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Late Paleozoic subduction–accretion along the southern margin of the North Qinling terrane, central China: Evidence from zircon U-Pb dating and geochemistry of the Wuguan Complex

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ABSTRACT

The Qinling Orogen separating the North China plate from the Yangtze plate is a key area for understanding the timing and process of aggregation between the two plates. Two competing and highly contrasting tectonic models currently exist to explain the timing and nature of collision; one advocates a Devonian continental collision while the other favors a Triassic collision. The Wuguan Complex, between the early Paleozoic North Qinling and the Mesozoic South Qinling terranes, can provide important constraints on the late Paleozoic evolutionary processes of the Qinling Orogen. Metamorphosed sedimentary rock of the Wuguan Complex have a detrital zircon age spectrum with two major peaks at 453 Ma and 800 Ma, several minor age populations of 350–430 Ma and 1000–2868 Ma, and a youngest weighted mean age of 358 ± 3 Ma, indicating a mixed source from the North Qinling terrane. The recrystallized zircons yield a weighted mean age of 333 ± 2 Ma, representing the metamorphic age. Geochemical analyses imply that the sedimentary rocks were originally deposited in an active continental margin dominated by an acidic-arc source with a subordinate mafic-ultramafic source. The youngest population of detrital zircons (358 Ma) suggests that the Wuguan Complex developed as forearc basin along the southern accreted margin of the North Qinling terrane during the early Carboniferous, whereas the ca. 520–460 Ma mafic rocks with E-MORB, N-MORB, OIB or island arc basalt signatures probably derived from the Danfeng Group. In combination with regional data, we suggest that the depositional age of the Wuguan Complex is ca. 389–330 Ma, but it was subsequently incorporated into tectonic mélange by the northward subduction of the Paleo-Qinling Ocean. A long-lived southward-facing subduction-accretionary system in front of the North Qinling terrane probably lasted until at least the early Carboniferous.

1. Introduction

The Qinling Orogen is one of the largest collisional orogens in eastern Asia and the most important metallogenic belts in China. It connects the Qilian-Kunlun orogenic collages to the west and the Tongbai-Dabie-Sulu orogenic belt to the east (Fig. 1a). The Shangdan ophiolitic suture zone in this belt was generally considered to represent the boundary between the North China and Yangtze plates and also suggested to have formed by closure of the Paleo-Qinling Ocean at the latest Silurian (e.g., Mattauer et al., 1985; Şengör, 1985; Hsü et al., 1987; Xu et al., 1988; Kröner et al., 1993; Zhang et al., 1995; Meng and Zhang, 1999; Zhang et al., 2001; Dong et al., 2011a,b,c; Tang et al., 2014; Zhang et al., 2014; Y. Li et al., 2015). However, this models is at odds with the tectonic constructions based on paleomagnetic data (Lin et al., 1985; Zhao and Coe, 1987; Enkin et al., 1992; Yang et al, 1992), Triassic (ca. 250–220 Ma) HP/UHP rocks in Tongbai-Dabie-Sulu areas (Ames et al., 1993; Li et al., 1993; Okay and Sengör, 1993; Ames et al., 1996; Hacker et al., 1998; Ye et al., 2000; Liu et al., 2009) and the presence of Triassic granitoids in the Qinling orogenic belt (N. Li et al., 2015). Additionally, the age and tectonic setting of the Au, Pb-Zn-Ag, Cu, and Mo-(Au)-(W) ore deposits remains controversial (e.g., B.R. Zhang et al., 1989; G. Zhang et al., 1989; Qi et al., 1993; Wang et al., 1996; Xue, 1997; Ding et al., 2003; Ma et al., 2004; Leach et al., 2005). Therefore, accurate knowledge of the structure and history of the Shangdan ophiolitic suture zone is important to place tighter constraints on the timing and mechanisms of ocean closure before continental collision of the North China and Yangtze plates. This will help improve existing tectonic models for the evolution of the Paleo-Qinling Ocean and mineralization.

