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Early Paleozoic Tectonic Evolution of Qinling Orogen - Evidence from Zircon U-Pb Dating and Hf Isotope of Granitoids in North Qinling Belt, Central China

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The Qinling orogen, as an important part of the central orogenic belt of China, underwent a long-term tectonic evolution, being a typical composite and multi-stage orogen. Its evolutionary history is critical for the understanding of the amalgamation between north and south China Blocks, and has attracted numerous studies from geologists at home and abroadin in the past three decades. This orogen is subdivided into the north Qinling (included southern margin of North China Block) and south Qinling belts (SQB) by the Shangdan suture zone (SDSZ). In which, the north Qinling belt (NQB) was regarded to evolved into an south active margin of North China Block due to the northward subduction of Qinling ocean basin along the SDSZ during the early Paleozoic (Zhang G W et al, 2001). However, the close timing of ancient Qinling ocean and tectonic evolution processes of the NQB is controversy (Mattauer, M et al., 1988; Zhang G W et al., 2001 and reference there in；Xu Z Q et al., 1986, 1996; Ren J S et al., 1991; Kröner et al., 1993; Gao S et al., 1995; Meng Q R et al., 2000; Ratschbacher et al., 2003; Dong Y P et al., 2011; Liu L et al., 2013).

The most striking feature of NQB is that many early Paleozoic granitoid plutons are widely outcropped in it, which provides us an idea object to reconstruct early Paleozoic evolutionary history of the Qinling orogen. In this study, we present new U-Pb and Hf analysis of zircons from these granitoids to determine the tectono-thermal magmatic events in NQB during early Paleozoic and amalgamation between the North and South Qinling blocks.

1 Geological Setting

The NQB is considered to be the oldest structural complex terrain in Qinling orogen, which is bounded by the Luonan - Luanchuan fault to the north and by the SDSZ to the south and composed mainly of four units of the Qinling, Kuanping, Erlangping and Danfeng groups. All units are separated from each other by the faults or ductile shear zones, respectively. Of which, the Kuanping group is outcropped in the most north of NQB and separated from North China block by the Tieluzi–Luanchuan fault, which has an assemblage of mica–quartz schists, greenschists and quartz-rich marbles. To the south of Kuanping group, the Erlangping group is bounded by the Zhuyangguan–Xiaguan fault and dominated by an ophiolite unit, clastic sedimentary successions and carbonate. The Qinling group, as several Precambrian lenticular bodies is sandwiched in the centre of NQB. They are composed mainly of the biotite–plagioclase and garnet–sillimanite gneisses, mica–quartz schists, graphite marbles and minor amphibolites. The Danfeng group is developed to the most south of NQB, and composed mainly by greenschist- to low amphibolite–facies metamorphic basalts and flysch turbidites, which distributes discontinuously along the SDSZ. Furthermore, many granitic plutons could be found in NQB, and most of them were intruded in the Qinling group.

The granitic and gabbroic plutons of NQB are widely developed in the Danfeng-Shangnan area. In which, granitic plutons are batholith with gneissic structure parallel to regional foliation, and consist predominantly of medium- to coarse-grained monzogranites and granodiorites with a representative mineral assemblage K-feldspar (~35%) + plagioclase (~20%, An=20~35) + quartz (~25%) + biotite (<10%) + hornblende (~8%) ± garnet (<2%). Some of small granitic plutons and dykes are fine- to medium-grained and weakly gneissic to massive in structure. They clearly intrude in the Qinling complex and batholith. The mineral assemblages of these plutons are K-feldspars (35~40%) + plagioclases (~20%) + quartz (~25%) + biotites (~10%) + minor muscovites and garnets. Their accessory minerals are zircons, apatites and opaque oxides. In addition, anatectic dykes could be found in Qinling complex, which is texturally similar to gneissic batholith, suggesting that they may be related to the same magmatic event.

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2 Discussion and Implications

Twelve samples representing the major lithologies from the granitic and gabbroic plutons and anatectic dykes of NQB in Danfeng-Shangnan area were selected for this study. Of these, 7 samples of QL-20, QL-30, QL-33, QL-41, QL-55, QL-58 and QL-59 were collected from gneissic granitoid batholiths; samples QL-25 and QL-50 were collected from the anatectic dykes; Sample QL-12 and QL-22 is collected from Anjiping massive granite and granitic dyke in Piaochi batholith. The sample QL-31 is from Ziyu gabbro (table 1). The in situ zircons dating and zircon Hf isotopic analyses of these samples were performed using an LA-ICP-MS and MC-ICPMS housed at the State Key Laboratory of Continental Dynamics, Northwest University, Xi'an. All analytical results are given in table 1.

