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# An Early Mesozoic transcontinental palaeoriver in South China: evidence from

**detrital zircon U–Pb geochronology and Hf isotopes**

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**Abstract:** Detrital zircon geochronology reveals that Late Triassic–Early Jurassic fluvial sandstones from the major basins of the South China Craton have similar age patterns and define four populations at 2.6–2.4 Ga, 2.0–1.7 Ga, 850–700 Ma and 480–210 Ma. The late Palaeoproterozoic group is predominant in all of the five samples, and yielded remarkable age peaks at *c*. 1.85 Ga. These zircons have εHf(t) values between −22.5 and +3.6, suggesting derivation from reworked Archaean crust and minor juvenile crustal additions in the late Palaeoproterozoic. These characteristics differ from those of the Yangtze Block but correlate well with those of samples from the eastern Cathaysia Block. Palaeocurrent analysis of the Early Mesozoic sandstones shows predominant west- and NW-directed palaeoflows, supporting derivation of the sediments from the Cathaysia Block. The remarkable similarities in provenance signatures and spatial changes of lithofacies of the Triassic– Jurassic around the South China Craton delineate an east–west-trending sedimentary zone extending from Korea to West China. Accumulation of these sediments was probably related to the development of an active continental margin produced by westward subduction of the Palaeo-Pacific Plate. A *c*. 2000 km long westerly draining transcontinental palaeoriver probably had existed in the Early Mesozoic and fed the basins in Korea, South China and West China.

**Supplementary material:** Sensitive high-resolution ion microprobe and laser ablation–inductively coupled plasma mass spectrometry zircon U–Th–Pb and Hf isotope data are available at www.geolsoc.org.uk/SUP18514.

East Asia underwent many dramatic changes in the Mesozoic Era, including closure of the Palaeo-Tethyan Ocean, amalgamation of major continental blocks and transition from a Palaeo-Tethyan to a Palaeo-Pacific regime. Being located at the juncture of the PalaeoTethyan and the Palaeo-Pacific domains, the South China Craton has long been considered to hold the key to understanding the Mesozoic tectonics of East Asia and thus has received much attention (e.g. Hsu *et al*. 1990; Zhou & Li 2000; Li & Li 2007). However, intensive Cretaceous and Cenozoic continental rifting, accompanied by rift-related magmatism and sedimentation, has extensively modified the Early Mesozoic structural systems and palaeogeographical configurations such that they remain poorly understood.

Syntectonic clastic sedimentary rocks commonly preserve a wealth of information on their source terranes and are frequently used to solve tectonic problems (e.g. Najman 2006, and references therein). In South China, Late Triassic–Early Jurassic fluvial and lacustrine deposits are widely developed in response to Mesozoic tectonic changes, marking the transition from a Palaeozoic carbonate platform to a Mesozoic continental environment (Wang 1985). They are mainly preserved in the margins of major Mesozoic– Cenozoic basins of the Yangtze Block, including the Pingle, Yueshan, Jianghan and Sichuan basins, and are sparsely distributed on the Cathaysia Block (Fig. 1). In addition, Middle–Late Triassic turbidites were deposited in the Songpan–Ganzi basin in West China, making it the largest exposed Triassic section in the world (Nie *et al*. 1994; She *et al*. 2006).

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Previous studies have focused on sedimentary rocks in the Hefei and Songpan–Ganzi basins. Using structural analyses, mass- balance calculations, detrital modes, geochemistry and zircon geochronology, various workers have proposed a close relationship between the clastic sedimentation and exhumation of the Qining– Dabie Orogen (e.g. Nie *et al*. 1994; Zhou & Graham 1996; Bruguier *et al*. 1997; Grimmer *et al*. 2003; Wang *et al*. 2003; Li *et al*. 2005; Liu *et al*. 2005; Wan *et al*. 2005; Weislogel *et al*. 2006). However, similar work on Jurassic sandstones of the Yueshan Basin to the east and the Jianghan Basin to the south (Fig. 1) suggests sediment derivation from the South China Craton rather than the Qinling– Dabie Orogen (Li *et al*. 2003*b*; Yang *et al*. 2010).

In this paper, we present 428 U–Pb ages and 112 Hf isotope analyses of detrital zircons and 492 palaeocurrent measurements for Late Triassic–Early Jurassic sandstones from the major Mesozoic–Cenozoic basins of South China. These data provide new insights into the provenance of the syntectonic sediments, as well as the Early Mesozoic tectonics and palaeogeography of East Asia.