The Wuguan Complex crops out along the southern margin of the Shangdan Suture Zone between the North Qinling and the South Qinling

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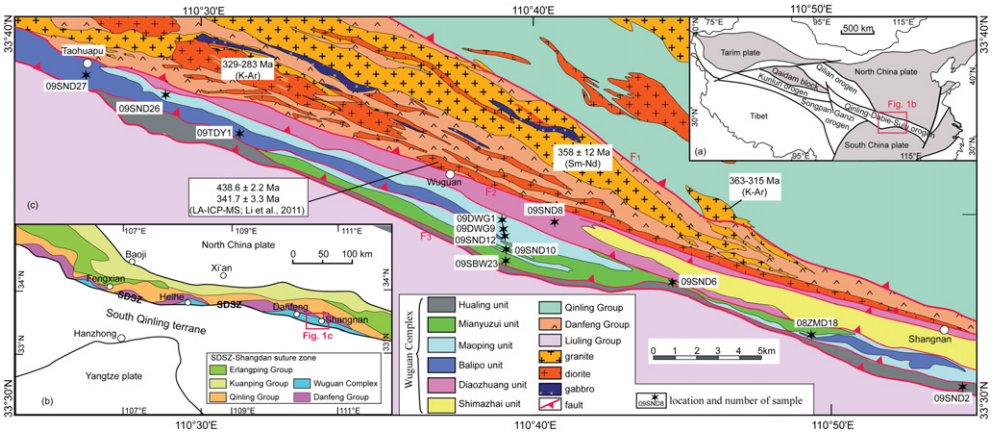

Fig. 1. (a) Location of the Qinling Orogen in the tectonic framework of China, which connects the Qilian and Kunlun orogens to the west and Tongbai-Dabie-Sulu orogen to the east. (b) Simplified tectonic framework of the Qinling Orogen (after Dong et al., 2011b; Wang et al., 2009; Chen, 2008) and location of the study area. (c) Geologic map of the Wuguan Complex (after Bureau of Geology and Mineral Resource of Shanxi Province, 1996; Pei, 1997) and locations of the studied samples for zircon U-Pb dating.

terranes. The age and composition of this complex provide critical constrains to reasonably understand late Paleozoic tectonic history of the Paleo-Qinling Ocean. In this paper, we present our petrographic, geochemical and systematic zircon U-Pb isotopic data of the metamorphosed sedimentary and igneous rocks from the Wuguan Complex. The new data provide (1) age constrains for the protoliths and overprinting metamorphism, (2) provenance data that aids in a more accurate determination of the tectonic setting of formation, and (3) delineate Late Paleozoic subduction-accretionary event along the southern margin of the North China plate.

2. Geological setting

The Qinling Orogen records a cycle of Paleo-Qinling Ocean closure between the North China and the Yangtze plates, which is considered to be the easternmost part of the Paleo-Tethyan Ocean (Li et al., 1978; Mattauer et al., 1985; Zhang et al., 1988, 1995). The Shangdan Suture Zone, which was traditionally considered as the most important boundary between the North China and the Yangtze plates (Mattauer et al., 1985; Xu et al., 1988; Zhang et al., 1988, 1995, 2001; Dong et al., 2011a,b), separates the North Qinling terrane from the South Qinling terrane (Fig. 1b). It is marked by discontinuously exposed arc-related ophiolitic assemblages, forearc sedimentary sequences, subduction- and collision-related granites, and a complex ductile shear zone-brittle fault systems (Yu et al., 1988; Zhang et al., 1988; B.R. Zhang et al., 1989; G. Zhang et al., 1989; C.L. Zhang et al., 1994; Z.Q. Zhang et al., 1994; Sun et al., 1995; Zhang et al., 1995; Sun et al., 1996; Q.R. Yan et al., 2009; Dong et al., 2011a,b). These rock assemblages, collectively known as the Danfeng Group, underwent green-schist to lower amphibolite facies metamorphism. The investigations demonstrate that the ophiolite sequences and subduction-related volcanic rocks consist mainly of metamorphosed mafic and ultramafic rocks exposed, from west to east, at Yuanyangzhen-Wushan, Guanzizhen, Tangzang, Yanwan, Heihe and Danfeng regions (e.g., Dong et al., 2011a, b; Li et al., 2014), indicating that its evolution involved the formation and consumption of the Paleo-Qinling oceanic basin.

