REE, Niobium, and Thorium Districts and Occurrences in New Mexico

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INTRODUCTION

Rare-earth elements (REE), niobium, and thorium typically occur together in nature. The REE include a group of 15 chemically similar elements called the lanthanide group since lanthanum is the first of the series (Fig. 1). Yttrium, although not a lanthanide, is sometimes included because it has similar chemical properties and typically occurs with the REE. The REE and yttrium have similar ionic radii (0.85-1.03 Å; Weast, 1970) and 3^+ valance, therefore they can easily substitute for one another and are always found together. Tantalum typically occurs with niobium (also known as columbium); both have similar ionic radii (0.68-0.69 Å) and 5^+ valance. Most deposits also contain some uranium.

REE, niobium, and thorium are found in over 100 minerals (Parker, 1965; Parker and Fleischer, 1968; Adams and Staatz, 1973; Anstett, 1986), but significant concentrations of them are rare. Some of the more common REE minerals in New Mexico are monazite (lanthanum-cerium phosphate), bastnaesite (cerium fluo-carbonate), xenotime (yttrium phosphate) and euxenite (REE columbite-titanite), among others. The major niobium ore minerals are complex iron-niobium-tantalum-REE oxides and include columbite-tantalite, microlite, euxenite, samarskite, and fergusonite. The major thorium mineral is monazite which contains between 3 and 10% ThO_2 and up to 70% REE and 2% Y_2O_3. Thorite and thorogummite also are common.

Industrial applications of these elements are varied. REE are used as petroleum cracking catalysts, metallurgical uses, ceramics and glass, electrical applications, as phosphors, and

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

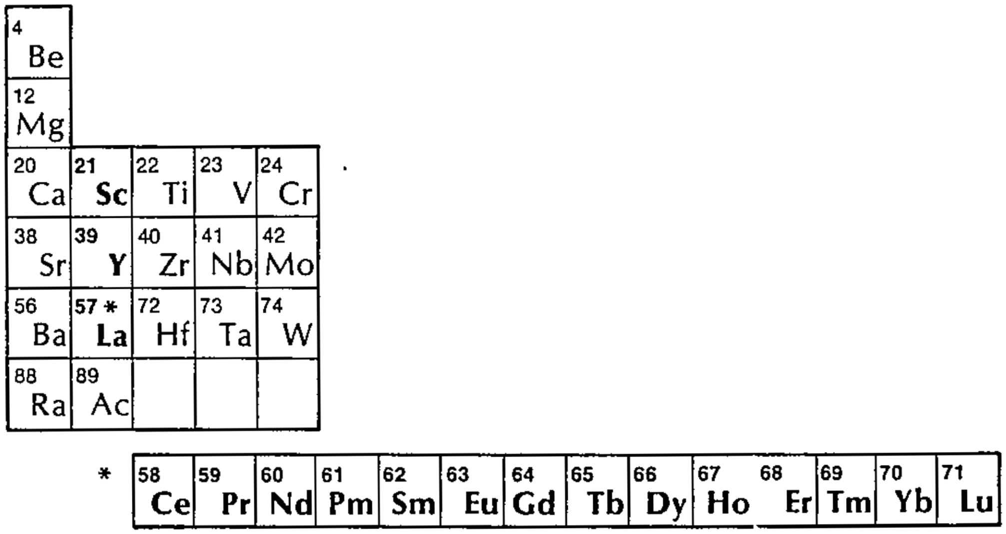

FIGURE 1—Section of the periodic table of the elements showing the REE and related elements.

other minor uses (Adams, 1965; Anstett, 1986; U.S. Bureau of Mines, 1987). Recent developments in superconductors may increase the demand for REE. REE are important components of permanent magnets; the most powerful of which uses a neodymium-iron-boron alloy. This application alone is worth approximately $100 million annually (Anstett, 1986).

Niobium (or columbium) and tantalum are used as metal alloys in electrical, construction, transportation, machinery, and oil and gas applications (Parker, 1965; U.S. Bureau of Mines, 1987). Thorium is used as a nuclear fuel in one commercial power plant in the U.S. (at Fort St. Vrain, Colorado). Nonenergy uses include incandescent lamp mantles, magnesium-thorium alloys, refractories, welding electrodes, among others (U.S. Bureau of Mines, 1987).

