Rare-earth elements in New Mexico

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Introduction

The rare-earth elements (REE) include a group of 15 chemically similar elements called the lanthanide group because lanthanum is the first of the series (Table 1). One of the group, promethium, is a fission product of uranium and occurs in nature only in trace amounts (Adams and Staatz, 1973). Yttrium, although not a lanthanide, is included as a REE because it typically occurs with REE and has similar chemical properties (Fig. 1). All REE, including yttrium, have a valence of 3 and similar ionic radii (0.85–1.03 Å; Weast, 1970); therefore, they can easily substitute for one another in crystal structures and are always found together. Scandium has chemical properties similar to those of the REE and is sometimes included with them; however, scandium and the REE don't always occur together in nature.

REE are grouped into two classes according to chemical similarities and geochemical affinities: the light REE or cerium group (La, Ce, Nd, Sm, Eu) and the heavy REE or yttrium group (Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Y). Typically one group tends to predominate over the other group in minerals although nearly all are usually present.

REE are found in more than 100 minerals (Adams and Staatz, 1973; Anstett, 1986), but significant economic concentrations of them are rare. Some of the more common REE-bearing minerals are monazite (lanthanum–cerium phosphate), bastnaesite (cerium fluocarbonate), xenotime (yttrium phosphate), and euxenite (REE columbite–tantalite), among others. Monazite generally contains 55–65% REE oxides although it can contain as much as 70% REE oxides and 2% Y_2O_3 (Anstett, 1986). Bastnaesite and xenotime contain appreciable amounts of REE. Apatites normally contain only small amounts of REE but can contain up to 20% total REE oxides (Roeder et al., 1987). Other minerals, especially multiple oxide minerals, such as samarskite (REE columbite–tantalite), contain substantial amounts of REE, but their economic significance is minor.

Industrial applications of REE include petroleum cracking catalysts, metallurgical uses, ceramics and glass, electrical applications, and other uses such as phosphors (Adams, 1965; Anstett, 1986; U.S. Bureau of Mines, 1987). Mixtures of REE chlorides are used as catalysts to convert crude oil into various petroleum products. They are important components of permanent magnets, the most powerful of which uses a neodymium–iron–boron alloy. This application alone is worth almost $100 million annually (Anstett, 1986). Superconductors allow the transmission of electric current with very low resistance and may replace current methods of producing and transmitting energy. Superconductors currently utilize a REE ceramic, but they function most efficiently at extremely low temperatures (−300°C to −175°C). Research is aimed at more practical superconductors and will most likely require a specific REE. Recent developments in superconductors and better, more powerful permanent magnets may increase the demand for REE.

REE are currently recovered by two companies in the United States. Molycorp Inc. mines bastnaesite from a carbonatite at Mountain Pass, California, and accounts for much of the country's REE production and reserves. Reserves at Mountain Pass are estimated to be 40 million tons of ore grading 12% bastnaesite (Anstett, 1986). AMC Ltd., a subsidiary of Renison Goldfields Ltd., recovers monazite as a by-product of titanium–zirconium placer deposits at Green Cover Springs, Florida. Total production of REE oxides from these two deposits in 1986 amounted to approximately 14,000 tons (U.S. Bureau of Mines, 1987).

Although current and past production of REE is low, reflecting the limited demand for these elements, technological advances in superconductors may significantly increase the demand for REE. Therefore the NMBMMR is investigating REE deposits in New Mexico; this article is a summary of known deposits and occurrences in the state.

Geology of REE in New Mexico

General

Four types of REE deposits are recognized in New Mexico: veins and breccias, pegmatites, carbonatites, and Cretaceous heavy-mineral, beach-placer deposits (Table 2, Fig. 2). The most significant deposits in the state are found in veins and breccias although some pegmatites contain substantial amounts of REE. Even though the largest REE deposit in the world occurs in a carbonatite, known carbonatites in New Mexico tend to be small and contain, at best, modest amounts of REE.

Minor amounts of REE have been produced from veins and breccias and pegmatites in New Mexico (Table 3). Most of this production occurred during the 1940's and 1950's (Jahns, 1946; Adams, 1965; Jahns and Ewing, 1976). None of the deposits in the state have yielded any ore recently, but a few areas are currently being investigated by mining companies. ☞

TABLE 1—REE and related elements.

