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Shear wave velocity structure of Reed Bank, southern continental margin of the South China Sea

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ABSTRACT

The shear wave velocity structure of a wide angle seismic profile (OBS973-2) across Reed Bank in the southern continental margin of the South China Sea (SCS) is simulated by 2-D ray-tracing method, based on its previous P-wave model. This profile is 369-km-long and consists of fifteen three-component ocean bottom seismometers (OBS). The main results are as follows.(1) The model consists of seven layers and the shear wave velocity increases from 0.7 km/s at the top of sediment layer to 4.0 km/s in the lower crust. (2) The Moho depth decreases from 20-22 km at the Reed Bank to 9-11 km at the deep oceanic basin with the shear wave velocity of 4.2 km/s below the Moho. (3) The Vp/Vs ratio decreases with depth through the sedimentary layers, attributed to increased compaction and consolidation of the rocks. (4) In the continental upper crust (at model distance 90-170 km), S-wave velocity (2.5–3.2 km/s) is relatively low and Vp/Vs ratio (1.75–1.82) is relatively high compared with the other parts of the crust, corresponding to the lower P-wave velocity in the previous P-wave model and normal faults revealed by MCS data, indicating that a strong regional extensional movement had occurred during the formation process of the SCS at the Reed Bank area. (5) The S-wave structures indicate that Reed Bank crust has different rock compositions from that in the east section of the northern margin, denying the presence of conjugate relationship of Reed Bank with Dongsha islands. According to P-wave models and other data, we inferred that Reed Bank and Macclesfield were separated from the same continental crust during the rifting and break-up process.

1. Introduction

Based on magnetic anomaly, it is generally accepted that the Cathysia begun to rift in Eocene (40 Ma) or even earlier in the Late Cretaceous (85–65 Ma), and then following multiple episodes of seafloor spreading from late Oligocene to mid Miocene (32–17 Ma) resulted in the formation of the South China Sea (SCS) with asymmetry conjugate margins in the north and south (Barckhausen and Roeser, 2004; Barckhausen et al., 2014; Briais et al., 1993; Franke, 2013; Ru and Pigott, 1986; Taylor and Hayes, 1980, 1983; Yao, 1996). However, at present there are still various points of view on the formation mechanism and spreading anomaly model of SCS and on the ages of basin magnetic anomalies and consequently on the chronology sequences of seafloor spreading between sub-basins. Taylor and Hayes (1980, 1983) estimated the age of the oceanic crust in the SCS ranged from Late Miocene to Middle Eocene, based on heat flow measurements and basement depth observations, and identified an abandoned E–W oriented spreading center with symmetric anomalies 5D through 6C to north and south in the eastern sub-basin and an older spreading center with a center anomaly 7 in the northwest of Macclesfield Bank. Briais et al. (1993) reinterpreted the youngest anomalies at the spreading axis identified by Taylor and Hayes (1983) to be 5C, and dated the anomalies in the triangular southwestern sub-basin as 6B through 5C much different from that of Yao (1996) and Ru and Piggott (1986). Barckhausen and Roeser (2004) and Barckhausen et al. (2014) presented a model largely agree with that of Briais et al. (1993) in the older part of the spreading history including the ridge jump at 25 Ma, but for the younger part, their model involves faster spreading rates and reinterpreted the end of the seafloor spreading at anomaly 20.5 Ma. For marginal conjugation relationship, Yao (1996) suggested Reed Bank and Dongsha block are two pieces from the same rigid continental block. Differently, Barckhausen and Roeser (2004) postulated Reed Bank broke-up from Macclesfield at around 25 Ma. For the boundary separating the eastern sub-basin from the southwestern sub-basin, some authors postulated the existence of a major N–S fault zone (around 116°E), often called Zhongnan Fault, through nearly the whole oceanic basin (Li, 1997; Ru and Piggott, 1986; Taylor and Hayes, 1983; Yao, 1996), while Barckhausen and Roeser (2004) and Barckhausen et al. (2014) suggested a transform fault with a shorter length exists only between

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Macclesfield Bank and Reed Bank, traced either along the eastern edges of Macclesfield and Reed Banks, or from the eastern edge of Macclesfield Bank to the western edge of Reed Bank.