Although current and past production of these elements in the U.S. is low reflecting the limited demand for these elements; the advancement of superconductors and more efficient magnets may significantly increase the demand for REE and niobium. Thorium may be used in more power plants in the future. Therefore the NMBMMR is investigating these deposits in New Mexico; Map 1 and Table 1 is a summary of known deposits in the state.

Geology of Deposits in New Mexico

General

Four types of REE, niobium, and thorium deposits are recognized in New Mexico: veins and breccias, pegmatites, carbonatites, and Cretaceous heavy mineral, beach-placer deposits (Table 1, Map 1). The most significant deposits in the state are

Table 1 - REE, thorium, and niobium districts and occurrences in New Mexico. *Chemical analyses by Lynn Brandvold and associates (NMBMMR chemical laboratory, samples collected by V. T. McLemore).

Map number	Name	Location	Type(s) of deposit(s)	Geological description and size of known deposits	REE minerals and associated commodities	Chemical analysis	Production and resource	Selected references
1	Laughlin Peak (Chico Hills)	east central Colfax County	veins, carbonatite dike	A carbonatite occurs in fracture zones in or adjacent to the large trachyte sill on Raspberry Mountain. The veins cut trachyte, Dakota sandstone, intrusive breccia and trachyandesite. 29 veins have been mapped.	brockite (Ce, Th), crandalite (Ce), xenotime, Th, U	150-2000 ppm Ce, 70-7000 ppm La, 146-20,000 ppm total REE, 70-10,000 Y, 150 ppm Nb 0.32% Th	----	Staatz, 1974, 1982, 1985, 1986, 1987; McLemore and North, 1987
2	Gallinas Mountains	12 mi southwest of Corona, northern Lincoln County	veins, breccia	Bastnaesite occurs as an accessory in epithermal copper sulfide-fluorite veins and breccia fillings in sandstone overlying alkalic trachyte hypabyssal intrusives. Most of the bastnaesite deposits are in the Yeso sandstone (Permian). The majority are in breccia zones where mineralization occurs as open space fillings and along joints and bedding planes.	bastnaesite, F, Cu, Ba	bastnaesite: 74.39% REO including 21.87% Ce, 25.61% Ce_2O_3, and 48.78% $(La, D_1)_2 O_3$ [5-10% bastnaesite in the deposit]; 1400 lbs fluorite contained 3.2% REEO	146,000 lbs of bastnaesite concentrate	Glass and Smalley, 1945; Soule, 1946a; Griswold, 1959; Perhac and Heinrich 1964; Perhac, 1970; DeMark, 1980
3	Capitan Mountains	Capitan	breccia veins	Deposits occur in the alaskite breccia veins that cut the Capitan Mountains. The veins consist of angular fragments of alaskite which have been recemented by red rhyolite. The veins are a few inches in width, lengths are unknown (buried by soil horizon).	allanite, Th	veins have up to 1.7% Th; *select sample assayed 2500 ppm La, 4350 ppm Ce, and 330 ppm Y	----	Griswold, 1959; Staatz, 1974; McLemore, 1983a; NMBMMR file data
4	Cornudas Mountains (Wind Mountain)	southern Otero County, NM; northern Hudspeth County, Texas	veins	Laccolith of porphyritic nepheline syenite that intruded Cretaceous and Permian strata. Adjacent areas have sills and dikes of similar composition. These injection veins and replacement bodies trend northeast.	eudialyte, Th, U, Be, Nb, F	*dike sample: 1235 ppm Cd, 700 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 and Red Hills	Sierra County	veins	More than 45 radioactive bodies that occur in a coarse-grained quartz monzonite. These bodies are elongate and range from a few feet to 300 ft in length and from a few inches to 20 ft in width.	thorite, bastnaesite, thorogummite, Nb, U, Th, Ba, F	up to 0.44% Th	----	Doyle, 1951; Melancon, 1952; Staatz et al., 1965; McLemore, 1983a, 1986
6	Zuni Mountains	Grants, Cibola County	veins	REE are associated with fluorite veins and occur along northwest trending faults in the Precambrian and Paleozoic rocks, mostly in Precambrian granites. Veins range from a few inches to 15 feet wide. Most of the veins have been brecciated.	bastnaesite, F, Ba	----	----	Zadra et al., 1952; Goddard, 1966, 1974 McLemore et al., 1986
7	Bromide District	Tusas Mountains	veins	REE in fluorite-uranium veins along the contact of the granite with the Moppin volcanics.	allanite, monzonite, xenotime, U, Th, F, Cu, Ba	----	----	Bingler, 1968; NMBMMR file data

