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Crustal Growth in the Northeastern North China Craton: Constraints from the Neoarchean Magmatism in the Liaoning Province, China

HAO Leran[1], YANG Debin[1, 2, *], FENG Yazhou[1] and XU Wenliang[1, 2]

[1] *College of Earth Sciences, Jilin University, Changchun 130061*
[2] *Key Laboratory of Evaluation of Mineral Resources in Northeast Asia, Ministry of Natural Resources, Changchun 130061*

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Abstract: Zircon LA-ICP-MS U-Pb geochronology, trace elements, whole-rock geochemistry and zircon Hf isotope study of the Neoarchean granitic rocks in the Liaoning area provides an important constraint for the exploration of the Precambrian crustal growth and evolution in the northeastern North China Craton. The dating results of magmatic zircon show that, the protoliths of the Diaoyutai monzogranite, Chengzitan amphibole quartz diorite in the western Liaoning area and the Anbo granitic gneiss in the southern Liaoning area respectively formed in 2519±9 Ma, 2505±10 Ma and 2519±11 Ma. That is, they all formed in the late Neoarchean. The Neoarchean granitic rocks in western Liaoning and southern Liaoning are characterized by high SiO_2, low Fe_2O_3 and MgO, classified as part of high potassium calc-alkaline granites with quasi-aluminum to weak aluminum. Enriched in LREE and LILE, depletion in HREE and HFSE, with weakly negative Eu anomalies and Sr, P, Ti deficit. All of the magmatic zircon have positive $\varepsilon_{Hf}(t)$ values, ranging from 0.4 to 6.1. The variation of T_{DM2} is in the range of 2618 ~ 2888 Ma. The Neoarchean granitic rocks in western Liaoning and southern Liaoning originated from the partial melting of Nascent lower crust under mantle-derived magmatic under invasion and formed in extensional tectonic setting.

Key words: granitic rocks, Neoarchean, petrogenesis, Liaoning, North China Craton

The North China Craton (NCC) is one of the largest Archean cratons in the world. The western to southern Liaoning area is located in the northeast NCC. There are a lot of Precambrian rocks in this area. The Neoarchean granitic rocks in this area are divided into Suizhong granites in western Liaoning, felsic gneiss and other migmatites in southern Liaoning. However, recent studies have shown that there are some magmatic complexes in the Archean mixed rocks, which have long been considered to be the basement of the NCC (Yang et al., 2008; Zhou et al., 2015; Zhang et al., 2016). In addition, their petrogenesis is still controversial. In view of this, Zircon LA-ICP-MS U-Pb geochronology, trace elements, whole-rock geochemistry and zircon Hf isotope study of the Diaoyutai monzogranite in Xingcheng area of western Liaoning, the Chengzitan gneisses and Anbo granitic gneisses in Dalian area of southern Liaoning Province, has been carried out in this paper, and then discuss the Precambrian crustal growth and Neoarchean tectonic evolution in eastern North China craton.

In the three samples from west Liaoning to south Liaoning, zircons are of short column or long column shaped, show idiomorphic or hypidiomorphic granular structure, with clear internal structure, typical magmatic oscillatory growth zoning and narrow metamorphic edge of individual zircon. Combined with the relatively high Th/U ratio of (0.3-1.75), suggesting a magmatic origin. The results of $^{207}Pb/^{206}Pb$ weighted average age of magmatic zircon indicate that Diaoyutai monzogranites (LDY01) formed in 2519 Ma, Chengzitan gneisses (16L25) formed in 2505 Ma, and Anbo granitic gneisses (17L01) formed in 2519 Ma. All of them were formed in the late Neoarchean.

Diaoyutai monzogranite rocks (LDY01) have a high SiO_2 content ranging from 73.05 to 73.38 wt.%, a loss of CaO (0.84 to 0.85 wt.%), with Na_2O+K_2O of 8.89 to 9.11 wt.% and a sodium-rich (Na_2O of 3.48 to 3.62 wt.%, Na_2O/K_2O of 1.52 ~ 1.55), the content of potassium is relatively high (K_2O up to 5.49 wt.%), and poor in Fe, Mg. The Anbo granitic gneisses (17L01) and Chengzitan gneisses (16L25) have similar major elements, but lower content of K_2O (2.64 to 3.52 wt.%) and higher content of Na_2O (6.01 to 7.57 wt.%), besides the content of Al_2O_3 was higher (15.31 to 18.22 wt.%), the content of MgO (1.08 to 2.83 wt.%) was poor. The TAS diagram shows that the samples are located in the monzogranit, quartz monzonite and granite areas, which are a set of medium-acid granitic rocks with the characteristics of rich silicon, rich in alkali, poor iron, magnesium, aluminum and depleted titanium, classified as part of high potassium calc-alkaline granites with quasi-aluminum to weak aluminum (Fig. 1).

