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Mesozoic geology of southwestern China: Indosinian foreland overthrusting and subsequent deformation

Liang Qiu [a,b], Dan-Ping Yan [a,*], Shuang-Li Tang [a,c], Qin Wang [a], Wen-Xin Yang [a], Xiangli Tang [a], Jibin Wang [a]

[a] State Key Laboratory of Geological Processes and Mineral Resources, School of Earth Sciences and Resources, China University of Geosciences, Beijing 100083, China
[b] Department of Geoscience, University of Nevada, Las Vegas, Nevada 89154, USA
[c] Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China

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ABSTRACT

The southwestern part of the South China Block (SCB) records Triassic and subsequent deformations and is a key region that provides evidence of the post-amalgamation tectonic evolution of Southeast Asia. Here, we outline the tectonothermal evolution of early Mesozoic orogenesis in this region using structural analysis and fission track thermochronology. This region is divided into three tectonic units (south to north): the Youjiang Fold-and-Thrust Belt (YFTB), the Qianzhong Massif (QZM), and the Thin-skinned Thrust Belt (TTB) of the southeastern Sichuan Basin, all three of which record three deformation events, here termed D_1, D_2, and D_3. D_1 deformation is represented by Triassic top-to-the-north thrusts (F_1) and fault-related folds (f_1) that are indicative of N–S shortening. The intensity of deformation decreases toward the north. The subsequent D_2 and D_3 deformations are marked by Cretaceous top-to-the-NW thrusting and fault-propagation folding, and Cenozoic NE–SW trending normal faults (F_3), respectively. The temperature–time (t–T) path obtained by apatite fission-track modeling of samples from the YFTB, QZM, and TTB areas provides evidence of uplift and denudation. The D_1 deformation at ~230–210 Ma is characterized by buried thrusts within the relatively stable YFTB and QZM, and an increase in depth of the TTB. This was coeval with the Late Triassic northward migration of uplift and denudation that is evidenced by a Late Triassic stratigraphic gap within the YFTB, a thin layer of coarse-grained continental clastics within the QZM, and a thick layer of clastic rocks within the TTB. The study area records a Triassic thrust system (D_1) that progressively migrated northwards and represents a foreland fold-and-thrust belt that formed during the Indochina–SCB collision. This initial deformation was subsequently overprinted by Late Jurassic to Cretaceous NW–SE thrusting (D_2) and the development of Cenozoic NW–SE extensional structures (D_3).

1. Introduction

The Phanerozoic tectonic history of Eurasia is marked by the progressive movement of continental masses away from the northern margin of Gondwana and the formation of subsequent convergent/orogenic systems (e.g., Gehrels et al., 2011; Metcalfe, 2011, 2013; Yang et al., 2012; Faure et al., 2016). The Indosinian orogeny occurred as a result of the amalgamation of the Indochina and South China blocks during the Triassic, in a tectonic setting associated with closure of the eastern branch of the Paleo-Tethyan Ocean (Deprat, 1914; Fromaget, 1932, 1941; Wang et al., 2013; Faure et al., 2014, 2016; Qiu et al., 2014, 2015; Halpin et al., 2016). This orogeny is recorded by the development of a Late Triassic unconformity, the emplacement of Triassic granitic plutons, and the development of extensive north-verging fold–thrust belts within the southwestern part of the South China Block (e.g., Lepvrier et al., 1997, 2008, 2011; Wang et al., 2007, 2013; Zhang et al., 2011). The timing, style, and magnitude of deformation within the foreland basin and fold–thrust belt that formed during this orogeny (e.g., DeCelles and Giles, 1996; Gehrels et al., 2003) remain poorly understood, primarily because the deformation and basin formation have been strongly overprinted by subsequent Mesozoic and Cenozoic deformation (e.g., Zhou et al., 2008; Zhang et al., 2009; Yan et al., 2011). The foreland deformation in the study area provides evidence required to reconstruct this orogeny and enables the testing of proposed tectonic models, such as the intracontinental setting model associated with boundary collisions

* Corresponding author at: China University of Geosciences, Beijing 100083, China.
E-mail address: yandp@cugb.edu.cn (D.-P. Yan).

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(Faure et al., 2016) and the intracontinental oblique subduction model of Wang et al. (2007).

The southwestern South China Block (SCB) is split into the Youjiang Fold-and-Thrust Belt (YFTB), the Qianzhong Massif (QZM), and the Thin-skinned Thrust Belt (TTB). This region records late Permian to Triassic foreland sedimentation and deformation associated with the Triassic orogeny (Indosinian) along the Song Ma and Song Chay sutures (e.g., Lepvrier et al., 2011; Faure et al., 2014). Previous studies focused on the tectonic history and basin–mountain evolution of this region, with Yang et al. (2012) suggesting that the Middle Triassic turbidites in this area provide evidence of the Indosinian orogeny and correspond to the formation of the syn-orogenic Youjiang foreland basin. Lehrmann et al. (2005, 2007) suggested that Permian carbonates in this area record a long history of platform evolution whereas Triassic clastic rocks reflect a rapid increase in tectonic subsidence, providing evidence of tectonic convergence and foreland basin development. However, no detailed investigation of the change in deformation over time and with variations in structural style and the uplift history of this area have been undertaken to date, meaning that it is currently not possible to outline the tectonic setting of this foreland basin and thrust–fold belt in the framework of the Indosinian orogeny.

Here, we present new structural and apatite fission track thermochronological data for the southwest SCB that constrain the kinematic and cooling history of the Indosinian foreland basin and fold–thrust belt. A ~370-km-long N–S cross-section running through the YFTB, QZM, and TTB areas (through points A–E in Fig. 2) forms the basis of our structural analysis. This analysis identified three tectonic episodes (here named D_1, D_2, and D_3), each with different structural styles, kinematics, and deformational sequences. Combining our new data with the results of previous studies, we infer a northward progression of Triassic thrusting (D_1) that was overprinted by D_2 thrusting and D_3 extensional tectonism.