Table 1 (cont'd)

Map number	Name	Location	Type(s) of deposit(s)	Geological description and size of known deposits	REE minerals and associated commodities	Chemical analysis	Production and resource	Selected references
8	Pajarito Mountain	Mescalero Indian Reservation, Otero County	unknown, possibly vein (occurrence in quartz syenite)	REE are associated with Precambrian alkalic rocks which are surrounded by Permian marine sediments. Radiometric dates suggest 1,230-1,140 m.y. for the syenite. Syenite, melasyenite and quartz syenite are present, along with syenite pegmatites.	allanite, thorite, eudialyte, F, zircon, apatite, elpidite	analysis of apatite: 0.306 wt% Y_2O_3, 4.48 wt% La_2O_3, 8.50 wt% Ce_2O_2, 3.69 wt% Nd_2O_3, 0.93 wt% Pr_2O_3	----	Kelly, 1968; Foord et al., 1983; Moore and Foord, 1986; Roeder et al. 1987
9	Petaca (including Ojo Caliente)	Tusas Mountains	pegmatite, placer deposits (niobium)	The average outcrop length is 410 ft, the average breadth is 35 ft. REE are restricted to albite-rich zones in the pegmatites. Some enrichment zones are located in fractures within the quartz cores. Host rocks include: muscovitic quartzite, schists, granitic gneiss and amphibolites.	monazite, samarskite, euxenite, hatchettolite, apatite, Cu, U, Bi, Nb, Ta, Be, F, mica	*average Nb of 87 pegmatites 0.04%; globe pegmatite analysis: 600 ppm, Y, 660 ppm Yb, 606 ppm Dy, 396 ppm Er, 186 ppm Gd, 3117 ppm eREE + Y, 10,332 ppm Th	112+ lbs-samarskite few hundred lbs of monazite; 12,000 lbs Ta-Nb-REE ore	Just, 1937; Jahns, 1946; Wright, 1948; Redmon, 1961; Bingler, 1968; Parker and Fleischer, 1968; Robertson, 1976; Merker, 1981
10	Harding district	Picuris Range, Taos County	pegmatite, placer deposits (niobium)	There are 3 types of pegmatites in the area: (1) long thin northeast trending dikes, (2) smaller pod-like occurrences, and (3) thick mineral-rich zones. A well defined pegmatite belt that is 250 ft long, 150-250 ft wide, and 5-20 ft thick is exposed trending west-northwest. The economically potential pegmatites are internally zoned. One of the largest tantalum deposits in the U.S.	microlite, monazite, allanite, tantalite-columbite, Be, CsO, apatite, U, Th, Li, Ta, mica, Thorite	----	22,000 lbs microlite (niobium ore); reserves estimated as 90,000 tons of 0.15% microlite ore	Soulé, 1946b; Jahns, 1946, 1953; Parker, 1965; Jahns and Ewing, 1976, 1977; Taggart, 1976; Brookins et al., 1979
11	Vermejo Park area	northern Taos County on the Vermejo Ranch	pegmatite veins(?)	These are highly localized deposits that are hosted by Precambrian granite, pegmatitic granites, and and gneisses. The REE occur in pegmatite dikes, lenses or pods, and along fractures.	allanite, thorite, thorogummite, apatite, zircon, uranophane, U, Th, Nb	91-337 ppm Ce, 40-137 ppm Y, 0-130 ppm La, 23-176 ppm Nb	----	Zalenka, 1984
12	Elk Mountain	southern part of Sangre de Cristo Range	pegmatite	The pegmatites occur in Precambrian schists and range in shape from thin sinuous dikes to thick pods that crosscut the host rock. All of the deposits contain quartz, albite, and microcline.	monazite, samarskite, gadolinite, euxenite, hatchettolite, tantalum, columbite, U, Th, mica	sample of nearby syenite; 116 Ce	500 lbs of Ta-U-REE	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	The pegmatites range in width from several inches to 43 ft and have lengths in excess of 350 ft. There are also discordant lenses. Most of the pegmatites are zoned.	microlite, Ta, Nb, Li, Be, mica, topaz	----	1.5 tons of microlite and several thousand tons of REE-Ta ore	Jahns, 1953; Sheffer and Goldsmith, 1969; Robertson, 1976; U.S. Geological Survey et al., 1980
14	El Porvenir	3.0 mi north of Porvenir, in the Las Vegas Range	pegmatite, veins	The pegmatites are contained in a coarse-grained granite that intrudes the Precambrian metamorphic rocks.	monazite, Mo, Cu, Bi, Ta, Nb, mica	samples of quartzite 546 ppm eTh, 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

