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Tectonothermal history of the NE Jiangshan–Shaoxing suture zone: Evidence from $^{40}Ar/^{39}Ar$ and fission-track thermochronology in the Chencai region

Fang Wang[a,b], Hanlin Chen[a,b,*], Geoffrey E. Batt[c], Xiubin Lin[a,b,*], Junfeng Gong[a,b], Genhui Gong[a,b], Lifeng Meng[a,b], Shufeng Yang[a,b], Fred Jourdan[d]

[a] Department of Earth Sciences, Zhejiang University, Hangzhou 310027, China
[b] Research Center of Structures in Oil and Gas Bearing Basin, Ministry of Education, Hangzhou 310027, China
[c] The Centre for Exploration Targeting, the University of Western Australia, M006, 35 Stirling Highway, Crawley, Western Australia 6009, Australia
[d] Western Australian Argon Isotope Facility, Department of Applied Geology & John de Laeter Centre, Curtin University of Technology, GPO Box U1987, Perth, Western Australia 6845, Australia

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ABSTRACT

The Jiangshan–Shaoxing suture zone, a component of the Neoprotozoic orogenic belt between the Yangtze and Cathaysia blocks in South China, has experienced a complex history of tectonic reactivation. Previous investigations of this significant tectonic boundary have focused on earlier stages of its tectonic history pre-dating the Early Paleozoic Wuyi–Yunkai orogeny, with more recent episodes rarely addressed. We here improve understanding of the later reactivation history of this suture zone through new $^{40}Ar/^{39}Ar$ and fission track thermochronological constraint derived for the ductilely strained Chencai Complex and the Lipu–Huangshan quartz diorite, together with sedimentological investigations of the proximal Wuzao Formation.

This combined constraint demonstrates the occurrence of as many as five discrete episodes of tectonic reactivation and deformation of the Jiangshan–Shaoxing suture zone. The 431 ± 4 Ma $^{40}Ar/^{39}Ar$ biotite cooling age of the Lipu–Huangshan quartz diorite records retrograde cooling of the Chencai region following high-grade metamorphism at c. 460–450 Ma during the Early Paleozoic Wuyi–Yunkai orogeny. Consistent younger $^{40}Ar/^{39}Ar$ ages of the gneissic Chencai Complex suggest that this retrograde cooling episode may extend to c. 390–400 Ma, with later ductile strain and/or thermal overprinting of biotite at c. 386 Ma suggesting that the terminal stage of the Early Paleozoic Wuyi–Yunkai orogeny may have continued significantly later than previously assumed. Although not reflected directly in the thermotectonic records compiled for the Chencai Complex, lithoclasts of these distinctive ductilely deformed gneisses represent a significant component of the conglomeratic gravels appearing in the late Triassic Wuzao Formation, demonstrating substantial uplift and erosion of the suture zone at this time, coincident with the Indosinian orogeny. Zircon fission track thermochronology of the samples from both Lipu–Huangshan quartz diorite and Chencai Complex yield much younger Cretaceous cooling ages of 144 ± 8 to 103 ± 6 Ma, with apatite fission track ages ranging from 66 ± 4 to 41 ± 3 Ma and mean apatite fission track lengths between 12.1 and 13.1 μm. Thermal history modeling of these low-temperature controls demonstrates significant cooling during the Cenozoic. These later activities reflect brittle deformation in the upper crust and erosional exhumation of these rocks coincident with the Yanshanian extension event and Himalayan tectonism.

These results together imply that the Jiangshan–Shaoxing suture zone represents a significant and long-lived lithospheric weakness that was preferentially reactivated during at least two episodes of tectonic activity in regional far-field domains. Examining the complex reactivation history of the fossil suture zone thus provides a useful window into the timing of episodes of broader tectonic activity across the wider region.

* Corresponding authors at: Department of Earth Sciences, Zhejiang University, 38# Zheda Road, Hangzhou 310027, China. Tel.: +86 571 87952791; fax: +86 571 87952791.
E-mail addresses: hlchen@zju.edu.cn (H. Chen), linxiubin1984@163.com (X. Lin).

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1. Introduction

The Jiangshan–Shaoxing suture zone (JSSZ) was formed by the Neoproterozoic amalgamation of the Yangtze and Cathaysia blocks (Fig. 1a) to form the South China Block (SCB) (e.g., Li et al., 1995; Zhao and Cawood, 1999, 2012; Li et al., 2002; Zhao and Guo, 2012; Wang et al., 2013). The SCB represents a geologically significant element of regional architecture (Zhao and Sun, 1994), including as it does the predominantly Precambrian volcanic and sedimentary rocks (Kong et al., 1994) and subordinate Paleoproterozoic gabbroic intrusions of the Chencai Complex, which together comprise the oldest crystalline basement domain of South China. The Chencai Complex underwent significant metamorphism under granulite facies conditions during the Early Paleozoic Wuyi–Yunkai orogeny, with metamorphic ages assigned to this episode ranging from 447 to 454 Ma (Li et al., 2010).

Previous studies of the JSSZ and SCB have focused on the primary emplacement and metamorphism of the crystalline rocks (e.g., Zhao and Sun, 1994; Zhao and Cawood, 1999; Li et al., 2010; Hu et al., 2011), leaving more recent deformation and exhumation of these rocks largely un-addressed.

