Selected Annotated Bibliography of Thorium and Rare-Earth Deposits in the United States Including Alaska

GEOLOGICAL SURVEY BULLETIN 1019-F

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CK ANNOTATED BIBLIOGRAPHY OF THORIUM AND RARE-EARTH DEPOSITS, UNITED STATES—Geological Survey Bulletin 1019-F

Selected Annotated Bibliography of Thorium and Rare-Earth Deposits in the United States Including Alaska

By KATHARINE L. BUCK

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

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SELECTED ANNOTATED BIBLIOGRAPHY OF THORIUM AND RARE-EARTH DEPOSITS IN THE UNITED STATES INCLUDING ALASKA

By Katharine L. Buck

INTRODUCTION

Thorium and rare-earth metals have come into strategic importance in this country in the last few years with the potential use of thorium in the production of atomic power and the development of new uses for the rare earths in the aircraft industry. The United States was thought to be dependent upon foreign sources of these elements because its entire supply from 1910 to 1950 was imported, principally from India and Brazil. By 1951 the foreign supplies of monazite, the main ore of thorium and the rare earths, were seriously curtailed because of restrictions imposed by the producing countries on the exportation of fissionable materials and their ores. In order to develop sources of these elements within the United States, a search has been made which has resulted in a significant increase in the known reserves (U. S. Congress Documents, 1953, p. 211–219).

The rare-earth metals are the elements ranging in atomic number from 57 to 71; they include lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutecium. Yttrium, atomic no. 39, and scandium, no. 21, occur almost inseparably with the rare earths proper and are usually included in the group. Thorium, no. 90, also occurs with the rare earths in nature.

USES

The principal early use of rare earths and thorium was in the manufacture of incandescent gas mantles. Monazite was mined in the United States for this purpose from the 1890's until 1911, when the tungsten lamp largely replaced the gas mantle. The manufacture of gas mantles is, however, still the main use of thorium, although the amount consumed in such manufacture is decreasing. Thorium is now used in the filaments of tungsten lamps, in radio tubes, in refractories, and in the chemical and medical industries. Pure thorium has recently been produced for experimental purposes and would probably have industrial use if it were in sufficient supply (U. S. Congress Documents, 1952, p. 112–113). The use of thorium in the manufacture of atomic energy is now in the planning stage (U. S. Atomic Energy Commission, 1954, p. 25), and it takes precedence over the development of other new uses.

The rare earths are more widely used than thorium in industry. Cerium compounds are used in the carbon-arc electrode cores of searchlights and motion-picture projectors. Mischmetal, a mixture of rare earths, is used in the sparking elements of cigarette lighters and, alloyed with copper, nickel, zinc, aluminum, and magnesium, in aircraft parts, gas turbines, and jet engines. Some of the rare earths are used in waterproofing, mothproofing, and mildew-proofing fabrics, in printing and dyeing, in the glass industry as coloring agents, polishing agents, and in the manufacture of certain special-purpose glasses.

THE INDUSTRY AND ITS PROBLEMS

The main ore mineral of thorium and the rare earths, monazite, occurs primarily in beach and river placer concentrations. In this country domestic placers have been mined for their monazite content alone only in the last 5 years and in the period 1893–1911. The monazite produced between these two periods has been a byproduct of the mining of other minerals, such as ilmenite or gold, and even now the economics of producing monazite are complicated by the problem of marketing the byproduct minerals in order to reduce the overall cost of mining.

Large deposits of bastnaesite, which have recently been discovered and may become the main source of rare earths in this country, interject another factor into the economics of production and use of rare earths and thorium. Bastnaesite contains an amount of thorium that is insignificant at current prices so that, if bastnaesite, instead of monazite, were to dominate as the rare-earth ore, byproduct production of thorium would drop considerably.

There is a ready market for rare earths in this country, but domestic mining operations are insecure because of the threat of the return of foreign imports which would place the price below the domestic cost of mining. The profitable mining of monazite is dependent on the market for byproduct heavy minerals. This factor is especially important in the Idaho field. The market for thorium as such is limited.

Thorium is purchased in the mineral monazite, which is sold for and graded on its combined rare-earth and thorium content.

