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Cretaceous Pacific plate movement beneath SE China: Evidence from episodic volcanism and related intrusions

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ABSTRACT

Extensive Late Mesozoic igneous rocks in SE China have been widely considered to be generated under the paleo-Pacific tectonic regime, the plate subduction model, however, remains controversial. This study focuses on the Cretaceous volcanic rocks in northwestern Zhejiang Province. Zircon U–Pb age determination indicates that Cretaceous volcanism in northwestern Zhejiang took place at three episodes of 140–130, 130–127 and 123–118 Ma, in good agreement with the coeval lower volcanic series in southeastern Zhejiang, but lacking the episode at 110–88 Ma corresponding to the upper volcanic series. The Cretaceous volcanic rocks in Zhejiang therefore show an oceanward younging trend. In situ zircon Hf isotope analyses of three episodes of volcanics yield $\varepsilon_{Hf}(t)$ values of −11.2 to −8.7, −4.8 to −2.4 and −4.4 to +2.2, respectively. The entire sequences display typical isotopic features of magma mixing, implying progressive involvement of juvenile component. Based on systematical researches on the Cretaceous volcanic rocks and a series of granitoid plutons in Zhejiang, it is also identified that the juvenile component involvement gradually occurred from the inland to the coast under an enhanced lithospheric extensional tectonic setting. All the observations in this study indicate the northwestward paleo-Pacific plate subduction with episodic slab rollback which triggered the arc system to retreat towards the Pacific Ocean, rather than the southwestward subduction related to the ridge subduction along the Lower Yangtze River belt.

1. Introduction

Voluminous igneous rocks and related major ore deposits have drawn much attention, and plate subduction might be an important drive force responsible for these events in both east and west Pacific margins (e.g., Gutscher et al., 2000; Sun et al., 2007). Located in the west Pacific margin, the South China block hosts one of the largest Mesozoic magmatic activities over the world, and is characterized by massive granitic intrusive-volcanic rocks and related metal deposits (He et al., 2010a; Pei and Hong, 1995; Sun et al., 2007, 2012; Zhou et al., 2006). A paleo-Pacific plate subduction model is now widely accepted to account for the Late Mesozoic tectono-magmatism in SE China. Nevertheless, the subduction pattern and its influences remain unclear and need further investigation.

A number of paleo-Pacific subduction models have been proposed, and some questions remain controversial: (1) when the subduction started, since late Permian (Li and Li, 2007) or early Jurassic (Zhou et al., 2006); (2) the migration of magmatic zones and metallogenic belts was due to slab rollback (He and Xu, 2012; L. Liu et al., 2012; Li and Li, 2007; Zhou and Li, 2000; Zhou et al., 2006) or changes of the subduction direction (Q. Liu et al., 2012; Sun et al., 2007); (3) subduction polarity, the slab drifted northwestward (Li and Li, 2007; Zhou and Li, 2000) or southwestward followed by northwestward (changed at ca. 125 Ma, Sun et al., 2007; Wang et al., 2011) or northeastward followed by northwestward (Q. Liu et al., 2012); and (4) a ridge subduction along the Lower Yangtze River belt did exist or not (Ling et al., 2009; Sun et al., 2010; Wu et al., 2012). There are additional unanswered questions (Sun et al., 2012): How to identify ridge subduction/slab tearing? How to distinguish ridge subduction from slab tearing? How to identify slab rollbacks?

Although many studies have been achieved on Late Mesozoic intrusive granites in SE China, few attentions have been paid on their volcanic counterparts (Charvet et al., 1994; Guo et al., 2012; L. Liu et al., 2012; Lapierre et al., 1997). The Late Mesozoic volcanic successions in SE China are best developed in Zhejiang, studies on these volcanic rocks are of great significance since they can provide important and maybe extra signatures for the magmatism and geodynamics.

This study focuses on the Late Mesozoic volcanic rocks in northwestern Zhejiang Province, adjacent to both coastal SE China and the Lower Yangtze River belt. Detailed zircon U–Pb dating of the entire volcanic sequences defines the geochronological framework of the Late Mesozoic magmatisms, and related systematical zircon Lu–Hf isotope analysis constrains the nature of the sources. Together with our previous work on the volcanic rocks in southeastern Zhejiang (L. Liu et al., 2012) and some other researches on the coeval intrusive granites, a NW–SE trending corridor across Jiangshan–Shaoxing fault has been estimated to retest and modify the existing models. Regular changes

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of the volcanism magnitudes and geochronological framework imply a northwestward subduction model during the Cretaceous. Enhanced lithospheric extension and retreated arc system towards the coastline furthermore indicate slab rollback. Meanwhile, a NE–SW trending corridor excludes the possibility of a southwestward subduction model related to ridge subduction along the Lower Yangtze River belt. Hence this study is essential for fully understanding the Late Mesozoic tectono-magmatism and geodynamics in this region.

