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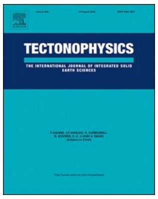

Lithospheric structure of the South China Sea and adjacent regions: Results from potential field modelling

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ABSTRACT

This work aims to investigate the crustal and lithospheric mantle thickness of the South China Sea (SCS) and adjacent regions. The crust-mantle interface, average crustal density, and lithospheric mantle base are calculated from free-air gravity anomaly and topographic data using an iterative inversion method. We construct a three-dimensional lithospheric model with different hierarchical layers. The satellite-derived gravity is used to invert the average crustal density and Moho (crust-mantle interface) undulations. The average crustal density and LAB (lithosphere–asthenosphere boundary) depths are further adjusted by topographic data under the assumption of local isostasy. The average difference in Moho depths between this study and the seismic measurement results is < 1.5 km. The results show that in oceanic regions, the Moho depths are 7.5–30 km and the LAB depths are 65–120 km. The lithospheric thickness of the SCS basin and the adjacent regions increases from the sea basin to the continental margin with a large gradient in the ocean-continent transition zones. The Moho depths of conjugate plots during the opening of SCS, Zhongsha Islands and Reed Bank, reveal the asymmetric spreading pattern of SCS seafloor spreading. The lithospheric thinning pattern indicate two different spreading directions during seafloor spreading, which changed from N-S to NW-SE after the southward transition of the spreading axis. The lithosphere of the SCS basin and adjacent regions indicate that the SCS basin is a young basin with a stable interior lithosphere.

1. Introduction

As one of the largest marginal ocean basins of the western Pacific, the South China Sea(SCS) is located at the junction of three major plates: the Eurasia plate, Pacific plate and Indo-Australian plate (Taylor and Hayes, 1983). The continental breakup and seafloor spreading in the SCS are affected by the interactions of the Tethys and Paleo-Pacific tectonic domains (Hall, 2002) and have always been issues of intense interest in the study of earth sciences. The tectonic activities in different geological periods leave their traces in the lithosphere, and it is important to study the three-dimensional crustal and lithospheric mantle structure of the SCS and adjacent regions to reveal the geological activity in the formation and evolution processes of the SCS.

Researchers have used various data and methods to study the crustal and lithospheric mantle structure of the SCS. In recent years, Earth scientists have performed several Expanding Spread Profiles (ESP) (Nissen et al., 1995; Hayes and Nissen, 2005) and wide-angle refraction/reflection seismic surveys with ocean bottom seismometers (OBS) (Qiu et al., 2001; McIntosh et al., 2005; Wang et al., 2006) in the SCS and adjacent regions, which show the one-dimensional deep lithospheric mantle structure of the SCS. Three-dimensional lithospheric mantle structure models of the SCS have also been calculated with large-scale seismic tomography based on the velocity anomaly and anisotropy (Yue-jun et al., 2000; Xu et al., 2007; Tang and Zheng, 2013). However, due to few observational seismic stations and low data resolution, the three-dimensional structure of the lithosphere cannot be precisely determined. The thermal lithospheric thickness and rheological structure of the SCS, which are calculated from the surface heat flow data (Shan et al., 2011), are limited by the accuracy and resolution of the measured heat flow data and exhibit low accuracy and reliability.

Gravity anomaly data map the density changes of shallow geological bodies and are commonly used in the inversion of shallow density anomalies. When constrained by seismic data, gravity anomaly data also provide fairly good information about the Moho depths. Assuming local isostatic compensation, together with the Moho depths and the density distribution in the lithosphere, the topographic elevation data provide information about the thickness of the lithospheric mantle (Zeyen and Fernàndez, 1994; Motavalli-Anbaran et al., 2013). In this

