Geophysical Research Abstracts
Vol. 12, EGU2010-3746, 2010
EGU General Assembly 2010

A New Model of the Early Paleozoic Tectonics and Evolutionary History in the Northern Qinling, China

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The Qinling Orogenic Belt extends from the Qinling Mountains in the west to the Dabie Mountains in the east. It lies between the North China and South China Blocks, and is bounded on the north by the Lushan fault and on the south by the Mianlue-Bashan-Xiangguang fault (Zhang et al., 2000). The Qinling Orogenic Belt itself is divided into the North and South Qinling Terranes by the Shangdan suture zone. Although the Shangdan zone is thought to represent the major suture separating the two blocks, there still exists debate about the timing and mechanism of convergence between these two blocks. For instance, some authors suggested an Early Paleozoic collision between the North China Block and South China Block (Ren et al., 1991; Kroner et al., 1993; Zhai et al., 1998). Others postulated left-lateral strike-slip faulting along the Shangdan suture at ca. 315 Ma and inferred a pre-Devonian collision between the two blocks (Mattauer et al., 1985; Xu et al., 1988). Geochemistry of fine-grained sediments in the Qinling Mountains was used to argue for a Silurian-Devonian collision (Gao et al., 1995). A Late Triassic collision has also been proposed (Sengor, 1985; Hsu et al., 1987; Wang et al., 1989), based on the formation of ultrahigh-pressure metamorphic rocks in the easternmost part of the Qinling Orogenic Belt at $\sim$230 Ma (e.g., Li et al., 1993; Ames et al., 1996). Paleomagnetic data favor a Late Triassic-Middle Jurassic amalgamation of the North China and South China Blocks (Zhao and Coe, 1987; Enkin et al., 1992). It is clear that most authors thought that the Qinling Mountains are a collisional orogen, even they have different methods about the timing of the orogeny. Based on new detailed investigations, we propose a new model of the Early Paleozoic Tectonics and Evolutionary History between the North China and South China Blocks along the Shangdan Suture.

The Shangdan suture is marked by a great number of ophiolites, island-arc volcanic rocks and other related rock assemblages. Our new geological and geochemical data revealed a lot of ophiolitic mélanges along the Shangdan suture, such as the Guojiagou, Ziyu, Xiaowangjian, Yanwan, Tangzang, Guanzizhen and Wushan areas from east to west. The ophiolite assemblage in Guojiagou, Ziyu area consists mainly of some blocks of E-MORB type and IAB-type basalts, while the pillow lavas from Xiaowangjian are IAB-type basalts. The basalts from the ophiolite assemblages in Yanwan, Tangzang and Wushan areas possess E-MORB geochemical compositions. The zircons of gabbro from Yanwan ophiolite mélange yield an U-Pb age of 516$\pm$3.8 Ma, which represents the formation age of the Yanwan ophiolite. Meanwhile, the basalts in the Guanzizhen ophiolite mélange show N-MORB type geochemical signature, and the zircons from gabbro yield a U-Pb age of 471$\pm$1.4 Ma, which constraints the formation age of the mature oceanic crust. Additionally, there also exists a U-Pb age of 523$\pm$26 Ma (Lu et al.,2003) and Cambrian-Ordovician radiolarites from the interlayed silicarites within the volcanic rock in the Guojiagou ophiolite mélange (Cui et al., 1995). All these geochemical and geochronological evidences indicate that there existed an oceanic basin and its subduction, which separated the Northern China Block from the Southern China Block during 523 –471 Ma.

Accordant with this ocean and its subduction, there had been existed an active continental margin, island-arc setting on the north side of the Shangdan ophiolite mélange which were marked by a series of moderate-basic intrude igneous mass along the Sifangtai-Lajimiao area (Li et al., 1993) and the Fushui area (Dong et al., 1997). In addition to, there also exist a great number of subduction-collisional granites intruding into island-arc basement along the active continental margin. Zircons from the Fushui intrusion yield a U-Pb age of 514$\pm$1.3 Ma (Chen et al., 2004), which constraints the time of the subduction.