2. Geological background

The South China block is bounded to the north by the Qinling–Dabie orogenic belt and to the west and southwest by the Tibetan and Indochina blocks, respectively. The Mesozoic igneous rocks are mainly distributed in the southeast region of the South China block, with an outcrop area of more than 220,000 km^2 (Fig. 1a; Zhou et al., 2006). Lithologically, over 90% of these magmatic rocks are granitoids or equivalent volcanic rocks. Triassic magmatic rocks occur mainly in the south part of the South China block, while those in the study area occur only as dispersed small plutons (Zhu et al., 2013). Jurassic granitoids are mostly distributed in the interior and in zones parallel to the coastline extending discretely northeastward for about 1000 km (He et al., 2010a,b; Li et al., 2003a). Jurassic volcanic rocks are preserved mainly in the Nanling Range, which were generated within a narrow time span of 180–170 Ma, forming an E–W trending bimodal volcanic belt (Xie et al., 2005), with some dacites or rhyolites distributing in northeastern Guangdong and southern Fujian (Guo et al., 2012) and little dacitic rocks in southeastern Zhejiang (L. Liu et al., 2012). Meanwhile, the widespread Cretaceous magmatic rocks, among which the volcanic rocks are twice larger in outcrop area than their intrusive counterparts within the same region, are distributed mainly in the coastal area. Produced in multiple cycles, the volcanic rocks are divided into upper and lower volcanic series which are separated by a ubiquitous regional unconformity (Charvet et al., 1994; Lapierre et al., 1997). The lower volcanic series contains mainly rhyolitic and dacitic volcanic rocks with minor andesites and basalts, while the upper series

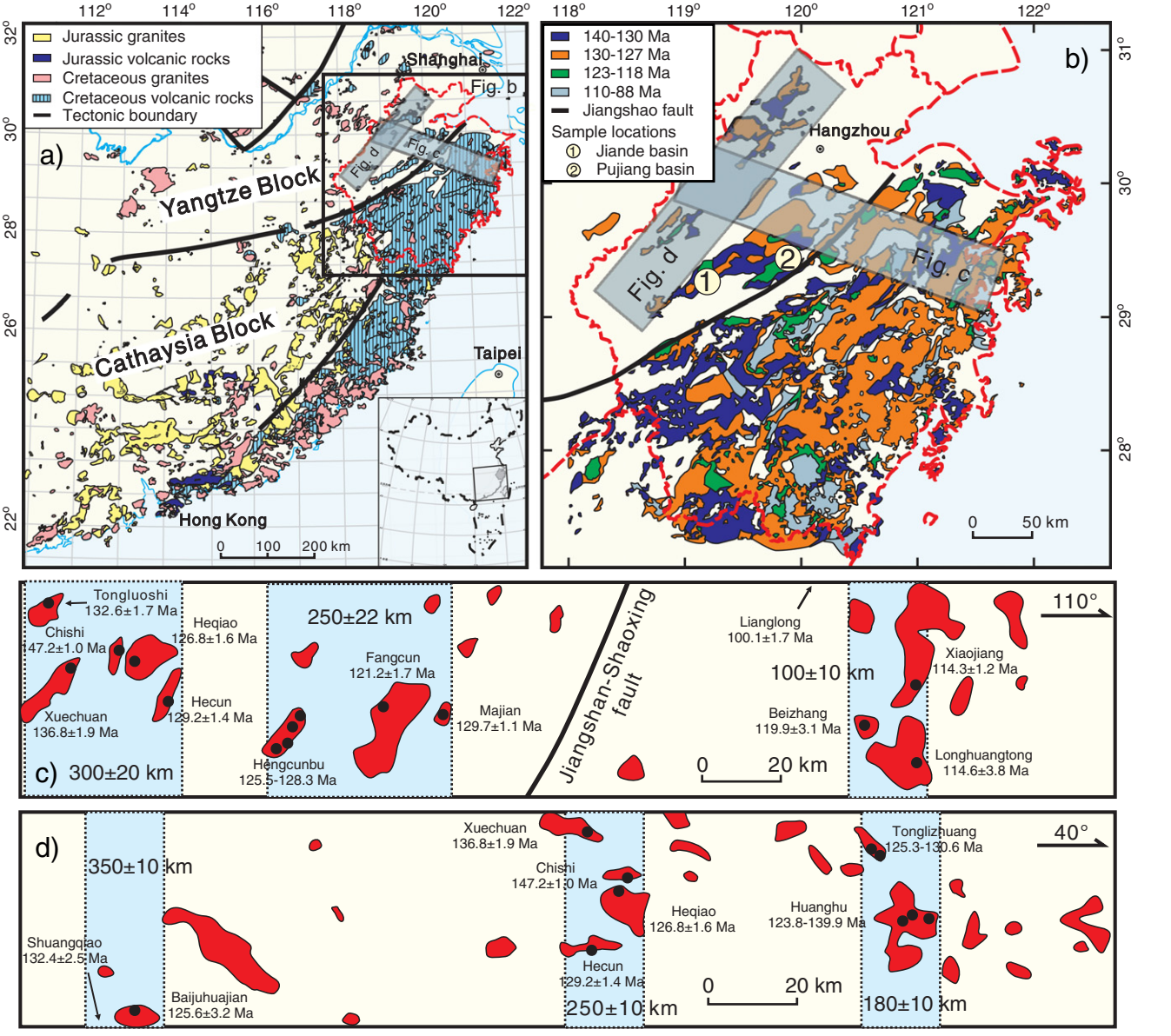

Fig. 1. (a) Simplified geological map of South China showing the distribution of Late Mesozoic granitic–volcanic rocks (modified from Zhou et al. (2006)). (b) Distribution of Cretaceous volcanic rocks in Zhejiang Province and sample locations of volcanic rocks from northwestern Zhejiang. (c) A series of NW–SE trending bead-shaped granite bodies in Zhejiang with systematical zircon U–Pb dating and Hf isotope analysis results (after Wong et al. (2011) and Wu et al. (2012)). (d) A series of NE–SW trending bead-shaped granite bodies in NW Zhejiang, around 300 km away from coastline, with systematical zircon U–Pb dating and Hf isotope analysis results (after Wong et al. (2009, 2011) and Wu et al. (2012)).