CHEN Youxin, PEI Xianzhi, LI Ruibao, LI Zuochen, PEI Lei and LIU Chengjun, 2013. Chronology, Geochemistry and Tectonic Significance of Meta-volcanic Rocks from Naij Tal Group, East Section of East Kunlun, China. *Acta Geologica Sinica* (English Edition), 87(supp.): 11-12.

Chronology, Geochemistry and Tectonic Significance of Meta-volcanic Rocks from Naij Tal Group, East Section of East Kunlun, China

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East Kunlun Orogenic Belt（EKOB）with long and complex tectonic evolution process is located at the Northeast margin of Qinghai-Tibet plateau, between Qaidam basin and A'nyemaqen tectonic melange belt, there are numerous metamorphic rocks such as Lower Paleozoic Naij Tal Group, Mesoproterozoic Xiaomiao Formation and Paleoproterozoic Baishahe Formation in EKOB. Although researchers have done lots of research work（Zhang KX et al. , 2001, 2004; Yin HF et al. , 2003; Wang GC et al. , 2007; Chen NS et al. , 2006, 2008; Chen YX et al. , 2011）, there are still many controversy on stratigraphic correlation, age and tectonic attribute. In the regional geological mapping and comprehensive study, most geologists argue that Naij Tal Group formed in the fore-arc basin of active continental margin or inter-arc basin（Pan YS et al. , 1996; Wang GC et al. , 2004; Zhang XT et al. , 2007）, but some geologists consider that Naij Tal Group formed in passive margin（Xu ZQ et al. , 2007; Ni JY et al. , 2010）. This study focus on petrology, geochemistry and zircon U-Pb isotope geochronology of meta-volcanic rocks from the Naij Tal Group, to ascertain its forming age and tectonic attribute, and discuss the regional tectonic evolution process of EKOB during the Early Paleozoic.

In Hatu－Kekesha area, Naij Tal Group distributes along northeast－southwest trend, intersects with regional tectonic line in large Angle. Naij Tal Group and Xiaomiao Formation show the ductile shear fault relationship in northwest，so does Baishahe Formation in east. Besides，fault is found between Naij Tal Group and Naochangjiangou Formation in south. Naij Tal Group mainly consists of quartz schist, with superimposed thickness more than 3761m, which can be divided into two units：biotite quartz schist－garnet two mica schist unit and quartz schist－sericite quartz schist unit combination with greenschist（metamorphic basic volcanic rock）.

Zircon grains from the meta-volcanic rocks are light yellow, transparent and with euhedral crystal shape. Most zircon grains are more than 80μm in length with length to width ratios between 1 and 2. Most zircon grains display pyramid terminations with oscillatory zoning, which show characteristics of a magmatic origin, while some zircon grains have overgrowth edges（10μm±）. The Th, U data and ratio of zircon grains indicate the magmatic genesis. The zircon U-Pb ages of meta-volcanic rocks from Naij Tal Group is evidently divided into five groups：2559Ma, 1472～1341Ma, 1142～918Ma, 595～557 Ma and 497～459 Ma. The former four groups record the precambrian tectonic-magmatic events in this area. The zircon grains of 497～459 Ma are of clear oscillatory zoning indicating the magmatic genesis, the $^{206}Pb/^{238}U$ weighted average age of which is（474±7.9）Ma（MSWD=0.59, n=11）indicating the forming age of meta-volcanic rocks is Ordovician.

The meta-volcanic rocks from Naij Tal Group includes epidote-chlorite albite schist, plagioclase hornblende schist and hornblende schist. The major element data show that the samples contain 44.08 to 50.46 wt% of SiO_2, 1.79 to 3.39 wt% of TiO_2, 13.26 to 14.50 wt% of Al_2O_3, $FeO>Fe_2O_3$, $K_2O<Na_2O$. The Niggli eigenvalue of meta-volcanic rock show that low-alkaline（*alk*=3.47~13.02）, poor aluminum（*t*= － 1.79 ～ － 37.65）and calcium（*c*=12.16 ～ 28.04）. The（Al+Fe+Ti）－（Ca+Mg）diagram shows that the protolith of meta-volcanic rocks are basalt, and The Zr/TiO_2－Nb/Y diagram indicates that basalts are divided into two series：tholeiite（include plagioclase hornblende schist and hornblende schist）of

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lower $Mg^{\#}$（43.09～46.44）and alkali basalt（include epidote-chlorite albite schist）of higher $Mg^{\#}$（57.20～76.00）. These suggest that the tholeiite magma has undergone crystallization differentiation of femic mineral, whereas the alkali basalt magma is similar to primitive magma.

The primitive mantle normalized trace element patterns are diagnostically enriched in large ion lithophile elements（Cs, Rb, U, etc.）and depleted in high field strength elements(Zr, Hf, Nb, Ta, etc.) similar to E-MORB and OIB. The REE data show higher REE contents（122.8 to 287.3 ppm）and LREE/HREE rations（2.75 to 10.04）. The chondrite normalized REE patterns for plagioclase hornblende schist and hornblende schist are characterized by rarely LREE enchrichment with δEu of 0.93～1.14, which are similar to E-MORB. While the chondrite normalized REE patterns for epidote-chlorite albite schist is characterized by significant LREE enrichment with δEu of 0.97～1.13, which are similar to OIB（Henderson P, 1984; Wilson M, 1989）.

Trace elements data show that the tholeiite has the characteristics similar to island arc volcanic rocks, while the alkali basalt is similar to E-MORB and OIB. The Ce/Nb－Th/Nb diagram shows that tholeiites were formed in back-arc basin setting, and the samples of the alkali basalts are draw near to E-MORB and OIB. In several studies it was argued that E-MORB is rare，but mainly formed in Mid-ocean Ridge and seamount nearby ocean ridge, sometimes, E-MORB and alkali OIB formed in back-arc basin of convergent continental margin（Frey et al, 1993; Niu et al, 1999; Gribble et al, 1996、1998; Leat et al, 2000; Benoit et al, 2002; Cole et al, 2006; Castillo et al, 2008）. As the LREEs are enriched, the meta-volcanic rocks change from tholeiite to alkali basalt, and the rocks are more similar to OIB. The Th/Yb－Nb/Yb diagram shows the rocks formed in volcanic arc array, the tholeiites come near to E-MORB, while alkali basalts draw near to OIB, indicating that the alkali basalt magma is similar to primitive magma. Moreover, the addition of Th indicates the magma is intermingled with fluid or surrounding rocks. Zircon U-Pb dating and geochemical study indicate that these meta-volcanic rocks were formed in back-arc basin environment caused by Proto-Tethys oceanic crust northward subducting into East Kunlun.

In recent years, more and more studies show that the crack of Rodinia super-continent is record in the west area of China, while the East Kunlun is overall discrete and local collision after the Rodinia super-continent cracking during Early Paleozoic（Chen NS et al., 2008; Wang GC et al., 2000; et al., 2007）. The Proto-Tethys oceanic crust northward subducted into East Kunlun and forms large volume island-arc granites, and at the same time or latter, formed the back-arc basin. The protolith of Naij Tal is volcanic-sedimentary series, formed in back-arc basin during Early Paleozoic, it is the important material record of Proto-Tethys oceanic crust northward subduction and back-arc spreading effect in East Kunlun.

Key Words：East section of East Kunlun; Naij Tal Group; Meta-volcanic rocks; LA-ICP-MS zircon U-Pb age; Geochemistry; Tectonic environment