Above all, more and more data suggest that there exists a back-arc basin on the northern side of the island-arc terrain. To the east, it is presented by the Erlangping group in Xixia area, which consists mainly of clastic sediments, carbonatites and basic volcanic rocks. The geochemistry of the basalts show that they were formed in a back-arc basin setting (Sun et al.,1996), and the radiolarites from the interlayed silicalites show the Orovician-Silurian age (Wang et al., 1995). Our new investigation reveals some new tectonic assemblages exposed in the Yinggerzui area, Qinghusi area to the west. The detailed geochemical studies indicate that they were formed in a back-arc basin.

All above evidences suggest that there had existed an Early Paleozoic subduction system, which consists of a subduction trench, island-Arc and back-arc basin along the northern Qinling zone. It is also indicated that the Paleo-ocean had been evolved into a complete evolutionary process including initial spreading (E-MORB ophiolite), maturated extension (N-MORB ophiolite) and subduction (Island-arc volcanic rocks). However, it is notable that there are large scale of Devonian clastic sediments distributing on the south of the Shangdan suture, and the pre-Mesozoic rocks in the South Qinling without any metamorphism or just underwent the low-greenschist facies metamorphism in some places, which are very different from the North Qinling Terrane consisting mainly of Precambrian rocks and evolving into an amphibolite facies metamorphism at $\sim$1.0 Ga and greenschist facies metamorphism at $\sim$400 Ma (Liu et al., 1993; Zhang et al., 1994). Accordingly, it is prefer that there only occurred a subduction of the Shangdan oceanic crust from south to north along the Shangdan suture on the south of the Northern Qinling Terrane.

However, the Piaochi and the Anjiping granites possessing the sym-collisional type granite geochemistry and formation age of 450-486 (Chen et al., 1991; zhang et al., 1996) indicate that there occurred a collisional event between the North Qinling Island-arc Terrane and the Northern China Block caused by closing of the Early Paleozoic back-arc basin. Additionally, the studies of the metamorphism show that there are two zones of high / ultra-high pressure metamorphic rocks outcropping along the both side of the Northern Qingling island-arc terrane. On the north, it is characterized by eclogite and coesite outcropping in the Guanpo area, and the metamorphic zircon U-Pb age of 507$\pm$38 Ma and 509$\pm$12 Ma by means of SHRIM (Yang et al., 2002). Meanwhile, there also exist some high pressure basic granulite (Liu et al., 1995) and felsic granulite (Liu et al., 1996) distributing in the Xigou fault on the south margin of the Northern Qingling island-arc terrane. Zircon U-Pb ages of 485$\pm$3.3 Ma by means of LA[U+FF0D]ICP[U+FF0D]MS method (Chen et al., 2004) and 518$\pm$12 Ma by means of SHRIM (Liu et al., 2003) constrain the time of the metamorphism. All these metamorphic data suggest the Northern Qingling island-arc terrane had been evolved into a deep subduction event during 485-518 Ma.

Based on all above evidences, we infer a new model about the tectonics and evolutionary history of the Norhtern Qinling Terrane. It is emphasized that the Early Paleozoic tectonics between the North China and Southern China Blocks had existed an ocean, island-arc and back-arc basin, and evolved into four stages of evolutionary stages: 1) initial spreading along the Shangdan zone during 516-523 Ma; 2) maturated ocean along the Shangdan zone during 516-471 Ma; 3) subduction along the south side of the Northern Qinling Terrane and formation of the Back-arc basin along the north side of the Northern Qinling Terrane during518-514; 4) closing of the back-arc basin, collision between the Northern Qingling island-arc terrane and the Northern China Block, and deep subduction of the Northern Qingling island-arc terrane during 518-485Ma.

This work was supported by NSFC (40772140 & 40972140)

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