Map number	Name	Location	Type(s) of deposit(s)	Geological description and size of known deposits	REE minerals and associated commodities	Chemical analysis	Production and resource	Selected references
15	Tecolote	8 mi southwest of Las Vegas in the foothills of the Las Vegas Range	pegmatite	The pegmatites are contained in a coarse-grained granite that intrudes the Precambrian metamorphic rocks.	monazite, Nb, Ta, Be, Mo, Cu, mica, tantalite-columbite	----	$10,000 worth of beryl, tantalite-columbite, and monazite	Harley, 1940; Robertson, 1976
16	Black Range	near Emory Pass	pegmatite	small, Tertiary pegmatites in rhyolite porphyry plug containing minor amounts of columbite in a seam of magnetite and ilmenite.	columbite	----	----	Kelley and Branson, 1947
17	White Signal	Burro Mountains	pegmatite, veins(?)	The pegmatites are in the western portion of the district and are very similar to those of the Gold Hill area. They occur as pods or lenses in the Proterozoic Burro Mountain granite.	allanite, euxenite, samarskite, cyrtolite, Th, Ta, Nb, Be, mica	702 ppm Th	----	Gillerman, 1964; O'Neil and Thiede, 1981; Richter and Lawrence, 1983; Richter et al., 1986
18	Gold Hill	Burro Mountains	pegmatite, veins	The pegmatites vary in size from pods a few inches in diameter to lens-shaped bodies several hundred feet long. The larger of these bodies are zoned. Two veins occur and are 2 ft wide and 46 ft long. The host rock is part of the Proterozoic Burro Mountain granite.	allanite, euxenite, samarskite, cyrtolite, thorite (vein), mica, quartz, Th	Thorium content in a vein is 0.05-0.72 wt%	Some possible production during the 1950's (unknown)	Gillerman, 1964; Hedlund, 1978; Staatz, 1974
19	Monte Largo area	22 mi northeast of Albuquerque in the Sandia Mountains	carbonatite dikes	Occurs as a dike 1-2 ft wide and approximately 200 ft long. The known deposits are in breccias in isolated exposures of the Precambrian rocks of the southwestern part of the district.	Th, U, mica, Nb	0.295% Nb oxide *selected sample 795 ppm Ce, 385 ppm La, 305 ppm Nd, 123 ppm Y, 75 ppm Pr	----	Lambert, 1961; Kelley and Northrop, 1975; McLemore, 1983b
20	Lobo Hill	Moriarty	carbonatite dike	Thin, carbonatite dike intruding syenites in Precambrian gneiss.	U, Th	230 ppm Th, 243 ppm Nb, 2225 ppm La, 3500 ppm Ce, 975 ppm Nd, 19 ppm Yb, 146 ppm Y	----	Loring and Armstrong, 1980; McLemore, 1984
21	Lemitar Mountains	Socorro	carbonatite dikes and veins	More than 100 carbonatite dikes and veins intrude the Precambrian granite and metamorphic rocks. They range in thickness from less than 1 inch to more than 3 ft. Some dikes can be traced 1900 ft. The dikes are fracture-controlled and form sharp contacts with the host rocks. The host rocks are granites, diorite/gabbro, and gneissic granites.	U, Th, Nb, Ti, Cu, Ba, F, bastnaesite	Maximum concentrations from selected samples: 0.19 wt% total REE, 0.25 wt% U_3O_8, 1950 ppm Th, 445 ppm Nb	----	McLemore, 1982, 1983b, 1987
22	Chupadera Mountains	Socorro	carbonatite dikes and veins	The veins and dikes are in a 2 mi^2 exposure of Precambrian rocks. They trend northeast and occur as swarms of steeply dipping dikes that cut foliation of the host. They are commonly 0.7-5 ft thick and can have widths of 200 ft and lengths of 1000 ft. The host rocks are interfingering quartz-feldspathic schists and gneisses and mica schist.	zirkelite, U, Th, Nb, Ti, Cu, Ba, F	ranges for selected samples: 46- 700 ppm Y, 8-4900 ppm Ce, 80-1700 ppm La, 110- 650 ppm Nb	----	McLemore, 1983b, 1987; Van Allen et al., 1986

