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GEOLOGY AND MINERALOGY

U. S. DEPARTMENT OF THE INTERIOR

A COMPREHENSIVE REPORT OF EXPLORATION BY THE BUREAU OF MINES FOR THORIUM AND RADIOACTIVE BLACK MINERAL DEPOSITS

Compiled by
D. E. Eilertsen
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Bureau of Mines
Washington, D. C.

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D. E. Eilertsen 1/ and F. D. Lamb 2/

INTRODUCTION

Late in the 19th century the United States was the world's principal supplier of monazite, a mineral in demand as a source of thorium for gas mantles. After 1895 production from Brazil surpassed that of the United States and in 1911, when monazite from India also became available, United States production virtually ceased. The total production of monazite in the United States from 1911 to 1948 was only about 50 tons as small mining operations in North Carolina and South Carolina were unable to compete with larger and richer beach deposits in Brazil and India.

The possibility of thorium being used eventually as an atomic energy source material prompted India in 1946, and Brazil in 1951, to restrict exports of monazite, thus effectively cutting off the United States from the major sources of thorium ores. Lean years for rare-earth and thorium processors in the United States followed these events and stocks of monazite sands in the United States were seriously depleted during that time. Under the sponsorship of the Atomic Energy Commission the Bureau of Mines, with the cooperation of the Geological Survey in some phases of the work, undertook a search for domestic monazite deposits, beginning in 1948. The search succeeded in 1949 and 1950 in locating minable reserves of monazite in Idaho and 3 dredges were put into operation on deposits near Cascade, Idaho as a direct result of the investigation. Late in 1951 the work was extended to include investigations in the southeastern states and toward locating deposits containing radioactive black minerals such as euxenite and samarskite which might prove to be profitable sources of columbium, tantalum, uranium and other metals as well as thorium and rare earths. The latter work, terminated on June 30, 1955, resulted in commercial operations at Aiken, South Carolina and Bear Valley, Idaho.

1/ Mining Engineer, Branch of Rare and Precious Metals, Washington, D. C.

2/ Assistant Chief, Branch of Rare and Precious Metals, Washington, D. C.

At its inception the program was under the supervision of the Special Minerals Investigation Branch of the Bureau. Headquarters of the Branch were established at Mt. Weather, Virginia, with a field office and ore-dressing laboratory at Boise, Idaho. The field office and laboratory were later transferred to Spokane, Washington and when the work was extended to the southeastern states a field office and laboratory were established at Shelby, North Carolina. In 1954 and 1955, a limited amount of work conducted in Alaska was supervised by the Bureau's staff at Juneau, Alaska. Analytical and radiometric laboratories participating in the program were located at Mt. Weather, Virginia; Raleigh, North Carolina; and Reno, Nevada. As of January 1, 1952, the special Minerals Investigation Branch was incorporated into the regional organization of the Bureau of Mines, and from that date the program was under the general supervision of the Branch of Rare and Precious Metals, Division of Minerals.

SUMMARY

The search for thorium and radioactive black minerals in the United States and Alaska began in 1948 and terminated on June 30, 1955. Exploration work was done on 49 projects located geographically as follows:

Western and Northwestern United States, including Alaska

California	Idaho	Montana	Wyoming	Alaska	Total
5	27	4	1	2	39

Southeastern United States

North Carolina	South Carolina	South Atlantic Coast	Total
5	4	1	10

All of the deposits investigated were placers except one, in Wyoming, which is a lode deposit. These investigations were in addition to hundreds of preliminary examinations of deposits made during field reconnaissance work.

Of the 39 deposits in the western part of the United States and Alaska, the Bear Valley deposit in Idaho is the only one being commercially exploited at the present time. Among the other areas investigated, 9 deposits, 8 in in Idaho, and 1 in Montana, contain radioactive and other minerals of potential commercial importance. The Idaho areas are: Big Creek, Clear Creek, Corral Creek, Pearsol Creek, and Scott Valley-Horsethief Basin in Valley County; the Gold Creek-Williams Creek deposits in Custer County; Rock Creek in Blaine County; and Camp Creek in Blaine and Camas Counties. The area in Montana is the Victor and McCalla deposit in Ravalli County. These ten areas have indicated reserves of radioactive minerals.

