A Preliminary Study on the Present Crustal Stress of Northern South China Sea

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The South China Sea (SCS) is the largest marginal sea in West Pacific formed by a combined effect of the Eurasian plate, Pacific plate and India-Australian plate, and is thus considered to be a unique natural laboratory to study oceanic dynamics and tectonic evolutions (Xie et al., 2006; Luan and Zhang, 2009). Besides, the SCS contains enormous petroleum resources for its favorable conditions of oil-gas generation, accumulation and preservation. It is therefore imperative to intensively study the marine in-situ stress and its controlling factors of the SCS. The current researches on the present crustal in-situ stress in the SCS are few limited by the nature conditions. This study conducted hydraulic fracturing measurements in coastal zone of Hainan Province and Xisha islands, Northern South China Sea (NSCS), supported by the project "In-situ stress observation and comprehensive study in key sea areas of China", and obtained the in-situ stress state in the region. In addition, interpretations of Formation Micro-Imager (FMI) logs in oil and gas fields have been done as well to extract stress information. Under constraints of in-situ stress measured data, FMI deduced stress data and tectonic environment in the research area, numerical modeling were established, and the stress field as well as its distribution characteristics were presented.

In-situ stress tests have been performed in Ledong (LD), Hainan Province and Xike 1-A well (XK1A), Xisha islands with the hydraulic fracturing measurement method (Fig. 1), in which the XK1A is so far the deepest in-situ stress test borehole with a depth of 1262 m in the sea area China. The stress measurement results from the LD borehole show that the stress fields are characterized by $S_t > S_h > S_z$ (0 to 200 m) and $S_h > S_z > S_r$ (200 to 300 m), respectively, indicating a horizontal stress domination regime. Implications of in-situ stress for fault activities have been discussed in further analysis. Orientations of the maximum horizontal principal stresses are predominantly NW–NWW. The stress regime of XK1A is $S_z > S_h > S_t$ characterized by normal faulting. The dominant vertical stress reveals the crustal basement of Xisha islands in a tensile stress environment particularly at deeper depth. Stress directions appear to be relatively well constrained in EW–NW.

In addition, some other indirect methods based on stress-related phenomena are utilized to estimate in-situ stress. For example, maximum principal stress orientations can be deduced from the induced fractures and borehole breakouts formed during drilling which were recorded by well logging. In the present study, FMI logs in two oil and gas fields from the Yinggehai basin and Qiongdongnan basin of the NSCS were interpreted to get stress information. The estimated predominant orientations of maximum horizontal principal stresses are NW–NNW and NWW, respectively, corresponding to the measurement results of hydraulic fracturing.

This study used the stress information obtained by in-situ stress measurements and FMI logs and focal mechanism inversion as constraint conditions, to calculate crustal stress field in the NSCS by standard linear viscoelastic model and finite element numerical simulation (see Fig. 1). The simulation demonstrates that the crustal stress field in the NSCS is characterized by different stress states in different zones due to different roles of the Eurasian plate, Pacific plate and India-Australian plate during the stress field evolution. Maximum principal stress directions are E-S in the areas near Taiwan Island dominated by the collision of Pacific plate and Eurasian plate. However, stress field gradually transforms to S-N, NW along marginal zones of the NSCS, experiencing extension induced by the Eurasian plate subduction under the Philippine plate at the Manila trench.

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Fig. 1. Sketch map showing tectonic setting of the Northern South China Sea (modified from Xu et al., 2010; Briais et al., 1993; Yao et al., 1999; Lin et al., 2009) and modeling result of crustal stress field (maximum horizontal principal stress directions) in the NSCS.
(a), Comparison of modeling result and in-situ stress measurement result of stress directions in XK1A and surrounding areas; (b), Comparison of modeling result and in-situ stress measurement as well as FMI log interpretation results of stress directions in Hainan island and surrounding areas. Rose diagrams from up to down are stress directions of Yinggehai basin and Qiongdongnan basin deduced from FMI logs which recorded induced fractures and borehole breakouts during drilling. Besides test result in borehole LD, stress direction in Damao tunnel measured by Wu and Liao (Wu and Liao, 2000) using borehole relief technology was added and marked as DM.

References
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