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Crustal structure across the post-spreading magmatic ridge of the East Sub-basin in the South China Sea: Tectonic significance

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ABSTRACT

The 140-km wide last phase of opening of the South China Sea (SCS) corresponds to a N145° direction of spreading with rift features identified on swath bathymetric data trending N055° (Sibuet et al., 2016). These N055° seafloor spreading features of the East Sub-basin are cut across by a post-spreading volcanic ridge oriented approximately E–W in its western part (Zhenbei–Huangyan seamounts chain). The knowledge of the deep crustal structure beneath this volcanic ridge is essential to elucidate not only the formation and tectonic evolution of the SCS, but also the mechanism of emplacement of the post-spreading magmatism. We use air-gun shots recorded by ocean bottom seismometers to image the deep crustal structure along the N–S oriented G8G0 seismic profile, which is perpendicular to the Zhenbei–Huangyan seamounts chain but located in between the Zhenbei and Huangyan seamounts, where topographic changes are minimum. The velocity structure presents obvious lateral variations. The crust north and south of the Zhenbei–Huangyan seamounts chain is ca. 4–6 km in thickness and velocities are largely comparable with those of normal oceanic crust of Atlantic type. To the south, the Jixiang seamount with a 7.2-km thick crust, seems to be a tiny post-spreading volcanic seamount intruded along the former extinct spreading ridge axis. In the central part, a 1.5-km thick low velocity zone (3.3–3.7 km/s) in the uppermost crust is explained by the presence of extrusive rocks intercalated with thin sedimentary layers as those drilled at IODP Site U1431. Both the Jixiang seamount and the Zhenbei–Huangyan seamounts chain started to form by the intrusion of decompressive melt resulting from the N–S post-spreading phase of extension and intruded through the already formed oceanic crust. The Jixiang seamount probably formed before the emplacement of the E–W post-spreading seamounts chain.

1. Introduction

The South China Sea (SCS), a western Pacific marginal sea, is located among the Eurasian, Philippine Sea and Indo-Australian plates (Fig. 1a). Based on bathymetric and tectonic characteristics, the SCS is divided into three Sub-basins, namely the East, Southwest and Northwest Sub-basins (Fig. 1b) (Briais et al., 1993; Yao, 1996). In the East Sub-basin, uncertainties still exist concerning the cessation of seafloor spreading activity either at ~15.5 Ma (Taylor and Hayes, 1980, 1983; Briais et al., 1993; Sun et al., 2009; Li et al., 2014) or at 20.5 Ma (Barckhausen et al., 2014). After the cessation of seafloor spreading activity, the post-spreading volcanic ridge (PSVR) was built partly along the extinct spreading ridge (ESR) oriented N055° in the eastern part of the East Sub-basin and partly across the ESR (E–W Zhenbei–Huangyan seamounts chain) in the western part of the East Sub-basin (Wang et al., 1984, 2009; Tu et al., 1992; Briais et al., 1993; Sibuet et al., 2016). Compared with the Hawaiian–Emperor seamounts chain produced by mantle plume activities (Morgan, 1972), the Zhenbei–Huangyan seamounts chain does not show obviously along-trend variation with age. Therefore, these seamounts chains are likely to have different mechanisms of formation, particularly in terms of their magma sources. Where do the magma source derived from to build the seamounts in the SCS and how do the magmatic activities affect the pre-existing oceanic crust?

Due to the geographic remoteness and large bathymetric depth of the East Sub-basin, the origin of the PSVR is largely unknown. A three-dimensional (3D) ocean bottom seismometer (OBS) seismic survey was carried out along a small E–W portion of the PVSR, in the area of the Zhenbei and Huangyan seamounts in May 2011 (Zhang et al., 2013). The 3D seismic structure is already published

