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Geochemistry and tectonic implications of late Mesoproterozoic alkaline bimodal volcanic rocks from the Tieshajie Group in the southeastern Yangtze Block, South China

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ABSTRACT

A SHRIMP U–Pb zircon age along with geochemical and Nd–Hf isotopic results are reported for the Tieshajie volcanic rocks in the southeastern Yangtze Block, South China. The Tieshajie volcanic rocks are bimodal in composition and are dominantly transitional alkaline basalts and alkaline rhyolites, with an eruption age of 1159 ± 8 Ma. The basaltic samples have high TiO_2 (2.14–3.12%) and relatively low Mg# (36–49) with variable $\varepsilon_{Nd(t)}$ values (−2.2 to +1.2), and display OIB-like incompatible elemental patterns, similar to many alkali basalts in continental rifts. These geochemical characteristics indicate that the primary magma of these basalts was probably derived from a moderately depleted asthenospheric mantle source and underwent fractional crystallization plus minor crustal contamination. The rhyolitic rocks are highly enriched in Th, Ta, Nb, REE, Zr, Hf and Y and depleted in Sr, P, Eu and Ti, showing affinity to A_1-type granites. Combined with their slightly positive $\varepsilon_{Nd(t)}$ values (+1.3 to +1.6) and negative $\varepsilon_{Hf(t)}$ values (−2.45 to −12.7), the Tieshajie rhyolites were most likely generated by partial melting of mafic lower crust induced by basaltic underplating following asthenospheric ascent.

The Tieshajie alkaline bimodal volcanic sequence is proposed to have developed within a continental rift setting on a passive continental margin. Combined with documented rift events in Yangtze Block during the late Mesoproterozoic, they may indicate onset of the amalgamation of Yangtze Block with other blocks within the Rodinia supercontinent. Integrating our data with the oldest arc-related igneous events in eastern Zhejiang, the transition of the regional tectonic regime from intracontinental rifting to interplate convergence occurred between ca. 1159 Ma and 970 Ma in the southeastern Yangtze Block.

1. Introduction

The South China Block (SCB) is affected by widespread and intensive magmatic activities in the late Mesoproterozoic and early-mid Neoproterozoic (Li et al., 2003; Zhou et al., 2002; Zheng et al., 2007, 2008). These igneous suites occur both along the SCB margins and within its interior areas, mostly with ages ranging from ~860 to 750 Ma (e.g. Zhou et al., 2002, 2006; Li et al., 2003; Wang et al., 2004, 2012) except the Shuangxiwu volcanic sequence (~920–890 Ma) along the eastern margin of the Yangtze Block (Li et al., 2009) and ca. 1142 Ma alkali basalts along the western margin of the Yangtze Block (Greentree et al., 2006).

The tectonic setting for these igneous suites remains a hotly contested issue. Some suggest that the magmatism formed during a typical Grenvillian orogen which asynchronously evolved from the western to the southeastern, and then to the eastern parts of the Yangtze Block during the period of 1150–900 Ma (e.g. Greentree et al., 2006; Ye et al., 2007; Li et al., 2008a, 2009), and that the post-825 Ma magmatism was controlled by the upwelling of a superplume (Li et al., 1995, 1999; Wang and Li, 2003). Others suggest that the magmatism was arc-related and lasted to 860–830 Ma or even younger (Wang et al., 2007; Li et al., 2011b; Zhao et al., 2011a; Zhang et al., 2012), and that the subsequent magmatism was caused by postorogenic relaxation soon after the assembly of the

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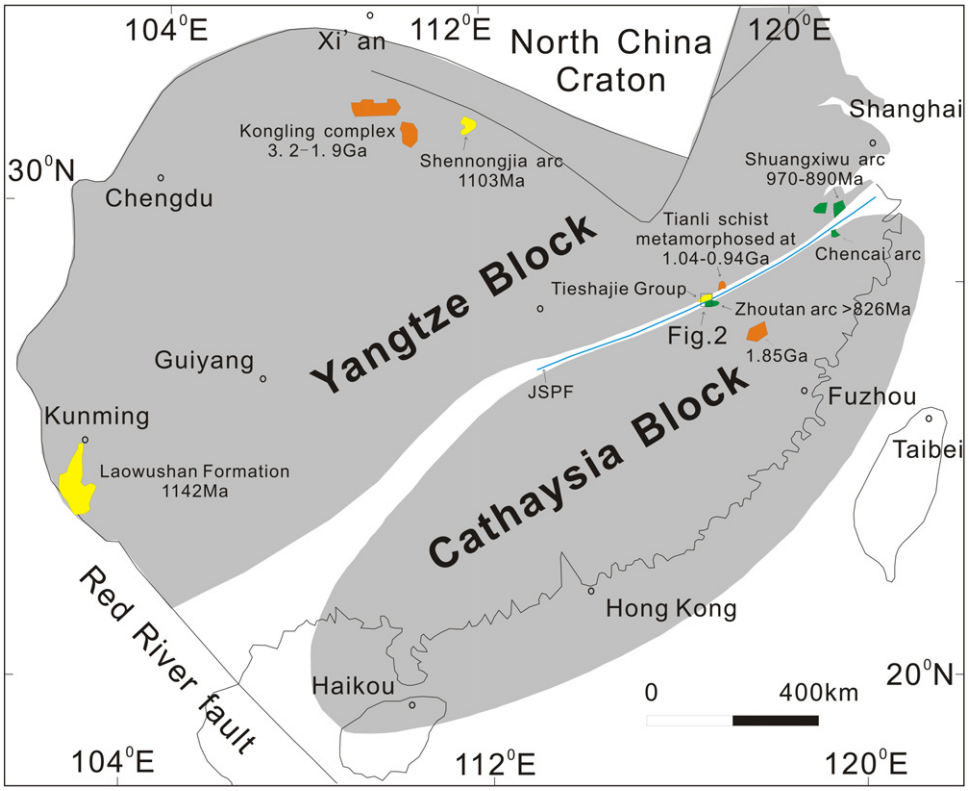

