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Widespread Paleoproterozoic basement in the eastern Cathaysia Block: Evidence from metasedimentary rocks of the Pingtan–Dongshan metamorphic belt, in southeastern China

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ABSTRACT

The Cathaysia Block in South China Block (SCB) is famous for its polyphase granitic magmatism and world-class mineralization, especially W, Sn and REE. Although isotopic data suggest that widespread igneous rocks were derived from Precambrian basement, outcrops of the basement rocks are rare in the Cathaysia Block. Therefore, the distribution of the Archean-Paleoproterozoic basement beneath Cathaysia Block is still unclear.

The northeastern-striking Pingtan–Dongshan metamorphic belt (PDMB) is located along the coastal region of southeastern China, and consists mainly of voluminous granites and volcanic rocks with minor metasedimentary rocks. These metasedimentary rocks were intruded or captured by 160–143 Ma granites. U–Pb dating of detrital and metamorphic zircons from seven metasedimentary rocks indicates that their protoliths were deposited between 183 Ma and 160 Ma, rather than pre-Devonian as previously proposed. Dating of metamorphic zircons suggests that the most important metamorphism took place at *ca* 97 Ma, consistent with emplacement of A-type granites and mafic magmatism in the coastal region, and implying an extensional setting.

Age spectra of detrital zircons in samples from the middle and southern PDMB exhibit a bimodal distribution with abundant Late Paleoproterozoic and Early Mesozoic zircons. In contrast, age spectra of detrital zircons from the northern PDMB display pronounced Neoproterozoic and Early Paleozoic age peaks as well as Late Paleoproterozoic and Early Mesozoic ones, suggesting a different provenance. The comparisons of age and Hf-isotope with the exposed rocks of the SCB suggest that the terrigenous material in these sediments was sourced from the Wuyi terrane, in the eastern Cathaysia Block.

The age spectra of detrital zircons from Early Paleozoic to Late Mesozoic sedimentary rocks in the SE SCB show that late Paleoproterozoic (1.9–1.8 Ga) detritus increases markedly in Middle Permian to Early Cretaceous sedimentary rocks. Comparison with zircon U–Pb–Hf isotopic data from exposed Paleoproterozoic rocks suggests that a Paleoproterozoic basement existed extensively beneath the eastern Cathaysia Block. It has been uplifted and eroded since Middle Permian time, and then covered by Late Cretaceous volcanic rocks. The uplift of the Paleoproterozoic basement was probably caused by the Late Paleozoic orogeny in the eastern Cathaysia Block.

1. Introduction

The study of metamorphic basement rock series has become a major research focus in solid Earth Science, as it can provide fundamental information on the composition, formation and evolution of the deep continental crust and the amalgamation and breakup of Precambrian supercontinents. Unfortunately, the exposures of pre-Neoproterozoic crystalline basement rocks are scarce in the South China Block (SCB). The oldest rocks are locally preserved in the Kongling terrane, in the northern Yangtze Block, which is composed of Mesoarchean to Early Paleoproterozoic TTG and high-grade metamorphic rocks (Gao et al., 2011; Jiao et al., 2009; Li LM et al., 2014; Qiu et al., 2000; Yin et al., 2013). However, early Precambrian basement rocks are unknown in the Cathaysia Block of the SCB. The oldest rocks identified in the Cathaysia Block are

