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Research paper

Seismic geomorphology and lithology of the early Miocene Pearl River Deepwater Fan System in the Pearl River Mouth Basin, northern South China Sea

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ABSTRACT

Multi-phase deepwater fan systems have formed in the Baiyun Sag of the Pearl River Mouth Basin on the northern margin of the South China Sea since the beginning of the Miocene. Integrated analysis of 2D/3D seismic, well log, core, and biostratigraphic data shows that the early Miocene Pearl River deepwater fan deposits consist of four 3rd-order sequences, SQ23.8, SQ21, SQ17.5 and SQ16.5. Each of them is bounded by regional discontinuity surfaces (3rd-order sequence boundaries). Of particular interest are the sandy deepwater fan deposits in the HST of SQ23.8 and LST of SQ21, which are absent in SQ17.5 and SQ16.5. The SQ23.8 deepwater deposits are relatively thin sheets, densely spaced sandy debris flow channels and MTDs, whereas in SQ21 they manifest as thicker sheets and larger channels. In terms of lithofacies, SQ23.8 deepwater deposits are massive sandstones, in contrast to SQ21 deposits of massive sandstones, normally graded sandstones, inversely graded sandstones, and locally interbedded ripple laminated siltstones. It is interpreted that SQ23.8 deepwater sands result from homochronous slumping of the shelf margin delta front, while SQ21 deepwater sands result from the erosion and re-deposition of the ancient SQ23.8 highstand shelf margin delta.

The Paleocene-Early Oligocene rift stage (57.5 Ma ~ 32 Ma) was characterized by extensive development of half-grabens and normal faults. Since 32 Ma, the drift stage has been characterized by thermal subsidence and weak tectonic activity. The distributions of deepwater sands in SQ23.8 and SQ21 are interpreted to have been controlled by seabed topography that was inherited from buried rift-related tectonic features. We propose that the primary controlling factor for the development of the early Miocene Pearl River Deepwater Fan System was likely sediment supply of the Pearl River influenced by the Baiyun Event and the uplift of Qinghai-Tibet Plateau. The specific location of the sandy deepwater fan was due to tectonic influence on paleotopography of the shelf. The interpreted two depositional models can help predict the types of deepwater depositional elements are in the Baiyun Sag of the Pearl River Mouth Basin and where deepwater sands are likely to occur.

1. Introduction

The significant oil/gas exploration potential in deepwater reservoir elements such as channel-fills, levees, sheets and mass-transport deposits has attracted extensive attention from both academia and industry (e.g. Posamentier and Kolla, 2003; Posamentier, 2003; Prather, 2003; Prather et al., 1998; Mayall

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et al., 2006; Weimer and Slatt, 2004, 2007). Regional basin tectonics, sediment supply and sea level fluctuations are regarded as the three main controlling factors of the deepwater clastic system, and their controls are commonly interdependent (Stow et al., 1984; Mutti and Normark, 1991; Reading and Richards, 1994; Richards et al., 1998). Over the last three decades, there has been persistent focus on relative sea level in order to predict the delivery and sedimentary formation of sandy deepwater deposits (Posamentier et al., 1988; Posamentier and Allen, 1999; Catuneanu et al., 2009; Helland-Hansen, 2009), despite the possibility that sediment supply might be the key driver for shelf margin progradation and delivery of deepwater sand even during periods of rising sea level (Covault et al., 2007; Carvajal et al., 2009). High cross-shelf sediment flux is very important for the occurrence of deepwater sands during rising sea level, especially in the region where a shelf margin delta develops (Deibert et al., 2003; Krassay and Totterdell, 2003; Carvajal and Steel, 2006, 2009; Comblells-Bigott and Galloway, 2006; Porebski and Steel, 2003, 2006; Carvajal et al., 2009).

In tectonically complex regions, the sea floor tectonic activity (e.g. salt diapirism, normal faulting, thrust faulting, etc.) and slope topography have significant effects on the routing (Kneller and McCaffrey, 1999; Huyghe et al., 2004; Callec et al., 2010; Kane et al., 2000), storage of sediment (Pickering and Corregidor, 2005; Shultz and Hubbard, 2005; Gervais et al., 2006; Jackson et al., 2008; Alves et al., 2009; Hubbard et al., 2009), and deepwater sedimentary processes (Prather et al., 1998; Posamentier and Kolla, 2003; Prather, 2003; Adeogba et al., 2005; Heiniö and Davies, 2007). These effects can be summarized as topographic variations that can cause complete ponding or deflection of sediment gravity flows and form the spatial confinement of the associated depositional units (Jackson et al., 2008). In addition, the old basin configuration (deep buried structure) may have some effects on the younger turbidite complex (Fugelli and Olsen, 2007). Previous studies have recognised that the inherited submarine inflexions controlled by buried faults influence deepwater turbidite systems (Higgs, 1988; Loncke et al., 2006; Fugelli and Olsen, 2007; Mayall et al., 2010). Thus,

