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Anatomy of a submarine channel–levee: An example from Upper Cretaceous slope sediments, Rosario Formation, Baja California, Mexico

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Abstract

To date, facies architecture models of submarine channel–levees have largely been derived from seismic data, isolated core data and limited field studies. We report field observations of an Upper Cretaceous submarine channel–levee complex within the Rosario Formation, Baja California, Mexico, which provide high-resolution data of lithofacies and ichnofacies distribution, and levee depositional thickness decay along transects perpendicular to the channel axis. Within the levee, both sandstone thickness and the overall proportion of sandstone decrease according to a power law away from the channel axis. Spatial variation in sedimentary structures away from the channel axis is predictable and provides an important link to the depositional flow regime. In channel-proximal locations, structureless sands, parallel lamination, overturned ripples, and ripple cross-lamination (including climbing ripple cross-lamination) are common; in channel-distal localities starved ripples are abundant. Sandstone bed thickness generally increases up stratigraphy within the levee succession, which is interpreted to indicate increasing turbidity current magnitude and/or contemporaneous channel floor aggradation reducing relative levee relief. However, in the most channel-proximal location sandstone bed thickness decreases with height; combined with evidence from both facies and palaeocurrent analysis this allows the position of the levee crest to be inferred. The thickest beds occur at higher levels with increasing distance from the channel axis, using this evidence we present a model for levee growth and migration of the crest.

Quantitative analysis of ichnofacies distribution reveals that traces typical of the Cruziana and Skolithos ichnofacies are superimposed over the ‘normal’ background Nereites ichnofacies, forming a ‘bioturbation front’ which is indicative of proximity to the channel. By analogy with modern canyons and channels, the association of Cruziana and Skolithos ichnofacies with the channel may be attributed to oxygen and nutrient enrichment and possible turbidity current transport of organisms responsible for these ichnofacies.

Keywords: Submarine channel–levees; Turbidity currents; Upper Cretaceous; Rosario Formation; Ichnofacies

1. Introduction

Studies of modern submarine channel–levee systems provide information about depositional processes, channel and levee geometry and lateral facies relationships but provide little information on vertical stacking patterns and internal facies distribution. Ancient systems at outcrop may provide a better opportunity to study the facies and architecture of channel–levees but they commonly lack both three-dimensional control and an unambiguous context. Confident identification of deep-marine levee deposits in ancient strata is of particular significance in the subsurface in a petroleum geology context, where

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data are restricted to essentially one-dimensional borehole data and images rendered from seismic data. However, although channel–levees may occur in a variety of settings, large scale, aggradational channel–levee sequences are rarely well preserved in the continental rock record, as they commonly form on oceanic or transitional crust. The Mesozoic rocks of the Baja California peninsula form one of the most areally extensive, best-exposed, longest lived (160 million years), least tectonized and least metamorphosed convergent-margin basin complexes in the world (Busby et al., 1998). In Canyon San Fernando, near complete cross-sectional, and related exposures of a channel–levee complex offer excellent opportunities for a detailed three-dimensional study of these architectural elements (Morris and Busby-Spera, 1990).

The purpose of this paper is to present data from an outcrop example of an Upper Cretaceous deep-marine channel–levee system, and to describe the growth of the levee and the resulting distribution of sedimentary facies. The nature of overbank flow and in-channel processes responsible for overbank deposition and levee growth are discussed. Additionally, the distribution of bioturbation within the levee is evaluated.

2. Geological setting

The field area lies north of Canyon San Fernando (near the town of El Rosario), on the Pacific coastal margin of the Baja California peninsula, Baja California del Norte, Mexico, (Fig. 1). The Rosario Formation is the youngest unit in a belt of Upper Cretaceous deposits comprising the Peninsular Ranges forearc basin complex, which crops out discontinuously along the Pacific margin of Baja California (Gastil et al., 1974; Morris and Busby-Spera, 1990). The sediments of the Peninsular Ranges forearc basin complex were sourced from volcanic and plutonic rocks of the Upper Jurassic to Upper Cretaceous Peninsular Ranges arc complex (Morris and Busby-Spera, 1988, 1990).

