INTRODUCTION TO REE METALLOGENY OF THE MONGOLIA

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Introduction

Rare earths already play a critical role in the electronics, automotive, environmental protection and petrochemical sectors. The use of rare earths is expected to grow in permanent magnets, consumer electronics, and automotive catalytic converters. In particular demand growth will be seen in the automotive industry as more electric components replace hydraulic systems and NiMH rechargeable batteries are used in hybrid vehicles.

In the past decade China has become the dominant supplier of ores (with over 90% of the total supply capacity) as well as the dominant processor and user of refined compounds. However, recent government regulations will reduce the amount of rare earths extracted from China. Supply of high demand elements cannot be met solely by China and will require the exploitation of other sources. With demand for most of the rare earths expected to grow over the next five years at 10% per annum, as well as supply expected to be limited within China to lower than current production levels. It is expected that the evaluation and research of rare earths in Mongolia should be studied in more detail.

Therefore, we are introducing general types of rare earths mineralization and metallogenesis as well as rare earths resources of Mongolia.

Types of rare earths mineralization of Mongolia

Rare earths are relatively weakly studied in Mongolia, and result of various geological studies indicate that there are 5 deposits, 71 occurrences and more than 260 mineralized areas. On the basis of detailed study of ore mineral assemblage and geological characteristics rare earth mineralization of Mongolia is divided into 5 groups (Table 1): REE related with alkaline granite; REE related with syenite and nepheline; REE related with carbonatite; Adsorption (Uranium) type REE and REE bearing placer.

REE (Nb-Zr-REE) mineralization related with alkaline granite include the Khalzan Buregtei deposit in western Mongolia, the Khan Bogd deposit in southern Mongolia, and a number of occurrences in western and southern Mongolia. The deposit type generally associated with highly fractionated magmatic phases including peralkaline pegmatite. The host granites are composed of potassium feldspar, quartz, albite, arfvedsonite, aegirine, fluorite, and various REE minerals, such as elpidite, zircon, pyrochlore, monazite, REE fluorcarbonate, polylithionite and others.

Quartz-epidote metasomatic rocks contain zircon, fergusonite, allanite, chevkinite and titanite in vein-like zones. Accessory minerals include amphibole, magnetite, zircon, epidote, ilmenite, fluorite, beryl, chevkinite, pyrite, and galena. REE pegmatites and quartz-fluorite veins may also occur. Alkaline granite related REE mineralization subdivided into four main mineral assemblages:

Columbite $(Mg,Fe^{2+},Mn)(Nb,Ta)_2O_6$– pyrochlore $(Na,Ca)_2Nb_2O_6(OH,F)$– zircon $(ZrSiO_4)$ - elpidite $(Na_2ZrSi_6O_{15}\cdot 3(H_2O))$- fluorite (CaF_2)

Pyrochlore $(Na,Ca)_2Nb_2O_6(OH,F)$ –columbite $(Mg,Fe^{2+},Mn)(Nb,Ta)_2O_6$- zircon $(ZrSiO_4)$– xenotime $(Yb(Y)PO_4)$

Zircon $(ZrSiO_4)$– pyrochlore $(Na,Ca)_2Nb_2O_6(OH,F)$– elpidite $(Na_2ZrSi_6O_{15}\cdot 3(H_2O))$- arm-

strongite $CaZrSi_6O_{15}•3(H_2O)$

Zircon ($ZrSiO_4$)– fergusonite ($(Ce,La,Nd)NbO_4$) – columbite $(Mg,Fe^{2+},Mn)(Nb,Ta)_2O_6$)-pyrochlore $(Na,Ca)_2Nb_2O_6(OH,F)$– chevkinite $(Ce,La,Ca,Th)_4(Fe^{2+},Mg)_2(Ti,Fe^{3+})_3Si_4O_{22}$

REE mineralizations related with nepheline syenite is mainly distributed in the northern Mongolia and associated with gabbro, ijolite, urtite, foyaite, syenite and nepheline syenites. The main examples are the Ujigiin Gol and Arasan Gol areas. The nepheline-rich rocks are composed of nepheline and pyroxene. Nepheline content ranges from 30% (in ijolite) to 90 persent (in urtite). Other minerals in nepheline-bearing rocks are microcline, lepidomelane, muscovite, and cancrinite. Alteration consists of albite and potassium feldspar replacement. This type is subdivided onto three ore mineral assemblages:

Cyrtolite (High U zircon) – pyrochlore $(Na,Ca)_2Nb_2O_6(OH,F)$ – fluorite (CaF_2) - eudialyte $Na_4(Ca,Ce)_2(Fe^{2+},Mn,Y)ZrSi_8O_{22}(OH,Cl)_2$

Pyrochlore $(Na,Ca)_2Nb_2O_6(OH,F)$– columbite $(Mg,Fe^{2+},Mn)(Nb,Ta)_2O_6$)– zircon ($ZrSiO_4$) xenotime ($Yb(Y)PO_4$)– gagarinite $NaCaY(F,Cl)_6$