Element	Symbol	Atomic number	Atomic weight
Lanthanides (rare-earth elements)			
Lathanum	La	57	138.9
Cerium	Ce	58	140.1
Praseodymium	Pr	59	140.9
Neodymium	Nd	60	144.2
Promethium	Pm	61	145
Samarium	Sm	62	150.4
Europium	Eu	63	152.0
Gadolinium	Gd	64	157.3
Terbium	Tb	65	158.9
Dysprosium	Dy	66	162.5
Holmium	Ho	67	164.9
Erbium	Er	68	167.3
Thulium	Tm	69	168.9
Ytterbium	Yb	70	173.0
Lutetium	Lu	71	175.0
Related elements			
Scandium	Sc	21	45.0
Yttrium	Y	39	88.9

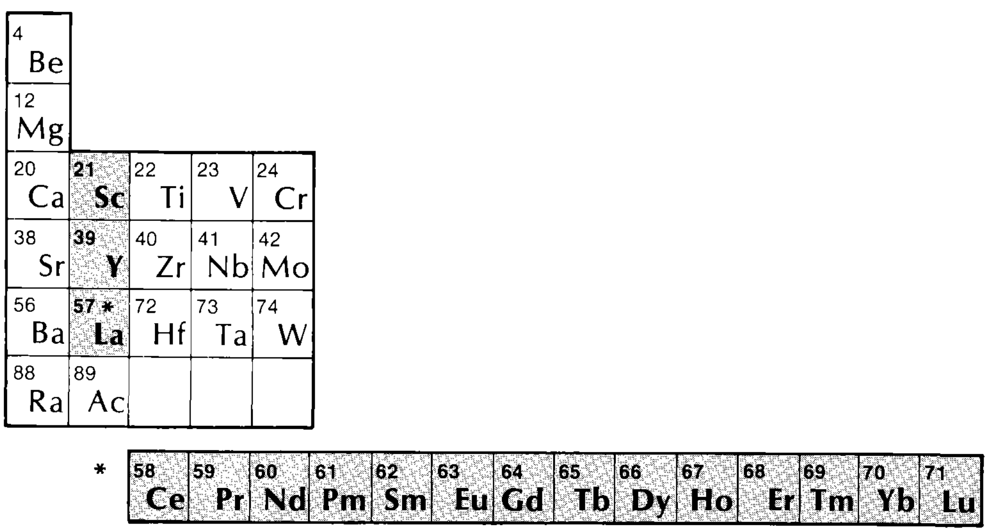

FIGURE 1—Section of the periodic table of the elements showing the REE and related elements.

Vein and breccia deposits

Vein and breccia deposits of REE occur as tabular bodies, narrow lenses, and breccia zones along faults, fractures, and shear zones. The deposits vary from a few feet to 1,000 ft long and from less than one inch to 10 ft wide. The veins are spotty, discontinuous, of variable grade, and may contain significant concentrations of niobium, thorium, and uranium in addition to REE.

Vein and breccia deposits are found at Laughlin Peak (1 in Fig. 2), Gallinas Mountains (2), Capitan Mountains (3), Cornudas Mountains (4), Caballo Mountains (5), Zuni Mountains (6), and the Bromide district (7). Many of these deposits are associated with fluorite veins. The Gallinas Mountains deposit had been a significant nonplacer and nonpegmatite deposit in the U.S. prior to the discovery at Mountain Pass. Deposits in the Capitan Mountains occur with quartz. The host rocks are alkalic and include trachyte, alaskite, nepheline syenite, syenite, and alkali granite. The veins in the Caballo Mountains might be Cambrian–Ordovician in age (McLemore, 1986) whereas the majority of the remaining deposits are probably Tertiary.

Elsewhere in the United States and the world, vein and breccia deposits of REE are commonly associated with alkalic rocks and carbonatite complexes (Heinrich, 1966; Adams and Staatz, 1973). Two small carbonatite dikes occur in the vicinity of REE veins at Laughlin Peak and REE veins might occur in areas in New Mexico where carbonatites have been found.

The mineralogy of known vein and breccia deposits in New Mexico is poorly understood. In the Laughlin Peak area, brockite, crandallite, and xenotime have been reported (Staatz, 1986). Bastnaesite occurs in the Gallinas Mountains (Glass and Smalley, 1945) and possibly the Zuni Mountains (Zadra et al., 1952). Specific mineralogy of other deposits in New Mexico is shown in Table 2.

