Available online at www.sciencedirect.com

SCIENCE DIRECT®

Sedimentary Geology 177 (2005) 175–194

Sedimentary Geology

www.elsevier.com/locate/sedgeo

Mixed sediment deposition in a retro-arc foreland basin: Lower Ellis Group (M. Jurassic), Wyoming and Montana, U.S.A.

William C. Parcell*, Monica K. Williams

Department of Geology, Wichita State University, 1845 Fairmount, Box 27, Wichita, KS 67260-0027, USA

Received 28 January 2004; received in revised form 17 January 2005; accepted 25 February 2005

Abstract

The "lower" Ellis Group (M. Jurassic) of northern Wyoming and southern Montana affords an excellent opportunity to examine the influence of tectonics, sea-level change, and incipient topography on facies dynamics and the evolution of mixed sediment ramp deposits. The Sawtooth, Piper, and Gypsum Spring formations (Bajocian to Callovian) represent sedimentation along the forebulge of a retro-arc foreland basin. The "lower" Ellis Group records deposition during two transgressive–regressive cycles, (1) a Bajocian-age cycle dominated by evaporites and red shales, and (2) a Bathonian-age cycle characterized by carbonates, evaporites, and red shales. These cycles are capped by a Callovian-age cycle distinguished by carbonates and red shales that is represented by the "lower" Sundance and Rierdon Formations. Transgressive episodes favored intensified chemical sediment production resulting in thick units deposited in subtidal to peritidal environments. Regressive periods are characterized by supratidal redbed progradation and subsequent shallowing–upward cycles. The depositional cycles in the lower Ellis Group developed due the interplay between sea-level change and tectonic subsidence related to the evolution of a retro-arc foreland basin. Differential subsidence before, during, and after deposition created paleohighs that locally influenced accommodation space and, thereby, complicated depositional and erosional patterns. This paper provides a regional framework for further analysis of the depositional history of the lower Ellis Group by addressing the stratigraphic relationships between the Sawtooth, Piper, and Gypsum Spring Formations.

Keywords: Clastic; Carbonate; Evaporite; Sequence stratigraphy; Jurassic

1. Introduction

Mixed siliciclastic and chemical deposits in ramp settings have been shown to respond to sea-level changes in a relatively predicable manner (Burchette and Wright, 1992; Azeredo et al., 2002). Although the controls on depositional facies patterns in passive systems are well documented, there are few published studies of the effects of local tectonic movements on mixed sediment depositional systems. However, this situation is recorded during the Middle Jurassic in the Western Interior of the United States where local

* Corresponding author.
E-mail address: william.parcell@wichita.edu (W.C. Parcell).

0037-0738/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.sedgeo.2005.02.007

tectonic movements related to the evolution of a retro-arc foreland basin influenced depositional and erosional patterns in a restricted ramp setting.

This paper presents a depositional model to examine the influence of tectonics, sea-level change, and incipient topography on facies dynamics and evolution of the mixed sediment Sawtooth, Piper, and Gypsum Spring formations. This is achieved using lithofacies distribution, bounding surfaces, and biostratigraphic zones within a sequence stratigraphic framework.

2. Geologic setting

The early Mesozoic was a time of great change for western North America as the continental margin evolved from largely passive depositional systems during most of the Paleozoic to tectonically-active basins in the early Mesozoic. A major shift in plate motions resulted in highly oblique convergence between the ancestral Pacific plates and the North American plate (Fig. 1). This intersection resulted in complex compressional, tensional, and transtensional forces, which produced a wide variety of depositional settings across the western North American plate including passive margin coastal plains to active margin mountains, arcs, and tectonic basins (Blakey, 1997). The Middle and Upper Jurassic deposits of Wyoming and Montana record at least four major transgressive–regressive marine inundations related to the development of a retro-arc foreland basin that was connected to the proto-Pacific Ocean (Fig. 1) (Peterson, 1954; Brenner and Peterson, 1994). With the onset of thrust faulting during the Middle Jurassic, a foredeep developed in present-day Utah and eastern Idaho depositing the Twin Creek Formation. To the east of this trough, the foreland basin was characterized by a ramp margin along the western edge of a cratonic forebulge (Fig. 2).

Sediments deposited on this forebulge are represented in northern Wyoming by the Gypsum Spring Formation, "lower" Sundance Formation, and "upper" Sundance Formation. In southern Montana, the cycles correspond to the Sawtooth Formation, Piper Formation, Rierdon Formation, and Swift Formation (Fig. 3). Early interpretations by Cobban (1945) and Peterson (1955) emphasized the shallow marine character of the Middle Jurassic section. However, Kilbarda and Loope (1997) and Kvale et al. (2001) have recently demonstrated that certain beds within the Sundance and Gypsum Spring Formations are also lagoonal to terrestrial in origin owing to the identification of aeolian limestone and dinosaur tracks.

Lithologies in the lower units of the Ellis Group vary widely depending on location in the basin and their position relative to paleostructures. The Sawtooth Formation in western Montana varies between limestone, dolomite, shale, siltstone, and sandstone. Cobban (1945) divided the Sawtooth Formation into three units: (1) a basal sandstone/siltstone unit, (2) a middle limestone/shale unit, and (3) an upper shale/siltstone unit. Lithologies in southern and eastern Montana are dominated by carbonates and evaporites. For these reasons, Imlay et al. (1948) defined the Piper Formation from exposures near Lewiston, Montana. The Piper is divided into three units (this time given formal member status): (1) Tampico Shale Member, (2) Firemoon Limestone Member, and (3) Bowes Member (Nordquist, 1955). The Gypsum Spring Formation of Wyoming is also informally divided into three major lithologic units based on lithology and regional continuity of strata. The basal unit contains predominantly white, massive gypsum or anhydrite with interbedded noncalcareous red shale and siltstone. The middle unit contains interbedded green–gray to varicolored shales and gray, black, and brown limestones. The informal upper unit contains primarily red to gray shale and siltstone.

2.1. The correlation quandary

Before discussion of the depositional evolution of the "lower" Ellis Group, the enduring problem of stratigraphic correlation of these units must be addressed. Two fundamental challenges persist. First, there is inconsistent use of the names "Gypsum Spring Formation" and "Piper Formation" because their formal type sections are recognized as incomplete and not representative of the units across much of Wyoming and Montana (Rayl, 1956; Meyer, 1984; Williams, 2003). The type section of the Piper Formation near Lewiston, Montana, as defined by Imlay (1948) represents only the upper third of the units that are commonly referred to as the Piper Formation elsewhere in Montana (Rayl, 1956). The