REE Geochemistry of Precambrian Metamorphic Rocks in Wutaishan Region

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Abstract

The metasedimentary-volcanic series of the Wutai and Hutuo groups experienced regional metamorphism and thus turned into moderate to low-grade metamorphic rocks. REE abundances and REE distribution patterns in the Shizui and Taihuai Subgroup metasedimentary-volcanic rocks are typical of the Archean, whereas the Gaofan Subgroup and the Hutuo Group show post-Archean REE geochemical characteristics. Five types of REE distribution pattern are distinguished: (1) rightward inclined smooth curves with little REE anomaly (Eu/Eu* = 0.73–0.95) and heavy REE depletion (e.g., the Late Archean metasedimentary rocks); (2) rightward inclined V-shaped curves with sharp Eu anomaly (Eu/Eu* = 0.48–0.76) and slightly higher ∑REE (e.g., the post-Archean metasedimentary rocks); (3) rightward inclined steep curves with negative Eu anomaly (Eu/Eu* = 0.73–0.76) and the lowest ∑REE (e.g., the post-Archean dolomites); (4) rightward inclined, nearly smooth curves with both positive Eu anomaly and unremarkable positive Eu anomaly (Eu/Eu* = 0.95–1.25) (e.g., the meta–basic volcanic rocks); and (5) rightward inclined curves with Eu anomaly (Eu/Eu* = 1.09–1.19) and heavy REE depletion (e.g., the meta-acid volcanic rocks). Strata of the two groups are considered to have been formed in an island-arc belt—an instable continental petrogenetic environment.

Located in the central part of the North China continental platform, the Wutaishan region is a typical area for the study of Early pre-Cambrian geology in China. The aim of this paper is to discuss the REE characteristics of the Wutai and Hutuo Group metasedimentary-volcanic rocks with the emphasis on their REE abundances and REE distribution patterns. Also discussed in this paper is the petrogenetic environment on the basis of REE data.

Geological Setting and Petrological Characteristics

The stratigraphic sequence of pre-Cambrian metamorphic rocks in the Wutaishan region is shown in Table 1. As the main part of the metamorphic series in the Wutaishan region, the Wutai Group is a suite of moderate- to low-grade metamorphic rocks which have undergone multi-episodic regional metamorphism and local thermodynamic metamorphism. The Shizui Subgroup has reached amphibolite-facies metamorphism, while the Taihuai and Gaofan subgroups have reached greenschist-facies and semi-greenschist-facies metamorphism, respectively. These three subgroups all stretch out in the direction from NE to SW and tend to progressively diminish. Their metamorphic grade decreases in the same direction as well (Fig. 1).

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1) The Shizui Subgroup mentioned here does not include the Banyukou Formation which has reached semi-greenschist-facies metamorphism and belongs to the Doucun Subgroup of the Hutuo Group. According to Yuan Guoqing et al. (Scientific Information on Shanxi Geology, 2(1985), the Banyukou Formation should be put into the Dashiling Formation of the Doucun Subgroup.
The principal rock types include amphibolite, plagioclase amphibolite, granulite, gneiss, greenschist, sericite-quartz schist, quartzite, phyllite, etc. The restoration of the original rocks is based on their geological field attitude, rock assemblage, texture and structure in conjunction with the petrochemical data available. The original rocks of the granulite are predominated by argillo-sandy rocks and those of the amphibolite, plagioclase amphibolite and greenschist by basic volcanic lavas, i.e., basaltic rocks. They represent a suite of volcano-sedimentary formations with volcanic rocks being dominant. The Hutuo Group is a sedimentary series intercalated with basic volcanic rocks, the principal part of which has undergone a regional metamorphism of greenschist-subfacies. The upper subgroup consists of metamorphic sandstone and conglomerate; the middle subgroup is composed mainly of thick-layered dolomitic carbonate rocks with phyllite occurring at the top; the lower subgroup is made up of metamorphic conglomerate, quartzite, slate and meta-basic volcanic rocks. These three subgroups are distributed largely within the bounds of Wutai County and stretch roughly from NE to SW. Clastic rocks, argillaceous rocks, carbonate rocks and basic volcanic rocks can be distinguished in terms of their primary compositions.

The average values of main chemical components in the meta-basic volcanic rocks of this region are listed in Table 2. As can be seen from AFM diagram and SiO$_2$/(FeO)/MgO and FeO/(FeO)/MgO diagrams, there are not only projected points representing the tholeiite series, but also those representing the calc-alkali basalt series. The basic volcanic rocks from this region all fall onto the field of island-arc tholeites in the $F_1$-$F_2$-$F_3$ diagram (Fig. 2). The FeO (total iron)-MgO-Al$_2$O$_3$ triangular diagram can be used to characterize the continental basalts. This shows that in this region are developed not only the calc-alkaline volcanic series, but also the tholeiite series. As viewed from its composition, the environment in which the calc-alkaline volcanic series formed is equivalent to the mature island-arc environment described by Miyashiro. According to Goodwin, the island-arc volcanic rocks are predominantly of calc-alkaline volcanic series. In the opinion of Miyashiro,

![Diagram](image_url)

Fig. 2. $F_1$-$F_2$-$F_3$ diagram of the pre-Cambrian basic volcanic rocks in the Wutaishan region. (after Pearce, 1976; the numbers in the figure are the same as the sequence numbers in Table 2).

- OFB — ocean-floor basalt
- CAB+LKT — calc-alkali basalt and island-arc tholeiite
- SHO — potash basalt
- WPB — basalt within the plate.

tholeiite-series volcanic rocks are almost ubiquitous in all tectonic environments such as ocean ridges, marginal seas, oceanic island arcs, island arcs and stable continents.