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Structural records of the Late Cretaceous–Cenozoic extension in Eastern China and the kinematics of the Southern Tan-Lu and Qinling Fault Zone (Anhui and Shaanxi provinces, PR China)

Jacques Louis Mercier [a], Pierre Vergely [a,*], Yue Qiao Zhang [b,c], Ming Jin Hou [d], Olivier Bellier [e], Yong Ming Wang [d]

[a] Département des Sciences de la Terre, UMR IDES CNRS, Université Paris-Sud, Bâtiment 504, F91405, Orsay Cedex, France
[b] Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing 100081, China
[c] Department of Earth Sciences, Nanjing University, Jiangsu Province, PR China
[d] Institute of Geology, Bureau of Geology and Mineral Resources of Anhui Province, Hefei, PR China
[e] CEREGE UMR 7330, Aix-Marseille Université, CNRS,IRD,OSU Pythéas. Europôle Méditerranéen de l'Arbois - BP80, 13545 Aix-en-Provence cedex 04 France

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ABSTRACT

Our study of the Late Cretaceous–Cenozoic extension in Eastern China is a kinematic analysis of faults (≈1500 striated fault data, 175 stress solutions at 90 sites) that has permitted us to separate stress fields belonging to six tectonic events. A WNW–ESE extension (1) has affected Eastern China from the Campanian to the Late Palaeocene–Early Ypresian. Under this extension, the Qinling (QLFZ) and Southern Tan-Lu (STLFZ) Fault Zones have been dextral transtensional fault zones. A first transpressional event (2) (NNE–SSW shortening) has occurred during the Late Ypresian–Lower Lutetian; the QLFZ and the STLFZ have been dextral transpressional fault zones. A NE–SW extension (3) has affected the Weihe graben during the Palaeogene; after a second transpressional event (4), the NE–SW extension (5) has been rejuvenated during the Late Miocene and the QLFZ has been a normal fault zone again and the STLFZ a sinistral transtensional fault zone; synrift subsidence has occurred in the Weihe graben. The second transpressional event (4) (WNW–ESE shortening) has occurred during the Late Oligocene–Early Miocene, during a period of uplifting and exhumation. At that time, the STLFZ and the QLFZ have become sinistral transpressional fault zones. A period of extension (6) has taken place during the Late Pliocene–Quaternary; the extensional direction has trended ≈NNW–SSE; during this event, the QLFZ has been a sinistral transtensional fault zone and the STLFZ a dextral transtensional fault zone. These results are compared with those previously published in order to evaluate the regional significance of these tectonic events.

1. Introduction

The Tan-Lu Fault Zone (TLFZ) extends in a NNE–SSW direction in Eastern China (Fig. 1); it is often considered as a major sinistral strike-slip fault zone (Xu, 1964) although on many outcrops, it exhibits clear brittle normal motions; these latter have essentially occurred during the Late Cretaceous–Cenozoic. The Qinling Fault Zone (QLFZ) extends in a WNW–ESE direction, on the northern border of the Qinling–Dabie orogen; it has been a major ductile strike-slip fault zone during the Palaeozoic–Mesozoic (Huang and Wu, 1992; Mattauer et al., 1985),and was subsequently exhumed, following which brittle shallow normal motions have been superimposed during the Late Cretaceous–Cenozoic. To analyse these Late Cretaceous–Cenozoic tectonics, we have conducted a structural analysis of the southern part of the TLFZ (STLFZ) and the surrounding areas in the Anhui Province during four summer missions. We have re-examined our fault data of the QLFZ and of the Weihe graben obtained during two summer missions (Bellier et al., 1988), adding new data of one summer mission, and paying special attention to the strike-slip motions on the QLFZ. Our purpose is to date the changes in the Late Cretaceous–Cenozoic tectonic regimes, to characterise them and to precise the kinematics of the QLFZ and of the STLFZ. Our present contribution first reappraises the chronostratigraphy of the Cenozoic formations and presents some already published dates from which we have constrained the dating of the tectonic events (Section 3), following which we present our data resulting from a structural analysis of the faults along the QLFZ and the STLFZ and in the surrounding areas. This has enabled us to separate the successive tectonic regimes (Sections 4 and 5). We discuss these Cenozoic tectonic regimes and the changes in the kinematics of the QLFZ and of the TLFZ and compare these results with those established in Eastern China by previous workers and re-examine the displacements on the QLFZ during the Late Pliocene–Quaternary (Section 6).

