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Structures within the oceanic crust of the central South China Sea basin and their implications for oceanic accretionary processes

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A B S T R A C T

Internal structures in mature oceanic crust can elucidate understanding of the processes and mechanism of crustal accretion. In this study, we present two multi-channel seismic (MCS) transects across the northern flank of the South China Sea basin to reveal the internal structures related to Cenozoic tectono-magmatic processes during seafloor spreading. Bright reflectors within the oceanic crust, including the Moho, upper crustal reflectors, and lower crustal reflectors, are clearly imaged in these two transects. The Moho reflection displays varied character in continuity, shape and amplitude from the continental slope area to the abyssal basin, and becomes absent in the central part of the basin where abundant seamounts and seamount chains formed after the cessation of seafloor spreading. Dipping reflectors are distinct in most parts of the MCS data but generally confined to the lower crust above the Moho reflection. These lower crustal reflectors merge downward into the Moho without offsetting it, probably arising from shear zones between the crust and mantle characterized by interstitial melt, although we cannot exclude other possibilities such as brittle faulting or magmatic layering in the local area. A notable feature of these lower crustal reflector events is their opposite inclinations. We suggest the two groups of conjugate lower crustal reflector events observed between magnetic anomalies C11 and C8 were associated with two unusual accretionary processes arising from plate reorganizations with southward ridge jumps.

1. Introduction

As a “Atlantic type” marginal basin in the West Pacific, the South China Sea has been well studied since last century including its spreading history (e.g., Taylor and Hayes, 1983; Briais et al., 1993; Li et al., 2014), dynamic model (e.g. Sibuet et al., 2016; Clift et al., 2008; Cullen et al., 2010; Tapponier et al., 1986), deformation features and break-up patterns of the continental margin (e.g. Sun et al., 2009; Ding et al., 2013; Franke et al., 2014; Morley, 2016), magmatism (e.g., Fan et al., 2017; Yan et al., 2008), tectono-sedimentary processes (e.g. Ding et al., 2016; Li et al., 2015a), and deep structures and geodynamic implications (e.g. Zhao et al., 2010; Wei et al., 2015; Xia et al., 2016). Most previous work focused on the spreading ridges and the continental margins. Research on the Cenozoic oceanic accretionary processes in the abyssal basin is limited, particularly for internal structures within the oceanic crust such as the Mohorovicic Discontinuity (Moho) and bright dipping reflectors in the upper and/or lower oceanic crust, which are common features in multi-channel seismic images (e.g. Mutter and Carton, 2013). The geometry of the Moho is important for understanding crustal structure and thickness, the degree and style of isostatic compensation, and magmatic flux from mantle to crust (Steinhart, 1967). The sub-horizontal dipping reflectors could signify regional extensional faulting within the mature oceanic crust at a slow-spreading rate (Mid-Atlantic ocean, e.g., Mutter and Karson, 1992), be symbols of a lithological fabric link to accretion processes of oceanic crust at a fast-spreading rate (Pacific Ocean, e.g., Ranero et al., 1997), or suggest off-axis processes including late faulting, hydrothermal alteration and off-axis magmatism at an ultrafast spreading rate (East Pacific Rise, e.g. Hallenborg et al., 2003). Recent studies have associated these dipping reflectors with anomalous accretionary processes caused by plate reorganizations and ridge jumps (Becel et al., 2015; Han et al., 2016). Overall, studies on the internal structures in the mature oceanic crust can provide important constraints on fundamental questions such as deformation style of the oceanic crust,