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1.91–2.5 Ga metamorphic rocks (i.e. the Badu complex and Mayuan Group) and the associated 1.85–1.91 Ga granites in SW Zhejiang and NW Fujian provinces in the eastern Cathaysia Block (Li LM et al., 2011a; Liu et al., 2009, 2014; Xia et al., 2012; Xiang et al., 2008; Yu et al., 2009, 2012; Zhao et al., 2014, 2015). A few meta-mafic rocks (1.77–1.78 Ga) outcrop in the Jianning area of northwestern Fujian Province and in the Chencai area of northern Zhejiang Province (Li XH, 1997; Li ZX et al., 2010). Some groups, such as the Wanquan, Taoxi, Mamianshan, Zhoutan and Longquan groups in the Wuyi terrane, which were originally defined as Paleoproterozoic to Mesoproterozoic metamorphic strata, actually formed mostly in the Neoproterozoic and were metamorphosed in early Paleozoic (Li LM et al., 2011b; Li WX et al., 2005; Li ZX et al., 2010; Wan et al., 2007; Xu et al., 2010; Yao et al., 2013; Yu et al., 2005, 2010). This re-evaluation of the chronological framework seems to vastly decrease the area of exposed Precambrian basement rocks, and implies that the early Paleozoic (Caledonian) orogeny played a crucial role in the tectonic and magmatic scenario of Cathaysia Block. However, an opposing model, emphasizing the significance of the "Cathaysia oldland" has been re-invoked on the basis of increasing amounts of evidence. Published Nd isotopic data from the Cathaysia Block indicate that the Precambrian basement rocks and their Phanerozoic derivatives predominantly originated from 1.7 to 2.2 Ga crust (Chen and Jahn, 1998; Chen et al., 1999; Hong et al., 1999; Shen et al., 1993). Moreover, more and more early Precambrian detrital/inherited zircons have been found in Neoproterozoic to Phanerozoic sedimentary and igneous rocks (e.g. Wang et al., 2007b, 2011, 2012; Xing et al., 2014; Yu et al., 2005, 2007a, 2009), supporting the existence of the early Precambrian magmatism and tectonics in the Cathaysia Block. There may be three reasons for the scarcity of early Precambrian rocks outside of NW Fujian and SW Zhejiang. First, the old rocks are covered by extensive Phanerozoic sedimentary and volcanic rocks. Second, they were strongly recycled and altered to form new successions. Third, the old detritus might come from another continent, which once was contiguous with the Cathaysia Block (e.g. Li XH et al., 2014; Yu et al., 2008).

As an effective probe of provenance characteristics, detrital zircons from sedimentary rocks can be used to dissect each tectonothermal event in their source area, and help to evaluate crustal evolution history (Griffin et al., 2004; Iizuka et al., 2005; Kemp et al., 2006; Rino et al., 2004). Recent studies on detrital zircons from late Neoproterozoic to early Paleozoic sediments in the Cathaysia block (Wang et al., 2007b; Wan et al., 2007, 2010; Yao et al., 2011, 2012; Yu et al., 2010) allow the Precambrian crust of the Cathaysia Block to be subdivided into two distinct tectonic domains, the Wuyi terrane to the northeast and the Nanling-Yunkai terrane to the southwest (Yu et al., 2010). However, whether there was an Archean-Paleoproterozoic crust in the Cathaysia and its possible areal distribution, have been unclear.

Along the coastline of Fujian Province there is a metamorphic belt with NE orientation, termed the Pingtan–Dongshan metamorphic Belt (PDMB), which is separated from the inner volcanic belt by the Changle-Nan'ao Fault (Fig. 1). The PDMB is characterized by polycyclic magmatism and multiple episodes of metamorphism and deformation in Mesozoic time (Chen, 1997; Huang et al., 1993; Kong et al., 1996; Shi and Zhang, 2010; Shi, 2011; Tong and Tobisch, 1996; Zhang et al., 2012). Some meta-sedimentary rocks are found locally along the PDMB, and show amphibolite facies metamorphic mineral assemblage (Chen, 1997; Yu and Shu, 2002; Yu et al., 2007a), much different from the inner late-Mesozoic volcanic belt. Due to the lack of accurate isotopic dating and ambiguous contact relationships with country rocks, the ages of the meta-sedimentary rocks have not been well constrained. Because of their high metamorphic grade, they were previously expected to have old formation ages (Huang et al., 1989; Zhuang et al., 2000).