Fig. 1. Simplified geological map of South China Block.

Modified after Li et al. (2007).

Yangtze and Cathaysia Blocks (Wang et al., 2004, 2012; Zheng et al., 2008) or reflects back-arc spreading above the long lived oceanic subduction zone along the northern and western margin of the Yangtze Block (Zhao et al., 2011b). It is likely that the above competing explanations for the Neoproterozoic tectonic regime are partly due to poor understanding of the late Mesoproterozoic history of the South China Block. Magmatism related to the late Mesoproterozoic tectonothermal event may shed new light on the subsequent tectonic evolution of the South China Block.

Located at the southeastern margin of Yangtze Block, the Tieshajie Group is late Mesoproterozoic in age and consists of a suite of greenschist-facies, slightly deformed bimodal volcanic rocks. In this paper, we present geochronological and geochemical data for the alkaline bimodal volcanic rocks from the Tieshajie Group. These data provide precise age constraints for the Tieshajie volcanic succession and enable us to better understand its petrogenesis and tectonic setting, and particularly allow us to correlate this magmatism with the late Mesoproterozoic tectonic evolution of the Yangtze Block in the context of Rodinia supercontinent assembly.

2. Geological background

The South China Block consists of two major Precambrian continental blocks with different crustal evolution history: Cathaysia Block in the southeast and the Yangtze Block in the northwest (Fig. 1). The Cathasyia Block has a Precambrian basement mainly exposed in NW Fujian and SW Zhejiang Province (Li et al., 1998, 2000). It experienced Paleoproterozoic and Neoproterozoic tectonomagmatic events at ~1.85 Ga and 860–800 Ma (Li et al., 2005, 2011b,c; Yu et al., 2009; Shu et al., 2011) and was overprinted by Paleozoic and early Mesozoic metamorphic events at 460–420 Ma and 250–220 Ma (Shu, 2006; Xiang et al., 2008; Charvet et al., 2010; Li et al., 2011a; Yu et al., 2012; Zhao and Cawood, 2012). In contrast, the Yangtze Block has a Mesoarchean core in its northern part (the Kongling area) (Qiu et al., 2000; Zheng et al., 2006; Liu et al., 2008a; Jiao et al., 2009) with widespread Neoarchean basement (Zheng et al., 2006; Zhang et al., 2006a; Wang et al., 2010) and experienced numerous tectonomagmatic and metamorphic events in the Archean and Proterozoic at 2.7–2.6 Ga, 2.5–2.4 Ga, 2.0–1.9 Ga, 1.1–1.0 Ga and 910–720 Ma (Zhang et al., 2006b; Greentree et al., 2006; Li et al., 2007; Liu et al., 2008a,b).

In the conjuncture area, the Jiangshan–Shaoxing–Pingxiang Fault (JSPF) is considered to be the major suture zone between the two blocks (Zhou and Zhu, 1993; Zhang et al., 2005; Wong et al., 2011), in which a large amount of Meso- to Neoproterozoic volcanic and sedimentary rocks occur, e.g. the Pingshui Group (Chen et al., 2009) and the Shuangxiwu Group (Li et al., 2009) in the Yangtze Block; the Chencai Group (Shui, 1988) and the Zhoutan Group (Hu and Liu, 2002; Deng, 1997; Yu et al., 1999; Li et al., 2011a) in the Cathaysia block.

The Tieshajie Group is distributed in a nearly EW direction and has a total outcrop area of about 38 km^2 in the conjuncture area on the Yangtze Block side. It is in unconformable contact with Mesozoic volcanic rocks and in fault contact with the Zhoutan Group (Yu et al., 1999; Li et al., 2011b) (Fig. 2a). The Tieshajie Group is composed of a variety of rocks, predominantly of siltstones, phyllites, metabasalts and rhyolites which were probably deposited in a shallow marine environment on a stable craton as indicated by the presence of marbles in the mafic rocks. Field relationships show the basaltic rocks occur in the lower part of the Tieshajie Group with the rhyolitic rocks in the upper part.

Sharp contrasts exist across the JSPF in both the degrees of metamorphism and styles and orientations of deformation structures. The rocks of the Tieshajie Group underwent greenschist-facies metamorphism while those of the Zhoutan Group experienced amphiolite-facies metamorphism and strong migmatization (Hu and Zhang, 1997; Li et al., 2011a). Folds are well developed in the