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Zircon U–Pb and Lu–Hf isotope study of the Neoproterozoic Haizhou Group in the Sulu orogen: Provenance and tectonic implications

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ABSTRACT

The Neoproterozoic Haizhou Group crops out sporadically in the Sulu orogen in east-central China. It is divided into the Jinping and Yuntai formations and consists of quartzite, quartz schist, marble and graphite- and apatite-bearing sequences. Major and trace element data for quartz schist from the two formations indicate that these rocks have a greywacke protolith and have been deposited during strong tectonic activity. LA-ICPMS U–Pb dating of detrital zircon yields ages of 635 to 1074 Ma for three samples from the Jinping Formation and 611 to 943 Ma for two samples from the Yuntai Formation. More than 78% of the detrital zircons from the two formations have U–Pb ages grouped between 700 and 890 Ma, with two clusters peaking at 758 Ma and 828 Ma, respectively. This indicates that their provenance is magmatic rocks of Neoproterozoic age that have a tectonic affinity to the South China Block (SCB). A few older zircon populations with peak U–Pb ages at 943 and 1074 Ma are also present. A younger population shows peaks at 661 and 611 Ma. This suggests that deposition of the Haizhou Group was later than ~611 Ma rather than during the Mesoproterozoic as previously thought. Zircon Lu–Hf isotope data collected from the same U–Pb sites show negative $\varepsilon_{Hf}(t)$ values of −22.8 to −7.4 and Hf model ages of 2341 to 3100 Ma. This indicates that the Neoproterozoic magmatic rocks were derived from reworking of ancient Paleoproterozoic to Archean crust. The results support the contention that the Haizhou Group is similar to the Wulian Group at the northwestern edge of the Sulu orogen, both having a SCB affinity, but that the Penglai Group does not belong to the SCB because of the absence of Neoproterozoic ages. This lends support to the conclusion that the Triassic suture between the North China and South China blocks is located along the Baichihe–Yantai Fault, which lies north of the Wulian Complex and south of the Jiaobei Terrane; thus the Wulian–Yantai Fault is not the suture zone as is traditionally proposed.

1. Introduction

The North China Block (NCB) occupies an area of more than 1,500,000 km^2 in China and is bounded by faults and orogenic belts. The Central Asian Orogen Belt (CAOB) bounds the block to the north, and the Qinling–Dabie–Sulu orogen separates the block from the South China Block (SCB) to the south (Fig. 1a). The Qinling–Dabie–Sulu orogenic belt extends over 1500 km in a broadly E–W direction in central China and was formed by the northward subduction of the SCB beneath the NCB in the Triassic (Hacker et al., 1998, 2000, 2006; Li et al., 1993, 2000; Liou et al., 1996; Zheng et al., 2003, 2008a,b, 2009). The Sulu orogen is the eastern segment of this belt and is detached from the main Qinling–Dabie segment by the Tan-Lu Fault (Fig. 1a). In the Sulu region, the orogen consists of three main tectonic units: the Sulu HP-UHP zone in the south, the Wulian Complex in the middle, and the Jiaobei Terrane in the northwest, separated by the Wulian–Weihai and Baichihe–Yantai faults, respectively (Fig. 1b).

Low-grade metamorphic rocks occur in all three units of the Sulu orogen, and their origin has been an important subject in the study of continental collision zones (e.g., Li et al., 2007; Zheng et al., 2005; Zhou et al., 2008a, b). They occur as the Penglai Group in the Jiaobei Terrane, as the Wulian Group in the Wulian Complex at the northern margin of the Sulu UHP zone, and as the Haizhou Group at the southern margin of the Sulu UHP zone (Fig. 1). Faure et al. (2001, 2002, 2003) suggested that the Jiaobei Terrane belongs to the SCB and that the Wulian–Yantai Fault is not the suture zone between the NCB and SCB. This was based on the following observations: (1) both the Jiaobei Terrane and the Sulu UHP zone underwent similar deformation in the Triassic (Faure et al., 2002, 2003); (2) granulite-facies restites in migmatite of the Jiaobei Terrane were considered as granulitized eclogites derived from the UHP rocks of the Sulu orogen (Faure et al., 2001), and (3) low-grade units (e.g. the Wulian and Penglai groups) may extend across the Wulian–Yantai Fault into the Haizhou Group in the Sulu HP-UHP zone (Fig. 1b, Faure et al., 2003; Lin et al., 2004). Tang et al. (2006) reported that some rocks of the Fenzishan Group (Fig. 1b) also belong to the SCB because two samples of