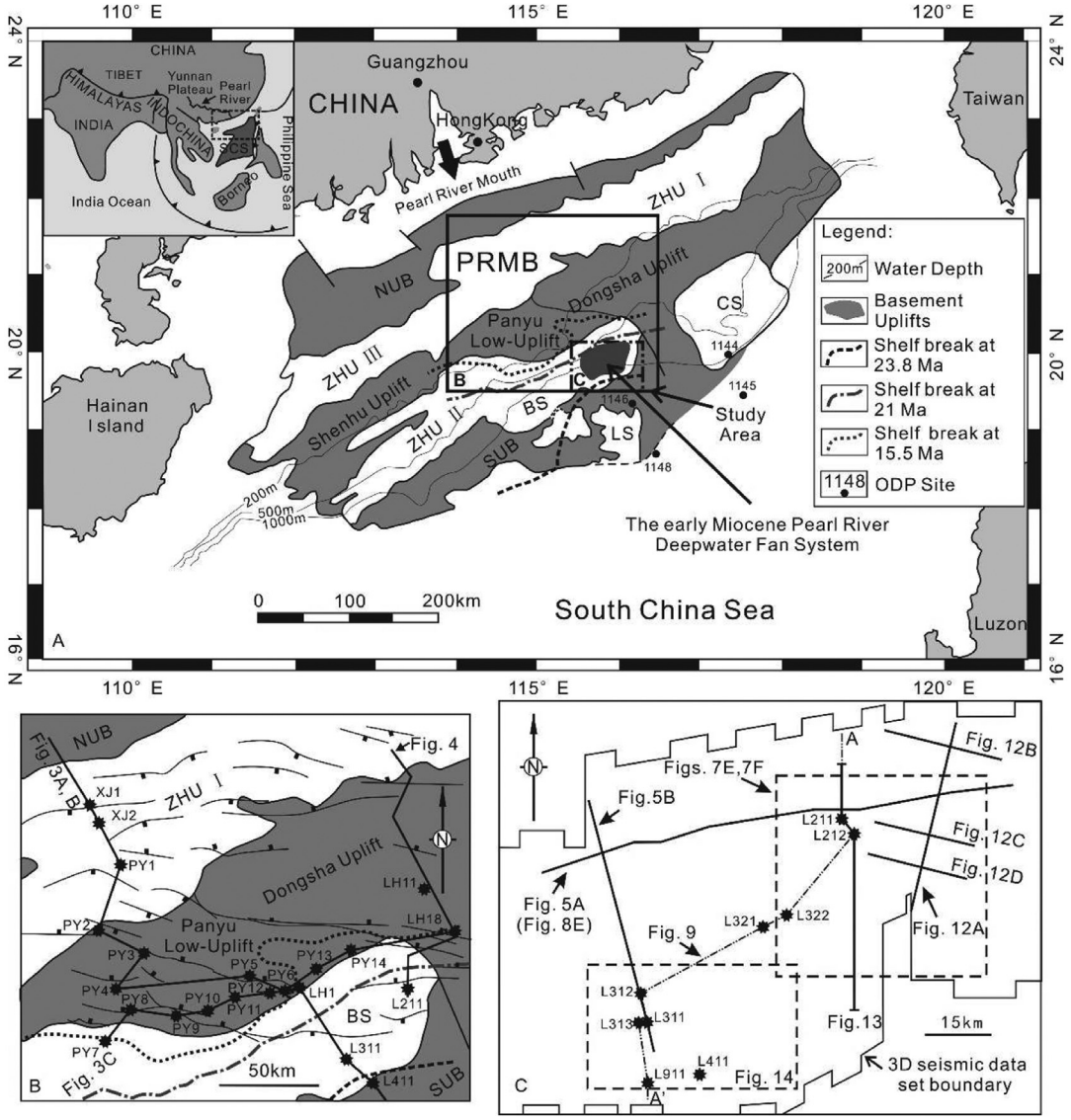

Fig. 1. (A) Location map showing the tectonic compartmentalisation of the Pearl River Mouth Basin and ODP Leg 184 Sites 1144, 1145, 1146 and 1148 in the northern South China Sea. Note the early Miocene Pearl River Deepwater Fan System mainly developed in the east area of the Baiyun Sag. Shelf breaks at 23.8 Ma, 21 Ma and 15.5 Ma are modified from Liu et al. (2011). Abbreviations: PRMB = Pearl River Mouth Basin; NUB = Northern Uplift Belt; SUB = Southern Uplift Belt; ZHU I = Zhu I Depression; ZHU II = Zhu II Depression; ZHU III = Zhu III Depression; BS = Baiyun Sag; CS = Chaoshan Depression; LS = Liwan Sag. (B) and (C) Study area and locations of figures used below.