## Geological setting

The South China Craton is composed of the Yangtze Block in the NW and the Cathaysia Block in the SE (Fig. 1), which were assembled in the Neoproterozoic, giving rise to the Jiangnan Orogen (Zhao & Cawood 1999).

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| **Fig. 1.** (**a**) Tectonic framework of East Asia, modified after Jeon *et al*. (2007). (**b**) Geological map of study area, modified after Cheng (1994). Mean palaeocurrent directions are shown by arrows with numbers: 1–7, this study; 8–10, Peng (1987); 11 and 12, Liu *et al*. (2005); 13 and 14, Qu *et al*. (2009*a*); 15, Qu *et al*. (2009*b*). |

The Yangtze Block is largely covered by Neoproterozoic to

Palaeozoic marine sedimentary rocks, upon which a few Mesozoic– Cenozoic continental basins developed (Wang 1985). The exposed Archaean basement is known only in the Kongling Terrane of the Yangtze Gorges area (Gao *et al*. 2011), and outcrops of Palaeoproterozoic rocks are rare and reported from the northern and western areas of the Yangtze Block (e.g. Zhang *et al*. 2006; Greentree & Li 2008; Wu *et al*. 2009; Xiong *et al*. 2009). In contrast, Neoproterozoic magmatic rocks with ages from 1.0 Ga to 700 Ma are widespread across the block, the origin of which remains controversial (e.g. Zhou *et al*. 2002; Li *et al*. 2003*a*; Wang *et al*. 2006).

The Cathaysia Block is divided into northeastern and southwestern segments in terms of its evolution history (Xu *et al*. 2007; Yu *et al*. 2009), and is characterized by intensive crustal reworking during the Mesozoic and mid-Palaeozoic (e.g. Wan *et al*. 2007). In the northeastern part of the Cathaysia Block, the basement is composed of gneisses, schists and amphibolites of Palaeoproterozoic age, containing many small granitoids dated at 1.9–1.8 Ga (Zhao & Cawood 1999; Zeng *et al*. 2008; Liu *et al*. 2009; Yu *et al*. 2009, 2010). In contrast, in southwestern Cathaysia the basement comprises largely Neoproterozoic sedimentary sequences, which yield Neoarchaean (2.6–2.5 Ga), Grenvillian (*c*. 1.0 Ga) and Neoproterozoic (800–700 Ma) zircons (Yu *et al*. 2010).

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| **Fig. 2.** Palaeocurrent rose diagrams for the Early Mesozoic sandstones. |

The northern margin of the South China Craton is marked by the Qinling–Dabie Orogen, which is generally considered to have the same basement as the Yangtze Block (Xue *et al*. 1997). The Qinling portion of the orogen consists of a northern arc and suture system and a southern passive margin. The northern Qinling is highlighted by arc magmatic rocks with ages of 490–470 Ma and 422–400 Ma (Lerch *et al*. 1995; Xue *et al*. 1996). The southern Qinling, however, is characterized by a thick pile of Ediacaran to Middle Triassic sediments and wide occurrence of Early Mesozoic (220–180 Ma) granitoids (Sun *et al*. 2002), although Palaeozoic (*c*. 440 Ma) bimodal magmatism has also been reported (Ma *et al*. 2005). The Dabie Orogen, extending eastward from the Qinling segment, consists of Precambrian metamorphic rocks that underwent ultrahighpressure (UHP) metamorphism during the Triassic (Zhang *et al*. 2009, and references therein) and subsequently were intruded by numerous Cretaceous granitoids (e.g. Ma *et al*. 1998). The Jiangnan Orogen, which lies along the SE margin of the Yangtze Block, is a NE–SW-trending tectonostratigraphic zone composed of deformed early Neoproterozoic (860–830 Ma) strata that are unconformably overlain by undeformed late Neoproterozoic strata (820–730 Ma) (Zhao *et al*. 2011).

## Stratigraphy and petrography

The Late Triassic–Early Jurassic sedimentary rocks in the northern part of the South China Craton typically consist of two coal- bearing, fluvial–lacustrine sequences, unconformably overlying the Late Palaeozoic–Middle Triassic Yangtze carbonate platform and underlying Middle Jurassic red beds. Late Triassic–Early Jurassic strata in the study area range in thickness from about 300 to 1000 m, and are estimated to be rhaetian to Hettangian in age based on their fossil assemblages (BGMrAP 1982; BGMrJP 1984; BGMrHP 1990; BGMrSP 1991). They are characterized by fining-upward sequences composed primarily of sandstone, siltstone and shale, often with basal conglomerate of variable thickness. Coal measures have been extensively mined from the Upper Triassic–Lower Jurassic sequence in most of the basins, and carbonized plant material is abundant in some horizons. Lenticular or sheet-like sandstone bodies with tabular cross-stratification are commonly observed in outcrops extending from the Yueshan Basin in the east to the Sichuan Basin in the west. These features suggest deposition mainly in meandering river environments.

