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Origin of the North Qinling Microcontinent and Proterozoic geotectonic evolution of the Kuanping Ocean, Central China

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ABSTRACT

The high Pb isotopic ratios among the North Qinling Microcontinent (NQM), the western margin of the Yangtze Craton (WYC) and the western part of South Qinling (WSQ) indicate an identical or very similar origin of their basement. In addition, the analogical peak values of Paleoproterozoic detrital zircons also agree that the NQM originated from the WYC. The evolution of the NQM and the Kuanping Ocean is closely related to the aggregation and break-up of the Columbia supercontinent. According to the formation of the Supercontinent Columbia in the Paleoproterozoic (ca. 2.0–1.8 Ga), the debris from the WYC accreted vertically to form the NQM. Then the Kuanping Ocean began its subduction when the Supercontinent Columbia was rifted after the Paleoproterozoic (ca. 1.8 Ga). As a result, the passive continental margin of the North China Craton (NCC) and the Yangtze Craton (YZC) turned into an active continental margin. The continental arc (the Xiong'er Group) at the southern margin of the North China Craton (SNCC) and separation of the Qinling Group from the WYC in the Paleoproterozoic to Mesoproterozoic (ca. 1.8–1.0 Ga) are also the consequence of this subduction. In the context of the amalgamation of the Neoproterozoic (ca. 1.0–0.9 Ga) Supercontinent Rodinia, the NQM and the YZC collided with each other, thereby generating the closure of the Songshugou back-arc basin. Moreover, the terrigenous clastic sediments from some cratons of the Rodinia Supercontinent and the remnant oceanic crust of the Kuanping Ocean constituted the protolith of the present-day Kuanping Group.

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1. Introduction

The Qinling Orogenic Belt, which is located between the NCC and YZC, forms the most important component of the Central China Orogenic Belt (Yang et al., 2003). As a significant boundary between South China and North China, its complicated evolutionary history can be traced back to the formation of the basement in the Archean (Zhang et al., 1996b, 1997).

The North Qinling Microcontinent (NQM) (formerly known as North Qinling terrane) and South Qinling (SQ) are the two main blocks in the Qinling Orogenic Belt. Isotopic ages of the metamorphic rocks and magmatite from the NQM indicate that the Shangdan Suture (SS) was generated from the collision between the NQM and SQ in the Neoproterozoic (Ling et al., 2003; Chen et al., 2006; Ling et al., 2007) and the evolution of the two blocks differs quite a lot until their collision. The Paleo-Tethys Ocean may be the principal factor which contributes to the evolution of the SQ (Zhang et al., 2001; Ratschbacher et al., 2003). However, the origin of the NQM remains a matter of debate as to whether it came from the NCC or the YZC (Zhang, 2001) or neither of them (Yang et al., 2010). Dong et al. (2003) regarded the NQM as an ocean island beside the NCC. Meanwhile, most of the studies consider the NQM as a microcontinent with a distinct geological evolution before the collision with the NCC (Dong et al., 2003; Yang et al., 2010).

The motivation of this paper is to provide an overview of the contemporary understanding about the nature and timing of the Kuanping Group, Qinling Group and Songshugou Ophiolite. Combined with the new data from our analysis of the amphibolite sample in the southern margin of the NQM, the possible link among the NQM, NCC and YZC is proposed to outline the tectonic

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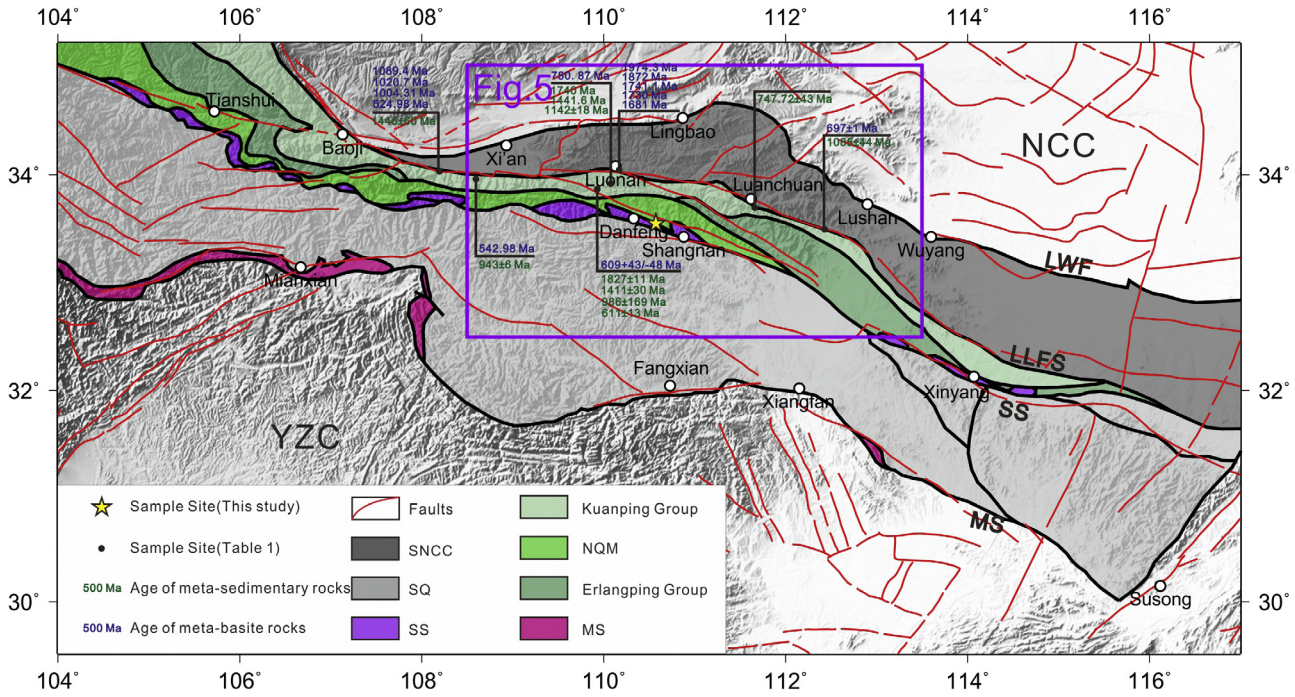