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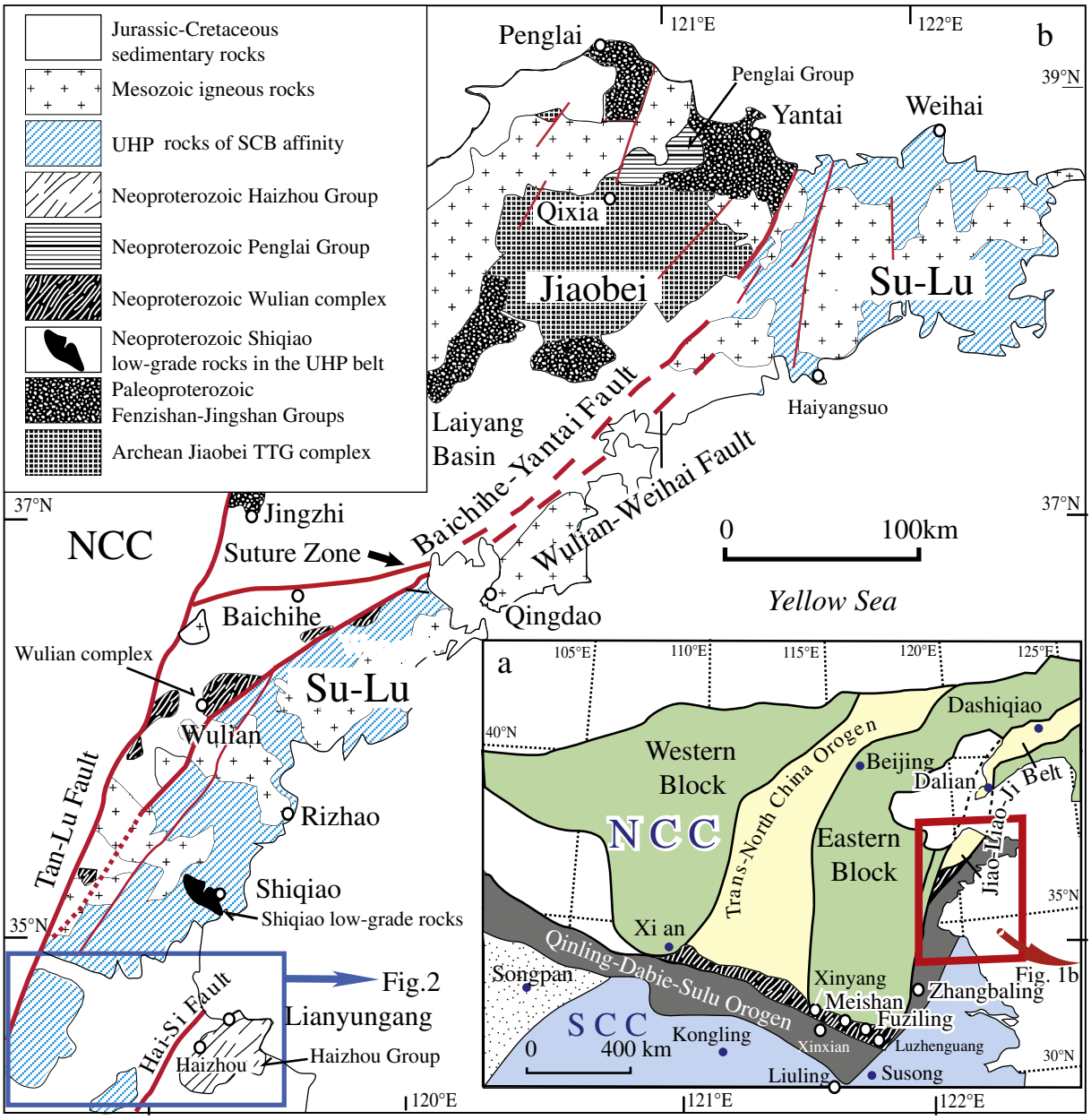

Fig. 1. (a) Main tectonic subdivisions of northern and central China (Li et al., 2004a; Zhao et al., 2005). NCB = North China Block; SCC = South China Block. (b) Geological sketch map of the Jiaodong Peninsula, including the Sulu orogenic belt of central-eastern China (after Zhou et al., 2008a).

impure marble yield SHRIMP U–Pb ages of 786 ± 67 and 240 ± 44 Ma for detrital igneous and metamorphic zircons, respectively. This suggests that the protolith of the marble was an impure limestone that was deposited synchronously with volcaniclastic rocks in a Neoproterozoic rift basin along the northern margin of SCB, but it was then thrust northward over the NCB during the Triassic continental subduction. On the basis of a combined study of zircon U–Pb geochronology and mineral O isotope geochemistry, Tang et al. (2007, 2008), furthermore placed the NCB–SCB suture along the Yantai–Wulian Fault in the eastern part of the Sulu orogen and suggested that the Jiaobei Terrane would have behaved like a microcontinent during the Triassic continental collision. However, Li et al. (2007) suggested that the suture lies north of the Wulian and Penglai groups, based on the SCB affinity of the detrital zircon U–Pb ages and Nd–Hf isotopic composition of the Penglai Group; their interpretation was that the Wulian and Penglai groups are similar to the Haizhou Group in terms of sedimentary sequences. However, Zhou et al. (2008a,b) did not support this view, but suggested that the suture lies north of the Wulian Complex and south of the Penglai Group, marked by the Baichihe–Yantai Fault. It is clear, therefore, that the location of the suture boundary between the NCB and SCB in the western part of the Sulu orogen is in dispute.

Several geochronological studies have helped to constrain the tectonic affinity of the Wulian and Penglai groups and their relations to the Haizhou Group (e.g., Huang et al., 2006; Li et al., 2007; Tang et al., 2006, 2007, 2008; Wu et al., 2004; Zheng et al., 2004; Zhou et al., 2003, 2008a,b). However, because no zircon U–Pb and Lu–Hf isotopic data are available for the Haizhou Group itself, there is no tight constraint on its provenance and relation to Neoproterozoic metasedimentary rocks in the Sulu orogen. In this paper, we present an integrated study of U–Pb and Lu–Hf isotopes in detrital zircons from the Haizhou Group. Our study extends the sparse U–Pb age data currently available and provides insights into the age populations present, the timing of magmatic events in the region, the nature of the magma in which the zircon formed and the magmatic and crustal evolution of the northern edge of the SCB during the late Precambrian.