetic zones and promoted enhanced cementation beneath these boundaries. Carbonate for early calcite cements was probably derived from sulphate reduction, marine water and oxidation of organic matter.

Stable-isotopic composition of later ankerite ($\delta^{18}O$ ~−11.9 to −6.0‰ VDPB, $\delta^{13}C$ ~−4.5 to −0.3‰ VDPB) suggests precipitation during progressive burial (*c.* 1.7 to 3.4 km, 72 to 122 °C) from evolved marine fluids. The carbonate and other mineralizing solutes were derived, increasingly with burial, from decarboxylation of organic matter and clay mineral transformations in adjacent siltstones and shales. These interbedded, overlying and underlying facies provided an important source of mineralizing solutes that influenced the extent of pervasive cementation during burial. The combination of stratigraphic and lithofacies control resulted in laterally extensive cements that differ to shoreface successions, although are similar in form to those described for many offshore mudstone-dominated successions. Limited early concretionary ferroan dolomite beneath the expression of the sequence boundary and some flooding surfaces, however, suggests cementation by meteoric fluids at times of relative sea-level lowstand. Similar processes have been demonstrated in more proximal successions in the Book Cliffs.

Keywords: Carbonate; Diagenesis; Utah; Cretaceous; Sequence stratigraphy

1. Introduction

Carbonate diagenesis is a common process within sedimentary basins and the resulting patterns of cementation have a major impact upon the macroscopic, microscopic and petrophysical properties of sedimentary successions

* Corresponding author. Fax: +44 161 247 6318.
E-mail address: p.machent@tesco.net (P.G. Machent).

0037-0738/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.sedgeo.2006.12.002

(e.g., Kantorowicz et al., 1987; Bjørkum and Walderhaug, 1990; Morad, 1998). It has recently been documented (e.g., McKay et al., 1995; Loomis and Crossey, 1996; Ketzer et al., 2003) that patterns of carbonate cementation in sandstone successions can be related to stratigraphic development of these successions that are dominantly controlled by variation in relative sea-level. In a recent large-scale outcrop study of a shoreface sandstone and associated coastal plain succession in the Upper Cretaceous Blackhawk Formation, Book Cliffs, Utah, Taylor and Gawthorpe (2003) and Taylor et al. (2004) demonstrated the spatial and temporal relationship between concretionary dolomite cementation and stratigraphic architecture. These studies proposed that organic-acids generated in coals leached detrital dolomite from underlying shoreface sandstones. This dolomite was remobilized down-dip by meteoric fluids at times of falling relative sea-level resulting in extensive concretionary dolomite precipitation at the meteoric/marine interface. Similar mechanisms have been proposed for subsurface shoreface sandstone successions (e.g., Prosser et al., 1993). Clear relationships between stratal architecture and cementation have also been documented in offshore siliciclastic mudstone-dominated successions (e.g., Macquaker and Taylor, 1996; Taylor and Macquaker, 2000). In these studies, laterally extensive cementation is proposed to form at times of depositional hiatus beneath major marine flooding surfaces, resulting in enhanced sediment residence times in early diagenetic zones (Taylor and Macquaker, 2000). There is little understanding, however, of the linkages between cementation processes operating in shoreface/coastal plain successions and those operating in offshore mudstone dominated successions. Such information is critical, however, for a complete understanding of basin-scale diagenesis in sedimentary successions.

In this study we present results from the integration of sedimentological and sequence stratigraphic analysis with petrographic and geochemical analysis of carbonate cementation from large-scale outcrops of distal lower-shoreface to offshore transition/offshore sandstones and siltstones of the Upper Cretaceous Kenilworth Member of the Blackhawk Formation, Book Cliffs, Utah, USA. In particular, this study aims to document the distribution of cements, and the stratigraphic, sedimentological and diagenetic controls giving rise to these distributions, within such a succession. The strength of this study is that the outcrops of the succession can be tied stratigraphically and sedimentologically into well-studied shoreface and coastal plain successions, thereby allowing linkages between proximal and distal successions to be made.

2. Geological setting

Earliest Cretaceous tectonism in western North America, expressed as Cordilleran-style foreland fold and thrust deformation, resulted in the development of a foreland basin and formation of the Western Interior Seaway (Burchfiel et al., 1992). By Maastrichtian times, this epeiric sea linked the polar ocean and the subtropical Gulf of Mexico (Fig. 1). The successions

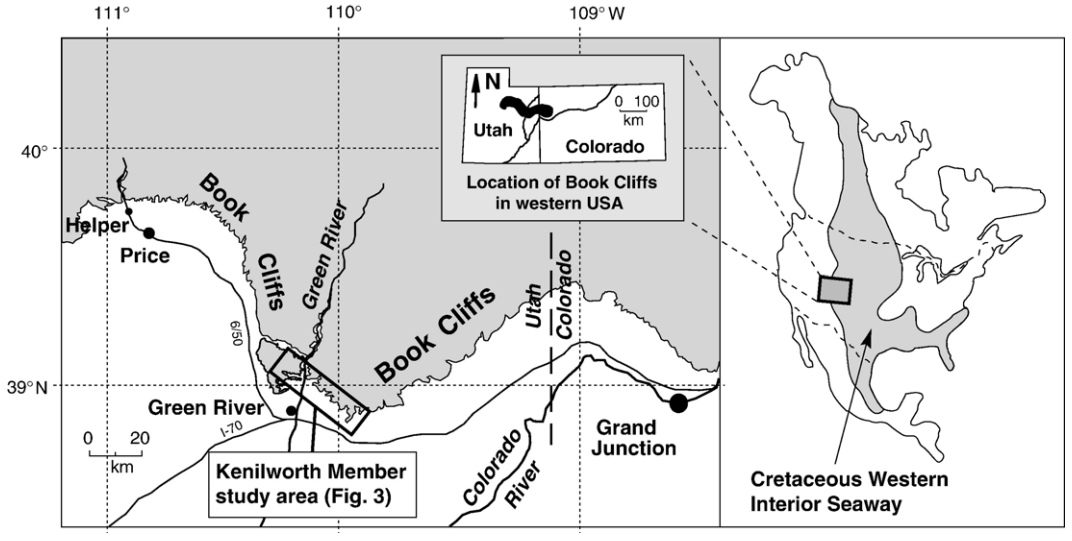

Fig. 1. Location map illustrating the position of the Cretaceous Western Interior Seaway in the USA, the general outline of the Book Cliffs in east-central Utah and the Kenilworth Member study area near Green River.