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Where was South China in the Rodinia supercontinent? Evidence from U–Pb geochronology and Hf isotopes of detrital zircons

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ABSTRACT

U–Pb geochronology and Lu–Hf isotopic studies on detrital zircons from late Neoproterozoic sediments of the Cathaysia block, South China, show abundant Grenville-age (~1.0 Ga) and Neoarchaean populations, and minor Eoarchaean (~3.8 Ga), Paleo- to Mesoarchaean (3.3–3.0 Ga), Mesoproterozoic (1.7–1.4 Ga) and Pan-African (0.70–0.54 Ga) populations. This is the first report of ~3.8 Ga material in the crust of the Cathaysia block. The presence of euhedral ~1.0 Ga zircons indicates that a Grenville orogenic belt was within or very close to the southern Cathaysia block. However, the provenance containing the ~3.8 Ga, 3.3–3.0 Ga, ~2.5 Ga, ~1.0 Ga and 0.70–0.54 Ga zircon populations cannot be found in the South China Block; the combination of zircon age distributions and the rounded, strongly abraded shapes of the Archean zircons suggesting long transport is consistent with derivation from other continental terranes previously linked with the southern part of the South China Block. Comparison with the tectono-magmatic history and compositions of rocks in western Laurentia – eastern Australia and eastern India – East Antarctica – western Australia, we suggest that these late Neoproterozoic sediments may have originated mainly from Eastern India-East Antarctica. This indicates that the South China Block was linked with the Eastern India - East Antarctica continents in the late Neoproterozoic rather than being located between the western Laurentia and eastern Australia continental blocks. U–Pb and Hf-isotope studies on detrital zircons provide an important independent constraint on the palaeogeography of the South China Block in the context of the breakup of Rodinia and the subsequent assembly of Gondwana in late Neoproterozoic time, and insights into the relationship between the Cathaysia and Yangtze blocks.

1. Introduction

The assembly and breakup of the supercontinents Rodinia and Gondwana have produced continuing debate in modern Earth sciences. In particular, the position of the South China Block (SCB) in these supercontinent reconstructions is controversial (Li et al., 1995, 2002; Piper, 2000; Jiang et al., 2003; Meert and Torsvik, 2003; Yang et al., 2004). Based on stratigraphic correlation and tectonic analysis, Li et al. (1995) proposed that the SCB may be a part of the missing link between Australia and Laurentia, and placed it between East Australia and Northwest Laurentia. This reconstruction was supported by later paleomagnetic studies (Piper, 2000). Li et al. (2002) subsequently modified their previous 'missing link' model, and placed the SCB between southwestern Laurentia and southeastern Australia, based on geochronology. However, stratigraphic comparisons suggest that the SCB may have been linked to northwestern India in Neoproterozoic time; it was probably separated from India and moved toward northwestern Australia in the early Cambrian (Jiang et al., 2003). Recently, paleomagnetic data have indicated that the SCB may have been connected with northwestern Australia and remote northeastern India during latest Neoproterzoic and early Paleozoic times (Yang et al., 2004). The location of the SCB relative to other microcontinents in Rodinia or Gondwana is still a contentious issue.

The main reason for this controversy, and the resulting variable positions of the SCB in these reconstructions, is that the paleomagnetic data in these time intervals do not provide unique information on the paleolongitude. Moreover, the stratigraphic comparisons between two blocks are generally not definitive (Li et al., 1995; Jiang

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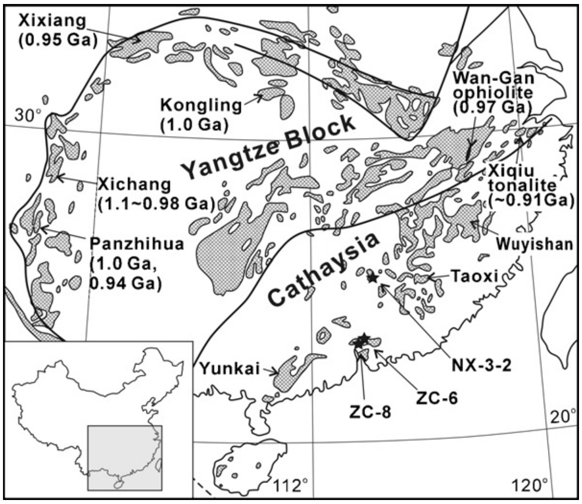

Fig. 1. Map of outcropping Precambrian metamorphic rocks in the South China Block and sample localities. Some igneous and metamorphic rocks of Grenville age occur along the western Yangtze block, implying there may be a remnant Grenvillian orogenic belt there (see text for details). The gray areas are outcropping Precambrian metamorphic rocks and the stars denote the sampling locations.

et al., 2003; Wang and Li, 2003). Therefore, another evidence must be used, if available, in the reconstruction of the supercontinents.

Neoproterozoic rifted basins were extensively developed on many continents during Rodinia's fragmentation (Hoffman, 1991), and were filled by clastic sediments from the surrounding blocks and adjacent continental areas. Thus, the age and composition of these sediments not only reveals the evolution of the continent in question, but also traces its affinity with other continental blocks. For example, detrital zircon age spectra of sandstones from Siberia and Tasmania have been used to elucidate the relationships of southeast Siberia – Laurentia and Tasmania – southwestern USA in the Rodinia supercontinent (Rainbird et al., 1998; Berry et al., 2001). This study presents U–Pb geochronology and Hf-isotope data on detrital zircons from the latest Neoproterozoic metasediments of the Cathaysia block of the SCB (Fig. 1). These sediments were deposited in rifted basins developed on the SCB during the breakup of Rodinia (Li et al., 1995; Wang and Li, 2003). The data provide new and independent constraints on the relationship of the SCB with other areas in Rodinia and Gondwana.

