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Tectono-thermal evolution of the Reed Bank Basin, Southern South China Sea

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ABSTRACT

The Reed Bank Basin in the southern margin of the South China Sea is considered to be a Cenozoic rifted basin. Tectono-thermal history is widely thought to be important to understand tectonics as well as oil and gas potential of basin. In order to investigate the Cenozoic tectono-thermal history of the Reed Bank Basin, we carried out thermal modeling on one drill well and 22 pseudo-wells using the multi-stage finite stretching model. Two stages of rifting during the time periods of ~65.5–40.4 Ma and ~40.4–28.4 Ma can be recognized from the tectonic subsidence rates, and there are two phases of heating corresponding to the rifting. The reconstructed average basal paleo-heat flow values at the end of the rifting events are ~60 and ~66.3 mW/m^2, respectively. Following the heating periods, this basin has undergone a persistent thermal attenuation phase since ~28.4 Ma and the basal heat flow cooled down to ~57.8–63.5 mW/m^2 at present. In combination with the radiogenic heat production of the sedimentary sequences, the surface heat flow of the Reed Bank Basin ranges from ~60.4 to ~69.9 mW/m^2.

1. Introduction

The Reed Bank Basin, also called Liyue basin or Lile basin in China, located on the southeastern margin of the South China Sea (hereafter SCS) has attracted great attention due to its unique structural characteristics and significant hydrocarbon potential. Investigation and research on this basin began in the early 1980s, most of which focused on the tectonic evolution of the SCS basin and the Dangerous Grounds and Palawan blocks. Taylor and Hayes (1980, 1983) described the lithology, sedimentary environments, and fossil zones of the Lower Cretaceous to Quaternary deposits from the Sampaguita-1 well, and discussed the tectonic evolution of the SCS based on paleogeomagnetic and geological data. Holloway (1982) discussed the origin and geological history of the North Palawan faulted blocks (including the Reed Bank). Since the 1980s, with the increase of regional geological and geophysical data, significant progress has been made in studying the Reed Bank Basin, including the division of the sedimentary strata (Hinz and Schluter, 1985; Schlüter et al., 1996; Yan and Liu, 2004), structures analyses (Liu et al., 2004; Yao et al., 2002), and deep crustal structure (Franke et al., 2011). However, some disputes related to the identification of Mesozoic and Cenozoic stratigraphy, and dating of the unconformities within the basin are still remain, due to the poor quality of the deep crust seismic reflection data and shortage of borehole data, which are mostly located on the Central Reed Bank.

As of yet, no work concerning the tectono-thermal evolution of the Reed Bank Basin has been carried out, but such information is critical to understand the tectonic evolution as well as the hydrocarbon potential of this basin. Based on the newly interpreted, yet unpublished 2D multi-channel seismic profiles, in combination with tectonic and borehole data, we attempt to analysis the Cenozoic tectonics and reconstruct the thermal history of the Reed Bank Basin in this study.

2. Geological setting

The Reed Bank Basin is situated around the Reed Bank on the NE margin of the Dangerous Grounds, and extends over an area of about 55,000 km^2 (Fig. 1a). Within the basin, the topography changes dramatically as numerous coral reefs, seamounts, sea knolls, trough valleys, and fault-depressed mesas are scattered throughout the basin floor.

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Sampled rocks suggest that the southern margin of the SCS including the Dangerous Grounds and the Reed Bank area once were a part of the South China continent (Kudrass et al., 1986; Hutchison, 2004). After a Cretaceous to Late Paleogene period of rifting, which led to the formation of numerous NE–SW trending half-grabens, the continental fragments were finally separated from the South China continent by seafloor spreading at about 30 Ma (Briais et al., 1993; Cullen et al., 2010) or earlier at ~37 Ma (Hsu and Sibuet, 2004). The oceanic basin of the SCS consists of three sub-basins: the East Sub-basin, the Southwest Sub-basin (Fig. 1a) and the Northwest Sub-basin, which is located close to the China margin.

The opening scenario of the SCS proposed by Taylor and Hayes (1983) and Briais et al. (1993) has been generally accepted, i.e. sea floor spreading occurring from 30 to 16 Ma (anomaly of 11-5C). The spreading history was complicated by two southward ridge jumps and a south-westward ridge propagation. Refinement of the earlier model has been proposed based on new ship-borne magnetic data (Barckhausen and Roeser, 2004), the timing of seafloor spreading in the central SCS has been revised to 31–20.5 Ma (anomaly of 11-6A1). Another difference to the earlier models is that Barckhausen and Roeser proposed that the rigid block of continental crust hindered the propagation of seafloor spreading into the southwestern part of SCS oceanic basin until around 25 Ma. The break-up of this block gave way for propagation and also caused a ridge jump in the pre-existing ocean. Hsu and Sibuet (2004) identified possible additional magnetic anomalies (anomaly of C17) in the south Taiwan and suggested an earlier start of seafloor spreading as old as 37 Ma. The question about what caused extension was recently discussed in detail by Cullen et al. (2010) with a comprehensive presentation of the different models in the literature. Whatever the opening scenario of the SCS might have been, Seafloor spreading at approximately the Late Oligocene and the end of the Early Miocene moved the Reed Bank from its Paleogene position to the present position (Briais et al., 1993; Taylor and Hayes, 1980).