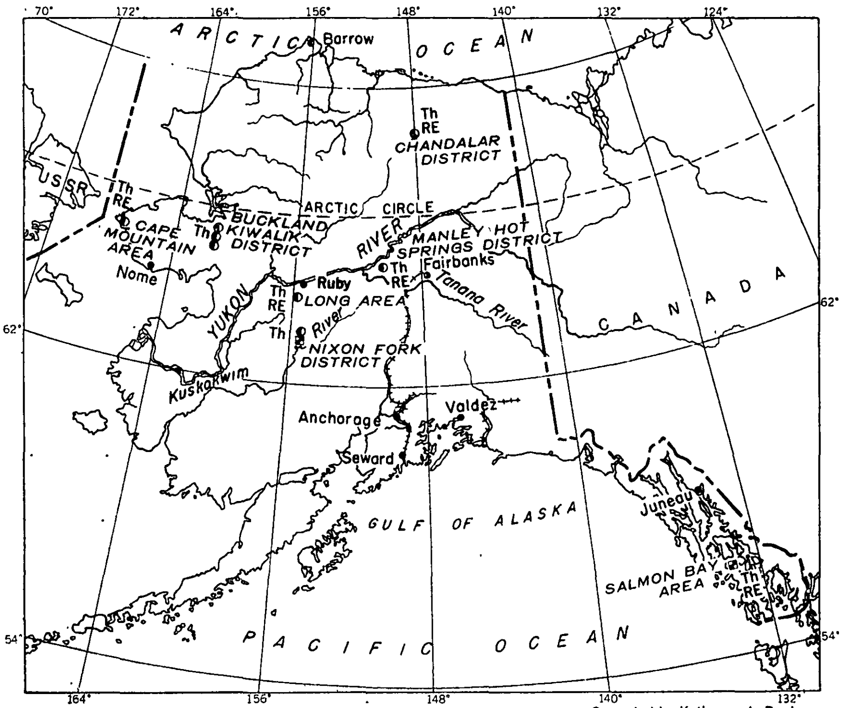
ORE DEPOSITS

Monazite is the principal ore mineral of both thorium and the rare earths. In this country, thorite is an important potential ore mineral of thorium, and bastnaesite is an important ore mineral of the rare earths. Monazite is essentially a phosphate of cerium and lanthanum and contains small variable quantities of the other rare earths, thorium, silicon, uranium, and other elements. It commonly contains from a few percent to 10.6 percent thorium. Minable monazite deposits are found generally in placers, but monazite also occurs as an accessory mineral in many granitic rocks, which are the ultimate source of the placer concentrations. Commercial monazite contains from 55 to 65 percent total rare-earth oxides plus thoria.

Thorite is a silicate of thorium and contains from 25.2 to 62.7 percent thorium and as much as 9.0 percent uranium. Thorite or a hydrated thoritelike mineral is the main ore mineral of some of the vein deposits recently discovered in this country, notably those in the Westcliffe and Powderhorn districts of Colorado and the Lemhi Pass district of Idaho. It also occurs along with bastnaesite in similar deposits in the Mountain Pass district of California.

Bastnaesite was a mineralogic curiosity until early in this decade when a large bastnaesite-barite deposit was discovered at Mountain Pass, Calif., and production began from a bastnaesite-fluorite deposit in the Gallinas Mountains of New Mexico. Bastnaesite is a fluocarbonate of the rare earths, primarily cerium and lanthanum, and contains less than 1 percent uranium and thorium.

Monazite is now being produced in the United States from the placers of the central Idaho region (Anonymous, 1949a, 1950a, 1952b, 1954a, 1954e) and from the placer deposit of the National Lead Co., Jacksonville, Fla. (Mertie, 1953, p. 15), where it is produced as a byproduct of ilmenite mining. Monazite was mined from stream placers in western North and South Carolina in the late nineteenth and early twentieth centuries for use in gas mantles. It has also been produced from a beach placer near Mineral City, Fla. (Santmyers, 1930, p. 11), and as a byproduct of the Climax molybdenum deposit of the Tenmile district, Colo. (Carlson and others, 1953, p. 11). Potential regions of monazite production are the drainage areas of the Idaho batholith in Idaho and Montana, the drainage areas of the western and eastern monazite belts of the southeastern States as outlined by Mertie (1953, p. 15, 24–30), and the drainage areas of the Tuscaloosa formation of the southeastern States (Mertie, 1953). Other districts



Compiled by Katharine L. Buck

Production category	Type of deposit	
	Vein	Modern placer
Potential producer of thorium and (or) rare earths as the principal product	◪	
Potential producer of thorium and (or) rare earths as a byproduct		◐

Abbreviations beside the map symbols indicate the commodities as follows.

Th RE Thorium and rare earths, thorium predominating

Th Thorium only

FIGURE 1.—Index map of thorium and rare-earth deposits in Alaska.

SELECTED ANNOTATED BIBLIOGRAPHY

Abbott, A. T., 1954, Monazite deposits in calcareous rocks, northern Lemhi County, Idaho: Idaho Bur. Mines and Geology Pamph. 99, 24 p.

Between North Fork and Shoup, Idaho, immediately north of the Salmon River, several thin beds of marble are interbedded with the paragneisses and schists that belong to the vast assemblage of metamorphic rocks derived from the pre-Cambrian Belt series. Crystalline aggregates and disseminated crystals of the radioactive phosphate mineral monazite occur sporadically within the beds of marble. Other minerals commonly associated with the monazite are actinolite, barite, siderite, apatite, ilmenite and magnetite. A genetic interpretation involves the migration of rare earth elements during metamorphism of sandy, argillaceous sediments of the Belt series to a more compatible environment of phosphatic limestone in which porphyroblasts of monazite were formed. Although relatively little is known at the present time concerning the value of these deposits, results of this investigation should encourage further exploration and development.—*Author's abstract*

Argall, G. O., Jr., 1954, New dredging techniques recover Idaho monazite: Min. World, v. 16, no. 2, p. 26–30.

Dredging operations for monazite begun in Idaho in 1950 and now carried on by Baumhoff-Marshall, Inc., Idaho-Canadian Dredging Co., and the Warren Dredging Corp. are described in detail and are contrasted with dredging operations for gold.

The main recovery problem in dredging for monazite is caused by the irregularity and wide variation in heavy-mineral content of the sand which do not allow the jigs to be set for a uniform feed. Test drilling and sampling are used to block out areas for dredging, and churn drilling is operated directly ahead of the dredges.

This newly created mining industry has made the United States independent of imports of monazite.

Atkinson, A. S., 1910, Mining for the rare minerals: Min. Sci., v. 61, p. 76–77.

Gadolinite from Llano County, Tex., and from Henderson County, N. C., has been mined and used for gaslight mantles. Gadolinite used in the Nernst lamp contains 40 to 45 percent yttria.

Bates, R. G., and Wedow, Helmuth, Jr., 1953, Preliminary summary review of thorium-bearing mineral occurences in Alaska: U. S. Geol. Survey Circ. 202, 13 p.