Samples of medium- to fine-grained sandstone were collected from Late Triassic–Early Jurassic outcrops in the Pingle (Ay14), Jianghan (Pq19) and Sichuan (Es02, Zs11 and Zs63) basins (Fig. 1). The sandstones are mostly sublithoarenite with >75 modal % quartz, <15 modal % lithic fragments and rare feldspar. Most of the lithic fragments consist of chert, consistent with the predominance of siliceous clast in the pebbles of conglomerates observed in the field. These compositions suggest that the sandstones were mainly recycled from pre-existing sedimentary rocks, in agreement with previous studies (Grimmer *et al*. 2003; Liu *et al*. 2005; Yang *et al*. 2010).

## Palaeocurrent analysis

About 500 palaeocurrent measurements were obtained from Late Triassic–Early Jurassic sandstones in the Yueshan, Jianghan and Sichuan basins. The sites are identified by locality number in Figure 1b. Most of these outcrops have undergone no or very weak deformation and all the data were measured with good precision from tabular cross-beds. Tilt corrections were applied for beds with dip angles greater than 10° and the data are presented in rose diagrams with vector means indicated (Fig. 2). In addition, previously published palaeocurrent data from the Pingle, Jianghan and Sichuan basins were compiled and are presented in Figure 1b.

As shown in Figures 1 and 2, west- and NW-directed palaeoflows (present coordinates are used throughout this paper) are dominant in most of the investigated areas. In the Yueshan Basin, 134 measurements yielded westerly palaeocurrents with mean flow azimuth of 263° (Figs 1 and 2: location 1). Palaeoflows from the Pingle Basin are somewhat variable, but also generally westdirected (Figs 1 and 2: locations 8, 9 and 10). In Jianghan, however, NW-directed palaeocurrents are predominant with mean directions ranging from 315° to 335° (296 measurements in total), although southwesterly palaeocurrents are also present in the NW margin of the basin (Figs 1 and 2: locations 2, 3, 4, 5, 11 and 12). For the Sichuan basin, although limited data reveal complex palaeoflows (Figs 1 and 2: locations 6, 7, 13, 14 and 15) that suggest multiple sources for this large Late Triassic–Early Jurassic deposit, westerly palaeocurrents are also present.

## Detrital zircon U–Pb geochronology and Hf isotopes

### Analytical methods

Zircon crystals were separated from the samples using standard crushing and separation techniques, and then mounted in epoxy. After polished, they were imaged using optical microscope and cathodoluminescence (CL) techniques, to guide the selection of analytical spots.

For samples Zs11 and Zs63, zircon dating was performed at the Beijing SHrIMP (sensitive high-resolution ion microprobe) Centre using the SHrIMP II system operated at the specifications of Williams (1998). Mass resolution during the analytical sessions was *c*. 5000 (1% height). The intensity of the primary O2− ion beam was 9 nA. Spot sizes were *c*. 30 µm and each site was rastered for 150 s before analysis. Five scans through the mass stations were made for each age determination. Standards SL13, with an age of 572 Ma, and TEMOrA, with an age of 417 Ma, were used for calibration (Williams 1998; Black *et al*. 2003). Data processing was carried out using the Isoplot programs (Ludwig 2001), and measured 204Pb was applied for the common lead correction.

Zircon dating of the other samples (Es02, Pq19 and Ay14) was carried out at the State Key Laboratory of Continental Dynamics, Northwest University in Xi’an, by laser ablation–inductively coupled plasma mass spectrometry (LA-ICP-MS) using an ELAN6100 ICP-MS system (Perkin Elmer/SCIEX, Canada) attached to a GeoLas 193 nm LA system (Micro-Las, Göttingen, Germany). Helium was used as carrier gas to enhance transport efficiency of the ablated material. A spot size of 30 µm was used for all analyses, with laser repetition rate of 10 Hz and energy density of 40 J cm−2. 202Hg is usually <10 c.p.s. for the gas blank, therefore the contribution of 204Hg to 204Pb is negligible. Detailed analytical processes are similar to those described by Yuan *et al*. (2004). Zircon 91500, with a 206Pb/238U age of 1065.4 Ma, was used as external standard for age calibration (Wiedenbeck *et al*. 1995). Isotopic ratios were calculated using GLITTEr 4.0 (Van Achterbergh *et al*. 2001), and common lead correction was made using the EXCEL program ComPbCorr# 151 (Andersen 2002). Probability density plots and concordia diagrams were made using the Isoplot program (Ludwig 2001).