On the other hand, more detailed and reliable seismic crustal structures of SCS, especially the deep part of the crust and Moho, have been gradually revealed by wide-angle seismic profiles of OBS, most of which were completed in recent years, and provide these questions mentioned above with some useful information that cannot be inferred from magnetic anomalies or gravity models. It has shown that the middle and eastern part of the northern margin of SCS is of volcanic type with a high velocity layer in the lower crust, the thick high velocity body beneath Dongsha islands in particular, that was interpreted as magma underplating or intruded mantle (Wang et al. 2006; Wei et al., 2011a, 2011b; Yan et al., 2001; Zhao et al., 2010). While no high velocity layer in the lower crust has been found in the OBS seismic models in the western part of the northern margin of SCS (Qiu et al., 2001; Wu et al., 2011). On the southern margin of SCS, it has shown that the middle and eastern parts of Nansha Block have similar tectonic characters with crust thickness of 20 km in continent and 5–6 km in basin without high velocity layer in the lower crust (Pichot et al., 2014; Qiu et al., 2011). Based on the similarity of crustal structure and Moho depth variation, Ruan et al. (2011) supposed Reed Bank and Macclesfield to be a pair of conjugate blocks. Nevertheless, we think there are still two problems in these seismic models. The high velocity layer in the lower crust, found in the northeastern part of the northern margin of SCS, is mainly identified by ray-tracing technique and inversion method but lacks substantial corresponding signals in the OBS seismic sections. The postulated conjugate relationship between Reed Bank and Macclesfield has not been analyzed from the aspect of rock characteristics or from detailed variation of velocity. For these problems, our previous studies (Wei et al., 2011b; Zhao et al., 2010) have simulated the shear-wave velocity structure of Dongsha area and obtained a low *Vp*/*Vs* ratio (1.73–1.78) for the high velocity layer in the lower crust revealed by P-wave model (Wang et al. 2006; Wei et al., 2011a). But for crustal structures in the southern margin of SCS, no shear-wave velocity model has been built from OBS data.

In this paper, we present a shear-wave velocity model from a wide-angle seismic profile (OBS973-2) crossing Reed Bank in the southern continental margin of SCS (Fig. 1), simulated by 2-D ray-tracing method and based on its previous P-wave model (Ruan et al., 2011) (Fig. 2), and compared it with that of northern margin for understanding the marginal conjugation relationship of SCS.

2. OBS data and P-wave velocity model

2.1. OBS data

In May of 2009, R/V "Shiyan 2" completed a wide-angle seismic profile (OBS973-2) in the southern margin of SCS that extends 369 km long in NW-SE direction across the northeastern Reed Bank to the central basin (Fig. 1). Seventeen OBS (three components and one hydrophone) were deployed along this profile in 20 km interval (OBS1 and OBS10 were lost). OBS data were sampled in 4 ms interval. An air gun array of 4 × 24.5 l shot at a pressure of 110 kg/cm2 every 120 s, giving an average shooting interval of 280 m approximately. Bathymetry measurement was also done simultaneously. The processing of OBS data includes correction of shooting time, localization of shooting coordinates, correction of OBS coordinates and time drift, and finally micro-adjust of OBS position by theoretic simulation of direct water wave (Zhao et al., 2010). We use filtering frequency band of 3–15 Hz.