Of the forty-seven known thorium-bearing mineral localities in Alaska, only a very few may have commercial possibilities. These are the Salmon Bay area, Prince of Wales Island; the Tofty tin belt in the Manley Hot Springs district, central Alaska; the Long area in the Ruby-Poorman district, central Alaska; the Nixon Fork area, central Alaska; the Buckland-Kiwalik district, eastern Seward Peninsula; the Cape Mountain area, western Seward Peninsula; and the Chandalar district, northeastern Alaska.

The thorium-bearing minerals at each locality are listed in the text and indicated on a map. Published and unpublished references are cited.

literature has been reviewed through 1949 and a few standard publications through early 1952.

Day, D. T., and Richards, R. H., 1906, Useful minerals in the black sands of the Pacific slope: Min. Res. U. S., 1905, p. 1175–1258.

Heavy-mineral analyses of various black sands obtained from placer mines throughout the western States are presented in tabular form by locality. Descriptions of the methods by which the sands were concentrated, methods of testing and examining the sands, results of concentration, and a bibliography are included.

Frondel, J. W., and Fleischer, Michael, 1952, A glossary of uranium- and thorium-bearings minerals: U. S. Geol. Survey Circ. 194, 25 p.

This glossary contains a compilation of (1) minerals containing uranium and thorium as major constituents, (2) minerals containing uranium and thorium as minor constituents, (3) minerals that might show uranium or thorium content, and (4) minerals that often contain uranium, thorium, or the rare earths as impurities or intergrowths. Formulas but not properties are given for most of the minerals, and their relations to other minerals are indicated. The uranium and thorium content of each mineral is listed by percent.

Gillson, J. L., 1949, Titanium, *in* Industrial minerals and rocks: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 1042–1073.

The geologic history common to most commercial beach-sand deposits includes a source area of crystalline rocks, a period of deep-soil formation and the decomposition of magnetite, a period of uplift and rapid erosion of the soil zone, heavy-mineral deposition in coastal-plain sediments, subsidence and straightening of the coast, and, finally, elevation and erosion of the coast.

Glass, J. J., and Smalley, R. G., 1945, Bastnäsite: Am. Mineralogist, v. 30, p. 601–615.

Bastnaesite, a fluocarbonate of cerium metals, occurs in the fluorspar deposits of the Gallinas Mountains, N. Mex., where the two minerals are associated with barite, barytocelestite, calcite, goethite, hematite, orthoclase, pyrite, quartz, and limonitic material along fissures and faults near the contacts of intrusive porphyritic quartz-monzonites, rhyolites, and syenites with Permian sediments that overlie Precambrian granites. The physical, optical, and chemical properties of bastnaesite specimens from this locality are described and compared with the properties of bastnaesite from five other localities. This comparison suggests that bastnaesite has a constant chemical composition. The comparison also indicates that most of the known occurrences of bastnaesite are in contact with metamorphic rocks. A bibliography is included.

Hess, F. L., 1908, Minerals of the rare-earth metals at Baringer Hill, Llano County, Tex.: U. S. Geol. Survey Bull. 340, p. 286–294.

A few hundred pounds per year of rare earths, mainly yttrium, and zirconium have been produced from this area for use in the Nernst lamp. The principal rare-earth minerals of the deposit are gadolinite, alanite, cyrtolite, fergusonite, and polycrase containing the elements yttrium, beryllium, cerium, praseodymium, neodymium, lanthanum, zirconium, niobium, and uranium. The minerals occur in a pegmatite that has been intruded into Precambrian granite.

Houk, L. G., 1943, Monazite sand: U. S. Bur. Mines Inf. Circ. 7233, 19 p.

This report includes analyses of foreign and domestic monazite sands, world-production figures for the period 1893–1938, a review of tariff history, domestic production and imports figures, a description of the uses of monazite, and a list of importers and consumers of monazite sands.

Kithil, K. L., 1915, Monazite, thorium, and mesothorium: U. S. Bur. Mines Tech. Paper 110, 32 p.

This paper presents the history of world production of monazite, including the German thorium conventions; descriptions of domestic and Brazilian deposits; methods of mining and milling monazite; a description of the separation, determination, and uses of mesothorium; and a selected bibliography on monazite, thorium, and mesothorium.

Kremers, H. E., 1949, The rare earth industry: Jour. of the Electrochem. Soc., v. 96, no. 3, p. 152–157.

The industrial treatment of monazite sand for the extraction of cerium and other rare earths and the uses of the rare earths are described briefly. A bibliography is included.

Levy, S. I., 1915, The rare earths, their occurrence, chemistry and technology: London, Edward Arnold, 345 p.

This well-documented older book includes descriptions of the minerals, the mode of occurrence, chemistry, and technology of the rare earths. The incandescent mantle industry, the chemical treatment of monazite, artificial silk and its application to the mantle industry, and other early technological and industrial uses of the rare earths are described.

Lindgren, Waldemar, 1898, The mining districts of the Idaho Basin and the Boise Ridge, Idaho: U. S. Geol. Survey 18th Ann. Rept., pt. 3, p. 677–679.

The heavy minerals derived from the granites of the Idaho Basin are found in the sand of the gravels and lake beds of the region. Throughout the basin, monazite forms a large percentage of the heavy minerals. Samples of monazite from 3 miles east of Idaho City and from Wolf Creek near Placerville are described. This is the first report of monazite placers in Idaho.

Mertie, J. B., Jr., 1949, Monazite, *in* Industrial minerals and rocks: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 629–636.