The chondrite-normalized REE patterns show that the three groups of samples have similar REE distribution pattern. They are rich in LREE and are deficient in HREE with weakly negative Eu anomalies or no anomaly (Fig. 2a). Trace elements also have similar characteristics, enrichment of Rb, Ba of LILE, deficient in HFSE Nb, Ta and P, Ti, with obvious positive Pb anomaly, they all show the attributes of

* Corresponding author. E-mail: yangdb@jlu.edu.cn

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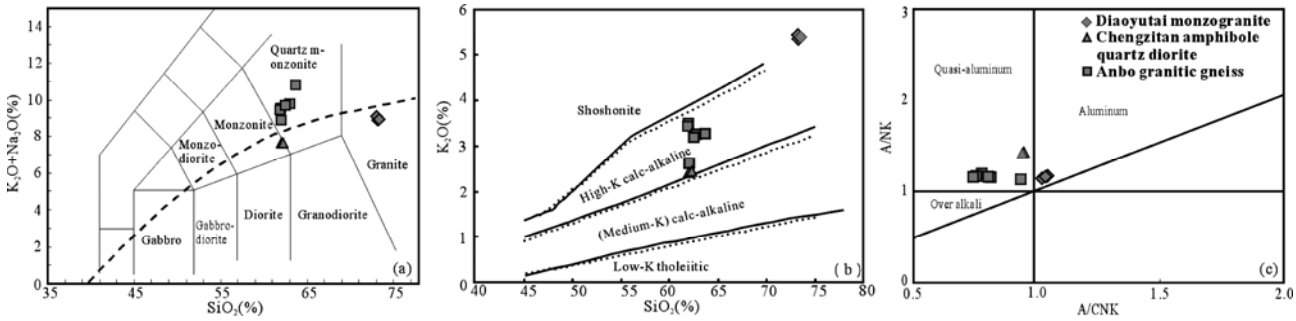

Fig. 1. Variability plot of major element for the Neoarchean granitic rocks.

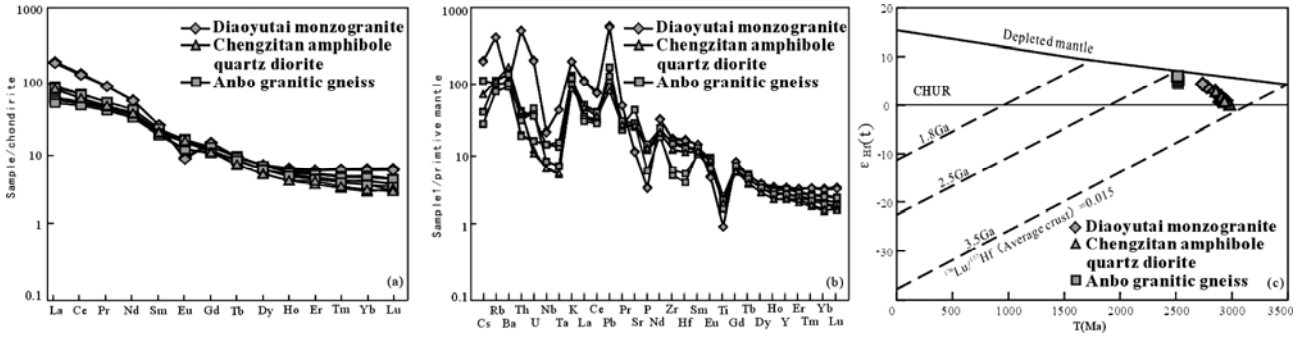

Fig. 2. Chondrite-normalized REE patterns (a) primitive mantel-normalized trace element spider diagrams (b) and Zircon Hf isotopic features (c) for the Neoarchean granitic rocks

shell source (Fig. 2b). At the same time, three groups of samples also have similar $\varepsilon_{Hf}(t)$ values, in which Diaoyutai granite of 1.0 to 4.5, Anbo granitic gneiss of 4.5 to 6.1, Chengzitan gneissic granodiorite of 0.4 to 3.1, both positive (Fig. 2c). Combined with relatively high contents of Y and Yb, depleted of Sr, and Nb/Ta ratio of 8.53 to 8.75, which accords with the elemental composition of the lower crust. It is suggested that Neoarchean granitic magma originated from partial melting of juvenile crustal material in Liaoning area.

The K_2O content of granitic rock samples in the western and southern Liaoning Province is high, poor in Mg, Cr, Ni, and Sr. It is characterized by arc magma and is lower than the original mantle Nb/Ta ratio as a whole. In the primitive mantel-normalized trace element spider diagrams (Fig. 2b), the samples showed obvious negative anomalies of Nb, Ta. The above results indicate that the formation of granitic rocks in the research area may be related to the plate subduction environment. In the diagram of tectonic environment, the samples are projected in the area of volcanic arc granite and syncollisional granite. In addition, the results of zircon saturation temperature calculation show that the granitic rocks in the study area are mostly "cold" granites, and there are more residues in the source area, the formation of which is mainly related to the addition of fluid. The average temperature of the Anbo granitic gneiss is 826 ℃, and there are few residues in the source region. The formation of the gneiss may be related to the under invasion of mantle-derived materials (Wu et al., 2007). The Neoarchean granitic rocks in western Liaoning and southern Liaoning originated from the partial melting of Nascent lower crust under mantle-derived magmatic under invasion and formed in extensional tectonic setting.

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About the first author

Hao Leran, male; born in 1996 in Changchun City, Jilin Province; graduate student; student of College of Earth Science, Jilin University; Email: 975666920@qq.com

About the corresponding author

Yang Debin, male, born in 1979 in Suibin City, Heilongjiang Province; professor; graduated from Jilin University; Email: yangdb@jlu.edu.cn, phone: 13504308830