The potential for REE in veins and breccias in the state is good; however, very little geologic work has occurred in most areas. Detailed geologic mapping, geochemical sampling, mineralogical studies, and drilling of these deposits are needed.

Pegmatites

A number of pegmatites have yielded production of REE in the past (Tables 2 and 3), but in general pegmatites are poor mining targets; the REE minerals are scattered throughout the rock and are difficult to mine

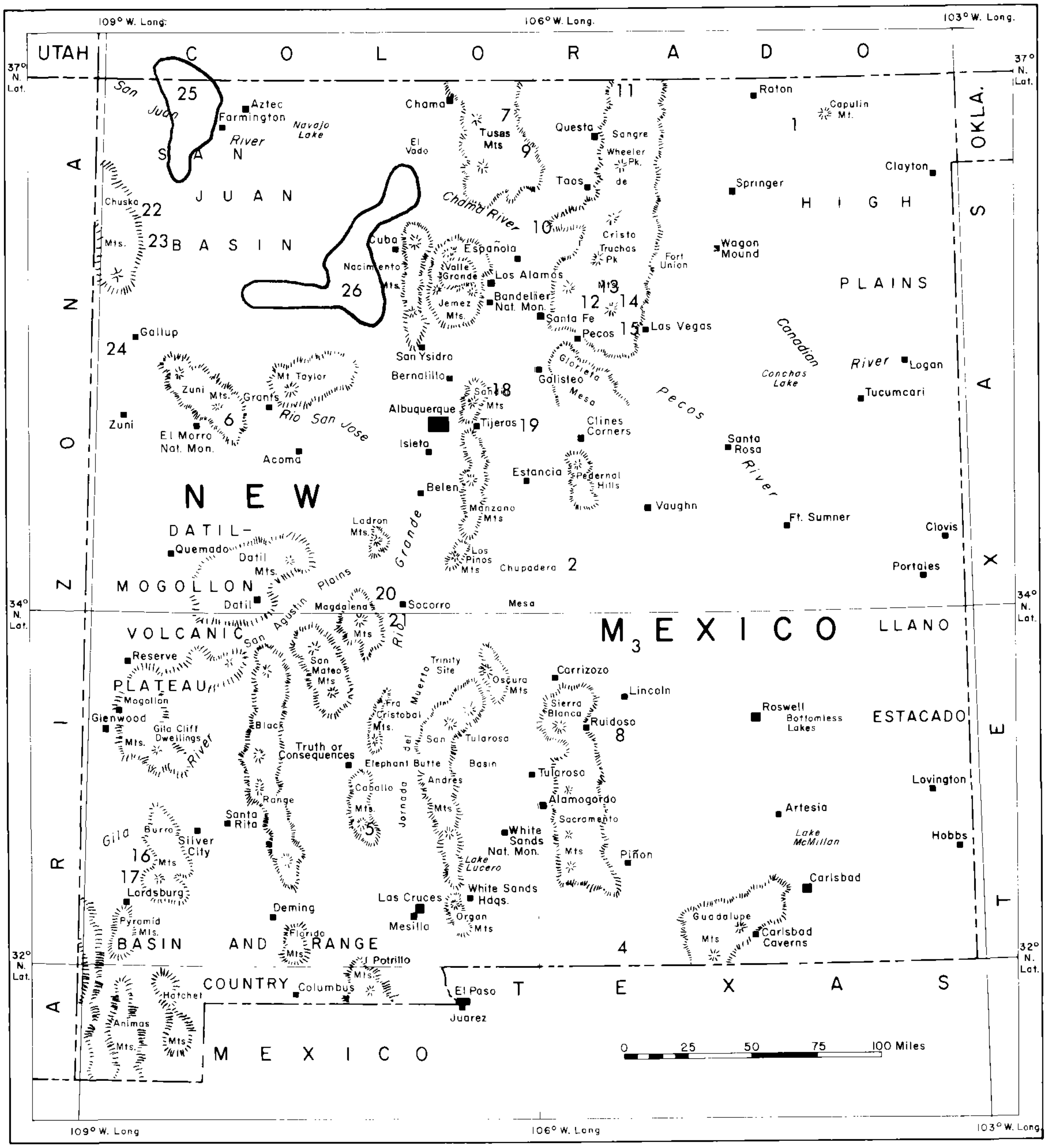

FIGURE 2—REE deposits and occurrences in New Mexico. Location numbers referred to in Table 2.

