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Seismic characteristics and processes of the Plio-Quaternary unidirectionally migrating channels and contourites in the northern slope of the South China Sea

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ABSTRACT

The Plio-Quaternary unidirectionally migrating channels (UMCs) and contourites in the northern slope of the South China Sea were investigated in this paper using seismic data. The UMCs include thalweg deposits (TDs) and laterally migrating deposits (LMDs), which result from the interaction between gravity flow and contour current. The LMDs migrating directions are northeast (NE) and west-southwest (WSW) and also display weak seismic reflection and obvious multi-stages. By contrast, the TDs show high seismic reflection and lateral aggradation.

Giant elongated, confined, and slope sheeted drifts, as well as sediment waves are widespread in the northern slope of the South China Sea. Helicoidal contour currents can generate giant elongated and confined drifts associated with moats. By contrast, tabular contour currents can develop slope sheeted drifts with rare moats. NE-migrating channels, giant elongated drifts, and a number of sediment waves are exclusively formed at water depths of 200 m–1200 m. Drifts, sediment waves, and few WSW-migrating channels are developed at water depths of 1200 m–3000 m.

The intermediate water contour current circulates clockwise, moving from Xisha Islands to Dongsha Islands and extending into the eastern part of Dongsha Islands because of the bathymetry. Deep water contour current may circulate counterclockwise and be transported northeastward through Dongsha Islands to Xisha Islands, bifurcating in the Xisha Islands because of topographical prominences.

1. Introduction

Gravity flow channels and contour current deposits are commonly developed on slopes. The channels are U- or V-shaped and include thalweg, levee, and slump deposits. These deposits are controlled by sediment supply, morphology, slope gradient, tectonic movement, and so on (Antobreh and Krastel, 2006; Armitage et al., 2009; Bertoni and Cartwright, 2005; Cunningham et al., 2005; Jobe et al., 2011; Lastras et al., 2009; Mountjoy et al., 2009; Shepard, 1981; Shepard and Emery, 1973; Weaver et al., 2000). The erosion and deposition of turbidity current and debris flow may contribute to the formation of channels (Shepard, 1981; Weaver et al., 2000). An increasing number of migrating channels attributed to the interaction between gravity flow and contour current has also been reported in West Africa, Brazil, and so on (Biscara et al., 2010; Rasmussen, 1994, 2003; Séranne and Abeign, 1999; Viana et al., 1999; Zhu et al., 2010). Fortunately, a series of NE- and WSW-migrational channels have developed in the northern slope of the South China Sea (SCS) (He et al., 2012; Zhu et al., 2010). However, studies on the genesis of these channels are limited (He et al., 2012; Zhu et al., 2010).

Contourites can reach kilometers of thickness and cover huge area (Faugères et al., 1993; Rebesco and Camerlenghi, 2008). Previous works have concentrated on bedforms, flow directions, frameworks, variability, and so on (Faugères et al., 1993, 1999; Hollister and Heezen, 1972; Kenyon and Belderson, 1973; Masson

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et al., 2004; Rebesco and Camerlenghi, 2008; Rebesco and Stow, 2001; Wynn and Stow, 2002). Plio-Quaternary contourites are well developed in the northern slope of the SCS (Lüdmann et al., 2005; Shao et al., 2001, 2007; Wang et al., 2010; Zhu et al., 2010; Gong et al., 2012). Accordingly, the present study investigated slope areas of the SCS near Dongsha Islands. Focus was given on the significant issue of the distribution of contourites in the northern slope of the SCS. This study also aimed to 1) summarize the seismic features of unidirectionally migrating channels (UMCs) and contourites, 2) examine the distribution of UMCs and contourites, 3) analyze the processes of UMCs and drifts, and 4) improve contour current circulation models.

2. Geological setting and oceanography

2.1. Geological setting

The SCS, located in the Asian continent and surrounded by Indochina, Kalimantan Island, the Philippine Islands, and Taiwan Island, is a semi-enclosed deep water basin. The SCS has an area of 3.5×10^6 km^2 and is more than 5000 m deep, trending northeast. The Luzon strait (300 km wide and 2500 km deep) is the main channel that connects the SCS with the Pacific Ocean (Li, 2002; Zhu et al., 2010). The SCS is the largest marginal sea in the west Pacific Ocean and is located in the southeastern margin of Eurasia, which is adjacent to the junction of Eurasian, Pacific Ocean, and Indian Ocean plates (Wang et al., 2003). The northern SCS margin is bounded to the east by Taiwan Island, to the west by Vietnam, and is connected southward to an abyssal plain nearly extending northwest. This SCS margin is 1500 km long and 600 km wide, covering an area of 9×10^5 km^2, and accounting for a quarter of the entire SCS (Luan et al., 2011) (Fig. 1).