The Bear Valley placers in Idaho and the Victor and McCalla placer in Montana, were the only two areas considered to have inferred reserves of radioactive minerals.

The total indicated and inferred reserves of radioactive minerals in the areas are shown below:

Cubic yards of gravel	Short Tons				
	U_3O_8	ThO_2	Euxenite	Uranothorite	Monazite
485,667,000	1,616	11,400	7,500	1,660	244,140

The tenors of radioactive minerals in the two Alaskan deposits investigated were found to be too low to be of economic importance.

The Southeastern States exploration work, started in October 1951 and finished in August 1954, was conducted on ten placer deposits. All of the deposits investigated were found to be marginal in grade, but during exploration on Hollow Creek, Aiken County, South Carolina four prospect holes were drilled by the Bureau in an adjacent area, lower Horse Creek. The results obtained from these holes encouraged outside interests to do some additional exploration in the area with Bureau of Mines advice and assistance. During this program a few holes were also drilled on upper Horse Creek which indicated that the better ground was upstream. Later a DMEA loan application, submitted by other outside interests was approved and further drilling in the area indicated the gravels to contain economic quantities of monazite, xenotime, and other heavy minerals. As a result, Marine Minerals, Incorporated was established to exploit the deposit.

The ten project areas investigated in the Southeastern States are: Knob Creek, Buffalo Creek, Sandy Run Creek, South Muddy Creek and Silver Creek, and First Broad River and Its Tributaries in North Carolina; Junction of North Tyger River with the Middle Tyger River, Rabon Creek and Big Generostee Creek, Broad River and Thicketty Creek, and Hollow Creek in South Carolina; and beach sands of the islands along the South Atlantic Coast. These areas have reserves of potential commercial value.

Six areas, South Muddy Creek, Silver Creek, Tyger River, Thicketty Creeks, Rabon Creek, and Big Generostee Creeks were determined to have inferred reserves.

The total indicated and inferred reserves of monazite in the areas are shown below:

Cubic yards of gravel	Short tons U_3O_8	Short tons ThO_2	Short tons Monazite
353,950,000	685	6,640	126,660

ACKNOWLEDGMENTS

The cooperation and assistance of all of the property owners and others who aided the engineers and employees of the Bureau of Mines in conducting the thorium and radioactive black minerals exploration program is gratefully acknowledged. Special acknowledgment is made for the guidance and encouragement extended the Bureau of Mines by members of the Division of Raw Materials, Atomic Energy Commission, and particularly for the efforts of the late R. G. Edmonds who guided much of the exploration program until his death in 1955.

PART I - WESTERN AND NORTHWESTERN UNITED STATES, INCLUDING ALASKA

By

R. H. Storch 3/, A. F. Robertson 3/, and D. C. Holt 3/

INTRODUCTION

The Western and Northwestern Radioactive Minerals Program was initiated early in 1948, under the supervision of the Special Minerals Investigation Branch of the Bureau of Mines to make a comprehensive search for monazite-bearing placer sands. Funds for the work were provided by the Raw Materials Division of the Atomic Energy Commission.

The program was instigated as a result of the embargo placed by Brazil and India on monazite, a rare-earths thorium phosphate mineral. These countries had been the principal suppliers of monazite to the United States.

The Special Minerals Investigation Branch, later referred to as the Special Minerals Section, commenced operation in California. Before completion of the work in California, an exploration program was started in Idaho and later continued in Montana, Wyoming, and Alaska. In addition, field reconnaissance work was done in Nevada, Oregon, and Washington, but no exploration projects developed in these States.