Fig. 1. Tectonic units of the North Qinling Orogen and its adjacent area. NCC = North China Craton; SNCC = southern margin of the North China Craton; YZC = Yangtze Craton; SQ = South Qinling; NQM = North Qinling Microcontinen; LWF = Lingbao–Wuyang Fault; LLFS = Luonan–Luanchuan–Fancheng Suture; MS = Mianlue Suture; SS = Shangdan Suture.

evolution of the NQM and Kuanping Ocean in the Proterozoic, which may be related to the formation processes of the supercontinents of Columbia and Rodinia.

2. Geological background

A wealth of studies about this area have led to the development of a consensus regarding the subdivision of tectonic units. In this study area (Fig. 1), the NCC, NQ and YZC are the three major tectonic units. The Luonan–Luanchuan–Fangcheng Suture (also known as the Kuanping Suture) separates the NQM from the southern margin of the NCC (Dong et al., 2003, 2014; Zhao et al., 2009) and the southern boundary of the Qinling Orogen is the Mianlue Suture which separates it from the YZC. The Shangdan Suture is known as the most important tectonic unit to distinguish the NQM from the SQ (Zhang et al., 1991).

2.1. The SNCC

As the basement of the southern margin of the North China Craton (SNCC), the Taihua Group (Fig. 2) is covered by the Mesoproterozoic Xiong'er Group and the Mesoproterozoic to Neoproterozoic sedimentary rocks (Zhang et al., 1991). The results of geochronological studies of the Taihua Group suggest its formation in the late Archean (Xue et al., 1995). Meanwhile, the Sm–Nd isochron age of the Taihua Group is established as 2766 ± 29 Ma (Xue et al., 1995), whereas the Hf model ages (T_{2DM}) range from 2.7 to 2.89 Ga (Shi et al., 2014), which suggest the formation of the Taihua Group is within the late Archean.

The Xiong'er Group comprises typical volcanic rocks, primarily including andesite and basaltic andesite. Zhao et al. (2001, 2004) indicate its formation in the Paleoproterozoic based on SHRIMP U–Pb isotopic ages (1.80–1.75 Ga). The magmatic rocks from the Xiong'er Group are typically bimodal volcanics which are characterized by higher Fe, K and lower Al, Ga, Mg, and have characteristics of the enrichment of light rare earth elements (LREE) and large ion lithophile elements (LILE) and loss of high field strength elements (HFSE) as the island-arc basalts (Zhao et al., 2001). The high potassic values in the basalts from the Xiong'er Group come from continental crust contamination (Zhao et al., 2002c; Zhang and Zhang, 2008; Xu et al., 2008). However, the origin of the Xiong'er Group remains quite controversial. Some researchers have proposed its origin from a failed triple continental rift environment (Zhai and Bian, 2000; Zhao et al., 2002c, 2004) or a large igneous province caused by a mantle plume (Zhao et al., 2002b; Peng et al., 2008); whereas others considered the Xiong'er Group as an Andean-type continental arc, according to the evidence from petrology and geochemistry (Zhao et al., 2002b, 2009). But all the arguments agreed that the Xiong'er Group was possibly on passive continental margin in the SNCC.

2.2. The NQM

The NQM is a combination of rocks of the Kuanping Group, the Erlangping Group and the Qinling Group (Fig. 2). The Kuanping Group, located beside the southern margin of the NCC, extends from Tianshui to the north of Tongbai-Xinyang (Yan et al., 2009). Its protolith is composed of flysch greywacke, meta-basic volcanic rocks and silicon magnesium carbonate (Li, 2002). The meta-basalts of the Kuanping Group are characterized by loss of or normal content of LREE and lower content of LILE, that came from a depleted mantle under the extensional basin (Wan et al., 1990; Zhang et al., 1994b; Zhang and Zhang, 1995). The isotopic ages of the Kuanping Group ranges from Paleoproterozoic to Mesoproterozoic. The upper intercept age of greenschist from the Guangdongping Group is 1827 ± 11 Ma and the lower intercept age is 418 ± 8 Ma (Li et al., 2002). However, the Sm–Nd isochron age of greenschist and amphibolite from the Kuanping Group ranges from 1.2 Ga to 0.94 Ga (Zhang et al., 1994b; Dong et al., 2003, 2008). The zircon U–Pb ages of the meta-basic volcanic rocks from the Erlangping Group (ca.

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