The characteristics, occurrence, production, economic control, and uses of monazite, the rare earths, and thorium are described. A bibliography is included.

——— 1953, Monazite deposits of the southeastern Atlantic States: U. S. Geol. Survey Circ. 237, 31 p.

Monazite, the principal ore mineral of thorium and the rare earths, was mined from fluviatile placers in the Piedmont province of the Carolinas from 1887 to 1917 with some interruptions. From 1917 to 1946 monazite was imported from India and Brazil; since 1946 the embargoes on exportation of foreign monazite have made it a scarce commodity in this country. Monazite is now being produced in Idaho as well as in Florida, where it is a byproduct of the ilmenite mining near Jacksonville.

New deposits of monazite have been discovered in the southeastern Piedmont, and the placers which were formerly mined have been re-evaluated. The latter were not exhausted by mining and many of the deposits have been rejuvenated. Mining in the area is complicated by the predominance of farming and by the uncertainty of the future value of monazite. These deposits are, however, a reserve which could be invaluable in a time of emergency.

Monazite in the southeastern Piedmont province of complex metamorphic and igneous rocks occurs in two belts, a western belt that is traced from east-central

Virginia southwestward into Alabama and an eastern belt from near Fredericksburg, Va., south-southwestward into North Carolina. These monazite belts may have been the sites of Precambrian valleys where detrital monazite was concentrated and later reconstituted into gneisses or remelted into intrusives.

The western monazite belt includes the area of placers formerly mined in the Carolinas. Results of sampling of the early headwater placers show as much as 8.4 pounds of monazite per cubic yard and a mean content of 5.7 percent thorium oxide. These placers do not contain enough yardage to be mined by large-scale methods.

The principal source rocks in the monazite belts are certain granitic intrusives, granitized and pegmatized country rock, and certain granitic phases of the Carolina gneiss. There is a mean tenor of 0.006 percent monazite in the bedrock.

Moxham, R. M., 1954, Reconnaissance for radioactive deposits in the Manley Hot Springs-Rampart district, east-central Alaska, 1948: U. S. Geol. Survey Circ. 317, 6 p.

The radioactive minerals eschynite, ellsworthite, columbite, monazite, and zircon have been found in the gold-tin placer deposits of the Tofty area, east-central Alaska. The bedrock source of these minerals was not found, although monazite is present in the granite country rock; geologic data suggest a common local bedrock source for both the cassiterite and the radioactive minerals of the Tofty tin placers.

Under present conditions the radioactive minerals of the Tofty placers are probably not sufficiently concentrated to be recovered as a byproduct of the gold and tin mining.

Murata, K. J., Rose, H. J., Jr., and Carron, M. K., 1953, Systematic variation of rare earths in monazite: Geochim. et Cosmochim. Acta, v. 4, p. 292–300.

Ten monazite samples from scattered localities have been analyzed for the individual rare-earth elements by a combined chemical and emission spectrographic method. Rules are given for the variation in the proportions of the rare-earth elements. Variation trends are explained by fractional precipitation and deviations from the trends by abnormally high or low temperatures.

Nininger, R. D., 1954, Minerals for atomic energy: New York, Toronto, London, D. Van Nostrand Co., Inc., 367 p. (See especially p. 16, 17, 87, 89, 91–100, 116, 128–131, 133–139, 142, 172–176, 213, 218, 219, 228, 229, 242, 243.)

Uranium, thorium, and beryllium minerals are discussed in this useful book according to their mineralogy and deposits, to the possibility of their occurrence in various broad geographic and geologic settings, and according to the equipment used in prospecting. Also discussed in detail are regulations pertinent to prospecting for these metals, along with the evaluation of discoveries, and a review of services available to the prospector by governmental and private agencies for sample examination and assay, property examination, and financial aid. Generalized maps of the United States and of the world show occurrence of these elements and their relation to various geologic features. Selected references are listed.

Marketing of the minerals is discussed, and a list of companies that may be interested in the purchase of monazite and rare-earth ores is found on page 309.

The mineralogy of thorium is described in some detail, and tables of the characteristics and tests for the identification of the various minerals are included. The productive deposits of monazite and significant deposits of other thorium minerals in Brazil, India, Ceylon, Indonesia, Malaya, Australia, the Union of South Africa, and the United States are briefly described.

The edges of the Precambrian shield areas of the world have produced the important primary deposits of uranium, but thorium minerals occur only as minor disseminated constituents of these old masses. The concentration of thorium minerals into placer deposits is aided by the mechanical and chemical breakdown of the parent rocks which is carried on most rapidly and to the greatest degree in those shields found in warm climates, such as the Brazilian and Indian shields.

Massifs or roughly equadimensional mountainous areas, seem to be favorable for primary uranium deposits but less so for thorium and beryllium. Examples of massifs which are source areas for placer deposits of monazite are the mid-African Highlands which contribute to the beach placers of Sierra Leone, to the river placers of the Gold Coast, and to the tin placers of central and southern Nigeria which also contain monazite and thorite, and the Korean Highlands which are a source of commercial monazite deposits.

The great linear mountain systems of the world with their large areas of crystalline rocks and their associated basins and plateaus of sedimentary rocks have produced great amounts of metals and offer many possibilities for primary and secondary deposits of uranium and thorium. The principal mountain chains of North and South America, the Alpine-Himalayan system, and the East-Australian Cordillera, are described in detail.

The broad plains areas of sedimentary rocks offer little possibility for primary deposits of uranium and thorium but may contain some secondary deposits of these metals. Local areas of igneous and metamorphic rocks within the plains may contain primary deposits of thorium minerals, and there may be secondary deposits near these source rocks.