*In situ* Hf isotope analyses were conducted by multicollector (MC)-ICP-MS using a Neptune system, equipped with a 193 nm laser, at the Institute of Geology and Geophysics, Chinese Academy of Sciences in Beijing. A 10 Hz repetition rate at 100 mJ and a 63 µm spot size were used to ablate zircons. The detailed analytical technique has been described by Wu *et al*. (2006). The 176Yb/172Yb value of 0.5887 and mean βYb value obtained during Hf measurement on the same spot were used for interference correction of 176Yb on 176Hf. Standard zircon 91500 was used for external correction. During analytical sessions, the obtained 176Hf/177Hf value of 91500 was 0.282303 ± 22 (2σ, *n* = 23), which was adjusted to 0.282305, a standard value recommended for 91500 (Wu *et al*. 2006). The initial 176Hf/177Hf ratios were calculated with reference to the chondritic uniform reservoir (CHUr) at the time of zircon growth from magmas. εHf(t) values are defined to denote a 0.1‰ difference between the sample and CHUr at the time of magma crystallization. The decay constant for 176Lu and the chondritic ratios of 176Hf/177Hf and 176Lu/177Hf used in calculations are 1.86510−11 a−1 (Scherer *et al*. 2001) and 0.282772 and 0.0332 (Blichert-Toft & Albarède 1997), respectively. Hf continental crust model ages (TDMC) were calculated by projecting the initial 176Hf/177Hf of zircon back to the depleted mantle growth curve using 176Lu/177Hf = 0.015 for the average continental crust (Griffin *et al*. 2000).

### Zircon U–Pb geochronology

Except for Zs11 and Zs63, more than 80 randomly selected grains of each sample were analysed, providing a probability greater than 95% of finding a population forming 5% of the total (Andersen 2005). 206Pb/238U ages are used for zircons younger than 1000 Ma and 207Pb/206Pb ages for older grains.

SHrIMP and LA-ICP-MS analyses yielded ages largely clustering around the concordia line (Fig. 3a–e), and only ages having <15% discordance and reverse discordance are plotted on probability density curves (Fig. 3f–j). All five samples (Ay14, Pq19, Es02, Zs11 and Zs63) show similar age patterns that are characterized by the presence of 1.9–1.8 Ga age peaks. There are four major populations (i.e. 2.6–2.4 Ga, 2.0–1.7 Ga, 850–700 Ma and 480–210 Ma; Fig. 3), with the 2.0–1.7 Ga population accounting for 41–56% of the total. Notably, the results show an increase in the proportion of

2.6–2.4 Ga zircons and a decrease of 1.9–1.8 Ga zircons from the Pingle Basin in the SE through the Jianghan Basin to the Sichuan Basin in the NW. A few minor populations with ages of 2.3–2.1 Ga, 1.2 Ga–900 Ma and 600–500 Ma are also present in some samples.

The youngest concordant zircons in most samples have ages of 250–207 Ma and roughly constrain the lower limit of their depositional ages, in agreement with the biostratigraphic chronology (BGMrJP 1984; BGMrHP 1990; BGMrSP 1991).

In this study, we did not examine the zircon internal structures in detail because we used a large number of zircon analyses for general interpretation. As shown in Figure 4, the majority of the zircons have Th/U ratios >0.30, indicating an igneous origin (Hoskin & Schaltegger 2003). Typical metamorphic zircons with low Th/U ratios (<0.10) are few.

### Hf isotope systematics

Hf isotopic compositions of zircons were measured for three samples from the Pingle and Jianghan basins (Es02, Pq19 and AY14). One hundred and twelve zircon grains showing less than 10% discordance were selected for analysis.