2. Regional geology and sample petrography

The SCB is composed of the Yangtze block to the northwest and the Cathaysia block to the southeast (Fig. 1). The Yangtze block has an old core consisting of granitic gneiss of ca. 2.90–2.95 Ga in its northern part (Qiu et al., 2000; Zhang et al., 2006) and Archaean basement is widespread beneath Proterozoic upper-crustal rocks (Zheng et al., 2006a). Neoproterozoic magmatism was extensive in the Yangtze craton (Fig. 1). In the Cathaysia block the basement metamorphic rocks, most of which are Neoproterozoic to early Paleozoic in age, are mainly found in the northeastern part (southern Zhejiang – northern and western Fujian – eastern Jiangxi, i.e. Wuyishan area) and the southwestern part (Yunkai area) (Fig. 1). The oldest rocks in Cathaysia are about 1.9–1.8 Ga in age and are limited to the southern Zhejiang and northwestern Fujian areas (Hu, 1994; Gan et al., 1995). Therefore the two blocks may have been constructed of different Precambrian crustal components, and might be juxtaposed only after ~1.0 Ga (Chen et al., 1991; Li et al., 1994; Li, 1999; Wang et al., 2006).

The studied area mainly consists of granitoids of various ages and strata of late Neoproterozoic to Mesozoic ages. Late Neoproterozoic (Sinian) sequences, the Yingyangguan Group and Lechangxia Group, are composed of a variety of schists and gneisses, with minor interbedded phyllite locally. They might have experienced migmatization in some areas (GDBGMR, 1988). The protoliths of these metamorphic rocks are mostly graywacke, quartz sandstone, feldspathic sandstone and a minor component of siltstone. The early Cambrian Bacun Group successions are mainly composed of meta-siltstone, phyllite and carbonaceous slate with lower-grade metamorphism than the Sinian strata. Their protoliths are siltstone, silty mudstone, black shale, indicating a suite dominated by fine-grained terrigenous clastic sedimentary rocks. Although some authors have proposed that there were Paleo- to Meso-Proterozoic metamorphic rocks in the southern Cathaysia (FJBGMR, 1985; Liu and Zhuang, 2003; Shu, 2006), more reliable geochronological works are needed to support their idea. The Sinian to Cambrian strata may be successive (GDBGMR, 1988), and all are unconformably overlain by the Devonian coarse clastic sediments. The early Paleozoic (Caledonian) orogeny in the SCB resulted in the absence of late Ordovician to middle Devonian sedimentation in the region, and also resulted in the metamorphism of some pre-Devonian sediments and the generation of contemporaneous (480–400 Ma) granites (FJBGMR, 1985; GDBGMR, 1988; Zhao, 1999; Yu et al., 2005).

Three metamorphic rock samples were collected for zircon analysis from Tanxi village in northern Guangdong (sample NX-3-2) and Zengcheng county in southern Guangdong (samples ZC-6 and ZC-8), central Cathaysia (Fig. 1), where late Neoproterozoic metamorphic rocks of amphibolite to greenschist facies and/or migmatites outcrop. The Tanxi metamorphic rocks outcrop in an area of about 10 km^2 with an east-west trend. They are in contact with the Cambrian low-greenschist facies strata on the northern margin by fault, and are intruded by Paleozoic to Mesozoic granites on the other sides. Extensive outcrops of metamorphic rocks (including migmatite) are distributed around the Zengcheng area and some were recently described as Mesoproterozoic strata based on Pb–Pb evaporation dating of zircons (Liu and Zhuang, 2003). Many of the metamorphic rocks have been migmatized during the Caledonian orogeny and then intruded by late granites (GDBGMR, 1988; Liu and Zhuang, 2003). Minor low-greenschist Cambrian strata are exposed in the Zengcheng area and are in fault-contact with the low amphibolite facies metamorphic rocks. They all are covered unconformably by post-Devonian sediments. Due to the cover of Quaternary sediments and intrusion of Paleozoic to Meso-

Table 1
Bulk compositions of three metamorphic rocks from the Cathaysia Block

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	DF[a]
NX-3-2	72.18	0.76	11.48	5.09	0.06	1.80	0.95	1.28	2.71	0.18	3.33	−4.3
ZC-8-1[b]	72.42	1.00	11.21	5.48	0.04	1.89	1.63	2.27	2.16	0.14	1.40	−3.0
ZC-8-4[b]	73.83	0.57	12.25	3.39	0.05	1.31	3.16	2.39	1.35	0.18	1.47	−1.5
ZC-6	65.04	0.80	13.52	7.99	0.13	3.20	0.55	0.93	3.67	0.21	3.74	−5.3

[a] DF is a discrimination function proposed by Shaw (1972) for distinguishing the protolith of the metamorphic rocks, positive value infers igneous and negative does sedimentary.
[b] ZC-8-1 and ZC-8-4 are the melanosome and leucosome of the migmatite ZC-8, respectively.