Coastal lowlands near granitic source rocks may contain placers of monazite or of other minerals from which monazite may be obtained as a byproduct. Such deposits occur in the southeastern United States.

Nitze, H. B. C., 1895a, Monazite and monazite deposits in North Carolina: N. C. Geol. Survey Bull. 9, 47 p.

Monazite is briefly described and its history, nomenclature, and crystallography are reviewed. Chemical analyses of monazite from various localities are given. The geologic and geographic occurrence of monazite is described. Also covered are the uses, methods of extraction and concentration, and the production and value of monazite. A bibliography is included.

——— 1895b, Monazite: U. S. Geol. Survey 16th Ann. Rept., pt. 4, p. 667–693.

The mineralogical and chemical nature of monazite is described and a brief sketch is given on the history and nomenclature of the mineral. The methods of analysis are presented. Geologic and geographic occurrence of monazite is presented in tabular form. The uses, methods of extraction and concentration, production and value are described. A good early bibliography is included.

Olson, J. C., Shawe, D. R., Pray, L. C., and Sharp, W. N., 1954, Rare-earth mineral deposits of the Mountain Pass district, San Bernardino County, Calif: U. S. Geol. Survey Prof. Paper 261, 75 p.

Bastnaesite, a rare-earth fluocarbonate, was discovered in the Mountain Pass district in April 1949. Geologic mapping has shown that rare-earth mineral deposits occur in a belt about 6 miles long and 1½ miles wide. One deposit, the Sulphide Queen carbonate body, is the greatest concentration of rare-earth minerals now known in the world. The report describes the district, the history of the discovery, the rare-earth and thorium deposits, and the alkalic igneous rocks with which the deposits are associated. Geologic maps of the district and of selected mineral deposits accompany the report.

The radioactive minerals occur in mineralized shear zones characterized by abundant hematite and goethite and in the carbonate rocks. The radioactivity is due almost entirely to thorium and its decay products. The uranium content of vein samples, determined chemically, is low, the highest value being 0.020 percent uranium. Thorium oxide, however, is more than 2 percent of some selected samples. The strongest radioactivity is attributable chiefly to thorite and thorogummite and, to a lesser extent, to monazite which occurs in and near the Sulphide Queen carbonate body.

Parks, R. D., 1949, Source materials for nuclear power, *in* Goodman, Clark, ed., The science and engineering of nuclear power; Cambridge, Mass., Addison-Wesley Press, Inc., v. 2, p. 1–18.

Thorium is not a particularly scarce element in the earth's crust; it is found in about the same quantity as tin, cobalt, zinc, or lead. Economically workable concentrations of thorium are, or have been, less common than those of tin, cobalt, zinc, or lead.

Monazite, for all practical purposes, has been the only commercial source of thorium, and it is generally considered to have been derived from pegmatite sources. Economic deposits have been concentrated into placers by the weathering of such pegmatites.

The monazite mining capacity of India is about 7,000 tons per year, which could be increased by shifting operations from low-monazite high-ilmenite sands to sands richer in monazite. The monazite mining capacity of Brazil is about 1,500 tons per year, which could be increased by adding equipment or going on two shifts. Australia's capacity is about 100 tons per year.

The monazite reserves of India were estimated 25 years ago to be over 2 million tons on a basis of beds 2 feet thick containing 10 percent monazite. They have not been seriously depleted. Brazilian deposits are thought to be of similar magnitude. Ceylon deposits are stated to be very rich but not extensive.

Petar, A. V., 1935, The rare earths: U. S. Bur. Mines Inf. Circ. 6847, 46 p.

This is a general paper, with a good bibliography, on the rare earths. A description and list of properties of the individual elements by family are included, and the history of their discovery is reviewed. Tables are presented of the abundances of rare earths in the earth and of rare-earth-bearing minerals and their occurrence. The chemical separation of these elements and the rare-earth industry, both foreign and domestic, are described. Tables of imports and exports, a discussion of tariff regulations, markets and prices, and a list of producers, dealers, and possible buyers of rare earths are included.

Pratt, J. H., 1916, Zircon, monazite, and other minerals used in the production of chemical compounds employed in the manufacture of lighting apparatus: N. C. Geol. and Econ. Survey Bull. 25, p. 19–69.

This is an excellent report on monazite and the rare earths. A description of the yttrium minerals is given with special attention to gadolinite. Thorium-bearing minerals are also described. Monazite is described as a source of thorium and cerium for use in incandescent lamp mantles, and its occurrence is covered thoroughly by a table of foreign and domestic localities, which lists the country rock and minerals associated with each locality. The uses of

lanthanum are reviewed. The Carolina and Idaho areas are described in more detail. Production in North Carolina from 1893 to 1915 is reviewed. A full description is given of the mining and cleaning of the Carolina monazite sands, including an attempt at mining saprolite. A description of the Brazilian deposits, the history of foreign trade in monazite, and import and export data on monazite and thoria are included.

Pratt, J. H., 1917, Monazite in the United States: Mineral Foote-Notes, v. 1, no. 10, p. 3–15.

A table of occurrences of monazite lists for each locality the country rock and associated minerals. The Carolina and Idaho deposits and the types of rock in which they occur are discussed. A description of monazite and a brief discussion of its uses are included.

Pratt, J. H., and Sterrett, D. B., 1910, Monazite and monazite-mining in the Carolinas: Am. Inst. Min. Eng. Trans., v. 40, p. 313–340.