Zircon ($ZrSiO_4$) – britholite $((Ce,Ca,Th,La,Nd)_5(SiO_4,PO_4)_3(OH,F))$ - rinkolite $(Na(Na,Ca)_2(Ca,Ce,Y)_4(Ti,Nb,Zr)(Si_2O_7)_2(O,F)_2F_3)$- pyrochlore $(Na,Ca)_2Nb_2O_6(OH,F)$ eudialyte $Na_4(Ca,Ce)_2(Fe^{2+},Mn,Y)ZrSi_8O_{22}(OH,Cl)_2$ – monazite $((Ce,La,Nd,Th)PO_4)$

Table 1. Types and main mineral assemblages of rare earth mineralization of Mongolia

	Ore types	Geology	Main mineral assemblage	Examples
I	Alkaline granite related REE	Rare metal bearing pegmatoid granite	Columbite-pyrochlore-zircon-elpidite-fluorite	Khalzan buregtei, Uran khem etc
		Rare metal bearing albitite	Prochlore- columbite-zircon-xenotime	Ulaan tolgoi, Khadan khar uul etc
		Rare metal bearing pegmatite	Zircon-pyrochlore-elpidite-armstrongite	North, Khiid, Argal
		Rare metal bearing pegmatite metasomatite	Zircon-fergusonite-columbite-pyrochlore-chevkenite	Tsahir khudag
II	Alkaline syenite and nepheline related REE	Alkaline syenite, nepheline syenite	Cyrtolite-pyrochlore-eudialyte-fluorite	Khondlon, maikhant etc
		Rare metal bearing alkaline syenite,nepheline and albitite	Zircon-columbite (zircon-xenotime - gagarinite)	Yarkhis, shar tolgoi etc
			Zircon-britolitr-rincolite-eudalite-pyrochlore-monazite	Khavirga khudag, unnamed etc
III	Carbonatite related REE	Rare metal bearing carbonatite (pluton)	Synchisite-bastnaesite-magnesite-fluorite	Luugiin gol, olgii etc
		Rare metal bearing carbonatite (volcan-pluton)	Bastnaesite-fluorite-apatite-magnetite	Mushgai khudag, khotgor etc
			Celestite-barite-fluorite-rare earth	Bayankhoshuu, Mushgai-2 etc
IV	Adsorption (uranium) type REE	Sediment hosted rare earth and uranium	Rare earth-uranospinite	Kharaat, Khavtsal etc
			Rare earth-nasturan-coffinite	Narst, Dorvoljin etc
V	REE bearing placer	Placer accumulation of rare earths and rare metal	Monazite	Ar khuruut, Dund bayan etc

REE mineralization related with carbonatite includes REE,P-Sr-Ba-fluorite-Pb occurrences that are associated with late Mesozoic alkaline volcanic-plutonic rocks. These complexes occur in intraplate areas and are controlled by major faults and anorogenic rifts. Typical examples are the Mushgai Khudag and Lugiin Gol occurrences in southern Mongolia. The main deposit types are (1) carbonatite and eruptive trachyte breccia with a carbonatite matrix containing of 0.1 to 0.8% REE, or are enriched in light REE and contain up to 18% Sr; (2) magnetite-apatite rocks with REE content of 1.0 to 14.5%; and (3) bastnaesite carbonatite with a REE content of 1 to 18%. In all three subtypes, the ore minerals include bastnaesite, carbonate, fluorite, celestine and barite, cerrusite, magnetite, apatite, and monazite. Other carbonatite occurrences are those as Bayan Khushuu, Khotgor, Ulgii, and Tsogt Ovoo. In these areas, the carbonatites occur as dikes up to 1-2 m wide within plutons or host rocks of late Paleozoic volcanic and sedimentary rocks. The carbonatites are composed of calcite with mica, apatite, fluorite, bastnaesite, synchizite, rutile, zircon, and sulfides. Main mineral assemblages of carbonatite related REE mineralization is:

Synchysite ($Ca(Y,Nd,Ce)(CO_3)_2F$) – bastnasite ($Ce,La,Y(CO_3)F$) – magnetite ($Fe^{3+}{}_2Fe^{2+}O_4$) – fluorite (CaF_2)

Bastnasite ($Ce,La,Y(CO_3)F$) – fluorite (CaF_2) – apatite ($Ca_5(PO_4)_3(OH,F,Cl)$) – magnetite ($Fe^{3+}2Fe^{2+}O_4$)

Celestine ($SrSO_4$) – barite ($BaSO_4$) – fluorite (CaF_2) – REE

Adsorption (Uranium) type REE mineralization is known at the eastern Mongolia and relatively weakly studied. There are two main ore mineral assemblages:

REE- uranospinite $(Ca(UO_2)_2(AsO_4)_2 \cdot 10(H_2O)$

REE – nasturan (UO_2) – coffinite $(U(SiO_4)_{1-x}(OH)_{4x}$

Main example of REE- uranospinite type is Kharaat deposit in south east Mongolia, which is situated in the center of Choir depression. Narst deposit of Sainshand depression is main member of REE – nasturan – coffinite type mineralization.