In the areas of El Rosario and San Carlos (Fig. 1) the Campanian to early Palaeocene Rosario Formation consists of a lower shallow-marine member, overlain by a deep-marine upper member that includes a submarine canyon-fill and a channel–levee complex in Canyon San Fernando (Morris and Busby-Spera, 1988, 1990; Morris, 1992; Morris and Busby, 1996; Dykstra, 2005; Dykstra and Kneller, in press a, b) (Fig. 2). The Rosario Formation unconformably overlies the continental El Gallo Formation (Morris and Busby, 1996) and records a transgression with a transition from shallow to deep-marine environments (Morris and Busby, 1996) (Fig. 3). The Rosario Formation in Canyon San Fernando is capped unconformably by a kaolinitic palaeosol followed by the non-marine to shallow-marine Palaeocene Sepultura Formation.

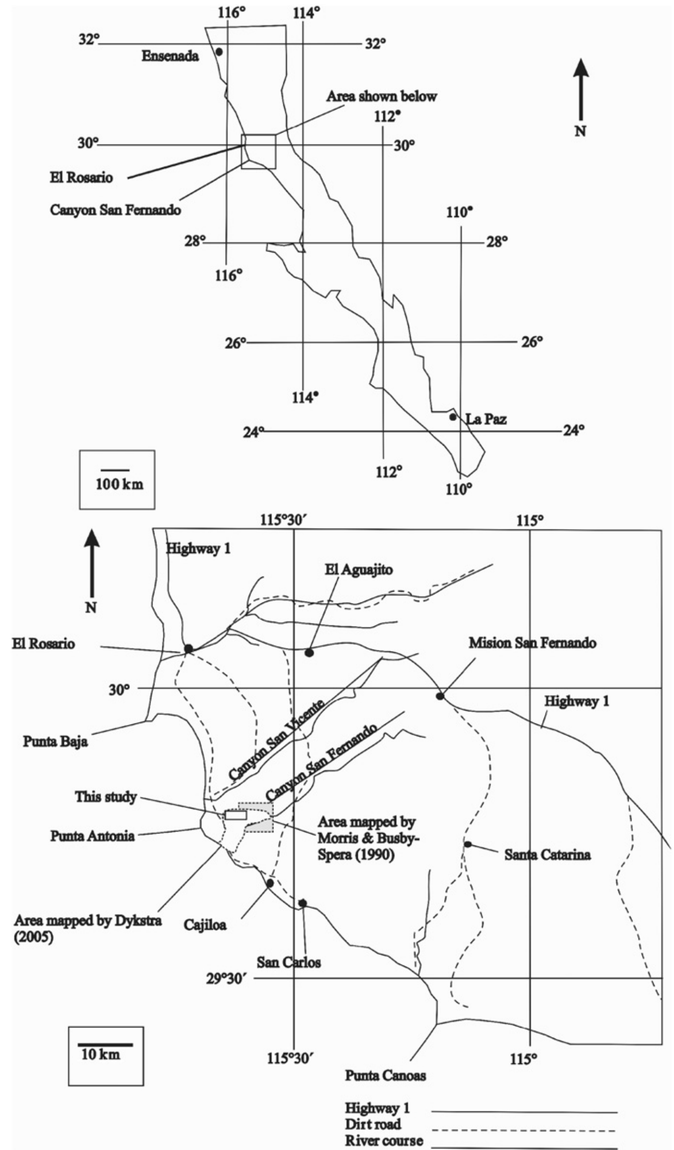

Fig. 1. Map of the Baja California peninsula showing the location of the study area, Canyon San Fernando. Inset area shows Canyon San Fernando which is one of a number of canyons feeding into the Pacific on the western margin of Baja California. The field area is accessed by dirt roads with the nearest town being El Rosario approximately 30 km to the north.

3. Field area: Canyon San Fernando

In the Canyon San Fernando area, the Upper Rosario Fm contains a mid-slope submarine canyon fill overlain by a genetically related, unconfined channel–levee complex. The entire canyon/channel complex is approximately 1 km thick (Morris and Busby-Spera, 1990) and was deposited over approximately 1.6 million years, a time-scale consistent with a third-order sea-level cycle (Dykstra and Kneller, in press a). Palaeocurrent directions and palaeogeographic reconstructions indicate that channels within the canyon and channel–levee complex dispersed to the south–southwest (mean palaeocurrent for channelised facies in the system is 198°) on a west–southwest facing