As shown in Figure 5, three major groups are recognized in these samples. The most prominent group, with crystallization ages of 2.0–1.7 Ga, yields εHf(t) values between −22.5 and +3.6 and Hf continental crust model ages clustering around 3.0–2.5 Ga, suggesting derivation by reworking of Archaean crustal materials with minor juvenile crustal additions at 2.0–1.7 Ga. A subordinate group having crystallization ages around 2.6–2.4 Ga gives εHf(t) values of −3.8 to +10.4 and Hf model ages from 3.3 to 2.4 Ga, implying significant addition of juvenile crust. Zircons with a broad age range between 1.0 and 0.7 Ga have εHf(t) values between −30.2 and +10.5, consistent with both crustal growth and crustal reworking. A few Palaeozoic grains have εHf(t) values of −14.1 to +0.9.

## Discussion

### Detrital zircon provenance

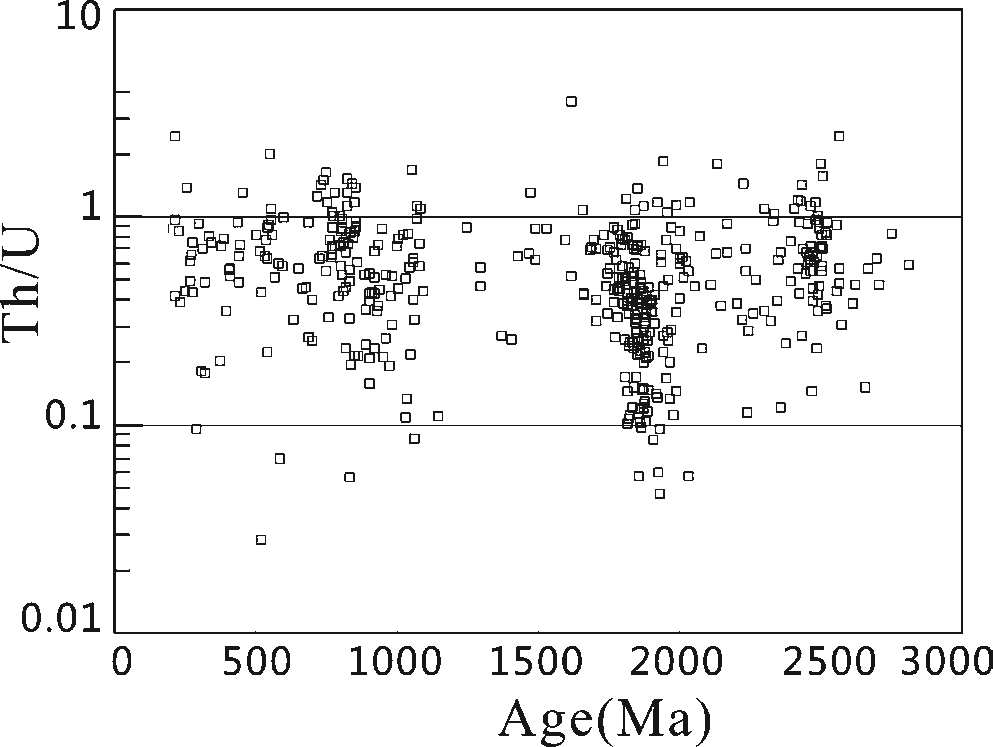
*Provenance of the Palaeoproterozoic zircons.* A striking feature of the detrital zircon age patterns for the Early Mesozoic sedimentary rocks of the South China Craton is the dominant 2.0– 1.7 Ga population, which accounts for 41–56% of the total. Interestingly, all the samples define prominent age peaks at *c*. 1.85 Ga (Fig. 3). Moreover, abundant late Palaeoproterozoic zircon grains have been frequently reported from contemporaneous clastic rocks in the South China Craton and adjacent areas (Grimmer *et al*. 2003; Weislogel *et al*. 2006; Jeon *et al*. 2007;

Wang *et al*. 2009*a*, *b*; Yang *et al*. 2010). These include the Lower– Middle Jurassic Daedong Supergroup in the western Korean Peninsula (Fig. 6a), the Upper Triassic in Wenbinshan, southeastern Cathaysia (Fig. 6b) and Pingle, southeastern Yangtze (Fig. 6c), the Lower–Middle Jurassic in Yueshan (Fig. 6d), the Lower Jurassic in Jianghan, northern Yangtze (Fig. 6e), the Upper Triassic– Lower Jurassic in Sichuan, western Yangtze (Fig. 6f) and the Middle–Upper Triassic in Songpan–Ganzi, West China (Fig. 6g). In addition, such grains have also been found from modern river sands in the Cathaysia Block (Xu *et al*. 2007) and the rangnim Massif of North Korea (Wu *et al*. 2007).