Table 1 (cont'd)

Map number	Name	Location	Type(s) of deposit(s)	Geological description and size of known deposits	REE minerals and associated commodities	Chemical analysis	Production and resource	Selected references
23	Sanostee	1.0 mi west of Sanostee Trading Post, San Juan County	heavy-mineral beach-placer deposit	Deposit occurs in and at the top of the lower unit of the Gallup Sandstone (Cretaceous). There are 6 en echelon heavy mineral lenses approximately 12 ft thick, 450 ft wide, and trace 1.5 mi. These were probably formed in the littoral zone of the Cretaceous sea.	zircon (principal mineral containing REE's), Ti, Nb, Th, U, monazite(?)	0.11 wt% Yttrium oxide; 0.11 wt% Nb oxide; 20.0 wt% Ti oxide; 0.12% $eThO_2$	predicted resource between 3.76-169 tons of yttrium oxide	Allen and Balk, 1954; Chenoweth, 1957; Dow and Batty, 1961; Bingler, 1963; Brookins, 1977; McLemore, 1983a
24	Toadlena	2.0 mi south-southeast of the settlement of Toadlena, San Juan County	heavy mineral beach placer deposit	Deposits are in the basal sandstone unit of the Gallup Sandstone (Cretaceous). An olive gray zone is 1,750 ft long and as much as 6 ft wide. Depositionally similar to the Sanostee.	zircon (principal mineral containing REE's), Ti, Nb, Th, U, monazite(?)	32 wt% Ti oxide; 0.05% radiometric U_3O_8	----	Archer, 1957; Chenoweth, 1957; Dow and Batty, 1961; Brookins, 1977; McLemore, 1983a
25	Gallup (Torrivo Anticline)	6 mi southeast of Gallup	heavy-mineral beach-placer deposit	A titaniferous sandstone deposit on top of the middle unit of the Gallup Sandstone (Cretaceous). Within an olive-gray heavy mineral zone which is less than 4ft thick, and can be traced N25°W for about 1000 ft. Depositional environment similar to Sanostee.	zircon (principal mineral containing REE's), Ti, Nb, Th, U, monazite(?)	*selected sample assayed 8375 ppm Ce, 4250 ppm La, 3250 ppm Nd, 650 ppm Pr, 550 ppm Y	----	Allen, 1956; Chenoweth, 1957; Sun and Allen, 1957; Houston and Murphy, 1977; McLemore, 1983a
26	Farmington placers	known deposits in the Farmington area San Juan basin	heavy mineral beach placer deposit	The deposits occur mostly in the Point Lookout Sandstone (Cretaceous). These deposits are beach concentrations and represent a transition from marine to non-marine beds. All are associated with clean, massive, well sorted, littoral marine sandstone, which are overlain by lagoonal coal and shale. They trend northwest, parallel to the direction of the Cretaceous sea strand lines.	zircon (principal mineral containing REE's), Ti, Nb, Th, U, monazite(?)	----	----	Chenoweth, 1957; Dow and Batty, 1961; McLemore, 1983a
27	Other placers	14 known deposits in south-central, southeastern, and east-central San Juan Basin	heavy mineral beach placer deposit	The deposits occur in many of the Cretaceous sandstones and have a depositional environment similar to the Farmington placers. Similar zones have been reported in the subsurface.	zircon (principal mineral containing REE's), Ti, Nb, Th, U, monazite(?)	----	----	Chenoweth, 1957; Dow and Batty, 1961; McLemore, 1983a

the veins and breccias, although some pegmatites contain substantial amounts of REE, niobium, and thorium. Although the largest REE deposit in the world is in a carbonatite, known carbonatites in New Mexico tend to be small and contain, at best, modest amounts of these elements. The world's largest thorium resources are in veins and breccia deposits (Staatz et al., 1979). All of the deposits in New Mexico, especially the carbonatites, have not been examined in detail for REE, niobium, or thorium content. Drilling of all deposits is required.