Our new LA-ICPMS zircon data demonstrate that the early Paleozoic granitoid magmatism occurred in NQB could be obviously classed into three stages with the peak ages of 500Ma, 450Ma and 418Ma (Fig. 1). The first-stage granitoids were strongly deformed and contemporaneous with high-pressure (HP) eclogite and granulite metamorphism in NQB (Liu et al., 2013 and reference there in). The granitoid magmatism is dominated by gneissic monzogranites and anatectic dykes with a gneissic structure parallel to regional foliation. They have high content of SiO_2, K_2O and low CaO, MgO, showing peraluminous and calc-alkaline series. They are characterized by the high LREE concentrations, moderate negative Eu anomalies, LILE-enriched, poor HFSE and depletion of Nb, Ta, Sr, Ti and P, suggesting a S-type granitoids derived from crustal source. All granitoids and anatectic dykes contain old inherited zircons with the ages of 2496Ma ~ 850Ma, and have highly negative ε Hf (t) values (-27.54 ~ -6.21, for Piaochi monzogranite; −17.05 ~ −0.53, for anatectic dyke) old T_{DM}^{C} (1589Ma ~ 2661Ma, 1252Ma to 2139Ma) (table 1, Fig. 2), indicative of derivation from weathered mid-Proterozoic crustal component. Thus, the first stage granitoid magmatism can be suggested to be formed by the partial melting of the continental crust due to the exhumation of the ultrahigh-pressure (UHP) rocks during continent-continent collision around 500Ma.

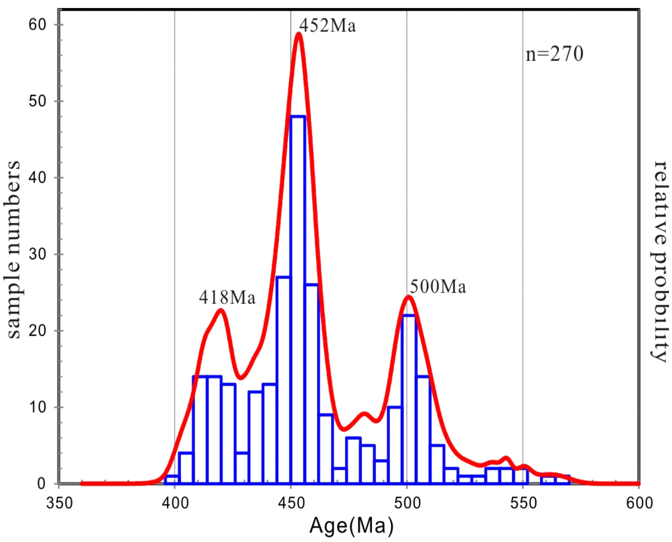

Fig. 1 Histogram of zircon U-Pb age of granitoids in NQB

The second-stage granitoids are widely developed in NQB. They are moderately deformed and composed mainly by I-type granodiorites and monzogranites,