The original objectives of the program were: (1) To locate alluvial placers containing monazite by field reconnaissance and hand sampling methods; (2) to determine the size and extent of monazite bearing alluvium in the individual deposits which previously had been recommended for exploration by churn drilling, trench pitting, or shaft sinking; (3) to evaluate the property by determining the quantities of monazite and other black sand minerals, in terms of pounds per cubic yard, which would affect the economic exploitation of the deposit. In 1950 the program was enlarged to include other radioactive minerals containing thorium and uranium; (4) to recommend methods for further development of the properties and assist in developing ways and means of mining and recovering the black sand concentrates; and (5) to assist in developing a method for separating the mineral constituents into marketable products in order to interest private industry in undertaking the exploitation of the newly discovered deposits.

3/ Mining engineer, Bureau of Mines, Spokane, Washington

To carry out the objectives of the program it was necessary in many instances to modify older exploration and field sampling procedures, develop new methods for final laboratory sample analyses, and train personnel in the necessity of accepting the new techniques arising from the development of a different type of mining industry in the United States.

Almost without exception, property owners were most agreeable and cooperative in permitting Bureau of Mines employees to trespass and carry out exploration work on their respective properties. This attitude contributed considerably to the success of the program.

SUMMARY

The Bureau of Mines completed 39 exploration projects in the Western and Northwestern United States and Alaska in an extensive search for radioactive minerals. Five of these projects were in California, 27 in Idaho, 4 in Montana, 1 in Wyoming, and 2 in Alaska. One lode monazite deposit in Wyoming was explored with a rotary drill. These investigations did not include hundreds of additional deposits on which preliminary examinations were made during field reconnaissance in California, Idaho, Washington, Oregon, Nevada, and Montana between 1949 and the end of the field season in October 1954.

Dr. J. Hoover Mackin of the U. S. Geological Survey submitted a preliminary report in July 1952 on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission entitled "Reconnaissance Geology of the Monazite Placers of the Long Valley District, Idaho." A second report entitled "Reconnaissance Geology of Placer Deposits Containing Radioactive Minerals in Bear Valley District, Valley County, Idaho," prepared by J. Hoover Mackin and Dwight L. Schmidt, was submitted to the same Division of the Atomic Energy Commission in January 1953. Mr. Schmidt also made a geological reconnaissance of the Camp Creek and Rock Creek placer areas in 1954.

The Bear Valley deposit, located in Valley County, Idaho is the only western deposit thoroughly investigated by the Bureau having reserves of radioactive minerals of economic importance that is being exploited at the present time. Nine other deposits included in this report are listed as having reserves; currently however, they are more of strategic importance than economic. The areas are: Big Creek Placers, Camp Creek Placers, Clear Creek Placers, Corral Creek Placer Area, Gold Creek and Williams Creek, Pearsol Creek Placer Area, Scott Valley and Horsethief Basin Placers, Rock Creek Placer Area, and Victor and McCalla Placer Areas. These 10 areas were considered to have indicated reserves.

Only two areas, the Bear Valley in Idaho and The Victor and McCalla in Montana, were considered to have inferred reserves.

The total indicated and inferred reserves in the areas are shown below:

Cubic yards of gravel	Short tons			
	Monazite	Uranothorite	Euxenite	U_3O_8
485,667,000	244,140	1,660	7,500	1,616
	Short tons			
	ThO_2	Ilmenite	Zircon	$(CbTa)_2O_5$
	11,400	1,876,230	51,280	10,780

The tenors of the Alaskan deposits investigated were found to be too low grade with respect to radioactive minerals to be of commercial interest.

FIELD INVESTIGATIONS

Projects

Field work, including churn drilling, dredge sampling, and test pitting, began at the Hammonton gold field in Yuba County, California in January 1949. (See Index Map in appendix.) The Hammonton field was chosen because it represented the largest single dredging operation in the United States. Between 1949 and October 1954 when field work was terminated, the deposits found in 39 exploration projects including 2 in Alaska were tested for monazite and other radioactive minerals by one or more methods including trenching, shaft sinking, churn drilling, rotary drilling, and dredge sampling. Several hundred additional alluvial deposits were examined and tested by panning and grab-sampling during field reconnaissance in California, Idaho, Montana, Oregon, Washington, and Nevada.