TABLE 2—Deposits and occurrences of REE in New Mexico. Location numbers refer to Figure 2. *Chemical analyses by Lynn Brandvold and associates, New Mexico Bureau of Mines and Mineral Resources, samples collected by V. T. McLemore; —, no data.

Location no.	Name	Location	Type(s) of deposit	REE-bearing minerals	Chemical analyses	References
1	Laughlin Peak	Colfax County	veins, carbonatite dikes	brockite, crandalite, xenotime	70–7000 ppm La, 70–10,000 ppm Y, 150–2000 ppm Ce	Staatz, 1982, 1985, 1986, 1987; McLemore and North, 1987
2	Gallinas Mountains	Corona	veins, breccia	bastnaesite (5–10%)	1400 lbs fluorite contained 3.2% REE oxides	Glass and Smalley, 1945; Soulé, 1946a; Perhac and Heinrich, 1964; Perhac, 1970; DeMark, 1980
3	Capitan Mountains	Capitan	breccia veins	allanite	*2500 ppm La, 4350 ppm Ce, 330 ppm Y	Griswold, 1959; McLemore, 1983a; NMBMMR file data
4	Cornudas Mountains (Wind Mountain)	Otero County	veins	eudialyte	*1235 ppm Ce, 770 ppm La, 270 ppm Nd, 242 ppm Y	Zapp, 1941; Collins, 1958; Warner et al., 1959; Barker and Hodges, 1977; NMBMMR file data
5	Caballo Mountains	Sierra County	veins	thorite, bastnaesite, thorogummite	—	Doyle, 1951; Melancon, 1952; Staatz et al., 1965; McLemore, 1983a, 1986
6	Zuni Mountains	Grants	veins	bastnaesite	—	Zadra et al., 1952; Goddard, 1966, 1974; McLemore et al., 1986
7	Bromide district	Tusas Mountains	veins	allanite, monzonite, xenotime	—	Bingler, 1968; NMBMMR file data
8	Pajarito Mountain	Otero County	unknown (possibly veins); occurrence in quartz syenite	allanite, thorite, eudialyte, elpidite, apatite	—	Kelley, 1968; Foord et al., 1983; Moore and Foord, 1986; Roeder et al., 1987
9	Petaca district	Tusas Mountains	pegmatite	monazite, samarskite, apatite	*660 ppm Y, 660 ppm Yb, 606 ppm Dy, 396 ppm Er, 186 ppm Gd	Just, 1937; Jahns, 1946; Wright, 1948; Redmon, 1961; Bingler, 1968; Robertson, 1976; Merker, 1981
10	Harding district	Picuris Range	pegmatite	microlite, monazite, allanite, thorite, tantalite–columbite	—	Soulé, 1946b; Jahns, 1946, 1953; Jahns and Ewing, 1976, 1977; Taggart, 1976; Brookins et al., 1979
11	Vermejo Park area	northern Taos County	pegmatite	allanite, thorite, thorogummite, apatite, zircon, uranophane	91–337 ppm Ce, 40–137 ppm Y, 0–130 ppm La, 23–176 ppm Nb	Zalenka, 1984
12	Elk Mountain	Sangre de Cristo Mountains	pegmatite	monazite, samarskite, tantalite–columbite	—	Holmquist, 1946; Jahns, 1946; Griggs and Hendrickson, 1951; Redmon, 1961; U.S. Geological Survey et al., 1980; Klich, 1983
13	Rociada district	Las Vegas Range	pegmatite	microlite, mica, topaz	—	Jahns, 1953; Sheffer and Goldsmith, 1969; Robertson, 1976; U.S. Geological Survey et al., 1980
14	El Porvenir	Las Vegas Range	pegmatite, vein	monazite	whole rock samples of quartzite: 582 ppm La, 1160 ppm Y; 959 ppm La, 1020 ppm Y by emission spectrometry (U.S. Dept. of Energy files)	Harley, 1940; Robertson, 1976

(continued on page 36)

TABLE 2 (continued)