Minor amounts of REE, niobium, and thorium have been produced from veins and breccias and pegmatites in New Mexico (Table 2). 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 has yielded any ore recently, but a few areas are currently being investigated by mining companies for REE potential (McLemore et al., 1988).

Veins and breccia deposits

Veins and breccia deposits occur as tabular bodies, narrow lenses, and breccia zones along faults, fractures, and shear zones. They 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 typically contain significant concentrations of REE, thorium, and uranium.

Veins and breccia deposits are found at Laughlin Peak (#1, Map 1), Gallinas Mountains (#2), Capitan Mountains (#3), Cornudas Mountains (#4), Caballo Mountains (#5), Zuni Mountains (#6), and Bromide district (#7). Many of these deposits are associated

Table 2--REE and niobium production from New Mexico deposits.

Map No. (Map 1)	Name	Production	References
2	Gallinas Mountains	146,000 lbs of bastnaesite concentrate	Griswold, 1959; Adams, 1965
9	Petaca district	112 lbs of samarskite, few hundred lbs of monazite, 12,000 lbs of Ta-Nb-REE ore including columbite-tantalite	Parker, 1965; Bingler, 1968
10	Harding	More than 22,000 lbs of microlite concentrate containing an average of 68% Ta_2O_5 and 7% Nb_2O_5, 500 lbs of tantalite-columbite	Parker, 1965; Jahns and Ewing, 1977
12	Elk Mountain	500 lbs of Ta-U-REE concentrate	Jahns, 1946; Holmquist, 1946
13	Rociada district	1.5 tons of microlite concentrate, several thousand tons of REE-Ta ore	Robertson, 1976; Sheffer and Goldsmith, 1969; Jahns, 1953
15	Tecolote	$10,000 worth of beryl, tantalite-columbite and monazite	Robertson, 1976
17	Gold Hill	Some production during the 1950's.	Gillerman, 1964

with fluorite veins. Deposits in the Capitan Mountains occur with quartz. The host rocks are alkalic and vary in composition from trachyte, alaskite, nepheline syenite, syenite, and alkali granite. The veins in the Caballo Mountains may be Cambrian-Ordovician (McLemore, 1986), whereas the majority, if not all, of the remaining deposits are probably Tertiary in age.

The most important deposits are in the Laughlin Peak area and the Gallinas Mountains. Thorium, yttrium and REE veins with associated niobium were first discovered in the Laughlin Peak area during the 1950's. Although there has not been any production, these veins have been examined sporadically since the 1950's. The veins are steeply-dipping, lenticular, fracture-filling deposits in Oligocene to Pliocene alkalic igneous rocks and Cretaceous sandstones. More than 30 veins have been located (Staatz, 1982, 1985, 1986, 1987) and adjacent areas remain unmapped. They range in size from 1-1/2 to 1800 ft long and less than one inch to 2 feet thick. Most of the veins parallel the strike of early faults. Total REE content ranges from 100 to 30,000 ppm (Staatz, 1985; Tschanz, 1958). Yttrium contents as high as 10,000 ppm are reported (Staatz, 1985). Niobium concentrations as high as 1200 ppm are reported (Staatz, 1985). Thorium content ranges from 30 to 24,000 ppm (Tschanz, 1958; Staatz, 1985; miscellaneous analyses by the authors). Uranium analyses range as high as 510 ppm U_3O_8 (McLemore, 1983a; McLemore and North, 1987), but are mostly less than 50 ppm.

The REE mineral bastnaesite was discovered in the Gallinas Mountains in 1943 during an investigation of the fluorite- and fluorite-copper-bearing veins and breccia deposits (Glass and

Smalley, 1945; Soulé, 1946a). Bastnaesite occurs as small yellow crystals in the fluorite veins with associated barite, quartz, calcite, pyrite, copper sulfides, galena, and iron oxides (Adams, 1965). About 146,000 lbs of bastnaesite concentrate was produced during the 1950's (Griswold, 1959; Adams, 1965). The deposits occur in the Yeso sandstone (Permian) and are probably related to younger intrusive alkalic rocks (Perhac and Heinrich, 1964). Niobium and thorium contents are insignificant.

