**Formation of the Super-large Bayan Obo Fe-REE-Nb Deposit, Inner Mongolia**

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1 Introduction

The Bayan Obo Fe-REE-Nb ore deposit in the Inner Mongolia, North China, the largest light REE deposit in the world, has drawn great interests of many geologists worldwide. Since the discovery of the main orebody in 1927, several major studies have been carried out over the last 80 years, focusing on the mineral constituents, geochronology, and geochemistry of this giant deposit. However, the genesis of this deposit(s), including its potential resources, particularly with regard to the mechanism of REE enrichment, still remains much debated (Yang et al., 2009; Lai and Yang, 2013).

2 Regional Geology

The Bayan Obo Fe-REE-Nb deposit is located in the Inner Mongolia Autonomous Region, north China. It is hosted in Palaeo- to Mesoproterozoic sediments of the Bayan Obo Group. The Bayan Obo Group, consisting of low grade sandstones, siltstones, limestones and dolomites, has been divided into two parts, a lower regressive series (H1–H10) and an upper transgressive series (H11–H17), which comprises six formations, i.e., Dulahala Formation (H1–H3), Jianshan Formation (H4–H5), Halahuoqite Formation (H6–H8), Bilute Formation (H9–H10), Baiyinbaolage Formation (H 11–H12), and Hujiertu Formation (H13-H17) (IGCAS, 1988).

3 Genesis of Dolomite Formation

The H8 dolomite is about 400 meters thick, extending across the Ghobi desert with a total length of about 18 km from east to west, with a width of 2-3 km. The H8 dolomite marble formation has been divided into four sub-types sedimentary limestone and dolostone (H8(s)), deformed mineralized coarse-grained dolomite marble (H8 (c)) and fine-grained dolomite marble (H8(f)), and carbonatite dykes (H8(d)) (IGCAS, 1988; Yang and Le Bas, 2004). The sedimentary carbonate rocks (H8s) north of the Kuangou fault zone show weak deformation without obvious metamorphism. They occur together with quartz sandstone, sandstone and shale, comprising the Mesoproterozoic Bayan Obo Group. In contrast, the mineralized fine- to coarse-grained dolomitic marbles (H8 (f) and H8(c)), occurring to the south of the Kuangou fault zone, are sheared, deformed and metamorphosed. Dolomite in the main ore-bearing unit (H8(f)) occurs with magnetite, monazite, bastnaesite, and parsite. Fine-grained monazite occurs as fracture fillings in dolomite. The REE contents of the H8 dolomite mainly vary from 1 wt% to several percents, therefore, the H8 dolomite marble in Bayan Obo can be described as a REE ore deposit (Lai et al., 2012).

The origin of H8 dolomite is debated. As previous studies shown, both sedimentary carbonate and carbonatitic dykes are closely associated with mineralization. Based on the wide distribution of fenitization within H8 dolomite and its neighbouring rocks, it is considered as crystallization of carbonatitic magma in origin. In fact, carbonatite dykes, associated fenite aureoles and alteration similar to those associated with Fe-REE-Nb ore bodies at Bayan Obo, are widely distributed in Bayan Obo. These alterations show alkali silicate assemblages containing aegirine-augite, (magnesio-) riebeckite, (magnesio-) arvedsonite, and phlogopite, accompanied by various amounts of apatite, albite and quartz with very high contents of REE, normally ranging from 1% to several percents (Zhang et al., 1995). Interestingly, no carbonatite dykes within the
H8 dolomite has been identified so far. Previously defined carbonatitic sub-type in H8 was mainly based on chemical compositions (e.g., Yang and Le Bas, 2004). By contrast, the similarities between micrite carbonate rocks (dolomitic-limestone) and the carbonate-host rock near the Bayan Obo ore deposit were taken as evidence for that it is sedimentary carbonate (Qiao et al., 1997).

4 Ages of Fe-REE-Nb Mineralization

The ages of the Bayan Obo deposits and carbonatite dykes nearby so far published range from 2.0 to 0.4 Ga. Most ages are Sm-Nd isochron ages published in the Chinese literatures, with a clear peak at 1.2-1.6 Ga (IGCAS, 1988; Fan et al., 2002; Liu et al., 2005). Monazite internal Th-Pb isochrons gave Caledonian ages ranging from 398 to 555 Ma (Wang et al., 1994); A zircon U-Pb age of 1925 ± 8 Ma, measured on a Bayan Obo carbonatite dyke was taken as the age of carbonatite magmatism (Fan et al., 2002). Sm-Nd mineral isochrons yield Mesoproterozoic ages of 1640 Ma (Ren et al., 1994; Zhang et al., 2003) and 1250 Ma (Zhang et al., 2003), and Sm-Nd whole rock isochrons yield Mesoproterozoic ages of 1580 Ma (Yuan et al., 1992) and 1286 Ma (Zhang et al., 2003), respectively. Others argued that ~2.0 Ga might be the age of the host rock (Le Bas, 2006). Late Palaeoproterozoic zircon ages of 1.9-2.0 Ga are now well constrained as the basement age, using mineral inclusions and trace element patterns (Liu et al., 2008). This age is close to but slightly older than the Late Palaeoproterozoic ages of 1.8 -1.9 Ga, widely spread in the North China craton.

5 Model for the Fe-REE-Nb Mineralization

On the geochemical discussion, we suggest a new model for the REE mineralization in the Bayan Obo region (H8 dolomite, Fe-REE-Nb ore bodies and the related fenitization), where we favor from the metasomatism caused by extreme REE-enriched fluids of mantle derivation channelled upwards along the regional rift after the formation of the sedimentary rocks (H1-H9). This model accords to the fact that Mesoproterozoic rifting was well developed along the north margin of the North China craton, known as the Langshan-Bayan Obo rift (Wang and Li, 1992), which resulted in Proterozoic sedimentation in an oceanic environment. As the rifting developed further, sedimentary rocks in the Bayan Obo region underwent large-scale thermal effects and metasomatolism along the regional rift structure. The wide distributing ages of 0.4–0.5 Ga indicate that Caledonian tectonic event was involved in another major REE-Nb (probably Fe) mineralization caused by the subduction of the Siberian plate to North China block. Considering the similarities between ore-bearing dolomitic rocks and the Wu carbonatite dyke, e.g., REE concentrations, trace-element patterns, the ore-forming fluids is probably related to carbonatitic magmas. Metasomatism of the sedimentary rocks by fluids genetically related to carbonatitic magmas could have repeatedly occurred through time to form the so-called Fe-Nb-REE deposit of the Bayan Obo region.

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References