Monazite and its occurrences in the United States are described along with the geology and deposits of the Carolina monazite region. A description of the separation and uses of monazite is included.

Roots, E. F., 1946, Cerium and thorium: Western Miner, v. 19, no. 8, p. 50–56.

Minerals carrying cerium and thorium (particularly monazite, thorite, auerlite, thorianite, and xenotime) are described, and placer and lode deposits of cerium- and thorium-bearing minerals, both foreign and domestic, are reviewed. Other items covered are the production and consumption of cerium and thorium; mining and milling; marketing, shipping, and duties; extraction of cerium and thorium compounds from monazites; byproducts and utilization; and grades, prices, and buyers of cerium and thorium products and ores.

Santmyers, R. M., 1930, Monazite, thorium, and cerium: U. S. Bur. Mines Inf. Circ. 6321, 43 p.

Thorium- and cerium-bearing minerals and ores, especially monazite, are reviewed, and tests for their identification, history of their discovery, and brief descriptions of their mode of occurrence and geographical distribution are given. Other topics especially well covered are domestic and world production, imports, exports, trade, and the tariff history of monazite, thorium, and cerium. The incandescent gas-mantle industry is described and other uses of thorium and cerium are discussed. Mesothorium is described and imports listed. A good bibliography is included.

At Mineral City, Fla., 4 miles south of Jacksonville Beach, monazite, along with zircon and rutile, was recovered as a byproduct of ilmenite mining (see p. 11). In 1925 there was a reported production of 2,000 pounds of monazite from this deposit.

Schaller, W. T., 1922, Thorium, zirconium, and rare-earth minerals: Min. Res. U. S., 1919, pt. 2, p. 1–32.

This report includes a review of the thorium and rare-earth industry with production and import data, both foreign and domestic; foreign and domestic producing localities; uses; and a review of the sources of ore. Monazite, thorite, auerlite, and thorianite are described; analyses of foreign and domestic monazites with percentage of thoria are given. A good selected general bibliography covering foreign and domestic occurrences is included.

Schrader, F. C., 1910, An occurrence of monazite in northern Idaho: U. S. Geol. Survey Bull. 430, p. 184–191.

Occurrences of monazite are reported in Idaho on Mussel Shell Creek, Nez Perce (now Clearwater) County, near Dent, and in the Pierce district, Idaho. The Mussel Shell Creek deposit is described, and analyses of the monazite from this locality are given.

The origin and distribution of monazite in Idaho are discussed and related to the Idaho batholith. A bibliography is included.

Sharp, W. N., and Pray, L. C., 1952, Geologic map of bastnaesite deposits of the Birthday claims, San Bernardino County, Calif.: U. S. Geol. Survey Min. Inv. Field Studies Map MF 4.

The Precambrian metamorphic complex, country rock in the Birthday claims area, is intruded at the Birthday claims by a body of shonkinite which contains most of the bastnaesite veins in the area. The shonkinite and enclosing gneiss are cut in turn by fine-grained granite bodies and other intrusives.

The barite-rich bastnaesite-bearing carbonate veins follow a west- to northwest-trending fracture system which cuts the Precambrian metamorphic complex as well as the intrusive sequence. The veins have been divided into six types on the basis of mineral content.

The main minerals of the veins are bastnaesite, calcite and other carbonates, barite, quartz, and fluorite. The paragenesis of the minerals, at least locally, is bastnaesite, barite, and the carbonates. Quartz and fluorite may have been deposited later.

Thorium is the main radioactive element in the veins and in the shonkinite, which is more radioactive than the country rock. The largest concentrations of thorium and uranium are in limonitic alteration products found in the weathered veins. Small amounts of these elements occur in the bastnaesite.

Sloan, Earle, 1908, Catalogue of the mineral localities of South Carolina: S. C. Geol. Survey, 4th ser., Bull. 2, p. 129–142.

The geographic limits of monazite zones in South Carolina are described, and detailed locations of monazite gravels in the State are given.

Soulé, J. H., 1946, Exploration of Gallinas fluorspar deposits, Lincoln County, N. Mex.: U. S. Bur. Mines Rept. Inv. 3854, 25 p.

Bastnaesite was discovered in the Gallinas deposits during the Bureau of Mines drilling program in 1943–44. Methods for separating the bastnaesite are discussed. Analyses of bastnaesite are included.

Staley, W. W., 1948, Distribution of heavy alluvial minerals in Idaho: Idaho Bur. Mines and Geology Min. Res. Rept. 5, 12 p.

The mineralogical and chemical composition of black sands, their commercial use, and the distribution of such sands in Idaho are described. Assay results on Idaho heavy sands are given by localities along with chemical and spectrographic analyses. The estimated tonnages of monazite, zircon, and ilmenite available in Idaho are listed; the amount of monazite is 181,500 tons.

Staley, W. W., and Browning, J. S., 1949, Preliminary investigation of concentrating certain minerals in Idaho placer sand: Idaho Bur. Mines and Geology Pamph. 87, 23 p.

Increasing interest in certain heavy minerals accumulated in placer deposits led to this study on the methods of concentrating monazite, zircon, ilmenite, and magnetite in material obtained primarily from dredging operations in the

Boise Basin, Idaho. The experimental method found successful in separating these minerals is a combination of screening, flotation, and magnetic separation.

Sterrett, D. B., 1907, Monazite and zircon: Min. Res. U. S., 1906, p. 1195–1209.

The monazite industry as a whole is reviewed, and the geology of monazite deposits and the mining and cleaning of the monazite sand in North Carolina, South Carolina, and Georgia are described. The deposits in Idaho and in foreign countries are reviewed. Figures are given on price, production, imports and exports of monazite.

