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Research paper

Geochemistry and provenance of a multiple-stage fan in the Upper Miocene to the Pliocene in the Yinggehai and Qiongdongnan basins, offshore South China Sea

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ABSTRACT

The Yinggehai and Qiongdongnan basins in the northwestern South China Sea preserve a large volume of Cenozoic sediments. However, their sources are still remain controversial and need a further research. This paper uses discriminant diagrams and bivariate plots of major, trace and rare earth elements, combined with heavy mineral data and detrital zircon U-Pb ages to determine the provenance, source area weathering and tectonic setting of the Upper Miocene to Pliocene sediments in the Yinggehai and Qiongdongnan basins, offshore South China Sea. The sandstone samples used in this study are characterized by four features: (i) The studied sandstones are first-cycle deposits, no recycling processes are recorded in these sediments, and there is a low degree of weathering conditions in the source areas. (ii) The sandstones from the DF fan, LD fan and Central Canyon System may have a similar source, being derived from an old upper continental crust mainly composed of felsic igneous source rocks. (iii) Detrital zircon U-Pb ages suggest that Central Vietnam is likely to be the dominant source of the DF fan, LD fan and Central Canyon System. (iv) The tectonic setting of the sandstones in the DF fan, LD fan and Central Canyon System belongs to the continental island arc (CIA) or the active continental margin (ACM) fields.

1. Introduction

The significance of sedimentary geochemistry in investigating the provenance of sedimentary suites, source area weathering and tectonic setting is well established in the literature (Bhatia, 1983, 1985; Wronkiewicz and Condie, 1990; McLennan et al., 1993; Cullers, 1994; Li et al., 2004; Armstrong-Altrin and Verma, 2005; Armstrong-Altrin et al.,2012, 2013, 2015b; Al-Harbi and Khan, 2008; Huntsman-Mapila et al., 2009; Hossain et al., 2010; Spalletti et al., 2012; Purevjav and Roser, 2013; Tao et al., 2013; El Talibi et al., 2014; Perri, 2014; Perri et al., 2012, 2015a, 2015b, 2016a, 2016b; Amendola et al., 2016; Castillo et al., 2015; Tao et al., 2016). Immobile trace element contents are good indicators of source rock geochemistry; these elements (such as rare earth elements, Y, Th, Zr, Hf and Sc) are transported from the source to sediments with minor modification due to sorting, fractionation, diagenesis or post-depositional process (Taylor and McLennan, 1985; McLennan, 1989). The mobile elements (K, Na, Ca and Al) are helpful for understanding weathering and palaeo-environmental conditions (Nesbitt and Young, 1984; Fedo et al., 1995, 1997). Heavy minerals can be used to identify the provenance and detrital zircon U–Pb geochronological studies provide age constraints on the maximum depositional age of sediments (Gong et al., 1997; Clift and Sun, 2006; Yan et al., 2007, 2011; Xie and Fan, 2010; Li et al., 2011; Wang et al., 2013, 2014, 2015a, 2015d, 2016; Cao et al., 2015; Chen et al., 2015; Jiang et al., 2015; Liu et al., 2016), making it a powerful tool for basin provenance analysis that has been widely used throughout the world in the last decade.

Large-scale submarine fans are widely distributed in the Upper Miocene to Pliocene strata in the Yinggehai Basin (YGHB) and Qiongdongnan Basin (QDNB). Their provenance, source weathering conditions and tectonic setting are still not fully understood.

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Previous provenance studies have illustrated that the Cenozoic sediments of the YGHB and QDNB are derived from three major source terrains, the Red River, Central Vietnam and Hainan Island (Clift and Sun, 2006; Yan et al., 2007, 2011; Xie and Fan, 2010; Wang et al., 2011; Wang et al., 2013, 2014, 2015a, 2015d, 2016; Sun et al., 2014; Cao et al., 2015; Chen et al., 2015; Jiang et al., 2015). The provenance of the DF fan, LD fan and Central Canyon System are still remain unclear, and the relationships of these gravity flow deposits are still poorly understood.

A provenance study is presented in this paper, based on petrographic and geochemical analyses of Upper Miocene to Pliocene sands from the YGHB and QDNB. In particular, heavy mineral and detrital zircon U–Pb geochronological data are further used to infer the provenance, source area weathering and tectonic setting for Upper Miocene to Pliocene sands from the DF fan, LD fan and Central Canyon System in the YGHB and QDNB, offshore South China Sea.