The northern SCS can be divided into the Pearl River Mouth Basin (PRMB), Qiongdongnan Basin (QDNB), Beibuwan Basin (BBWB), and Yinggehai Basin (YGHB), from east to west (Fig. 1). PRMB has an area of about 1.78×10^5 km^2 and a width of 240 km, trending NE (Wang et al., 2007). Baiyun and Liwan sags are relatively negative reliefs to the east by Dongsha Uplift in the northern PRMB, with water depths of 200 m–1500 m (Figs. 1 and 2). The Indian Plate and Eurasian Plate collision resulted in the uplift of Tibet, which changed the geomorphology of China into west high–east low since the Tertiary Period and caused sea level fluctuations (Qin, 1996). The Pearl River carries large amounts of sediment into the PRMB and forms into a large delta (the Pearl River Delta). Consequently, this delta is an abundant source of slope gravity flow (Fig. 1).

The QDNB is located between Hainan Island and Xisha Islands, trending NE, and covers an area of 4.5×10^4 km^2 (Fu, 2009). The Tibet Plateau is moving northward and the Red River Fault is undergoing right-handed rotation since 5.5 Ma ago, which lead to continental shelf rapid progradation. The Dadu River and Jinsha River flow into the Yangtze River, which feeds into the Red River (Li et al., 2011). Furthermore, the sediment supply of gravity flow is controlled by the Red River west of the basin, whereas Hainan Island is in the east (He et al., 2012). The study area is located in the PRMB and QDNB with water depths of approximately 200 m–3000 m (Fig. 1). An obvious important unconformity (T1) was found in the seismic profile that crosses ODP1146 and ODP 1148, which may have been standing for 5.2 Ma (Lüdmann et al., 2001; Wang et al., 2000). The Plio-Quaternary channel and contourites that were above T1 were investigated in this study (Fig. 3).

2.2. Characteristics of intermediate and deep water

The water circulation of the SCS shows a vertical sandwich structure that is relatively complex (Yuan, 2002). This water circulation can be subdivided into surface water mass, intermediate water mass, and deep water mass (Chao et al., 1996; Chen, 2005; Wyrtki, 1961; Fang et al., 1998). Current studies on the intermediate water mass and deep water mass focus on the western Taiwan Island

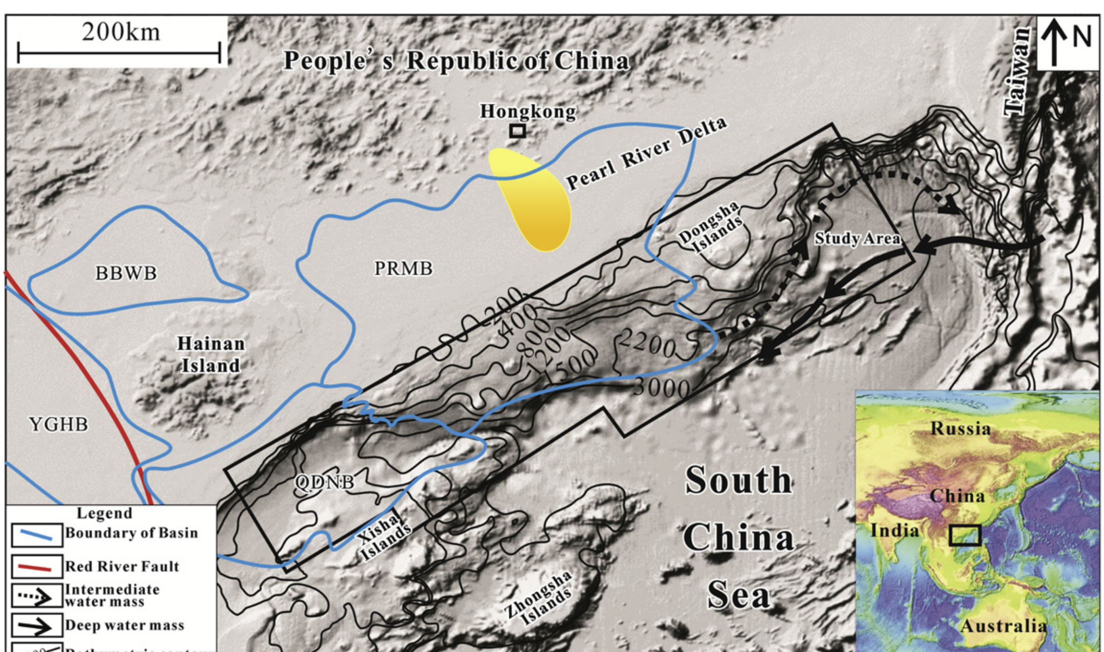

Figure 1. The geographical map and motion of intermediate and deep water in the northern South China Sea. PRMB: Pearl River Mouth Basin; QDNB: Qiongdongnan Basin; YGHB: Yinggehai Basin; BBWB: Beibuwan Basin. The Red River Fault locates in YGHB. Red River Delta locates in northern Hainan Island. The intermediate water mass shows southwestward to northeastward movement. The deep water mass is intrusion of NPDW, moves along from northeast to southwest, northern slope of the SCS (Fang et al., 1998; Chen, 2005; Yuan, 2002; Shao et al., 2007; Lüdmann et al., 2005; Xie, 2009; Gong et al., 2012).The basal map after Wang et al. (2010).