* Corresponding author. Fax: +33 169154911.
E-mail address: vergely@geol.u-psud.fr (P. Vergely).

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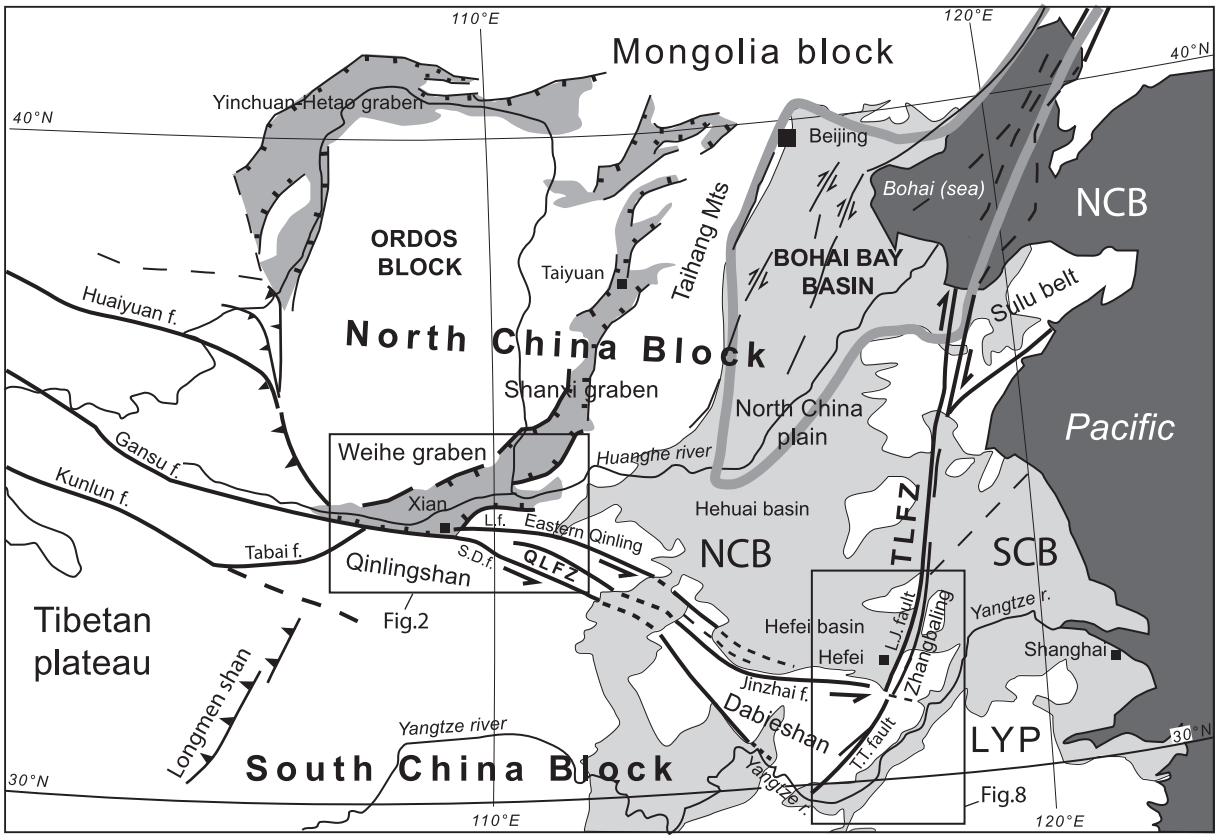

Fig. 1. Regional setting of the Tan-Lu and Qinling Fault Zones, and of the Cenozoic Basins in the China Plain and around the Ordos Block (after Zhang et al., 1995, modified). TLFZ: Tan-Lu Fault Zone; QLFZ: Qinling Fault Zone; SCB: South China Block; NCB: North China Block; LYP: Lower Yangtze Platform; T.T.: Taihu–Tongcheng fault; and L.J.: Lujiang–Jiashan fault. The senses of slip on the TLFZ and QLFZ are the Present day ones.

