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Cretaceous stress field evolution and origin of the Jiaolai Basin, Eastern North China

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ABSTRACT

The Jiaolai Basin, to the east of the Tan-Lu Fault Zone (TLFZ), is a Cretaceous NE-trending basin in eastern North China and has a multi-episodic evolution. Different from other contemporary NW-trending en-echelon graben systems west to the TLFZ, the origin of the Jiaolai Basin (three episodes: K_{1l}, 135–120 Ma; K_{2q}, 120–105 Ma; K_{2w}, 88–65 Ma) cannot be simply explained by the sinistral displacement of the TLFZ at the beginning of the Early Cretaceous (around ca. 135 Ma). The purpose of this paper is to investigate the critical factors (e.g., bounding faults, tectonic setting, stress field) driving the development of the Jiaolai Basin and constraint its evolution. Three episodes of two-dimensional finite element models were generated in order to determine the roles of the boundary conditions and to reveal the tectonic development of the basin. When compared to the calculated maximum horizontal compressive stress (σ_{Hmax}) trajectories and the observed data, along with a comparison between the Von Mises Stress (u_{Von}) and the depocenters of the basin, the calculated results can be well proved by the geological evidence both in stress field evolution and in the basin patterns. Our analysis show that the three episodes of the maximum principle stress trajectories changed from NE-SW (earlier Early Cretaceous, K_{1l}) NNE-SSW (later Early Cretaceous, K_{1q}) then E-W (Late Cretaceous, K_{2w}). Moreover, the results show a good consistency between the $u_{Von}$and the depocenters in the basin through geological cross-sections. Via models we suggest that the origin and evolution of the Jiaolai Basin were controlled by three episodes of tectonic events, (i) the reactivated bounding faults and the post-orogenic extension of the Sulu Orogen during the earlier Early Cretaceous, (ii) the lithospheric delamination of the thickened lithosphere during the later Early Cretaceous, and (iii) the likely far-field effects produced by the collision between the Kohistan-Drags arc complex and Asia during the Late Cretaceous. The Jiaolai Basin evolved from extension to pull-apart experiencing volcanic activity during the three episodes of the Cretaceous.

1. Introduction

Generally referred to craton destruction, lithospheric thinning occurred widely in the Eastern Block of the North China Craton since the Early Cretaceous. Such a process is characterized by intracontinental rifting, within-plate volcanic eruption and emplacement of metamorphic core complexes (Menzies et al., 2007; Zheng et al., 2001; Ren et al., 2002; Rudnick and Gao, 2003; Rudnick et al., 2004; Wu et al., 2005; Zhai et al., 2007). Particularly conspicuous are the Mesozoic rhomboid-shaped basin systems associated with the reactivation of the Tan-Lu Fault Zone (TLFZ), including the NW-trending Bohai Basin and the NW-trending en-echelon graben system (e.g., the Jiyang Grabens, the Luxi Grabens and the Liaohe Grabens) as well as the NE-trending Jiaolai Basin (Liu, 1986; Allen et al., 1997; Zhang et al., 2007, 2008; Hou and Hari, 2014) (Fig. 1). It is easy to understand the mechanism of the basins (the Bohai Basin and the en-echelon graben system) west to the NNE-trending sinistral TLFZ according to the "Liddell shear model" (Fig. 1), which is related to the NW-wards subduction of the Izanagi Plate at the Early Cretaceous (Cottrel and Tarduno, 2003; Maruyama et al., 2007, 2009; Zhu et al., 2010; Isozaki et al., 2011). However, the origin of the NE-trending Jiaolai Basin contradicts the sinistral displacement of the TLFZ (Fig. 1). The shear fractures/faults (trending of R, R′ in "Liddell shear model", Fig. 1) controlled by the NNE-trending sinistral TLFZ should strike from NWW to NNW and the corresponding basins should be around NW-trending. However, the major elongation of the Jiaolai Basin strikes NE. The initiation of the Jiaolai Basin cannot be simply explained by the sinistral displacement of the TLFZ at the beginning of Early Cretaceous (around ca. 135 Ma). The evolution of the stress field and the kinematics of the Jiaolai Basin remain unclear.

