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Precambrian Mantle Characteristics as Recorded by the Episodic Mafic Magmatism in the Liaodong Peninsula

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1 Introduction

Mafic rocks are widespread throughout the Liaodong Peninsula and vicinity, northeastern North China Craton, providing important constraints on their mantle source characteristics of individual episodes, as they have distinct geochemical and even isotopic characteristics that record the tectonic setting during their formation. At least eight mafic magmatic events were recognized, e.g., three of the early Precambrian (the Neoarchean, the Middle Paleoproterozoic and the Late Paleoproterozoic), two of the late Precambrian (the Middle Mesoproterozoic and the Neoproterozoic) and three of the Phanerozoic (the Late Triassic, the Middle Jurassic and the Early Cretaceous) (Li and Chen, 2015, 2016). In this contribution, we mainly focused on three episodes of the Precambrian mafic magmatism, viz. the Neoarchean, the Paleoproterozoic and the Mesoproterozoic.

2 Spatial-temporal Distribution and Geochemistry of the Precambrian Mafic rocks

Neoarchean basalts are mostly distributed in the TTG, with some in the quartz diorite and a few in the quartz monzodiorite batholiths. The basalts are preserved as (pyroxene) amphibolites and outcropped as deformed layers generally about ten centimeters to fifty meters thick in the supracrustal sequences. They are commonly dark-colored and foliated, with a fine- or medium-grained texture. Zircon SHRIMP and LA-ICP-MS U-Pb dating of the basalts indicates that they erupted at 2545–2510 Ma and were subsequently metamorphosed at 2491–2486 Ma, similar to the formation ages and timing of metamorphism of widespread Neoarchean TTG. On the basis of chondrite

normalized REE patterns, the basalts can be further divided into two types, viz. the depleted and the enriched. The depleted basalts plot along the same mixing array as the late Archean basalts elsewhere and most samples plot towards deep depleted mantle or enriched component, in contrast with the enriched all falling into the arc-related basalt field. The depleted basalts show geochemical characteristics of mixing between oceanic plateau basaltic and arc-related basaltic magmas, whereas the enriched may reflect contribution of an arc-like fertile sub-continental lithospheric mantle source (Fig. 1). That is to say, the rising mantle plume head may govern the genesis of the depleted basalt, suggesting plume–lithosphere interaction (Li and Wei, 2017).

Paleoproterozoic mafic rocks occurring as the gabbro/diabase dyke and basalt are massive, and have undergone greenschist–amphibolite facies metamorphism and generated a locally gneissic texture. Zircon LA-ICP-MS and SIMS U-Pb dating of the mafic rocks indicates that they were fixed at 2.2–2.1 Ga and metamorphosed at ca. 1.9 Ga, similar to the formation ages and timing of metamorphism of volcanics within the Jiao–Liao–Ji Belt. Their major and trace element compositions suggest tholeiitic to calc-alkaline series in the north and calc-alkaline in the south. The mafic rocks plot between the primitive mantle and enriched component (Fig. 1), indicating a somewhat enriched mantle source and the enrichment of the mantle source beneath the Liaodong Peninsula was probably caused by metasomatism of subduction zone fluids/melts (Li and Chen, 2014).

Mesoproterozoic gabbro/diabase dykes intruded into both Archean basement and Mesoproterozoic cover rocks. These undeformed and unmetamorphosed dykes are dominated by plagioclase and clinopyroxene, with minor amounts of orthopyroxene and hornblende. Several methods (e.g., zircon LA-ICP-MS and SHRIMP dating,

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and baddeleyite SIMS and LA-ICP-MS dating) of dating have yielded emplacement ages of 1.3–1.2 Ga. They mainly plot coherently within or near the OIB, and some samples plot towards N-MORB field (Fig. 1). The majority are geochemically classified as continental flood basalts, with some being either continental flood basalts or alkali basalts that formed within continental rift settings or have E-MORB compositions. The alkaline rocks have OIB affinities and may have been generated by a low degree of partial melting of a depleted region of the asthenospheric mantle with limited involvement of the lithospheric mantle, a process that is typical of magmatism within a rift (Li and Chen, 2016; Li et al., 2016).