2. Geological setting

The QLFZ extends for more than 1000 km, on the northern border of the Qinling–Dabie orogen, from the north-eastern corner of the Tibetan Plateau as far as the STLFZ where it appears to terminate (Fig. 1). It comprises several vertical, WNW–ESE striking, ductile shear zones related to the Palaeozoic and Triassic subductions and Mesozoic deformations which have been exhumed, following which, brittle shallow deformations have been superimposed during the Late Cretaceous–Cenozoic age (Bellier et al., 1988; BGMR Shanxi, 1989; Mattauer et al., 1985; Ratschbacher et al., 2003; Sun et al., 2002; Xu, 1987 and ref. herein). In the Eastern Qinlingshan, the QLFZ comprises two major, active, N110–135°E striking, sinistral strike-slip faults (Fig. 2A): the Shangxian–Danfeng fault has a western continuation into the frontal Qinling fault, while the Lonan fault passes westward to the Huxian fault buried under the Quaternary deposits of the Weihe graben (Bellier et al., 1988; Peltzer et al., 1985; Ratschbacher et al., 2003; Zhang et al., 1995). East of 112°E, the active Shangxian–Danfeng fault (S.D.f., Fig. 1) splits into two branches, one bordering the Dabieshan to the north, the other to the south; this latter disappears under the alluvial plain of the Yangtze River while the Lonan fault (L.f.,Fig. 1) passes eastward under the Hefei basin, north of the Dabieshan.

The Tan-Lu Fault Zone extends in a NNE–SSW direction, for more than 2000 km, from the Yangtze River to the south as far north as the Bohai (sea). The Qinling–Dabie and Sulu belts, which result from the Mid.–Late Triassic South China Block/North China Block (SCB/NCB) collision, appear to be left-laterally separated by ~500 km on the opposite sides of the TLFZ (Fig. 1). This separation has been considered as an offset and the TLFZ as a major sinistral strike-slip fault (Xu, 1964; Xu, 1993a, 1993b; and ref. herein); however, such large offsets are debatable (Wan et al., 1996; Wan, 2011) not being supported by constrained geological markers; the normal kinematics have started during the Late Cretaceous and continued during the Cenozoic (Grimmer et al., 2002; Mercier et al., 2007; Ratschbacher et al., 2000; Schmid et al., 2001; Vergély et al., 2007; Wan et al., 1996; Xu, 1993b; Xu and Zhu, 1994; Zhang et al., 1999; Zhu et al., 2001, ref. herein). The STLFZ comprises several major faults, particularly the ≈N50°E striking, ESE dipping, Taihu–Toncheng fault (T.T.f; Fig. 1) that separates the Dabieshan from the Lower Yangtze Platform, and the N–S to N20°E striking, W dipping, Lujiang–Jiashan fault (L.J.f.) that separates the Zhangbaling massif from the Hefei basin and extends to the north as far as the Shandong Peninsula (Wan et al., 1996).

The TLFZ and the QLFZ have been active during continental extension in Eastern China (Tapponnier and Molnar, 1977). This extension is responsible for the formation of the Late Cretaceous–Cenozoic basins on the Lower Yangtze Platform (LYP), of the Cenozoic Bohai and Hefei basins (Ma and Wu, 1987; Ma et al., 1982, 1984; Ye et al., 1987), and, to the west, of the Weihe, Yinchuan–Hetao and Shanxi Cenozoic graben surrounding the Ordos block (Deng and You, 1985; Li and Ren, 1986; Liu and Gan, 1981). Geophysical data show a crustal thickness of 40 km under the Ordos massif and of 35–38 km beneath the Weihe graben and an upper mantle uplift of 5–6 km under the latter (Xu et al., 1993). Similar analyses show that the North China plain is an area of reduced crustal (34–35 km) and lithospheric thickness and that the crust is warmer and more highly fractured than under the western rifts (Ma et al., 1982). From field data obtained in and around the Weihe graben, we had separated three extensional Cenozoic tectonic regimes having extensional directions striking successively ~WNW–ESE, ~NE–SW, and ~NNW–SSE although these have not been well dated (Bellier et al., 1988, 1991; Zhang et al., 1998, 1999).