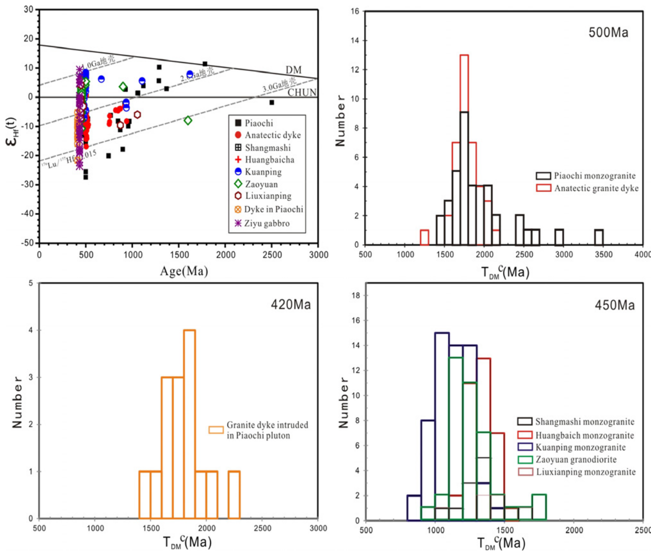

Fig. 2 Zircon Hf isotopic compositions of granitoids in NQB

characterized by calc-alkaline to high-K calc-alkaline, and metaluminous to peraluminous with a variation of SiO_2, K_2O, Na_2O and MgO. They have variable REE concentrations and Eu anomalies, and LILE-enriched and HFSE-depleted, especially for the Nb, Ta, Sr, Ti and P. Several granitoids, such as the Liuxianping pluton, show high Sr, Y and Sr/Y ratios, indicating a geochemical feature of post-collision granitoids. Compared with the first-stage granitoids, they have relatively high and variable ε Hf (t) values of −10.77 to +7.13(table 1), which overlap the ε Hf (t) range of gabbroic formed in second stage (table 1, Fig. 2). Their TDMC ranges from 875 Ma to 1787 Ma, being relatively younger than those of first-stage granitoids (table 1, Fig.2). Furthermore, several groups of zircons with the Mid- to Neo-Proterozoic ages can be found in this stage granitoids (table 1). Such Hf isotopic characteristics are likely indicative of a binary mixing between an older crustal component and a juvenile of mantle-derived magma triggered by the break-off of subducted plate during post-collisional setting.

The third-stage granitoid plutons are relatively small voluminous with massive structures, and dominantly tow mica-granite and monzogranites. They are high in SiO2, K2O and FeOT, belonging to the high-K calc-alkaline

Table 1 Summary of LA-ICPMS zircon U –Pb ages and Hf isotope composition of granitoid plutons of NQB in the Danfeng-Shangnan area

sample No.	Pluton name	rock type	crystallization ages of igneous zircons and its Hf isotopic composition	forming ages of xenocrystic/inherited zircons
QL-20	Piaochi	Gneissic monzogranite	496.1±4.2Ma(6 analyses on igneous zircons); $\varepsilon_{Hf}(t)$= -27.54~ -6.21, T_{DM}^{C} = 1589-2661 Ma	2496~1777Ma (3 analyses on inherited zircons), 1364~1052Ma (5 analyses on inherited zircons), 842~964Ma(5 analyses on the magmatic zircons)
QL-22	Dyke in Piaochi	granite	411.7±3.7Ma (15 analyses on magmatic zircons); $\varepsilon_{Hf}(t)$ = -21.49 ~ -5.12, T_{DM}^{C} = 1460~2290 Ma	
QL-12	Anjiping	granite	416.7±1.8Ma (20 analyses on magmatic zircons)	880±13Ma (3 analyses on the inherited zircons), 490.2±5.9Ma (1 analyses on the inherited zircon), 450.9±6.9Ma(2 analyses on the inherited zircons)
QL-30	Kuanping	Gneissic monzogranite	452.8±2.0Ma (15 analyses on the magmatic zircons); $\varepsilon_{Hf}(t)$ = 2.24 ~ 7.18, T_{DM}^{C} = 874~1125 Ma	500.7±2.0Ma (16 analyses on inherited magmatic zircons), $\varepsilon_{Hf}(t)$ = -4.34 ~ 8.58; T_{DM}^{C} = 841~1500 Ma
QL-33	Shangmashi	Gneissic monzogranite	445.7±5.3Ma (9 analyses on magmatic zircons); $\varepsilon_{Hf}(t)$ = -2.42 ~ 3.83; T_{DM}^{C} = 1041~1352 Ma	
QL-41	Huangbaich	Gneissic monzogranite	447.8±2.5Ma (27 analyses magmatic zircons); $\varepsilon_{Hf}(t)$ = -6.05 ~ 2.02; T_{DM}^{C} = 1134 ~ 1540 Ma	474.9±7.5Ma (8 analyses on the inherited magmatic zircon)
QL-55	Kuanping	Gneissic monzogranite	450.7±2.8Ma (16 analyses on the magmatic zircons); $\varepsilon_{Hf}(t)$ = -5.07 ~ 4.81, T_{DM}^{C} = 993 ~ 1481 Ma	483.9±7.6Ma (5 analyses on the inherited magmatic zircons), 1691.1±17Ma, 1244±36 Ma, 937±8.9Ma and 668±6Ma, (4 analyses on inherited zircons), 471~514Ma (10 analyses on inherited zircons)
QL-58	Zaoyuan	Gneissic granodiarite	456.1±1.9Ma (22 analyses on the magmatic zircons); $\varepsilon_{Hf}(t)$ = -10.59 ~ 2.38, T_{DM}^{C} = 1110 ~ 1781 Ma	464.4±3.8Ma (3 analyses inherited magmatic zircons), 1599±6.9Ma (1 inherited zircon)
QL-59	Liuxianping	Gneissic monzogranite	449.9±8.4Ma (10 analyses on magmatic zircons); $\varepsilon_{Hf}(t)$= -6.46 ~ 4.35; T_{DM}^{C} = 1015 ~ 1571 Ma	1058±21Ma (2 analyses on the inherited zircon), 475±11Ma(3 analyses on the inherited zircons)
QL-25	Anatectic dyke	granite	501.2±4.2Ma (18 analyses on the magmatic zircons); $\varepsilon_{Hf}(t)$ = -17.05~ -0.53; T_{DM}^{C} = 1252 ~ 2139 Ma; 442±16Ma (6 analyses on the zircon rims)	730±6Ma, 616±5Ma and 559±7Ma (3 analyses on the inherited zircons).
QL-50	Anatectic dyke	granite	501.4±8.1Ma (15 analyses on magmatic zircons); $\varepsilon_{Hf}(t)$ = -12.49~ -5.44, T_{DM}^{C} = 1557 ~ 1905Ma	935±16Ma (4 analyses on the inherited zircons), 856±11Ma (4 analyses on the inherited zircons), 747.5±6.6Ma (7 analyses on the inherited zircons)
QL-31	Ziyu	Gabbro	432.2±2.3Ma (33 analyses on magmatic zircons), $\varepsilon_{Hf}(t)$ = -39.47~ 9.57	