REE bearing placer is almost not studied and found only two locations: Ar khuruut-Dund Bayan and Tsagaan Chuluut. These occurrences are situated within monazite bearing granitic rock and making small placer accumulation which might be derived from the granite.

Metallogenesis of REE mineralization of Mongolia

REE mineralizations of Mongolia are divided into three main metallogenic belts (Figure 1):

- Tuva-Hubsugul metallogenic belt
- Marginal area of central Mongolia
- South Mongolian metallogenic belt.

Tuva-Hubsugul metallogenic belt includes rare metal and rare earth element bearing alkaline granites in Khan Khokhii and Hubsugul area together with Achit nuur, Tsagaan Shiveet and Tuva area. This metallogenic belt is subdivided into Deluun-Altan Khokhii and Uran Khem – Alag Erdene sub zones.

Deluun – Altan Khokhii occupies western part of Tuva-Hubsugul belt and consists of Khalzan Tsakhir, Ulaan Tolgoi – Khan Khokhii, Khondlon and Shar Tolgoi ore districts.

Uran Khem – Alag Erdene occupies east part of Tuva and consists of alkaline granite, nepheline and other alkaline complexes with REE mineralization.

Marginal area of central Mongolia occupies relatively wide area, surrounding Khangai-Khentei uplift, and subdivided into North Khangai-Selenge sub zone, Sharga – Gobi Altai sub zone and East Gobi – Kherlen sub zone.

North Khangai –Selenge sub zone contains 7 ore districts: South Songino; Oigon – Bulnai; Teshig – Zelter; Egiin davaa-Battsengel; Sant-Dulaanhaan; Lakh uul and Ovoot Undur.

Sharga – Gobi Altai sub zone contains three potential ore districts: Ikh Bogd; Darvi-Serkh and Mushgai – Tsogt ovoo

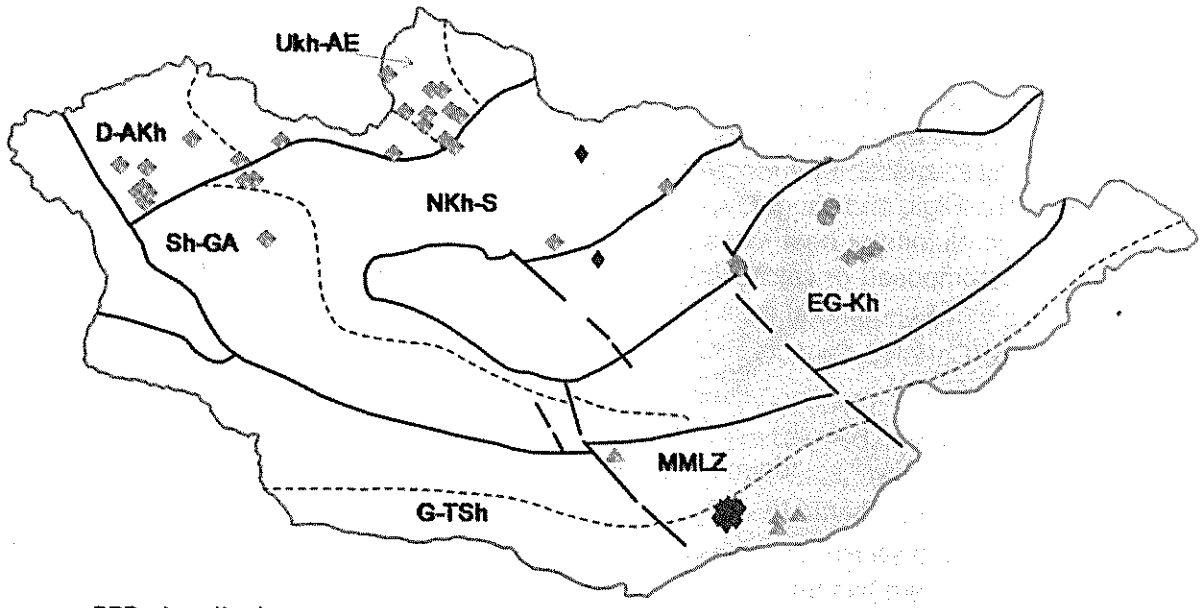

Figure 1. Metallogenic subdivision of REE mineralization of Mongolia

East Gobi – Kherlen sub zone locates at the eastern most part of the belt and contains four potential ore districts: Zaart – Khavirga; Kherlen – Bayan Ulaan; South Kherlen and Mogoi Chuluut

South Mongolian metallogenic belt occupies southern most part of country and subdivided into two main ore zones: Main Mongolian Lineament zone and Gobi- Tein Shan zone.

Main Mongolian Lineament zone contains Baruun Khuurai – Aj Bogd; Ikh Shankhai – Ulgii and Undur naran – Narst potential ore districts.

Gobi- Tien Shan zone contains five potential ore districts: Tsagaan Bogd – Tost; Khar khad – Khan Bogd; Lugiin gol – Khutag uul; Ulaan badrakh –Zamiin Uud and Nukht davaa.