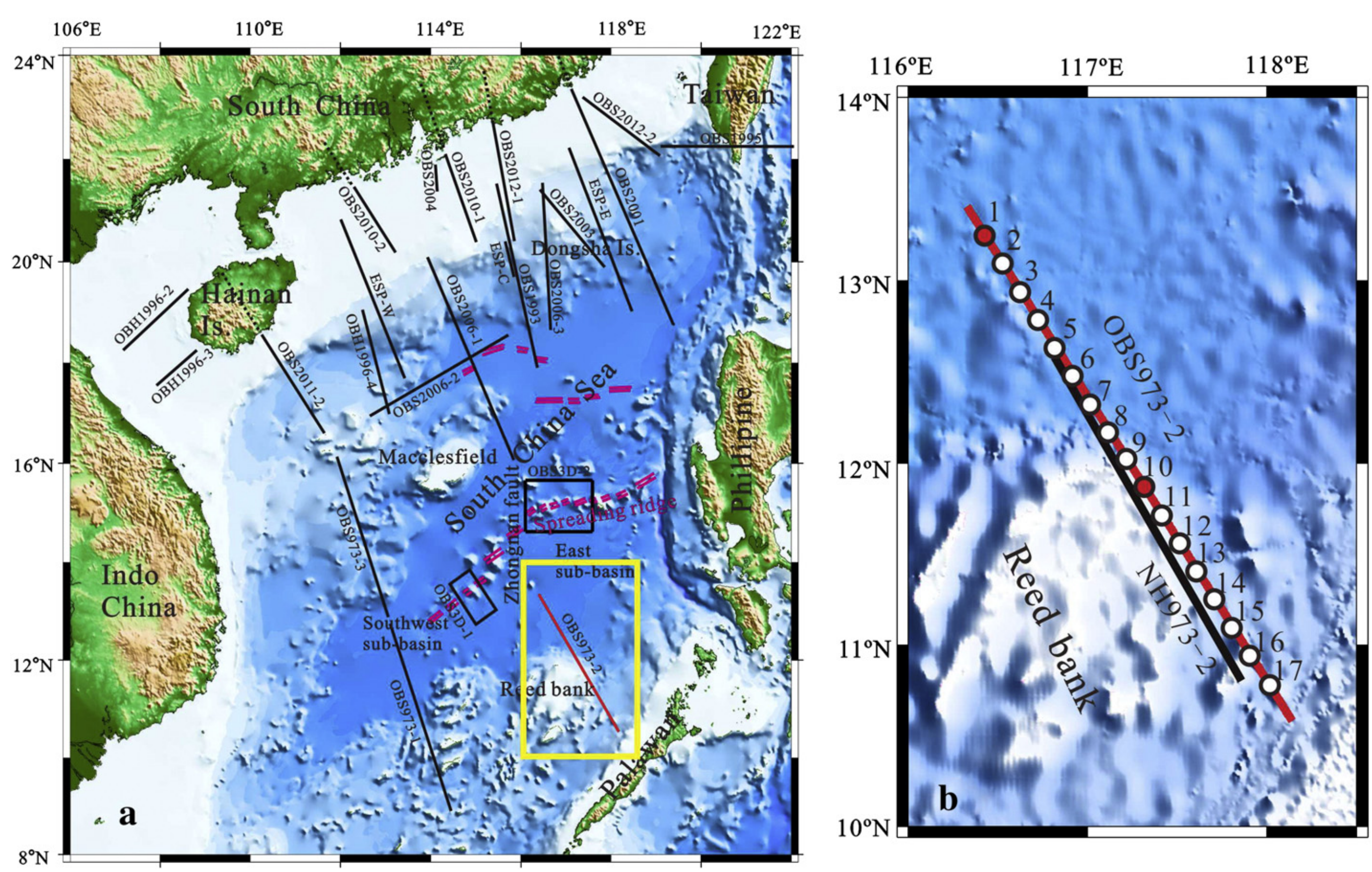

Fig. 1. (a) The distribution of deep seismic experiments in the SCS. The black solid lines represent deep seismic profiles; the yellow box shows the study area. (b) The red line is the profile OBS973-2, the white dots indicate OBS positions along the profile OBS973-2, the red dots indicate the lost OBSs, and the black line stands for multi-channel seismic profile NH973-2.