——— 1911, Monazite and zircon: Min. Res. U. S., 1909, pt. 2, p. 897–905.

The monazite deposits near Centerville, Idaho, the operation of the Centerville Mining and Milling Co. along Grimes and Quartz Creeks, Idaho, and the methods of mining and concentrating are described. Estimates of the monazite and thoria content of the deposits are given.

Trites, A. F., and Tooker, E. W., 1953, Uranium and thorium deposits in east-central Idaho and southwestern Montana: U. S. Geol. Survey Bull. 988–H, p. 157–209.

Monazite occurs in Precambrian pegmatites of the Deer Creek district, Montana (p. 184–191), at the Divide nos. 1 and 2 claims and at the Gray Goose claims where allanite also occurs in the pegmatite. The Lookout no. 3 claim in the same district contains an hydrothermal carbonate vein, a sample of which contained 0.24 percent thorium oxide and 2.71 percent rare earths, cutting Precambrian(?) gneissic hornblende diorite.

The 11 deposits examined in the Lemhi Pass district (p. 191–208) contain thorium. Thorite is the main thorium-bearing mineral and occurs in quartz-hematite veins which fill fractures in the Precambrian Belt series and which measure from less than 1 foot to 50 feet in width and from 10 to more than 700 feet in length. Other minerals in the veins are goethite, chalcedony, and barite. Samples from the veins contain as much as 6.6 percent calculated thorium oxide, and spectrographic analysis indicates the presence of yttrium, cerium, samarium, neodymium, gadolinium, and lanthanum.

Copper veins also occur as fracture fillings in the Belt series in the Lemhi Pass district. The radioactivity of these veins is similar to that of the quartz-hematite veins, and it is thought to be caused by thorium.

The claims and mines checked in the Lemhi Pass district are the Wonder Lode mine, the Buffalo nos. 1 and 2 claims, the Wonder Lode no. 18 claim, the Lucky Strike nos. 1 and 2 claims, the Trapper nos. 1 and 4 claims, the Radio claim, the Brown Bear claim, the Last Chance claim, and the Shady Tree claim.

United States Atomic Energy Commission, 1954, Sixteenth semiannual report of the Atomic Energy Commission: Washington, D. C., U. S. Govt. Printing Office, p. 25.

The Atomic Energy Commission now has an homogeneous thorium reactor in the planning stage. This reactor will use thorium as a blanket from which uranium 233 will be produced. Construction of the reactor is planned to begin in the fiscal year 1957 and to be completed in the fiscal year 1959.

United States Congress Documents, 1952, 82d Cong., 2d sess., H. Doc. 527, v. 4, p. 22, 23, 112–114.

The current need to increase domestic supplies of thorium and the rare earths has led to the discovery of deposits of monazite in Idaho and bastnaesite in New Mexico and California. New techniques for separating the rare earths will

make it possible to develop new individual uses for these elements, which are now often used in the mixture known as mischmetal.

Embargoes on the exportation of monazite from Brazil and India have raised the price of domestic monazite. The development of new uses for the rare earths has been discouraged because the supply has been considered limited and the price, even of foreign ore, has been unstable. The recent bastnaesite discoveries could supply all the current requirements for rare earths for many years, and monazite mining could be abandoned if bastnaesite had a higher thorium content. Hence the thorium content of monazite continues to make it a mineral essential to our nation, and it is estimated that the probable production of monazite from Idaho will be from 3,000 to 5,000 tons a year for the years 1952 to 1955.

Experiments with pure thorium are being carried on, and they indicate that the properties of the metal are such that there will be a continuing demand for thorium, even outside the field of atomic energy.

United States Congress Documents, 1953, 83d Cong., 1st–2d sess., Hearings on S. R. 143, pt. 1, p. 211–219.

The United States is now becoming self-sufficient in rare-earth metals, largely through the intense search made for rare-earth-bearing minerals since 1950. Promising deposits and adequate reserves of monazite have been found in South Carolina and in Idaho, and a large deposit of bastnaesite has been found at Mountain Pass, Calif. Foreign supplies have been seriously curtailed since January 1951, although there is a possiblity that these sources might be reopened to the United States. Shipments of monazite have been contracted for from Africa for a 3-year period.

Substitutes are available for the rare earths in certain of their uses, such as in carbon-arc electrodes and in flints for lighters.

Recommendations made to assure adequate supplies of rare earths are:

1. A stockpile sufficient for a 5-year emergency.
2. Continued exploration for new placer deposits of monazite and byproduct minerals.
3. Development of markets for the byproduct minerals of monazite placer mining.
4. Continued studies to improve recovery of monazite and heavy minerals from placers and to improve extraction of rare earths from the ore.
5. Extensive study of the treatment of bastnaesite and its separation from gangue minerals.
6. Studies of the separation of individual rare-earth elements from their ores.
7. Research in metallurgy on the value and uses of the individual rare-earth metals.

West, W. S., and Matzko, J. J., 1953, Buckland-Kiwalik district, 1947, *in* Gault, H. R., and others, Reconnaissance for radioactive deposits in the northeastern part of the Seward Peninsula, Alaska, 1945–47 and 1951: U. S. Geol. Survey Circ. 250, p. 21–27.