Location no.	Name	Location	Type(s) of deposit	REE-bearing minerals	Chemical analyses	References
15	Tecolote	Las Vegas Range	pegmatite	monazite, tantalite–columbite	—	Harley, 1940; Robertson, 1976
16	White Signal	Burro Mountains	pegmatite, veins(?)	allanite, euxenite, samarskite, cyrtolite	—	Gillerman, 1964; Richter and Lawrence, 1983; Richter et al., 1986
17	Gold Hill	Burro Mountains	pegmatite, veins	allanite, euxenite, samarskite, cyrtolite, thorite	—	Gillerman, 1964; Staatz, 1974; Hedlund, 1978
18	Monte Largo Hills	Sandia Mountains	carbonatite dikes	—	*795 ppm Ce, 385 ppm La, 305 ppm Nd, 123 ppm Y	Lambert, 1961; Kelley and Northrop, 1975; McLemore, 1983b
19	Lobo Hill	Moriarty	carbonatite dike	—	*2225 ppm La, 3500 ppm Ce, 975 ppm Nd, 146 ppm Y	Loring and Armstrong, 1980; McLemore, 1984
20	Lemitar Mountains	Socorro County	carbonatite dikes, veins	bastnaesite	Total REE—0.19 wt%	McLemore, 1982, 1983b, 1987
21	Chupadera Mountains	Socorro County	carbonatite dikes, veins	zirkelite	46–700 ppm Y, 8–4, 900 ppm Ce, 80–1700 ppm La, 110–650 ppm Nb	McLemore, 1983b, 1987; Van Allen et al., 1986
22	Sanostee	San Juan County	heavy-mineral, beach-placer deposit	zircon, monazite	—	Allen and Balk, 1954; Chenoweth, 1957; Dow and Batty, 1961; Bingler, 1963; Brookins, 1977
23	Toadlena	San Juan County	heavy-mineral, beach-placer deposit	zircon, monazite	—	Archer, 1957; Chenoweth, 1957; Dow and Batty, 1961
24	Gallup	McKinley County	heavy-mineral, beach-placer deposit	zircon, monazite	*8375 ppm Ce, 4230 ppm La, 3250 ppm Nd, 650 ppm Pr, 550 ppm Y	Allen, 1956; Chenoweth, 1957; Sun and Allen, 1957; Houston and Murphy, 1977
25	Farmington placers	Farmington area	heavy-mineral, beach-placer deposit	zircon, monazite	—	Chenoweth, 1957; Dow and Batty, 1961; McLemore, 1983a
26	Other placers	San Juan Basin	heavy-mineral, beach-placer deposit	zircon, monazite	—	Chenoweth, 1957; Dow and Batty, 1961; McLemore, 1983a

and process selectively. At least 75 pegmatites in New Mexico contain minerals of REE, thorium, and uranium; 49 of these pegmatites occur in the Petaca district (9 in Fig 2).

The pegmatites generally are Precambrian in age and intrude granitic and metamorphic rocks; however, some in the Burro Mountains are Tertiary. They vary in size but are typically several hundred feet long and several tens of feet wide. The REE-bearing minerals commonly occur in the albite-rich zones and some concentration of REE minerals occurs in fractures within the quartz cores.

Numerous REE-bearing minerals have been reported to occur in pegmatites in New Mexico (Northrop, 1959; Jahns, 1946); the more common minerals include monazite, samarskite, apatite, allanite, microlite, and thorite. Geochemical analyses of selected samples from pegmatites in the Petaca district are shown in Table 2.

Carbonatites

Carbonatites are unique carbonate-rich rocks of apparent magmatic origin that are characterized by distinct but variable mineralogy, composition, and associated alteration. They commonly contain minerals of REE, uranium, thorium, niobium, and other valuable elements. In New Mexico, carbonatites have been found in five areas: Lemitar and Chupadera Mountains, Socorro County (20 and 21 in Fig. 2 and Table 2); Monte Largo Hills, Bernalillo County (18); Lobo Hill, Torrance County (19); and Laughlin Peak, Colfax County (1).