REE and possibly niobium are associated with the Precambrian alkalic rocks at Pajarito Mountain in the Mescalero Indian Reservation. Several mining companies and the U.S. Geological Survey have investigated this deposit, although specific details concerning the type of deposit, mineralogy, and economic importance are unavailable. Veins and breccia deposits are likely to be found in the area.

Elsewhere in the United States and the world, veins and breccia deposits 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-thorium veins at Laughlin Peak and REE, niobium, and thorium 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 known. 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 1.

The potential for REE, niobium, and thorium 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 REE and niobium production in the past (Table 2), but in general pegmatites are poor mining targets because the REE, niobium, and thorium minerals are scattered throughout the pegmatite and are difficult to selectively mine and process. At least 75 pegmatites in New Mexico contain REE, niobium, thorium, and uranium minerals; 49 of these occur in the Petaca district.

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

Numerous REE-, niobium-, and thorium-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 1.

Microlite was mined from the Harding pegmatite during 1943-1947 and more than 12,000 lbs of tantalum concentrate was produced (Parker, 1965). It is estimated that the Harding pegmatite contains about 90,000 tons of ore containing 0.15% microlite or about 155,000 lbs of tantalum, making it one of the country's largest deposits in the 1960's (Parker, 1965). However, the Harding pegmatite is owned by the University of New Mexico as a natural museum for collectors and field study; it cannot be considered as a viable economic resource.

Carbonatites

Carbonatites are unique carbonate-rich rocks of apparent magmatic origin which are characterized by a distinct, but variable mineralogy, composition, and associated alteration. They commonly contain REE, niobium, uranium, and thorium. In New Mexico, carbonatites have been found in five areas: Lemitar and Chupadera Mountains, Socorro County (#21, 22, Map 1, Table 1); Monte Largo Hills, Bernalillo County (#19); Lobo Hill, Torrance County (#20); and Laughlin Peak, Colfax County (#1).

In New Mexico, the carbonatites occur as dikes with associated stockworks; large intrusive bodies such as Iron Hill, Colorado and Mountain Pass, California have not been found in the state. All of the carbonatites, except for the one at Laughlin Peak, intrude Precambrian host rocks and are most likely Paleozoic in age (McLemore, 1983b, 1987). The Laughlin Peak carbonatite intrudes a phonotephrite that was dated by potassium-argon methods as 25.3 $\pm$ 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 pinchouts, faults, or erosion. A few dikes in the Lemitar and Chupadera Mountains can be traced intermittently along strike for over 1,000 ft (McLemore, 1982; Kent, 1982).

REE-, niobium-, and thorium-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, niobium, and thorium contents are variable. A select sample from the Monte Largo carbonatite reportedly contained 0.295% Nb_2O_5 (Kelley and Northrop, 1975). Four samples of carbonatites from the Lemitar Mountains ranged in composition from 503 to 661 ppm La, 999 to 1201 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 1.

The potential for mineable concentrations of REE, niobium, and thorium in carbonatites in New Mexico is uncertain. None of the areas have been explored 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 formed on beaches or in long-shore 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 1, Map 1). Although beach-placer deposits are found in strata of all ages, the known deposits in New Mexico are restricted to Cretaceous rocks.

These deposits range in color from olive-gray, rust-brown, to maroon; they are commonly called black sandstones. They occur at the top of beach deposits and at 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.

Detrital minerals comprise about 50-60% of the sandstones and consist predominantly of magnetite, ilmenite, and other iron-titanium oxide minerals. 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 9375 ppm Ce, 4230 ppm La, and 550 ppm Y. the niobium content of the Sanostee deposit is estimated as 0.11% (Bingler, 1963).

The 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 ore 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 and niobium 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, niobium, and thorium deposits in New Mexico are veins and breccias. Pegmatites can be mined sporadically but with little REE production. Exploration of these deposits, especially the veins and breccias and carbonatites is required to properly assess the mineral potential in New Mexico. The NMBMMR plans to continue geologic mapping and geochemical sampling of some of these areas and additional potential targets.