Nine seismic sequence boundaries, i.e. Tm, Tg, T80, T70, T60, T40, T32, T30, and T20 (Fig. 2), are identified in the Reed Bank Basin based on the comprehensive analysis of seismic profiles, dragnet and core samples (Yao et al., 2012). Seismic line Ly2 exhibits that the Cenozoic strata of the Reed Bank Basin has a two-layer structure. The lower section is characterized by half-graben and heavy faults which formed during rifting and filled with syn-rift sediments, whereas the post-rift section is characterized by a wider distribution of deposits accompanying the regional subsidence during the Neogene (see Fig. 3). Similar structures can be found in the studied seismic profiles used in this study, which cannot be shown here due to confidentiality requirements.

3. Data and method

3.1. Data and sources

3.1.1. Wells

Drill well Sampagita-1, which located on Central Uplift of the Reed Bank Basin (Fig. 1), has been used for lithology information and subsidence calibration. This well has been published by Taylor and Hayes (1983) and Yao et al. (2012).

3.1.2. Present-day heat flow

Present-day heat flow, which can provide necessary constraints on the thermal history reconstruction, is the final episode of the entire scenario of basin tectono-thermal evolution, and the only one which may be measured directly (He et al., 2001, 2002). As of yet, no heat flow has been published in the Reed Bank Basin, but heat flow measurement performed in the adjacent areas may provide us with some valuable information (Yao et al., 2012).

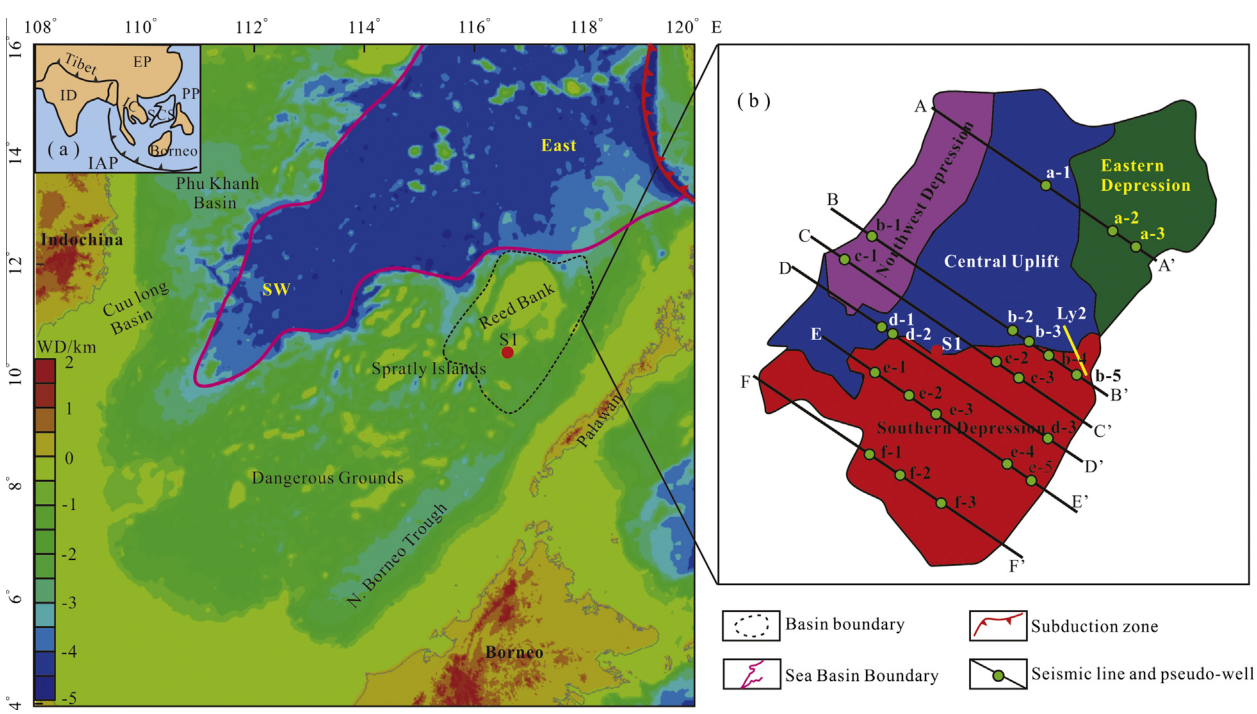

Fig. 1. (a) Geographical location and tectonic settings of the Reed Bank Basin. Boundary of the Reed Bank Basin is after Yao et al. (2012) and Ding et al. (2013). NW – northwest sub-sea basin, SW – southwest sub-sea basin, EP – Eurasian Plate, PP – Pacific Plate, IAP – India-Australian Plate, IC – Indochina Block, ID – India Block. (b) Structural division of the Reed Bank Basin. Green circles represent the pseudo-wells while the red circle represents the drill well S1 (Sampagita-1). The black lines denote the seismic profiles used in this study while the yellow one denote the seismic profile Ly2 published by Yao et al. (2012). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)