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Storm-reworked shallow-marine fans in the Middle Triassic Baise area, South China

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ABSTRACT

Shallow-marine fans have been analyzed for sedimentary characteristics and genetic mechanisms far less commonly than deep-marine fans. Based on outcrop observations, this study reveals that large-scale submarine fans in the Middle Triassic Baise area, south China, consisted of a braided channel-levee facies complex in the inner fans; sinuous channel-levee facies complex, overbank facies and crevasse splay facies in the medial fans; and sand sheet facies in the outer fans, which present different lithology assemblages and depositional successions. The lithofacies of dominant massive sandstone, secondary graded sandstone and laminated sandstone from bottom to top is similar to the Bouma sequence, indicative of gravity flow processes. However, the laminated sandstones mostly bear sedimentary structures of gutter casts, wave-generated ripple marks, hummocky cross-bedding, wave-generated cross-bedding and ripple bedding, and were thus attributed to frequent storm reworking processes. Moreover, discontinuous deposition recorded by abrupt sediment grain-size changes, distinct interfaces and divergent paleocurrent orientations occurred between the laminated sandstones and the underlying massive (or graded) sandstones. Accordingly, storm reworking processes together with abundant fossils of *Daonella*, *Ammonite* and *Crinoidea* indicate a shallow-marine paleo-environment. As a whole, this study provides a good example of large-scale shallow-marine fans and laminated sandstones resulted from storm reworking.

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1. Introduction

Shallow-marine fans (or shallow-water fans, or shelf fans) have been reported and analyzed for sedimentary characteristics and genetic mechanisms far less commonly than deep-marine fans (or deep-water fans), although both of these are mainly controlled by various gravity flows (Tokuhashi, 1996; Villa and Bahamonde, 2001; Posamentier and Walker, 2006). Myrow and Hiscott (1991) identified that shallow-water gravity flow (e.g., liquefied flow and turbidity current) deposits in the Chapel Island Formation, southeast Newfoundland, Canada, were composed of three kinds of lithofacies including middle-, thick-layered massive siltstone, graded to poorly laminated sandstone, and graded to well laminated sandstone. Okay et al. (2011) revealed that a large-scale shelf fan was constructed by a main channel 800 m in width and 30– 50 m in depth, and six secondary channels in the northern Istanbul Strait, Black Sea, at 30– 75 m water depth. According to data of drilling cores, seismic profile and paleontology in the Huangliu Formation of Yinggehai Basin, southern China (He et al., 2011), Wang et al. (2015) confirmed that large-scale gravity flow fans had dominated by turbidity current in a shallow-marine environment at 40– 110 m water depth, and were attributed to continuous sediment supply and sea-level regressions (Xie and Fan, 2011).

Wave (e.g., storm), tide and biological activities were revealed to have commonly influenced shallow-marine fans but not deep-marine fans, providing evidence of the shallow-marine fan formations (Qiao et al., 2011). Fenton and Wilson (1985) revealed that a storm-influenced turbidity fan had formed at paleo-water depth of 90– 200 m in the late Ordovician Mallacoota Beds, Australia. Myrow and Hiscott (1991) observed that hummocky cross-stratified sandstone locally directly overlies slide deposits and raft-bearing beds in the shallow-water fans of the Chapel Island Formation, southeast Newfoundland, which was associated with large storms. According to drilled core observations in the Pearl River Mouth Basin of southern China, Qiao et al. (2011) proposed that shallow-marine fans were deposited with various bedding structures (e.g., parallel bedding, small-scale ripple cross-bedding, contorted bedding, flaser bedding, ripple bedding and lenticular bedding) and bioturbation structures in a shelf environment.

To emphasize large-scale submarine fans formed in a shallow marine environment and the role of storm-reworking processes, this paper focused on the identification of storm-reworked shallow-

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marine fans in the Middle Triassic Baise area, south China, and further summarized their sedimentary facies associations, typical lithofacies and depositional sequences.

2. Geologic setting

The Middle Triassic Baise area belonged to the Nanpanjiang Basin (also called as Youjiang Basin), which was a continental margin basin during the Devonian-Triassic (Fig. 1A). Closely related to the Honghe-Majiang Ocean (a branch of Paleo-Tethys) developing and later declining, the Nanpanjiang Basin experienced tectonic evolution from a rift basin (in the Devonian) to a passive continental margin (in the Carboniferous to early Triassic) and then to a foreland basin (in the Middle Triassic) (Lehrmann et al., 2015a, 2007; Du et al., 2009, 2013; Huang et al., 2013) (Fig. 1B).