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| **Fig. 3.** Left panels show U–Pb concordia plots of detrital zircons from the Pingle Basin (**a**), Jianghan Basin (**b**) and Sichuan Basin (**c**–**e**). right panels show corresponding relative probability plots of U–Pb ages for concordant detrital zircons. |

Previously, detrital zircons with ages of 2.0–1.7 Ga have been interpreted as coming either from the North China Craton (Bruguier *et al*. 1997; Li *et al*. 2005; Weislogel *et al*. 2006) or the Yangtze Block including the Dabie Orogen (Grimmer *et al*. 2003; Wang *et al*. 2009*b*; Yang *et al*. 2010). However, based on our study, the North China Craton is not a likely source of the late Palaeoproterozoic zircons in the Yangtze Block. First, the paucity of Archaean–Early Palaeoproterozoic zircons in samples Ay14 and Pq19 is contradictory to the extensive occurrence of Archaean basement rocks in the North China Craton (Zhai & Santosh 2011, and references therein). Second, modern sediments from major rivers of the North China Craton all show a predominance of Archaean over Palaeoproterozoic age populations (Yang *et al*. 2009), a finding incompatible with the present data. Although Palaeoproterozoic detrital zircons have also been reported from the North China Craton and adjacent areas (Darby & Gehrels 2006), the age peaks are exclusively at *c*. 2.0 Ga, older than those of the South China sediments.

Likewise, neither the Yangtze Block nor the Dabie Orogen could have been the main source for the Triassic–Jurassic sandstones. Although increasing evidence shows that Palaeoproterozoic rocks and inherited zircons are present in the Yangtze Block and Dabie Orogen (e.g. Zheng *et al*. 2006), detrital zircon geochronological data suggested that exposures of such rocks are relatively limited (Yang *et al*. 2007). Thus, sediments sourced from the Yangtze Block and the Dabie Orogen would be dominated by Neoproterozoic grains, as shown in Figure 6f and h. Consequently, the distinct age patterns of the Early Mesozoic sedimentary rocks, along with their Hf isotopic characteristics (Fig. 5), rule out a main derivation from the Yangtze Block and the Dabie Orogen.

