Journal of Sedimentary Research

Journal of Sedimentary Research, 2009, v. 79, 184–209
Research Article
DOI: 10.2110/jsr.2009.026

HYPERPYCNAL RIVERS AND PRODELTAIC SHELVES IN THE CRETACEOUS SEAWAY OF NORTH AMERICA

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ABSTRACT: **Despite the historical assumption that the bulk of marine "shelf" mud is deposited by gradual fallout from suspension in quiet water, recent studies of modern muddy shelves and their associated rivers show that they are dominated by hyperpycnal fluid mud. This has not been widely applied to the interpretation of ancient sedimentary fluvio-deltaic systems, such as dominate the mud-rich Cretaceous Western Interior Seaway of North America. We analyze two such systems, the Turonian Ferron Sandstone Member of the Mancos Shale Formation, in Utah, and the Cenomanian Dunvegan Formation in Alberta. Paleodischarge estimates of trunk rivers show that they fall within the predicted limits of rivers that are capable of generating hyperpycnal plumes.**

The associated prodeltaic mudstones match modern hyperpycnite facies models, and suggest a correspondingly hyperpycnal character. Physical sedimentary structures include diffusely stratified beds that show both normal and inverse grading, indicating sustained flows that waxed and waned. They also display low intensities of bioturbation, which reflect the high physical and chemical stresses of hyperpycnal environments. Distinct "mantle and swirl" biogenic structures indicate soupground conditions, typical of the fluid muds that represent the earliest stages of deposition in a hyperpycnal plume. Hyperpycnal conditions are ameliorated by the fact that these rivers were relatively small, dirty systems that drained an active orogenic belt during humid temperate (Dunvegan Formation) to subtropical (Ferron Sandstone Member) "greenhouse" conditions. During sustained periods of flooding, such as during monsoons, the initial river flood may lower salinities within the inshore area, effectively "prepping" the area and allowing subsequent floods to become hyperpycnal much more easily. Although shelf slopes were too low to allow long-run-out hyperpycnal flows, the storm-dominated nature of the seaway likely allowed fluid mud to be transported for significant distances across and along the paleo-shelf. Rapidly deposited prodeltaic hyperpycnites are thus considered to form a significant component of the muddy shelf successions that comprise the thick shale formations of the Cretaceous Western Interior Seaway.

INTRODUCTION

General facies models for the interpretation of ancient marine mudstones historically assume that most shelf mud is deposited in quiet water by simple suspension settling (Pettijohn 1975; Bhattacharya and Walker 1992; Nichols 1999; Prothero and Schwab 2004; Boggs 2006). In a landmark paper Rine and Ginsburg (1985) presented one of the first major studies of a high-energy prograding muddy shoreline and inner shelf deposit along the modern Suriname coast. Other major delta complexes, such as the Mekong in Vietnam (Ta et al. 2005), the Atchafalaya in the Gulf of Mexico (Augustinus 1989; Allison and Neil 2003; Rotondo and Bentley 2003), the Po in the Adriatic (Cattaneo et al. 2003 and Cattaneo et al. 2007), the Fly in Papua New Guinea (Walsh et al. 2004), among others (Allison and Nittrouer 1998), show major mud-dominated coastlines and inner-shelf mud belts, typically elongated downdrift of the river mouth. Other oceanographic studies emphasize the importance of rapidly deposited fluid muds in shelf construction (McCave 1972; Nittrouer et al. 1986; Kineke et al. 1996; Kuehl et al. 1996; Kuehl et al. 1997; Kineke et al. 2000; Hill et al. 2007; Liu et al. 2002; Bentley 2003).

Many modern shelf muds are now recognized to have accumulated as prodeltaic deposits. These may be deposited directly from hyperpycnal mud plumes related to times of elevated river discharge during floods (Fig. 1). Rapid flocculation of clays and sediment settling may also occur within an initially low-sediment-concentration hypopycnal plume, causing it to evolve into a hyperpycnal flow (Parsons et al. 2001) (Fig. 1). This can happen quickly, within hours or days of the initial river flood. Storms, fair-weather waves, and tides may also resuspend mud at the sea floor, which subsequently migrates along the shelf as a dilute, hyperpycnal geostrophic fluid-mud belt (Nemec 1995; Kineke et al. 2000; Mulder and Alexander 2001; Bentley 2003; Rotondo and Bentley 2003; Draut et al. 2005). These mudstones typically show distinctly laminated to bedded fabrics with a corresponding lack of bioturbation, reflecting much more rapid sedimentation rates than recorded during pelagic settling of clay from suspension (e.g., MacEachern et al. 2005; MacEachern et al. 2007a). Sediment accumulation rates of up to 20 cm per year have been recorded in the modern Atchafalaya mud belt, compared to less than 1 cm/year in the more distal offshore (Allison and Neill 2003).

Despite these advances in our understanding of mud transport and deposition in modern shelves, most studies of ancient hyperpycnal deposits or of similar "sustained" flow turbidites focus on sandstones

 1527-1404/09/079-184/$03.00