In this study, we have carried out *in situ* U–Pb dating and Hf-isotope determinations on zircons separated from seven meta-sedimentary rocks in the PDMB, and obtained a total of 423 concordant U–Pb ages and 221 Hf-isotope data. The aim of this study is to constrain the formation and metamorphic ages of the meta-sedimentary rocks, and further to reveal the relationship of the PDMB with continent further inland. Integrating previously published geochronological data, we attempt to unravel the formation age, distribution area, exposure and denudation of the crystalline basement of the eastern Cathaysia block.

2. Geological background and sampling

The SCB is bounded by the Qingling-Dabie-Sulu orogen to the north, the Tibetan Plateau to the west and the Indochina block to the southwest. The SCB consists of the Yangtze Block to the northwest and the Cathaysia Block to the southeast (Fig. 1). Since its amalgamation with the Yangtze Block in early Neoproterozoic time, the Cathaysia Block has suffered intensive polyphase tectonic-magmatic events, including Early Paleozoic, Late Paleozoic, Early Mesozoic and Late Mesozoic ones. An Early Paleozoic tectonothermal event, the Kwangsian or Wuyi-Yunkai orogeny (Li ZX et al., 2010; Wang et al., 2011, 2012), is marked by an angular unconformity between strongly deformed pre-Silurian strata and the overlying Middle to Upper Devonian coarse-clastic rocks (Huang et al., 1980; Ren, 1991), as well as variable degrees of metamorphism and subsequent anatexis (granitic magmatism). A Late Paleozoic orogeny, whose geodynamic setting and distribution are poorly known, probably includes an early phase of compression (Middle-Late Carboniferous) and later extension (since Early Permian) in the eastern Cathaysia Block (Yu et al., 2013). The Early Mesozoic (Indosinian) orogeny is characterized by a regional angular unconformity between Late Triassic and Early Jurassic strata, and voluminous S-type granites. The Late Mesozoic (Yanshanian) tectono-magmatic event strongly affected the eastern margin of the SCB and produced abundant igneous rocks with magmatic features typical of active continental margins, and is ascribed to the westward subduction of the paleo-Pacific Plate (Li ZX and Li XH, 2007; Zhou and Li, 2000; Zhou et al., 2006).

The Zhenghe-Dabu Fault and the Changle-Nan'ao Fault are the most significant NE-trending faults in the southeastern SCB (Fig. 1); they divide the Cathaysia block into the Early Paleozoic fold-thrust belt, the late Mesozoic volcanic belt, and the PDMB. The PDMB, extending along the coastal region of Fujian Province, is up to 400 km long and 20 km–40 km wide. The metamorphic belt includes both deformed and undeformed granites, and volcanic rocks with minor meta-sedimentary rocks (BGMRFJ, 1985, 1997; Shu and Xu, 2002). These metamorphic rocks were termed the Aojiao Group, and have been subdivided into the Yanya and Qinyingshan formations. The former consists mainly of migmatites and granitic gneisses; the latter is composed of meta-sedimentary rocks. Recent studies show that the granitic gneisses or "migmatites" in the Yanya formation probably are deformed granites (Yu and Shu, 2002; Nie, 2007). Therefore, the redefined Aojiao "Group" only includes meta-sedimentary rocks of the Qinyinshan Formation. The granitic intrusions are widely distributed in the PDMB, including dominant early Cretaceous I-type granites, late Cretaceous A-type granites and minor Jurassic granites (e.g. Cui et al., 2013; Feng et al., 2011, 2014b; Li WX et al., 2003; Liu et al., 2011, 2012; Shi and Zhang, 2010; Tong and Tobisch, 1996). It is generally believed that these granites are genetically associated with the subduction of the paleo-Pacific plate and late post-orogenic extension, respectively (Cui et al., 2013; Jahn et al., 1990; Lapierre et al., 1997; Liu et al., 2012; Zhou and Li, 2000; Zhou et al., 2006). Jurassic to Early Cretaceous granites generally