2. Geological setting

2.1. Geological background of the YGHB

The YGHB is a northwest-southeastern (NW-SE) elongated Cenozoic sedimentary basin with an area of 120 000 km^2, which lies between the island of Hainan and the eastern coast of Vietnam (Clift and Sun, 2006; Mazur et al., 2012) (Fig. 1a). There are four primary structures in this basin: Central Sag Zone, Honai Sag Zone, Lingao uplift, Yingdong Slope Zone and Yingxi Slope Zone (Feng et al., 2013).

The tectonic evolution of the basin can be divided into two stages: a Paleogene extensional rifting event and a Neogene post rift thermal subsidence (Gong et al., 1997). The sedimentary strata in the rifting stage include the Eocene, the Early Oligocene Yacheng formation and the Late Oligocene Lingshui formation. In the subsidence stage, the basin is filled with the Lower Miocene Sanya

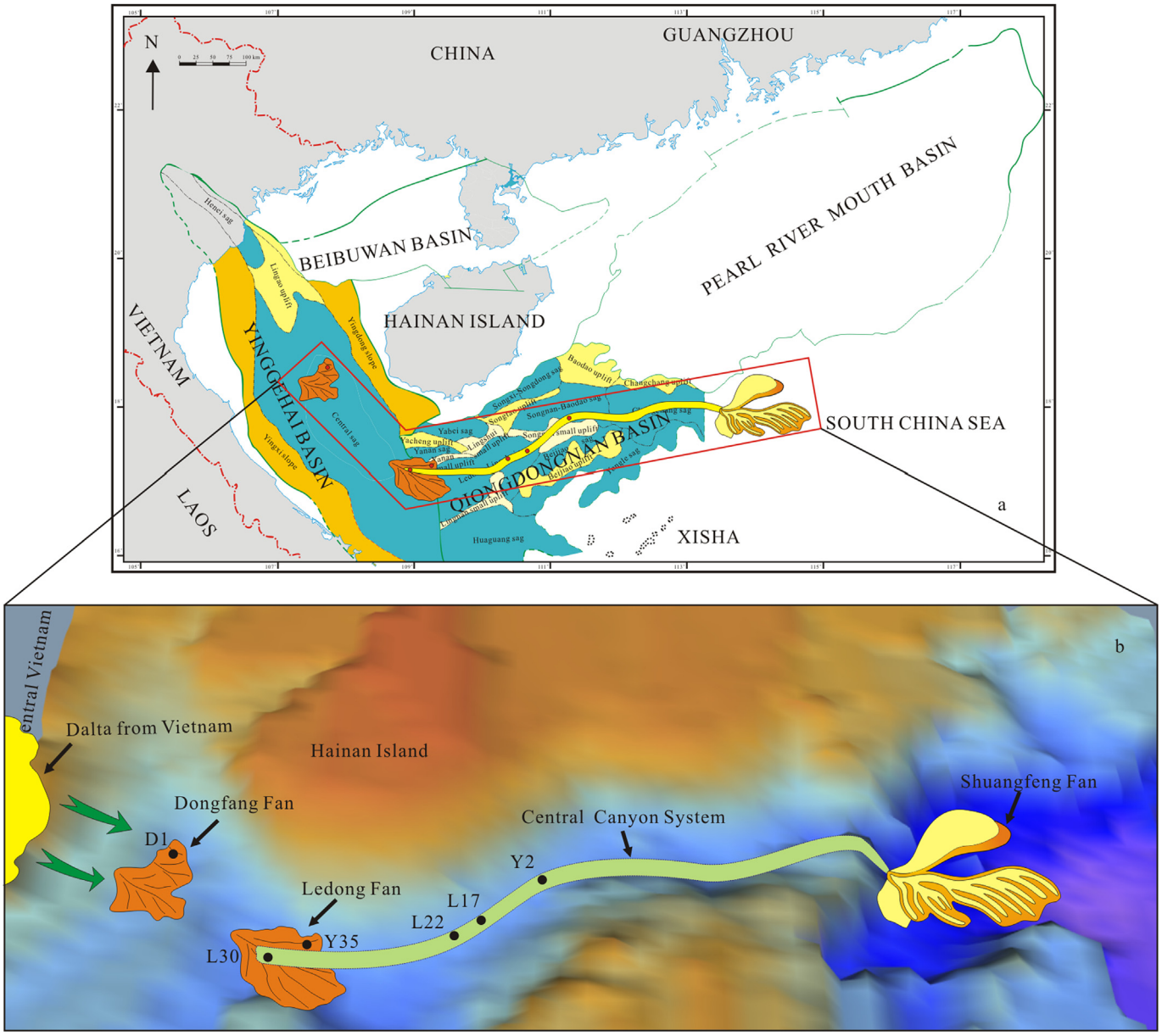

Fig. 1. Geologic sketch map and drilling locations in the YGHB and QDNB, (a) Modified after (Zhu and Mi, 2010).