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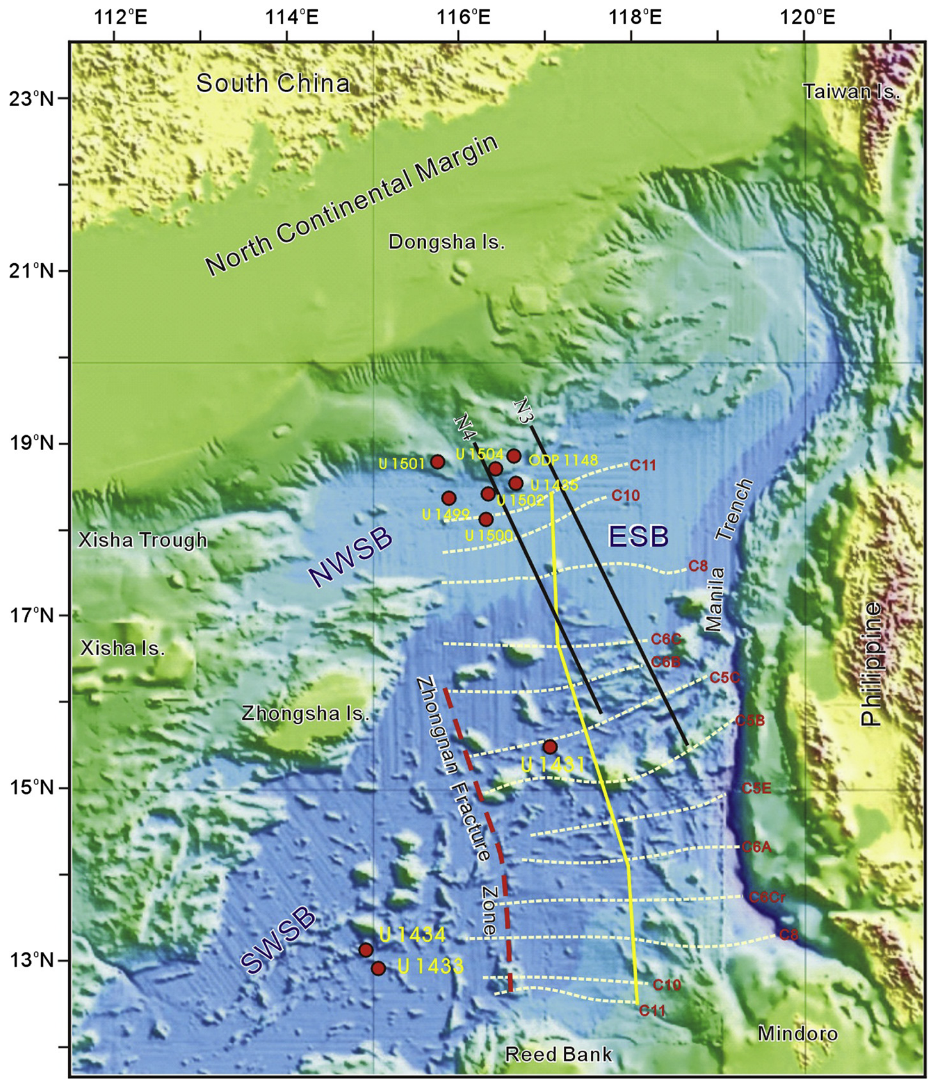

Fig. 1. Major tectonic and morphological features in the South China Sea. Black lines show the multi-channel seismic transects used in this study. Solid yellow line shows the path used to study the asymmetric spreading by comparing the distance between magnetic anomalies on the northern and southern flanks of the fossil spreading ridge. Dashed yellow lines are the interpreted magnetic anomalies (referred from Briais et al., 1993; Li et al., 2014). Dashed red line shows the boundary between the ESB and the SWSB/NWSB (referred from Franke et al., 2014). IODP Expeditions 349, 367 and 368, and ODP Leg 184 drill sites are indicated by red dots.

mantle flow and melt migration, and the processes and mechanism of crustal accretion.

In this paper, we present an interpretation of multi-channel seismic (MCS) images across the central South China Sea (SCS) basin. By integrating constraints from MCS data on the geometry, internal structure, amplitude and distribution of these events, we focus on the origin of bright dipping reflectors within the oceanic crust, including the Moho, the upper-crustal reflectors (UCR), and the lower-crustal reflectors (LCR). Our results, combined with published works, illuminate possible controls on these internal reflectors imaged in the oceanic crust including mantle flow, ridge jumps, and post-spreading magmatism.

2. Geological setting

The SCS is situated at the junction of the Eurasian, Pacific, and Indo-Australian plates. The basin can be divided into three sub-basins – East Sub-basin (ESB), Southwest Sub-basin (SWSB) and Northwest Sub-basin (NWSB) (Fig. 1). The SCS has undergone nearly a complete Wilson cycle from latest Cretaceous to Paleogene continental rifting, seafloor spreading in the Oligocene–middle Miocene, and eastward subduction under the Philippine Sea plate starting in early Middle Miocene (i.e. Taylor and Hayes, 1983; Briais et al., 1993; Cullen et al., 2010; Franke et al., 2014; Li et al., 2015a; Ding and Li, 2016; Sibuet et al., 2016).

2.1. Opening history and driving mechanism

A model for the opening scenario of the SCS was firstly proposed by Taylor and Hayes (1983) and Briais et al. (1993) on the basis of the magnetic anomalies, indicating that seafloor spreading occurred between 32 and 16 Ma. In contrast, Barckhausen et al. (2014) suggested a cessation age of 20.5 Ma based on more recent ship-borne magnetic data. Although there is 3–4 Myr differences in the cessation time, most agree that seafloor spreading occurred in the ESB first, followed by a southward ridge jump and a re-orientation of the spreading geometry from westward to southwestward ridge propagation (Briais et al., 1993; Huchon et al., 2001; Li et al., 2014; Ding and Li, 2016). Analyses of deep tow magnetic modeling shows the SCS is a low to intermediate spreading basin, with the full spreading rate varying from ~20 to ~80 km/Myr (Li et al., 2014).

Shipboard results of microfossil biostratigraphy and palaeomagnetic results from IODP Expedition 349 (South China Sea Tecton-