The South Qinling terrane is mainly composed of Neoproterozoic-Triassic rocks that were interpreted as being representative of the passive margin of the Yangtze plate (Mattauer et al., 1985; Xu et al., 1988; Zhang et al., 1988; Ren et al., 1991; Zhang et al., 1995; He et al., 2005), but some researchers suggest this terrane represents a micro-continental block that belongs to the South China plate prior to the middle Devonian because of the opening of the Mianlue Ocean (Zhang et al., 1995; Li et al., 1996; Meng and Zhang, 1999; Zhang et al., 2001; Xu et al., 2002; Dong et al., 2011b). The Neoproterozoic volcano-sedimentary rocks were named as the Wudang and Yaolinghe groups characterized by ca. 780–755 Ma and ca. 685 Ma rift-related igneous rocks (Ling et al., 2008, 2010) respectively, which was generally interpreted as the basement of the South Qinling terrane (Zhang et al., 1995; Meng and Zhang, 1999; Zhang et al., 2001; Dong et al., 2011b). Yan et al. (2006, 2008, 2012) suggested a forearc environment as the Devonian-Carboniferous deposits of the South Qinling terrane based on their integrated provenance and tectonic setting studies. In particular, detrital zircon U-Pb data (Chen et al., 2010; Wu et al., 2012; Wang et al., 2014) also support that the Devonian sediments deposited in the South Qinling terrane derived from the North Qinling terrane rather than the South China plate. Based on the systemic analysis of petrological, geochemical, zircon U-Pb and microfossil data, and regional geology, Wang et al. (2009) proposed that the South Qinling terrane is comprised of an early Paleozoic continental arc developed ontop of a Neoproterozoic basement, and associated with a late Paleozoic accretionary complex and forearc/backarc basin that was formed by a double subduction of the Paleo-Qinling Ocean between the North China and Yangtze plates during Cambrian-early Triassic.

The North Qinling terrane mainly comprises Precambrian basement units, Neoproterozoic and early Paleozoic ophiolites, and volcanic-sedimentary assemblages, which were all unconformably overlain by Carboniferous and/or Permian clastic sediments. From north to south, the Kuanping, Erlangping, Qinling and Danfeng groups (Fig. 1b) are separated from each other by thrust faults or ductile shear zones. Previous studies suggested that the Kuanping Group represented a Mesoproterozoic ophiolitic mélange in a backarc basin (Zhang et al., 1991; Zhang and Zhang, 1995; Yan et al., 2008; Q.R. Yan et al., 2009) or a marginal basin sequence (e.g., Xue et al., 1996; Ratschbacher et al., 2003), but recent investigations (e.g., Q.R. Yan et al., 2009; Diwu et al., 2010) indicate that it actually contains two units with different lithology, petrogenesis and age. The greenschists and amphibolites originated from N-MORB-, E-MORB-, and T-MORB-type tholeitic basalts, representing ca. 943–611 Ma oceanic crust remnants of a backarc basin (Zhang and Zhang, 1995; Yan et al., 2008; Diwu et al., 2010). The meta-clastic unit is dominated by metamorphosed terrestrial clastic sediments deposited in the Early Paleozoic, with several detrital zircon U-Pb age groups at 600–689 Ma, 800–1200 Ma and 1600–3000 Ma (Diwu et al., 2010). The Erlangping Group (locally called Yunjiashan, Xieyuguan or Caotangou Group) comprises early Paleozoic ophiolitic and island arc volcanic-sedimentary rocks (Li et al., 1978; Xu et al., 1988; Zhang et al., 1988; Sun et al., 1996; Q.R. Yan et al., 2009; Wang et al., 2009). The Qinling Group comprises gneisses, marbles and amphibolites (Zhang et al., 1988; You et al., 1991) distributed along the northern side of the Danfeng Group as several lenticular units, which were strongly overprinted by early Paleozoic deformation and metamorphism (Liu et al., 1996; Chen et al., 2004; Zhang et al., 2011).