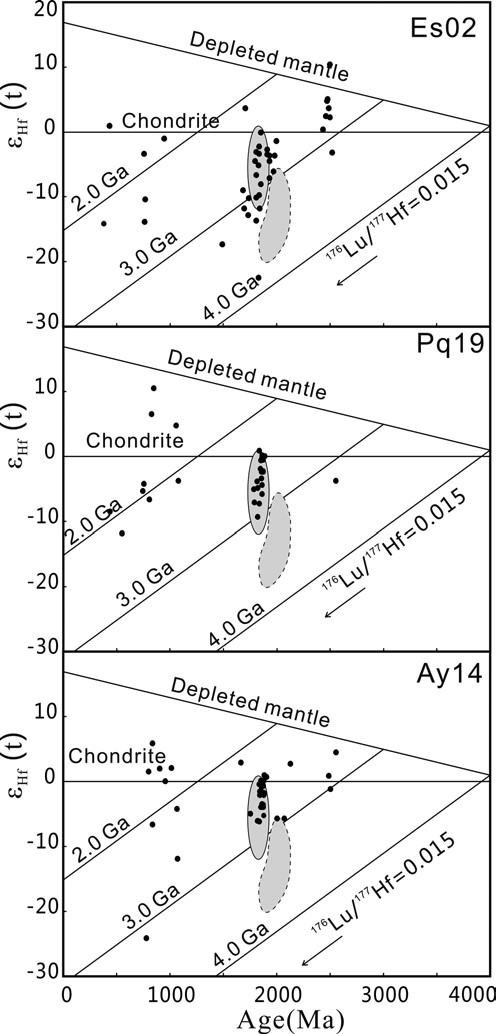


**Fig. 4.** Age v. Th/U ratio for all the concordant zircons.

Thus, based on the following arguments, we propose that the eastern Cathaysia Block was the major source area of the Late Triassic–Early Jurassic clastic sedimentary rocks in South China. First, this interpretation is strongly supported by the observed westerly and northwesterly palaeocurrents (Figs 1 and 2). Second, this model best explains the spatial variation of the detrital zircon age patterns. As is shown in Figure 6, the Palaeoproterozoic population predominates over other Precambrian groups in the eastern regions (Daedong, Wenbinshan, Pingle and Yueshan), whereas Neoarchaean and Neoproterozoic grains become increasingly abundant toward the west (from Jianghan to Sichuan and to Songpan–Ganzi). Lastly, U–Pb age patterns and Hf isotope systematics of the detrital zircons are consistent with those of basement rocks of the eastern Cathaysia Block (Figs 5 and 6j). recently, 1.9–1.8 Ga granitoids have been frequently reported in the eastern Cathaysia Block (e.g. Wan *et al*. 2007; Zeng *et al*. 2008; Liu *et al*. 2009), with Hf continental model ages ranging from 3.0 to 2.5 Ga (Yu *et al*. 2009), identical to those of the late Palaeoproterozoic zircons described in this study. Although the present remains of the Palaeoproterozoic crust are limited in Cathaysia, a much larger Precambrian block might have existed in the Early Mesozoic.

*Provenance of the other populations.* The subordinate age groups can also be traced to sources in the South China Craton. The provenance of the 2.6–2.4 Ga zircons corresponds to the Neoarchaean basement rocks of the Yangtze Block or the Qinling–Dabie Orogen (e.g. Zhang *et al*. 2004). Notably, the samples show a westward increase in the number of zircons with ages of 2.6–2.4 Ga along a line from the Pingle Basin to the Jianghan Basin and then to the Sichuan Basin (Fig. 3), consistent with increasing input from the Yangtze Block or the Qinling–Dabie Orogen. This is further supported by the presence of south- and SW-directed palaeocurrents in the western Jianghan Basin and the Sichuan Basin (Fig. 2).

The 850–700 Ma group of zircons is correlated with the widespread Neoproterozoic granitic gneisses and granitoids within and around the Yangtze Block. The 480–370 Ma zircons were probably derived from Palaeozoic granitoids in the Qinling–Dabie Orogen (e.g. Xue *et al*. 1996; Ma *et al*. 2005; Zhang *et al*. 2007) as well as the Cathaysia Block (e.g. Zeng *et al*. 2008). The 250– 210 Ma zircons correspond to the Triassic granitoids that crop out in the Cathaysia Block and along the eastern margin of the Yangtze

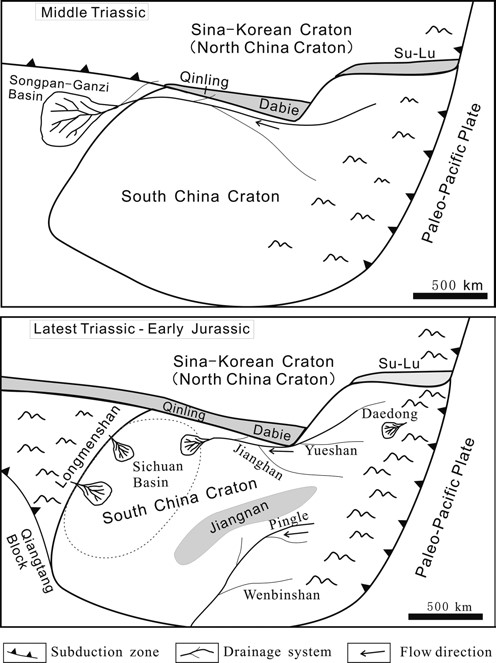


**Fig. 5.** Age v. εHf(t) diagrams. Areas outlined by continuous lines and dashed lines refer to the main ranges of Hf compositions for Palaeoproterozoic zircons from the Cathaysia (Xu *et al*. 2007) and Yangtze (Liu *et al*. 2008) blocks, respectively.

Block (Li *et al*. 2006; Wang *et al*. 2007). The presence of a zircon population with ages of 600–500 Ma in almost every sample is difficult to explain, because the nearest known source rocks with such ages lie in NE China (Wilde *et al*. 2003) and Tibet (Liu *et al*. 2006). Zircons of the same ages also occur in Jurassic sedimentary rocks of the Hefei Basin, which lies north of the Dabie Orogen (Li *et al*. 2005), and in low-grade metamorphic rocks of the northern Dabie Terrane (Chen *et al*. 2003). These observations imply the possible existence of thermal events of Pan-African age in the South China Craton.