Uranothorianite and thorite are the most important of the radioactive minerals found widely distributed in the Buckland-Kiwalik district. These minerals occur mainly in well-defined placer zones within areas of granitic rock and are thought to be concentrated accessory minerals from the differentiate phases of certain of the granitic rocks. It is possible, however, because of the presence of metallic sulfides, that some of the uranium was introduced during a period of hydrothermal alteration of the granitic rocks. Concentrations of uranothorianite are found in the headwaters of the Peace River and Quartz and Sweepstakes

Creeks on Granite Mountain; in the Hunter Creek-Connolly Creek area; and on Clem Mountain. The Peace River placer locality may be a lead to a high-grade uranium lode.

White, M. G., and Stevens, J. M., 1953, Reconnaissance for radioactive deposits in the Ruby-Poorman and Nixon Fork districts, west-central Alaska, 1949: U. S. Geol. Survey Circ. 279, 19 p.

In the Long area of the Ruby-Poorman district are two small granite bodies with an average equivalent uranium content of 0.005 percent. This radioactivity is due largely to uranothorite(?) disseminated throughout the granite. No high concentrations of the mineral were found.

In the Nixon Fork district uraniferous thorianite, allanite and other radioactive minerals whose radioactivity is principally due to thorium, were found in the placers of Hidden, Ruby, and Eagle Creeks. Bedrock occurrences are found at the Whalen mine where the rare-earth mineral parisite is found along with allanite, radioactive hematite and sphene, and zircon; in the monzonite of the Ruby Creek area which contains zircon and sphene; and the Nixon Fork mine.

Anonymous, 1949a, Monazite production: Min. Cong. Jour., v. 35, no. 7, p. 71.

Rare Earths Mineral Co., McCall, Idaho, is extracting monazite from Idaho sands and is contracting to ship 16,000 tons of concentrated sand during the next 10 years.

——— 1949b, Monazite research: Min. Cong. Jour., v. 35, no. 9, p. 82.

University of Idaho School of Mines is conducting a research program on the rare earths recovered as byproducts in the milling of monazite sand.

Idaho placer gravels are being treated for monazite content at a plant at McCall, Idaho.

——— 1950a, Idaho—Operation of a bucket-line dredge on Big Creek: Eng. Min. Jour., v. 151, no. 11, p. 130.

A bucket-line dredge on Big Creek, Idaho, is producing monazite and gold and is handling 5,000 to 6,000 yards of gravel daily.

——— 1950b, Wyoming—Atomic energy representatives investigating the uranium deposits reported at Sundance: Eng. Min. Jour., v. 151, no. 6, p. 126.

The uranium deposits at Sundance, Wyo., contain low-grade uranium and rare-earth oxides.

——— 1952a, Companies join with Heim to develop bastnasite: Eng. Min. Jour., v. 153, no. 1, p. 108.

The Gallinas district, Lincoln County, N. Mex., produces each month several carloads of rare-earth ore which is shipped to Lindsay Light & Chemical Co.

——— 1952b, Fred Baumhoff, Centerville, Idaho: Eng. Min. Jour., v. 153, no. 2, p. 168–169.

Fred Baumhoff, operating near Cascade, Idaho, has shipped 1,000 tons of monazite to Lindsay Light & Chemical Co.

——— 1952c, Southern California's rare-earth bonanza: Eng. Min. Jour., v. 153, no. 1, p. 100–102.

The massive bastnaesite-barite veins of the Mountain Pass district are described, and an estimate of their size and grade is given. The ore-dressing problem is discussed. A history of the discovery and development of the district is presented.

Anonymous, 1954a, Atlantic beaches radioactive: Min Cong. Jour., v. 40, no. 1, p. 63.

The U. S. Geological Survey has released maps showing the location of radioactivity anomalies detected along parts of the Atlantic Ocean beach from Cape Henry, Va., to Cape Fear, N. C., and from Savannah Beach, Ga., to Miami Beach, Fla. These anomalies may or may not indicate the presence of uranium or thorium.

——— 1954b, Dredges work Idaho sand: Eng. Min. Jour., v. 155, no. 3, p. 190.

Dredges operating in the Long Valley, Idaho, area are recovering monazite from gravels which contain about 15½ pounds per cubic yard of black sand which in turn contains about 7½ percent monazite. The black sand is separated at Boise in the Baumhoff-Marshall, Inc. plant. Half of the monazite, which contains about 60 percent rare-earth metals, is purchased by Lindsay Light & Chemical Co. and half by the Government for stockpiling.

Bear Valley, Idaho, is reported to be a new source of radioactive elements, including thorium and rare earths. Production in Bear Valley is scheduled to begin by September 1954.

——— 1954c, Idaho dredge plans: Min. Cong. Jour., v. 40, no. 8, p. 127.

Preparations are being made for large-scale dredging in Bear Valley, Idaho, where a plant for processing the dredge products is to begin operations by September 1954. Monazite, thorium, tantalum, columbium, and uranium are to be recovered.

——— 1954d, Survey eastern coast: Min Cong. Jour., v. 40, no. 6, p. 98.

The U. S. Geological Survey has released maps showing the location of radioactivity anomalies detected along parts of the Atlantic Ocean beach between Cape Fear, N. C., and Edisto Island, S. C., and along the Gulf of Mexico between Sanibel and Caladesi Islands, Fla. These anomalies may or may not indicate the presence of uranium or thorium.

——— 1954e, Three of central Idaho's placer deposits are currently producing radioactive minerals: Eng. Min. Jour., v. 155, no. 5, p. 93.

The Bureau of Mines announces the production of rare-earth minerals—thorium, uranium, columbium, and tantalum—from the Big Creek, Boise Basin, and Ruby Meadows placers in Idaho. The Bureau lists as potential producers Bear Valley, Secesh Meadows, Scott Valley, Horsethief Basin, Pearsol and Corral Creeks.

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