Rare earth deposits, resource assessment, and actual situation of mining

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Rare earth elements have been produced from a wide variety of mineral deposit types. These include deposits formed in high-temperature magmatic environments and low-temperature surface environments. The important types of rare earth deposits that have supplied or have potential to supply rare earth are carbonatite, hydrothermal/magmatic-iron, placer, alkaline-rock related, and ion-absorption deposits.

Carbonatite deposits consist of rare-earth rich carbonatite, an igneous rock composed of carbonate minerals such as calcite and dolomite. This type of deposits occurs in rift zones such as eastern Africa in addition to continental crust regions. The carbonatite deposits are represented by Mountain Pass in the U.S.A. and Maonuipin in China, in which major ore minerals are bastnasite, monazite and apatite. Carbonatite deposits are enriched in light rare earths because ore minerals of this deposit type are enriched in lighter rare earth elements.

Hydrothermal/magmatic iron deposits form by crystallization from volatile-rich iron oxide magmas or by precipitation of iron oxides and other minerals in permeable rocks such as breccia and carbonate rocks from iron-rich saline solutions. Magmatic iron deposits are represented by Kiruna in Sweden, and hydrothermal ones by Olympic Dam in Australia and Bayan Obo in China. Major REE-bearing ore minerals are bastnasite, monazite and apatite, which are enriched in LREEs.

Ion-absorption deposits occur in the weathering crusts of REE-enriched granitic rocks on the surface. Due to weathering, clay minerals such as halloysite and kaolinite form from igneous minerals of the granites and these clay minerals adsorb positively charged REEs released from REE-bearing minerals in granites. In general, the weathering ore concentrates REEs two to five times more than the host granites. This deposit type is distributed in southern China, where highly evolved REE-enriched granites are exposed in a humid, warm environment. At present, ion-absorption deposits are the important source for HREEs.

Placer deposits form by mechanical concentration of heavy mineral particles from weathered debris. The common types are beach placers and alluvial placers. Ilmenite and rutile are the main target minerals but zircon, monazite and xenotime are recovered as by-products. Placer deposits are distributed along the coasts of major continents where Precambrian metamorphic and igneous rocks are exposed. The representative placer deposits are Eneabba in western Australia and Andhra Pradesh in India. Although placer deposits are generally enriched in monazite and, hence, LREEs, xenotime-rich placer deposits can supply Y and HREEs.

Alkaline-rock related deposits contain alkaline magmatic deposits and hydrothermal deposits related to alkaline magmatism. Alkaline rocks commonly contain REE anomalies but they are low grade and are not economic in general. Some alkaline rocks enriched in HREEs may become exploitation targets. The hydrothermal deposits related to alkaline magmatism are represented by Strange Lake and Thor Lake in Canada.

The world reserves of REEs are estimated as 88Mt (USGS Mineral Summaries, 2006), which is more than 500 times larger than the 2006 annual production (15,5000t). China supplies more than 90 percents of REEs in the world at present, which are mainly produced from Bayan Obo hydrothermal iron deposit, Maonuipin carbonatite deposits and ion-absorption deposits in southern China. LREEs will be stably supplied from these carbonatite deposits, but HREEs will become short because the production of HREEs heavily depends on ion-absorption deposits in China.