### Sedimentary response to the rising of an active margin

In the South China Craton, ‘Indosinian-aged’ (Triassic) tectonism and associated magmatism have long been recognized and generally thought to be related to continental collisions between the Indochina, South China and North China blocks (e.g. Wang *et al*. 2007; Shu *et al*. 2008). In accordance with these events, dramatic changes were recorded in the contemporaneous basins, characterized by the prevailing coal-bearing fluvial–lacustrine sediments unconformably overlying the pre-Middle Triassic marine carbonates. Therefore, the Late Triassic–Jurassic sedimentary rocks of the northern part of South China are commonly considered as ‘synorogenic’ foreland basin deposits that responded to the development of the Qinling– Dabie Orogen (Grimmer *et al*. 2003; Liu *et al*. 2005). Indeed, these sediments are probably sourced by a recycled orogen, as implied by their high compositional maturity (Li *et al*. 2003*b*; Yang *et al*. 2010). However, a link between orogenesis and clastic sedimentation remains ambiguous, and the first detritus from the Dabie Orogen was



**Fig. 7.** Palaeogeographical scenarios of East Asia during the Middle Triassic to Early Jurassic.

not shed to the Jianghan Basin until the Middle Jurassic (Li *et al*. 2003*b*). Instead, the Early Mesozoic basins derived their sediments mainly from the east, suggesting the existence of an uplifted terrane in the Cathaysia Block that is previously unacknowledged. recent discoveries of Permian–Triassic subduction-related granitoids from the coastal regions of South China (e.g. Li *et al*. 2006; Sun *et al*. 2011) have documented that an active continental margin probably developed on the Cathaysia Block in response to the early subduction of the Palaeo-Pacific Plate. rise of this orogen might have dramatically changed the palaeogeography and led to the erosion of the Palaeoproterozoic crust of Cathaysia and, more importantly, its recycled material, which supplied detritus to the basins to the west.

### A transcontinental palaeoriver hypothesis

As documented by detrital zircon geochronology and palaeocurrent data, the Triassic–Jurassic sediments around the South China Craton show remarkable similarities in provenance signatures. This east–west-trending sedimentary zone extends from the western Korean Peninsula to West China and was fed by the same source in the Cathaysia Block. Considering a palaeogeographical framework characterized by topographic highs in the east and lows in the west (Wang 1985), we hypothesize that a westward-draining transcontinental palaeoriver system probably had existed along the northern margin of the Yangtze Block since the Middle Triassic. This is further supported by the spatial variation of lithofacies from alluvial fan deposits in western Korean Peninsula (Egawa & Lee 2009) to fluvial sandstones in the Pingle, Yueshan and Jianghan basins and to turbidites in the Songpan–Ganzi remnant ocean basin (Zhou & Graham 1996).

The Early Mesozoic Palaeoriver might have shed detritus from headwaters in the east through the Yueshan, Jianghan and Sichuan basins to the Songpan–Ganzi Basin, which is *c*. 2000 km to the west (Fig. 7), a distance comparable with that of the proposed Jurassic transcontinental palaeodrainage network in North America (Dickinson & Gehrels 2009). A southwesterly flowing tributary might also have developed between the coastal orogen in Cathaysia and the uplifted Jiangnan Orogen, feeding the basins in Pingle and Wenbinshan since the Late Triassic. This drainage system was then modified by the uplifting of the Qinling–Dabie Orogen to the north and the Longmenshan belt to the west in the late Triassic, giving rise to the Sichuan intracontinental basin (Fig. 7).

## Conclusions

Detrital zircon geochronology of the Early Mesozoic fluvial–lacustrine sediments from the Pingle, Jianghan and Sichuan basins of the South China Craton yielded major populations at 2.0–1.7 Ga, 2.6– 2.4 Ga, 850–700 Ma and 480–210 Ma, among which the first is dominant. Most of the Palaeoproterozoic zircons have negative εHf(t) values and Hf continental crust model ages between 3.0 and 2.5 Ga. Palaeocurrent analysis of these sandstones shows predominant west- and NW-directed palaeoflows. The age patterns, Hf isotopes and palaeocurrent directions are incompatible with derivation from the Yangtze Block or the North China Craton. Instead, the sediments were mainly sourced from the eastern Cathaysia Block with subordinate contributions from the Yangtze Block or the Qinling–Dabie Orogen. The Triassic–Jurassic sediments around the South China Craton show remarkable similarities in provenance signatures, revealing a syntectonic sedimentary zone extending from Korea to West China that probably developed in response to the subduction of the Palaeo-Pacific Plate. It is proposed that a westward-draining transcontinental palaeoriver system probably had existed across the Yangtze Block since the Middle Triassic, which might have originated from the eastern Cathaysia Block and shed detritus through the Yueshan, Jianghan and Sichuan basins to the Songpan–Ganzi Basin.

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