2. Geologic setting

The SCB formed as a result of the amalgamation of the Yangtze and Cathaysia blocks during the Neoproterozoic, and it records deformation during early Paleozoic and Mesozoic tectonic events (e.g., Wang et al., 2013; Qiu et al., 2014). The SCB contains folded and metamorphosed Proterozoic basement material (Zhou et al., 2002; Wang et al., 2012) and a folded Phanerozoic sedimentary cover sequence (Fig. 1; Charvet et al., 1996; Ren, 1996; Yan et al., 2006; Wan, 2011). The basement in this area is dominated by Neoproterozoic epimetamorphic sandy–argillaceous detrital flysch sediments that are intercalated with volcanics, all of which are overlain by a cover sequence containing Paleozoic and early Mesozoic marine sediments and Middle Triassic to Cretaceous clastic sediments (Yan et al., 2003).

The southwestern SCB is divided into three tectonic units: the Youjiang Fold-and-Thrust Belt (YFTB) to the south, the central Qianzhong Massif (QM), and the northernmost Thin-skinned Thrust Belt (TTB; Fig. 2). The boundaries between these units are the NW–SE striking Ziyun–Luodian Fault and the NEE–SWW striking Zunyi–Hezhang Fault (Fig. 2). This region is separated from the Xuefengshan tectonic belt to the east by the Zunyi–Pingba Fault and from the Panxi–Kangding belt to the west by the Shizong–Mile Fault (Fig. 2).

2.1. Major faults

The 300-km-long NW–SE striking Ziyun–Luodian fault zone forms the northeastern margin of the YFTB and was active during the early Paleogene and late Neogene, producing a sinistral displacement of 50–100 km (Tang et al., 2014). The fault zone dips to the NE and contains top-to-the-NE or top-to-the-SW secondary thrusts and folds that provide evidence of a left-lateral transpressional event (E. Wang et al., 1998; P.L. Wang et al., 1998; Li et al., 2014; Fig. 2).

The NE–SW striking Huayingshan Fault separates the TTB to the northwest from a Mesozoic multi-layer thin-skinned thrust belt to the southeast (Yan et al., 2003). This fault is interpreted to be a leading thrust within a thin-skinned, northwestward-verging duplex and imbricate system that formed between the Triassic and the Early Cretaceous (Yan et al., 2003, 2009). The Huayingshan Fault displaces Cambrian to Triassic sediments and records top-to-the-northwest thrusting during the period between the Triassic and Early Cretaceous (BGMRSC, 1991; Yang et al., 2010).

The NE–SW trending Shizong–Mile Fault displaces Carboniferous to Permian pillow lavas, Devonian to early Permian radiolarian cherts, and the Babu intraplate basalts (Faure et al., 2014). This fault is probably an extension of the pre-existing Neoproterozoic Jiangshao suture that was reactivated during the Mesozoic (Fig. 1; Dong and Zhu, 2000).

The NNE–SSW striking Zunyi–Pingba Fault dips to the east at 50–70° and records three active stages of faulting: a Late Jurassic to Early Cretaceous top-to-west thrusting event involving sinistral shearing, Paleocene normal and dextral strike-slip faulting that controlled the coeval formation of a red-bed basin at 65–59 Ma, and top-to-the-east thrusting from the Eocene to the present day (Deng et al., 2010).

2.2. Youjiang Fold-and-Thrust Belt

The YFTB is bounded by the Shizong–Mile Fault to the northwest, the Ziyun–Luodian Fault to the northeast, and the Song Chay Fault to the southwest (Figs. 1 and 2; Cai and Zhang, 2009; Yang et al., 2012; Faure et al., 2014). The oldest unit in this belt is a Cambrian carbonate unit that crops out within the core of a superposed anticline, and the only intrusive rocks are late Mesozoic diabase dikes (BGMRGX, 1985). The belt records significant marine sedimentation between the late Proterozoic and the Middle Triassic (Song et al., 2009), leading to the deposition of a ~7-km-thick sequence of marine sediments that form a passive continental margin sedimentary sequence (Fig. 3; Galfetti et al., 2008; Yang et al., 2012). This belt was formed by the overthrusting of Paleozoic sedimentary rocks onto the Youjiang Basin (Lepvrier et al., 2011; Faure et al., 2014). The deposition of marine sediments was terminated by Indosinian orogeny-related Late Triassic uplift and northward migration of the basin (Yang et al., 2012). The belt also records the transition from a Permian passive continental marginal setting to a Triassic syn-orogenic foreland basin and fold–thrust belt associated with closure of the Paleo-Tethyan Ocean and subsequent Indochina–SCB collision (Fig. 1; BGMRYN, 1990; Lehrmann et al., 2007; Cai and Zhang, 2009; Yang et al., 2012). However, the subsequent deformation and kinematic history of the belt remains unclear.

2.3. Qianzhong Massif

The QZM is triangular in plan view and is bounded by the Huayingshan Fault to the northwest, the Ziyun–Luodian Fault to the southwest, and the Zunyi–Pingba Fault to the southeast. The QZM has a basement of Proterozoic marine clastic sediments that are overlain by a cover sequence of Paleozoic to Middle Triassic marine carbonates and Late Triassic to Jurassic terrestrial clastic sediments (Fig. 3; BGMRGZ, 1987). Intrusive rocks are absent in this belt and the highest metamorphic grade is greenschist facies metamorphism of Proterozoic metapelites. The QZM typically has a higher relief than adjacent tectonic units, probably as a result