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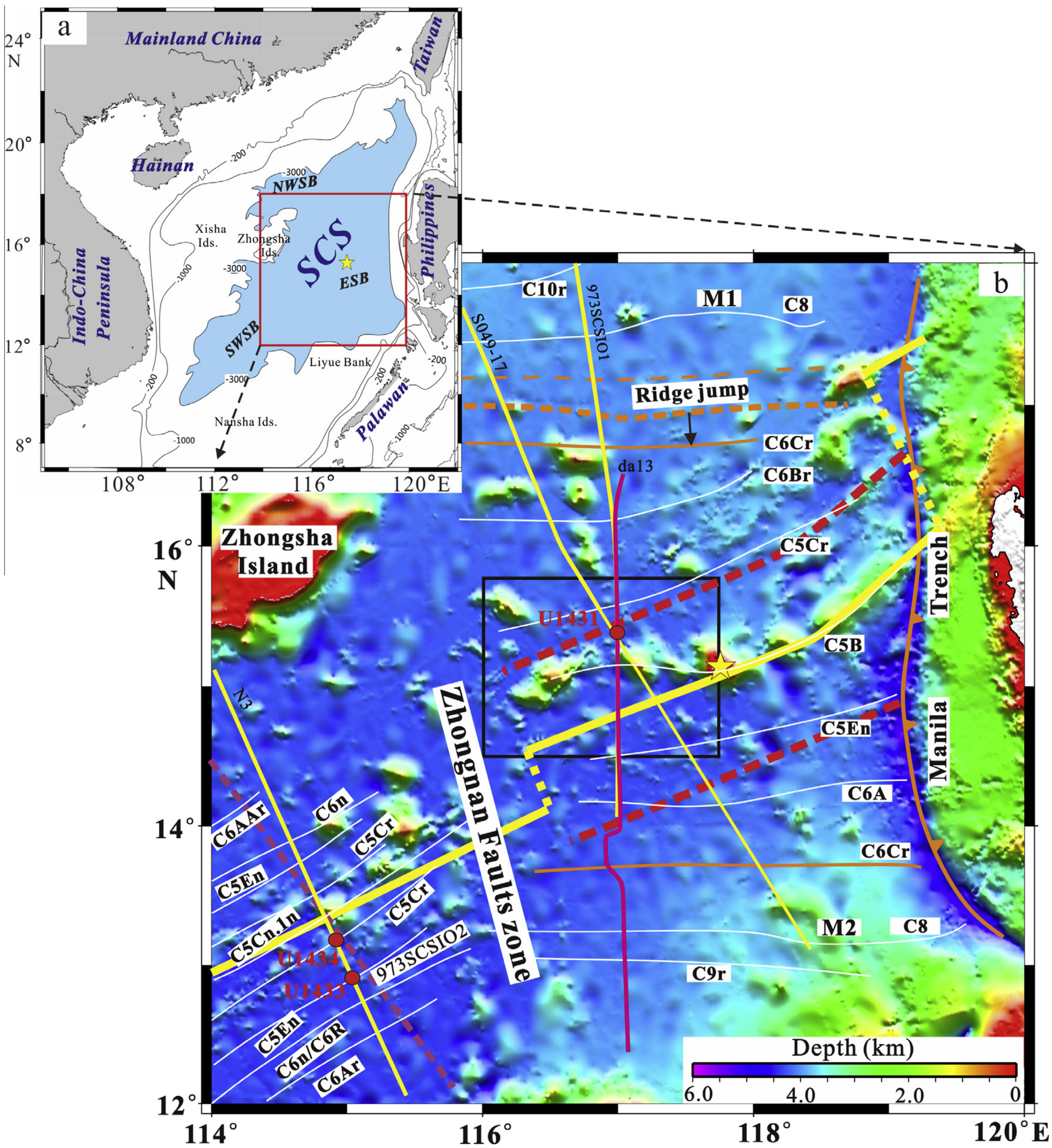

Fig. 1. (a) Bathymetric map of the South China Sea with 200, 1000 and 3000-m isobaths. NWSB, ESB, SWSB are the Northwest, East and Southwest Sub-basins, respectively. (b) Shaded-relief image of the portion of South China Sea identified as a red box in a). The red broken lines are the boundaries of the oceanic domain formed during the last spreading phase characterized by N055° rift trends, the solid yellow line represents the potential location of the extinct spreading ridge (ESR), the dashed yellow lines represent the transform fault located in the Zhongnan faults zone, between the ESB and SWSB (Sibuet et al., 2016). A ridge jump (Li et al., 2014) is underlined by the black arrow between the orange dashed and solid lines. The magnetic anomalies (white thin lines), the deep-tow magnetic survey profile da13 (thin red line) and multichannel seismic profiles SO49-17, 973SCSIO1 and N3 (thin yellow lines) are from Li et al. (2014, 2015). Orange line with triangles indicates the Manila Trench and the yellow star marks the location of Huangyan Island. Red dots indicate Sites U1431, U1433, U1434 drilled during the IODP 349 expedition (Expedition 349 Scientists, 2014).

(Wang et al., 2016). In this paper, we focus on the N–S G8G0 profile, which is almost perpendicular to the PVSR and located between the two Zhenbei and Huangyan seamounts, where the topography is reduced. The obtained velocity and density structures will be used to unravel the mechanism of the post-spreading magmatic emplacement.

2. Tectonic setting

The SCS marginal sea is located at the confluence of three major plates (Eurasian, Philippine Sea and Indian-Australian plates) (Fig. 1a). The East Sub-basin, the largest basin among the three SCS Sub-basins, is the major constituent of the SCS. The abyssal plain in the East Sub-basin lies in between 4300 and 4500 m deep. East of the Zhongnan faults zone, which separates the East and Southwest Sub-basins, the Zhenbei–Huangyan seamounts chain is trending E–W over a distance of 240 km and consists of five major seamounts, which stand nearly 4000 m above the seafloor (Yao, 1996) (Figs. 1b and 2). Its width is ~40 km. Further east, this chain changes direction to NE–SW over 100 km and disappears near the Manila trench.

Based on the original magnetic anomalies interpretation (Taylor and Hayes, 1980; Briais et al., 1993; Li et al., 2011), Li et al. (2014) re-identified and relocated the magnetic anomalies by using recent deep-tow magnetic surveys and IODP Expedition 349 results. They