As a result of a long history of lithospheric thinning since the Early

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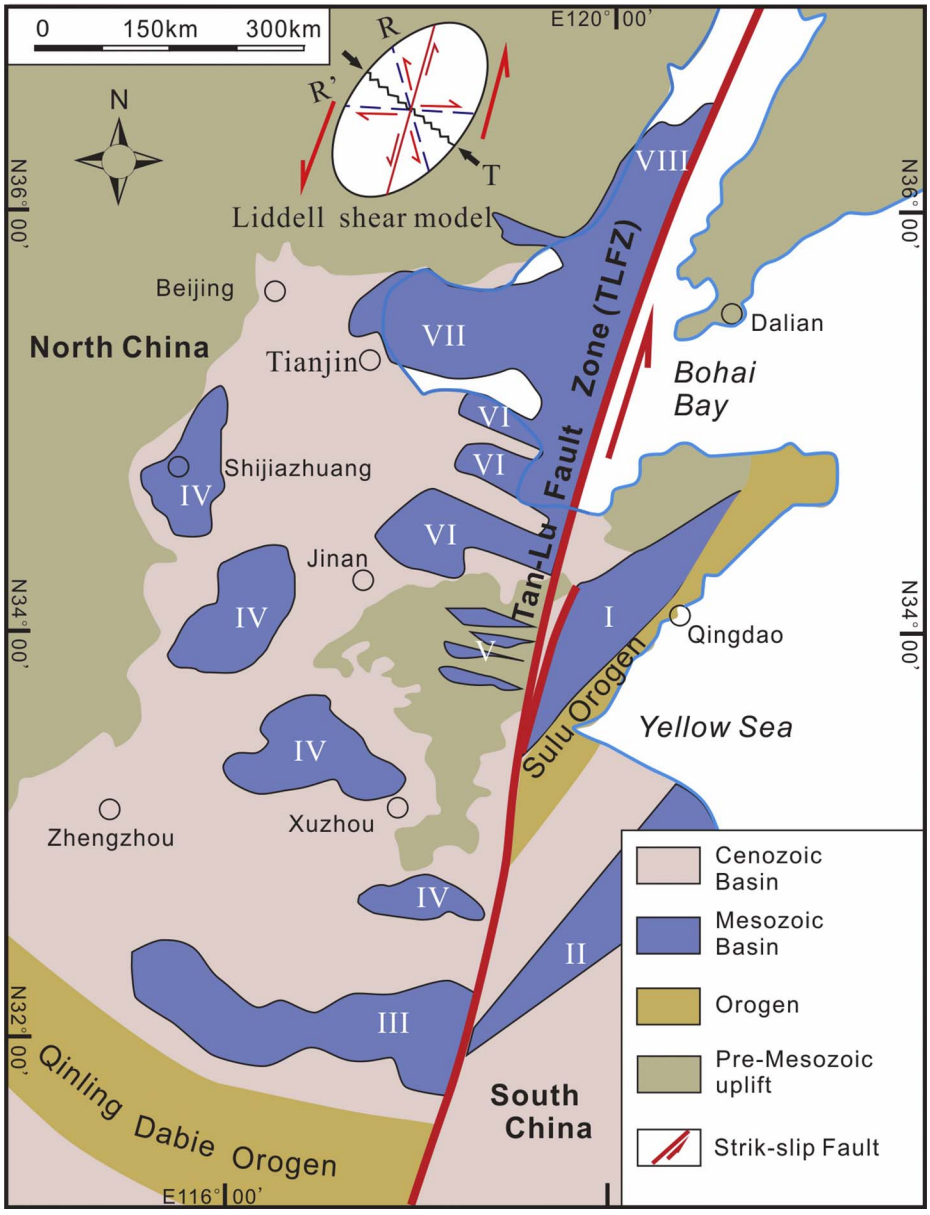

Fig. 1. The distribution of the Mesozoic basins along the TLFZ in North China (after Hou et al., 2014). I, Jiaolai Basin; II, Subei Basin; III, Hefei Basin; IV, Xu-Shi Basins; V, Luxi Grabens; VI, Jiyang Grabens; VII, Bohai Sea Basin; VIII, Liaohe Graben.

Cretaceous, it is commonly accepted that the Jiaolai Basin underwent extension and compression during the Cretaceous (Dai et al., 1995; Zhang et al., 2008; Zhu et al., 2012). The main controversial point is the origin of the Jiaolai Basin. Is the initiation of the Jiaolai Basin controlled by the strike-slip TLFZ as a pull-apart process or by the lithosphere extension? Different models have been proposed in previous papers to explore the hypotheses for the Jiaolai Basin, herein referred as the "**Pull-apart Model**" and the "**Extensional Model**" (Dai et al., 1995; Zhang et al., 2008). Based on previous studies about the displacement, uplifting and extension of the Jiaolai Basin, the "**Pull-apart Model**" suggests that the Jiaolai Basin was a strike-slip pull-apart basin, whose uplifting and subsidence were closely controlled by the strike-slip mechanics of its bounding faults. The basin during its development experienced successively NE-SW pull-apart at the earlier Early Cretaceous to NW-SE extension at the later Early Cretaceous, and followed by the N-S pull-apart at the Late Cretaceous (Dai et al., 1995). Although this model addresses the importance of the TLFZ during the development of the Jiaolai Basin, it is difficult to explain the extension of the basin in the transpressive tectonic environment east to the TLFZ. Based on field observation, isotopic data of the volcanic rocks and structural interpretation of seismic profiles, the "**Extensional Model**" suggests that the early NW-SE extension during the earlier Early Cretaceous and W-E extension during the later Early Cretaceous initiated the Jiaolai Basin. This was followed by a NW-SE compression which resulted in shortening of the basin and sinistral strike-slip of the TLFZ at ~90 Ma (Zhang et al., 2008; Zhu et al., 2012). The tectonic regime transformed from Early Cretaceous W-E extension to Late Cretaceous N-S extension, and ended by compression (Zhang et al., 2008). Although the evidence shows that the Early Cretaceous extension played an important role in initiating the Jiaolai Basin, the fact that the sinistral strike-slip of the TLFZ was at the earlier Early Cretaceous (140–120 Ma) rather than 90 Ma cannot be neglected. Moreover, the tectonic environments in the eastern North China Craton are also controversial, for instance: (1) There is extension following the continent-continent collision between the North China Craton and the South China Craton (Gao et al., 2002, 2004; Zhai et al., 2007; Zhang et al., 2008), (2) mantle plume activity underneath the North China Craton (Wilde et al., 2003), and (3) back-arc extension related to oceanic plate subduction in the Pacific Ocean (Wu et al., 2005; Deng et al., 2007; Sun et al., 2007; Zhu et al., 2012). In summary, so far no single model has been able to properly explain the