Such dynamic elements of the geological development of the block, however, have significant and widespread implications for regional understanding, with post-peak metamorphic relaxation and exhumation history offering insights into the response of the SCB to the dramatic and varied tectonic events affecting South China since the Early Paleozoic. We here evaluate these dynamic elements of regional history through thermotectonic constraint developed by $^{40}Ar/^{39}Ar$ and fission track thermochronology of the crystalline rocks, and from regional records of surface processes provided by the sedimentology of proximal basins.

2. Geological background

The NE–SW striking JSSZ stretches 280 km from the Gulf of Hangzhou in the northeast through Shaoxing and Jiangshan into Jiangxi Province in the southwest (Fig. 1a). This suture zone juxtaposes Neoproterozoic Shuangxiwu Group continental arc sequences in the Yangtze block to the west against the high-grade metamorphosed Chencai Complex of the Cathaysia block to the east.

The Chencai Complex is derived from Meso-Neoproterozoic tholeiite, gabbro, marble and turbiditic mudstone and sandstone protoliths (Kong et al., 1994), with the oldest pre-metamorphic intrusions dated at c. 1781 ± 21 Ma (e.g., Li et al., 2010). These protoliths were metamorphosed to greenschist to granulite facies and ductilely deformed during the Early Paleozoic Wuyi–Yunkai orogeny (Zhao and Cawood, 1999; Li et al., 2010; Hu et al., 2011). The complex has been modified by significant post-metamorphic thrust imbrication (Kong et al., 1995; Xiao and He, 2005), but the timing of this compressional deformation has not previously been established with confidence.

The SCB sits at the periphery of a number of post-Early Paleozoic Wuyi–Yunkai tectonic episodes affecting Asia, including the Indosinian orogeny, Yanshanian magmatism and Himalayan tectonism (e.g., Chen, 1999; Shu et al., 2008; Wang et al., 2011, 2013), but the individual expression of these episodes and their relative significance to the post-metamorphic deformation and exhumation of the Chencai Complex remain unresolved, and forms a key motivation of the present study.

3. Field geology and sample descriptions

The Lipu–Huangshan quartz diorite may intrude the Chencai Complex, but the two are today exposed exclusively in fault contact across a right-lateral oblique thrust (Fig. 1b, Zhejiang Geological Bureau, 1975). Both units are sporadically intruded by the middle Triassic Dashuang quartz monzonite and early Cretaceous granites, with this crystalline sequence overlain unconformably by the late Triassic Wuzao Formation (Fig. 1b, Zhejiang Geological Bureau, 1975). This entire sequence is itself in fault contact with the overlying Cretaceous Dashuang Formation, with this structural boundary believed to mask a primary unconformable relationship (Fig. 1b, Zhejiang Geological Bureau, 1975). Pliocene basaltic Shenxian Formation and Quaternary sediments sporadically occur unconformably above the Dashuang Formation (Fig. 1b, Zhejiang Geological Bureau, 1975).

The Chencai Complex comprises a variably metamorphosed package of quartz schist, garnet-muscovite schist and marble.

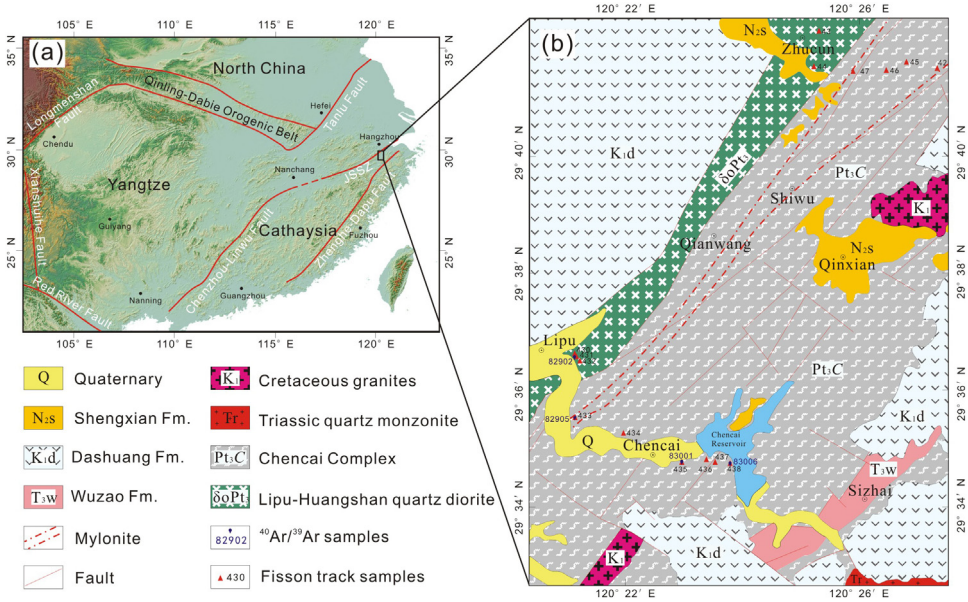

Fig. 1. (a) Sketched topography of South China, showing the tectonic setting of the Chencai region. (b) Geological map of the Chencai region (modified from Zhejiang Geological Bureau, 1975), showing the sample locations.