peraluminous shoshonitic series. Geochemically, this stage granitoids show high REE and very low negative Eu anomaly, with strongly depletion of Nb, Ta, Sr, P and Ti, indicating a highly fractional granitiod similar to the A-type granite. Their ε Hf (t) values range from -21.49 to -5.21, and TDMC from 1460–2290 Ma (table 1, Fig. 2), suggesting that they were formed by the partial melting from old crust materials in the later post-collision setting transformed from compression to extension.

All mentioned above indicates that continent-continent collision had been occurred between southern North China plate and south Qinling micro-plate along the Shangdan Suture around 500Ma, and then three stages of syn-, psot- and later collision granitoid magmatism lasted at least 100 Ma from 500Ma to 400Ma. The first-stage magmatism possibly related to continent-continent collision, as evidenced by the occurrence of the HP eclogites and granulites along the southern margin of the Qinling Complex (Liu L et al., 2013). The second-stage magmatism formed in the post-collision setting, corresponding to break off of the subducted plate. The third-stage granitic magmatism represents tectonic transformation from compression to extension during later post-collision period.

Reference

Dong, Y.P., Zhang, G.W., Neubauer, F., Liu X.M., Genser, J. and Hauzenberger, C., 2011. Tectonic evolution of the Qinling orogen, China: Review and synthesis. Journal of Asian Earth Sciences, 41: 213–237.

Gao, S., Zhang, B.R., Gu, X.M., Xie, X.L., Gao, C.L., Guo, X. M., 1995. Silurian-Devonian provenance changes of South Qinling basins: implications for accretion of the Yangtze (South China) to the North China cratons. Tectonophysics 250, 183–197.

Kroner, A., Zhang, G.W., Zhuo, D.W., and Sun, Y., 1993. Granulites in the Tongbai area, inling belt, China: geochemistry, petrology, single zircon geochronology and mplications for tectonic evolution of eastern Asia. Tectonics 12, 245–255.

Liu, L., Liao, X.Y., Zhang, C.L., Chen, D.L., Gong, X.K., Kang, L., 2013. Multi-matemorphic timings of HP-UHP rocks in the North Qinling and their geological implications. Acta Petrologica Sinica. in press.

Mattauer, M., Matte. Ph., Malavieille, J., Tapponnier, P., Maluski, H., Xu, Z., Lu, Y., Tang, Y., 1985. Tectonics of Interthe Qinling belt: build-up and evolution of eastern Asia. Nature 317, 496–500.

Meng, Q.R., Zhang, G.W., 2000. Geological framework and tectonic evolution of the Qinling orogen, Central China. Tectonophysics 323, 183–196.

Ratschbacher. L, Hacker, B.R., Calvert, A., Webb, L.E., Grimmer, J.C., McWilliams, M.O., Ireland, T.R., Dong, S., Hu, J.M., 2003. Tectonics of the Qinling (Central China): Tectonostratigraphy, geochronology, and deformation history. Tectonophysics 366, 1–53.

Ren, J.S., 1991. The basic characteristics of the tectonic evolution of the continental lithosphere in China. Regional Geology of China 4, 289-293（in Chinese with English abtract）

Xu, Z.Q., Lu, Y.L., Tang, Y.Q., Mattauer, M., Matte, PH., Malavieille, J., Tapponnier, P., 1986. Deformation characterisitics and tectonic evolution of the Eastern Qinling orogenic belt. Acta Geological Sinica, 3, 238-247（in Chinese with English abtract）

Zhang, G.W., Zhang, B.R., Yuan, X.C., Xiao. Q.H., 2001. Qinling Orogenic Belt andContinental Dynamics. Science Press, Beijing. pp. 1–855.