In New Mexico, the carbonatites occur as dikes with associated stockworks; large intrusive bodies such as those at Iron Hill, Colorado and Mountain Pass, California have not been found here. All carbonatites, except the one at Laughlin Peak, intrude Precambrian host rocks and are probably Paleozoic in age (McLemore, 1983b, 1987). The Laughlin Peak carbonatite intrudes a phonotephrite that was dated by potassium–argon methods as 25.3 ± 0.9 m.y. (Staatz, 1986). The dikes range in thickness from less than one inch to more than 3 ft, and they are discontinuous along strike because of pinch-outs, faults, or erosion. A few dikes in the Lemitar and Chupadera Mountains can be traced intermittently along strike for more than 1,000 ft (McLemore, 1982; Kent, 1982).

TABLE 3—Production of REE-bearing minerals from New Mexico deposits. Location numbers refer to Figure 2 and Table 2.

Location No.	Name	Production
2	Gallinas Mountains	146,000 lbs of bastnaesite concentrate
9	Petaca district	112 lbs of samarskite, few hundred pounds of monazite, 12,000 lbs of Ta–Nb–REE ore
10	Harding district	More than 22,000 pounds of microlite concentrate containing an average of 68% Ta_2O_5 and 7% Nb_2O_5
12	Elk Mountain	500 lbs of Ta–U–REE concentrate
13	Rociada district	1.5 tons of microlite concentrate, several thousand tons of REE–Ta ore
15	Tecolote	$10,000 worth of beryl, tantalite–columbite, and monazite
17	Gold Hill	Some production during the 1950's

REE-bearing minerals in these carbonatites include apatite, fluorite, and complex iron–titanium oxides. Bastnaesite occurs in a Lemitar carbonatite dike (McLemore, 1982, 1983b, 1987). REE contents are variable. Four samples of carbonatites from the Lemitar Mountains ranged in composition from 503 to 661 ppm La, 999 to 1,201 ppm Ce, 59 to 76 ppm Sm, and 90 to 122 ppm Y (McLemore, 1987). Samples of the Chupadera carbonatites ranged from 80 to 1,700 ppm La, 8 to 4,900 ppm Ce, and 46 to 700 ppm Y (Van Allen et al., 1986). Other analyses are listed in Table 2.

The potential for minable concentrations of REE in carbonatites in New Mexico is uncertain. None of the areas have been explored at depth; only a few shallow trenches have been dug in some areas. It is possible that greater potential lies at depth; drilling is needed, especially in the Lemitar and Chupadera Mountains where numerous dikes are found at the surface.

Heavy-mineral, beach-placer sandstones

Heavy-mineral, beach-placer sandstone deposits are concentrations of heavy minerals that were formed on beaches or in longshore bars in a marginal marine environment (Houston and Murphy, 1977). Numerous beach-placer sandstone deposits are found in the San Juan Basin and at least three wells have penetrated similar deposits in the subsurface (Table 2). Although beach-placer deposits may be found in strata of all ages, the known deposits in New Mexico are restricted to Cretaceous rocks.

These deposits vary in color from olive gray, to rust brown, to maroon; they are commonly called black sandstones. They occur at the top of beach deposits and, in places, in two or more intervals. They rarely extend for more than several hundred feet in length and are only tens of feet wide and 3–5 ft thick.

Heavy minerals compose about 50–60% of the sandstones and consist predominately of magnetite, ilmenite, and other iron–titanium oxide minerals. REE-bearing minerals found in these deposits include monazite, zircon, apatite, and allanite, among others. Very little geochemical work has been done; one sample from the Gallup placer contained 8,375 ppm Ce, 4,230 ppm La, and 550 ppm Y.

The individual beach placers in New Mexico are low tonnage and probably low grade; they remain undeveloped. It is estimated that collectively the resources amount to a total of 4,741,200 tons of material containing 12.82% TiO_2, 2.07% ZrO_2, 15.51% Fe, and less than 0.10% $eThO_2$ (radiometric equivalent; Dow and Batty, 1961). The REE content is unknown and probably low. Additional deposits probably remain undiscovered in the San Juan Basin. Similar deposits have been intercepted in several holes during drilling for coal by the NMBMMR. However, the small size, low grade, and difficulty in recovering economic metals currently discourages large-scale mining.

Summary

Economically, the most important REE deposits in New Mexico are found in veins and breccias. Pegmatites can be mined sporadically but yield little REE production. Exploration of the REE deposits, especially of the veins, breccias, and carbonatites, is required to properly assess the REE potential in New Mexico. The New Mexico Bureau of Mines and Mineral Resources plans to continue geologic mapping and geochemical sampling of some of these areas and additional potential targets.

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