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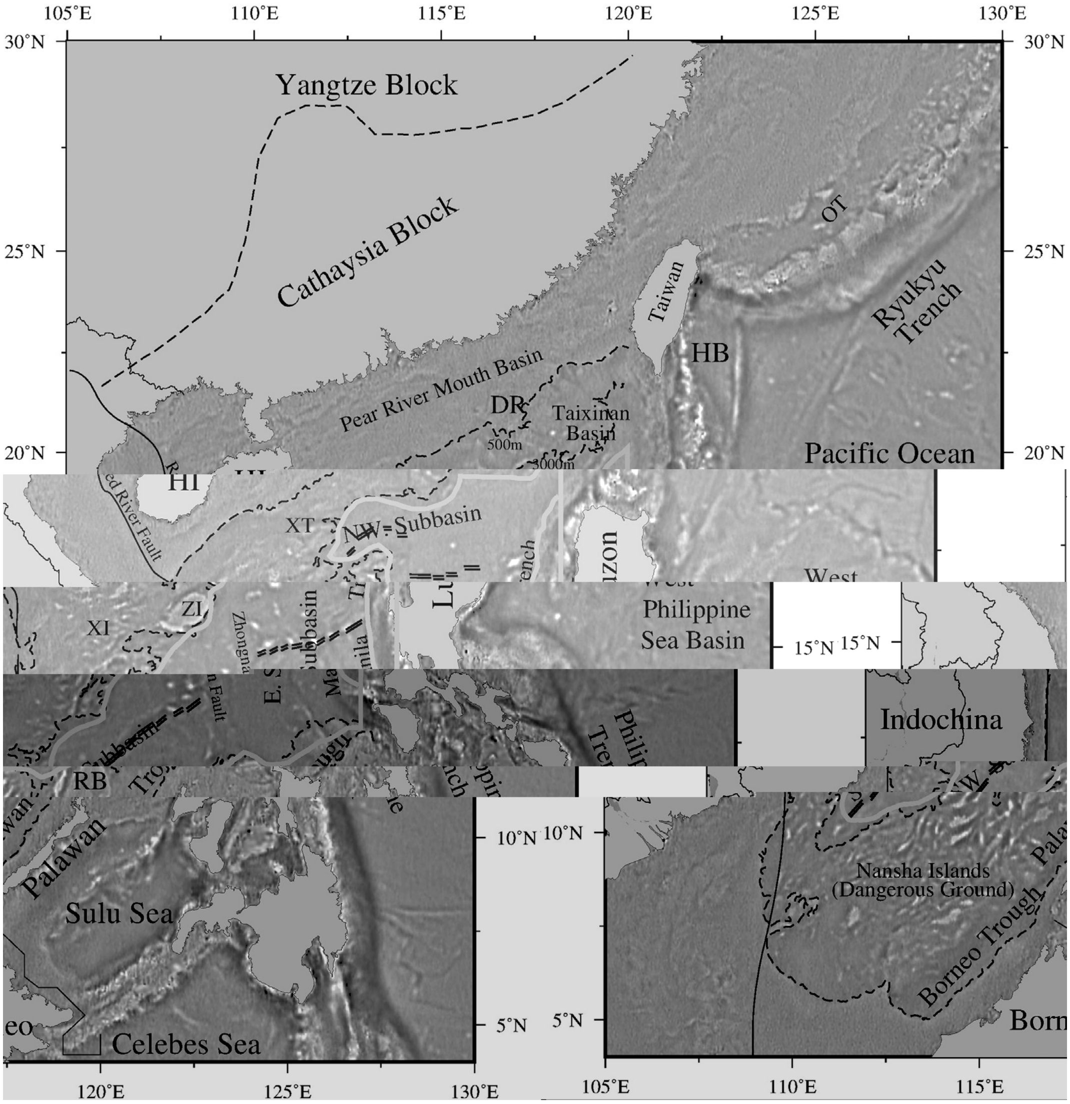

Fig. 1. Major tectonic settings in the South China Sea region. The base map is vertical gravity gradient maps from satellite altimetry (Sandwell et al., 2014) and onshore are filled with gray. E. Subbasin, East Sub-basin; NW. Subbasin, Northwest Sub-basin; SW. Subbasin, Southwest Sub-basin; HI, Hainan Island; DR, Dongsha Rise; RB, Reed Bank; XI, Xisha Islands; ZI, Zhongsha Islands; XT, Xisha Trough; HB, Huatung Basin; OT, Okinawa Trough; SCS, South China Sea. Offshore dashed lines indicate the bathymetric isolines: 500 m and 3000 m.

study, we use an iterative inversion method to present a three-dimensional crustal and lithospheric mantle thickness model in the SCS and adjacent regions to provide a comprehensive view of the geological structure of the SCS. In our modelling approach, the gravity anomaly data are used to obtain the Moho depths and average crustal density. Topographic data are used to constrain the LAB depths and average crustal density based on local isostasy. The final three-dimensional lithospheric mantle structure is obtained when the misfits between the forward gravity and topography and the observed values are within the tolerance level.

2. Geological setting

As one of the mature marginal sea basins of the western Pacific (Hall, 2002), the SCS has a complex geological structure (Fig. 1) because of the interaction among different plates (Yao et al., 2006). The SCS is located at the junction of three major plates: the Eurasian plate on the north side, the Indo-Australian plate on the west and south side, and the Pacific plate on the east side. From ~50.3 Ma to ~47.7 Ma, the northward drift of the Indian plate collided with the Eurasian plate (Besse and Courtillot, 1988); separated from the Antarctic plate, the Australian plate collided with the Philippine Sea plate before 25 Ma and with the Eurasian plate before 5 Ma. In the Oligocene, the Philippine plate drifted northward and collided with the Eurasian plate at 5 Ma, which formed Taiwan Island (Hall, 1996). The interactions among the plates deformed the crust and the lithosphere of the Eurasian plate, which triggered and promoted Cenozoic seafloor spreading in the SCS.

The complex lithospheric structure beneath the SCS is the result of the demise of the Paleo-SCS and the seafloor spreading in the SCS (Hall, 1996). In the Jurassic, micro-blocks such as North Palawan, Luconia Shoals, Nansha Island (Dangerous Ground) and Reed Bank were fore-arc basins of the Andean arc of Southeast Asia (Briais et al., 1993; Hall, 1996). In the Tertiary, influenced by the interaction of the plates and dragging of the proto-SCS, the SCS formed via continental breakup and seafloor spreading (Taylor and Hayes, 1980, 1983; Briais et al., 1993; Hall, 2002; Zahirovic et al., 2013). Nansha Island and Reed Bank drifted southward and formed the complex geological structural units in the south margin of the SCS basin (Taylor and Hayes, 1980, 1983). The tectonic boundaries of the SCS basin are as follows: the north is the extension of the South China Block, which is a tensional passive boundary (Li et al., 2007; McIntosh et al., 2014); the east is the Manila Trench, which is a subduction zone (Morton and Blackmore, 2001); the south is the collision boundary, where the proto-SCS subducted under Borneo (Hall, 2002); the west is bounded by the Ailaoshan/Red River