

Rare Earths

James B. Hedrick, rare-earth commodity specialist for the U.S. Geological Survey, has prepared the following information on the rare earths, which have been used commercially since the 1880s.

As if classified as a top-secret project, the rare earths have been shrouded in secrecy. The principal ore mineral of the group, bastnäsite, rarely appears in the leading mineralogy texts. The long names of the rare-earth elements and some unusual arrangements of letters, many Scandinavian in origin, may have intimidated even those skilled in phonics. Somewhat obscurely labeled, the rare earths are neither rare nor earths (the historical term for oxides). They are a relatively abundant group of metallic elements that occur in nature as nonmetallic compounds and have hundreds of commercial applications.

The rare earths are defined as a group of 17 elements, comprised of scandium, yttrium and the lanthanides. The similar radii and oxidation states of the rare earths allows liberal substitution of the rare earths for one another into the crystal lattice sites of minerals. This substitution accounts for their wide dispersion in Earth's crust and the characteristic occurrence as a group of elements within more than 100 minerals. The principal ores of the rare earths are bastnäsite, ion-adsorption lateritic clays, loparite, monazite and xenotime.

Commercial development of the rare earths started with the invention of the incandescent lamp mantle by Auer von Welsbach around 1884. Rare-earth production in Scandinavia was prompted by this invention, which initially was made with the oxides of lanthanum, yttrium and zirconium.

World production of rare earths was estimated at 98,200 metric tons of equivalent rare-earth oxides in 2002. China was by far the largest producer, with 90 percent of the world's total. Lesser amounts came from India, Kazakhstan, Kyrgyzstan, Malaysia, Russia, Ukraine and the United States.

In 2003, there was no rare-earth mine production (lanthanides, yttrium and scandium) in the United States. However, the United States has remained a supplier of bastnäsite concentrates and rare-earth compounds that were previously processed by Molycorp, Inc., a subsidiary of Unocal Corp. Molycorp last mined and processed bastnäsite in 2002 at its Mountain Pass, Calif., mine and was maintaining the operation on standby. Industrial rare-earth products and concentrates are available from Molycorp's stocks.

In 2002, the approximate distribution of rare earths by use was as follows: glass polishing and ceramics, 30 percent; petroleum refining catalysts, 28 percent; metallurgical additives and alloys, 19 percent; automotive catalytic converters, 14 percent; permanent magnets, 3 percent; rare-earth phosphors for lighting, televisions, computer monitors, radar and X-ray intensifying film, 3 percent; and miscellaneous, 3 percent. In 2002, yttrium consumption was estimated to have decreased to 334 metric tons from 473 metric tons in 2001.

The estimated use of yttrium, based on imports, was primarily in lamp and cathode-ray tube phosphors, followed by lasers and electronics, and ceramics and oxygen sensors. Scandium was used primarily in lightweight, high-strength, aluminum alloys for sports and camping equipment,

including baseball and softball bats, bicycle frames, lacrosse stick handles and tent poles. Small amounts of scandium metal or compounds were used in specialty lighting, analytical standards and as target materials in X-ray analysis.

Rare earth principal ores

The principal ores of the rare earths are bastnäsite, ion-adsorption lateritic clays, loparite, monazite and xenotime. Several of the ores occur in unique geologic settings whereas others are found in similar occurrences worldwide.

Monazite was the principal ore of the rare-earth elements and thorium. Since the 1880s and 1890s it has been the source of elements to make incandescent lamp mantles and lighter flint alloys, the earliest commercial applications. Monazite ore is recovered mostly from heavy-mineral sand sedimentary deposits. Early high-cost production in the 1880s was from Sweden and Norway; with lower cost alluvial placer sand production from North Carolina beginning in 1893. Brazilian littoral deposits having higher grades began production in 1895 and India started production in 1911. Monazite's high thorium content has limited its use since the 1990s.

Bastnäsite is the principal ore produced in the world and is enriched in the cerium, lanthanum, praseodymium, neodymium and europium. Bastnäsite was first commercially recovered from the igneous carbonatite at Mountain Pass, Calif., in 1952, primarily for cerium to be used in glass polishing. Europium abundance in the ore allowed for a true red-color phosphor for color televisions in the 1960s. Since 1985, bastnäsite production in China increased dramatically and continued to increase and dominate the market from the 1990s to the present.

The mineral xenotime, was the principal ore of yttrium and the other heavy rare-earth elements. Yttrium was used in phosphors, and combined with zirconium to make high-temperature, high-strength structural ceramics. It also was used in synthesized crystals for lasers. Xenotime is produced from alluvial heavy-mineral sands deposits mined for tin, titanium, and zirconium minerals.

Ion-adsorption lateritic clays from southern China replaced xenotime as the principal source of yttrium and the other heavy rare-earth elements in the 1990s. These intensely weathered clays have rare-earth ions adsorbed into the clay mineral structure.

Loparite is a complex oxide mineral mined in Russia from an alkaline massif. Commercially produced since 1951, loparite occurs in association with alkaline rocks of magmatic origin. It is also known to occur in carbonatites. Loparite has a perovskite structure with coupled substitutions, polymorphism, defect chemistry and a tendency to become metamict.

Originally published as *Geotimes* Mineral Resource of the Month, May 2004
Used with permission.



Sample of rare earth ore with penny for scale. Image from *Minerals in Your World*.