The Precambrian mafic rocks in the Liaodong Peninsula witnessed a transformation from Neoproterozoic plume head–lithosphere interaction mantle source, Paleoproterozoic sub-continental lithospheric mantle source metasomatized by subduction zone fluids/melts, to Mesoproterozoic plume tail/asthenospheric–lithospheric mantle interaction mantle source.

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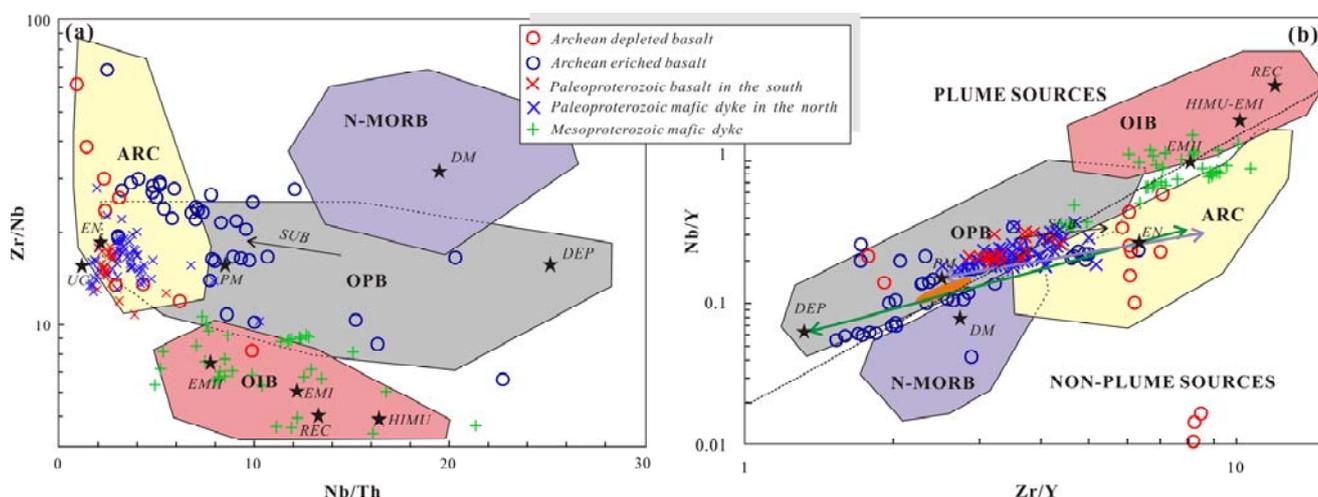


Fig. 1 Plots showing the distribution of the mafic rocks on the (a) Nb/Y vs. Zr/Y and (b) Zr/Y vs. Nb/Y diagrams.

Abbreviations: UC, upper continental crust; PM, primitive mantle; DM, shallow depleted mantle; HIMU, high μ (U/Pb) source; EM1 and EM2, enriched mantle sources; ARC, arc-related basalts; N-MORB, normal mid-ocean ridge basalt; OIB, oceanic island basalt; OPB, oceanic plateau basalt; DEP, deep depleted mantle; EN, enriched component; REC, recycled component. Black arrow–subduction (SUB); Green arrow – a plume mixing array for late Archean non-arc basalts; Purple arrow – a plume mixing array for early Archean non-arc basalts. Green arrow – a plume mixing array for late Archean non-arc basalts; Purple arrow – a plume mixing array for early Archean non-arc basalts. The yellow shaded field represents the distribution of the Kiziba Formation basalts that were derived from partial melting of a primitive mantle source with narrow elemental ratios (modified after Li and Wei, 2017).