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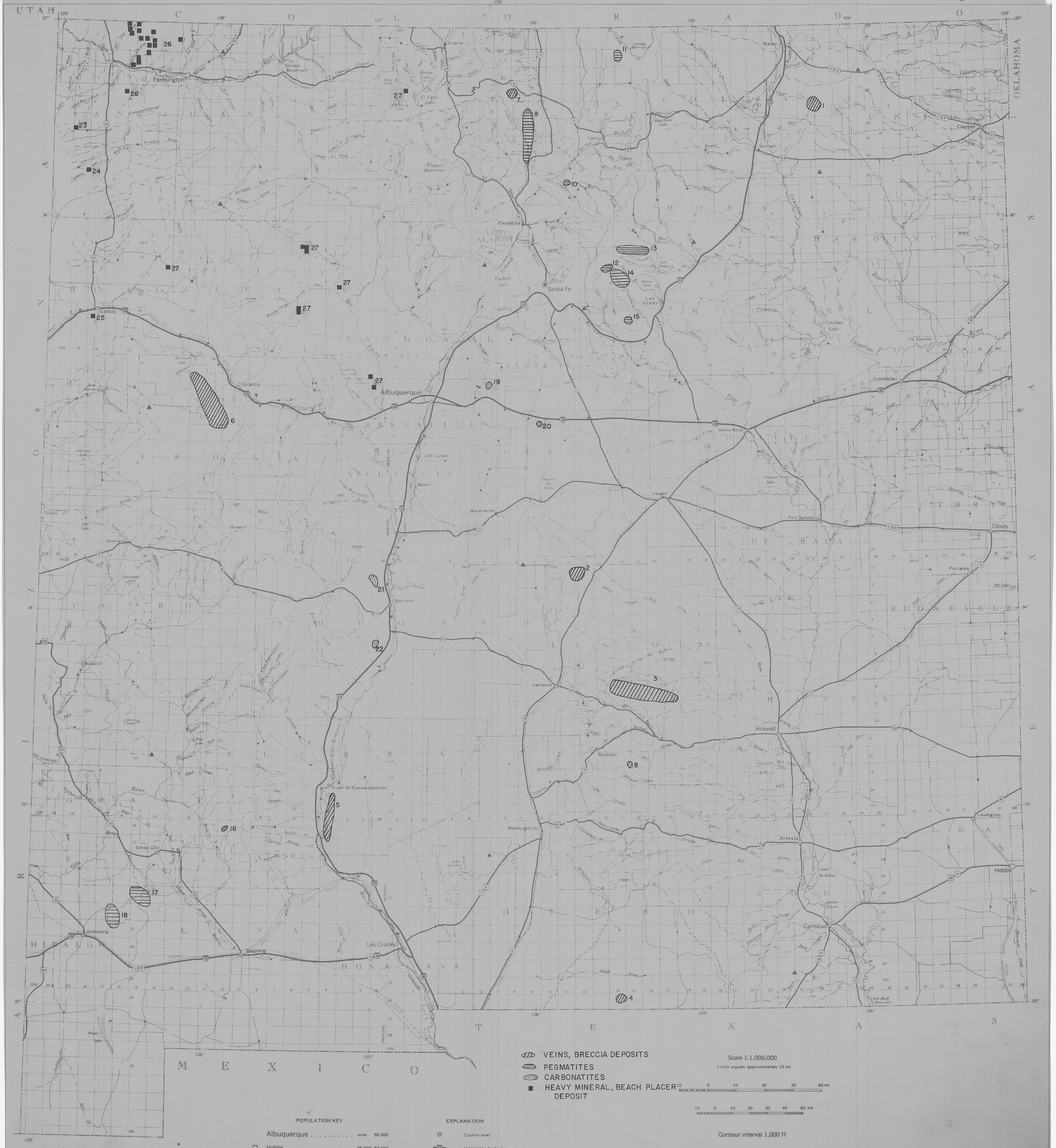
Plate 1

OF-324
RESOURCE MAP



Modified from: "State of New Mexico, 1981" by the New Mexico State Highway Department; "Base Map of New Mexico, 1979" by the United States Geological Survey; selected 7½ and 15 minute topographic quadrangle maps by the United States Geological Survey.

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REE, Thorium, and Niobium Districts and Occurrences in New Mexico

1988

by Virginia T. McLemore, Robert M. North, and Shawn Leppert