The nature and tectonic setting of the Middle Triassic Nanpanjiang Basin, where submarine fans were widely deposited, have been intensely analyzed using various methods. Rare earth elements (REE), trace elements and major elements of turbidites, and trace elements of volcanic rocks show that the Nanpanjiang basin was located between an active continental margin and a continental island arc (Chen et al., 2003; Yang et al., 2008; Du et al., 2013). Sandstone QFL (Q-monocrystalline and polycrystalline quartz; L-lithic; F-feldspar) compositions and a dominant NWW-oriented paleocurrent indicated the sediment came from the recycled orogenic belt (the Qinzhou orogenic belt or the Yunkai Uplift), which lay to the southeast of the basin (Qin et al., 1999; Chen et al., 2003; Lehrmann et al., 2007, 2015a; Yang et al., 2008; Yang et al., 2012). Indicated by greater subsidence rates in the southern Basin than those in the northern Basin, the foreland basin was presumably resulted from convergence of the South China block

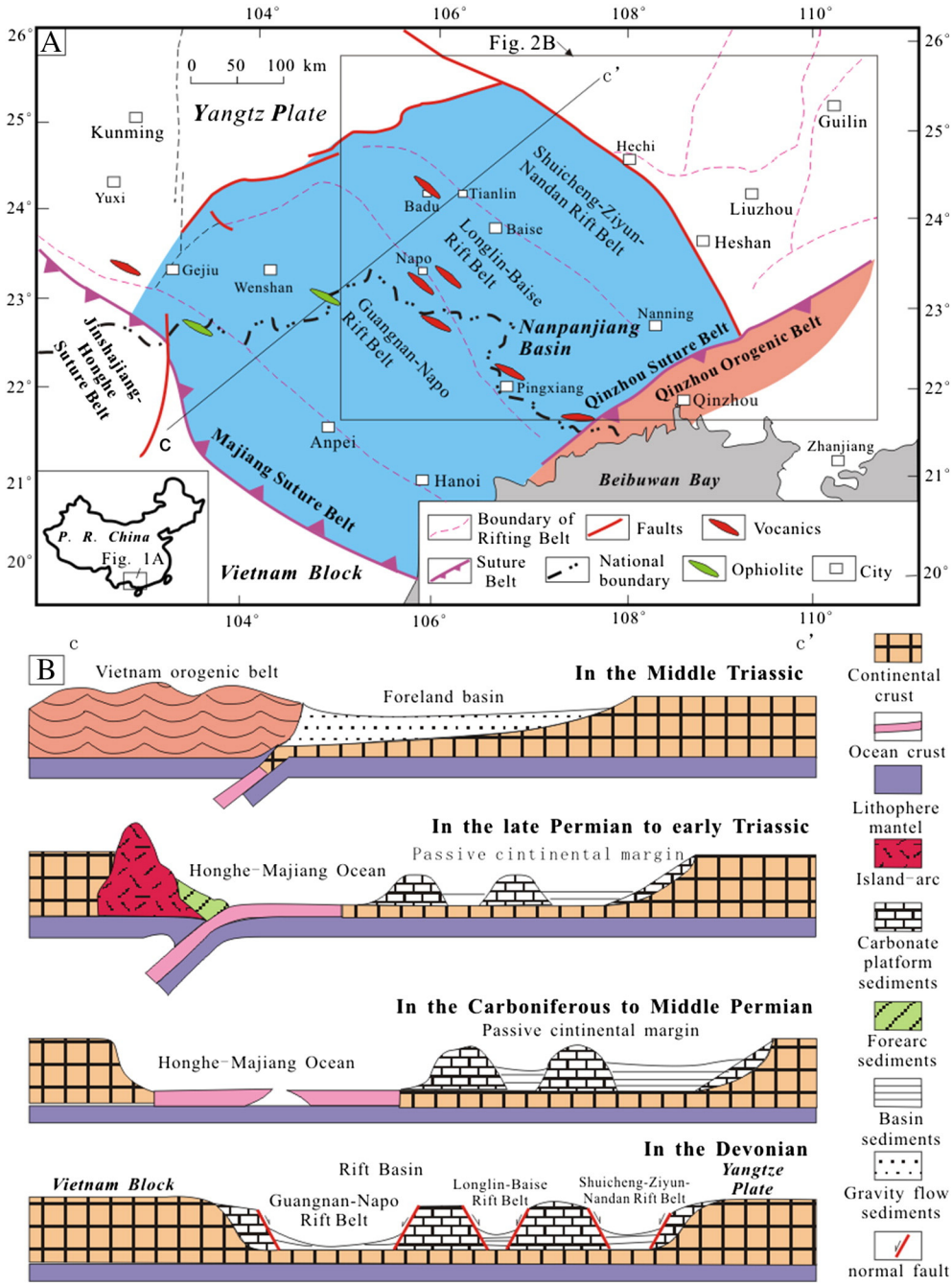

Fig. 1. Schematic map and sections showing (A) the tectonic framework and (B) the evolution stages of Nanpanjiang Basin (after Du et al., 2013).

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