Listed below are the individual areas covered in Part I of this report. Numbers preceding each area refer to the numbers used to locate the deposits on Figure 1 in the appendix. Figure 2 in the appendix shows the locations of the Alaskan deposits.

Published Idaho Reports

(For sale by Office of Technical Services,
Department of Commerce, Washington 25, D. C.)

Index Map
Key No.

1. Boise Basin, Boise County, RME-3129
3. Big Creek Placers, Valley County, RME-3131
4. Scott Valley and Horsethief Basin Placers, Valley County, RME-3133
13. Bear Valley Placers, Valley County, RME-3130
14. Pearsol Creek Placer Area, Valley County, RME-3134
17. Beaver Creek Placer Area, Valley County, RME-3132
18. Corral Creek Placer Area, Valley County, RME-3135
19. Camp Creek Placer Area, Blaine and Camas Counties, RME-3136
20. Rock Creek Placer Area, Blaine County, RME-3139

Published Wyoming Report

(For sale by Office of Technical Services,
Department of Commerce, Washington 25, D. C.)

1. Deadwood Conglomerate, Bald Mountain Deposit, Sheridan and Big Horn Counties, RME-3128

Unpublished California Reports

1. Hammonton Placer Deposit, Yuba County
2. Waterford Placer Deposit, Stanislaus County
3. Beach Sands, Monterey Peninsula, Monterey County
4. Folsom Field, American River, Sacramento County
5. through 8. Placer Deposits of the Merced, Stanislaus, Calaveras Mokelumne Rivers of California

Unpublished Idaho Reports

2. Secesh Meadows Placer Area, Idaho County
5. through 9. Stolle Meadows, Kelly Meadows, Squaw Meadows, Peace Valley and Dry Creek of Central Idaho
10. Clear Creek Placers, Valley County
11. Alexander Flats, Elmore County
12. Warren Meadows, Idaho County
15. Gold Fork Placer Areas, Valley County
16. Grouse Creek Placer Area, Idaho County
21. Gold Creek and Williams Creek Placer Area, Custer County
22. Garden Valley Placer Area, Boise County
23. Meadow Creek and Valley Creek Placer Area, Custer County
24. West Mountain Placer Area, Valley County
25. Poverty Flats, Reed Creek and Dead Sheep Creek Placer Areas, Blaine County

Index Map
Key No.

26. Lake Creek Placer Area, Idaho County
27. Johnson Creek Placer Area, Gem County
28. Mud Flats Placer Area, Elmore County
29. Kelly Creek and Stanley Creek Placer Areas, Custer County
30. Rabbit Creek Placer Area, Boise County
31. Elk City Placers, Idaho County

Unpublished Montana Reports

1. Trail Creek Placers, Beaverhead County
2. Rye Creek Placer Area, Ravalli County
3. Price and Powder Gulch Placer Areas, Silver Bow County
4. Victor and McCalla Placer Areas, Ravalli County

Unpublished Alaska Reports

1. Preliminary Investigations of Tin and Radioactive Minerals in Gold Placer Deposits near Tofty, Yukon River Region

2. Preliminary Investigations of Radioactive Placers on Vulcan Creek-Clear Creek, Radium Gulch, and Bear Creek, Seward Peninsula.

General Geology and Mineralogy

California Placers

Only the most general geology will be discussed as it is more thoroughly presented in the individual project reports.

The geology 4/ of 8 placer deposits examined in California, with the exception of Monterey Beach sands, is essentially the same. All of the deposits were formed by east-west flowing rivers and streams at points where they leave narrow mountain canyons and spread out in wider valleys. Gold and other heavy minerals in these placer deposits were derived from pre-Cretaceous metamorphic rocks of the Sierra Nevada Mountains.

4/ State of California, Division of Mines, Bulletins:
No. 36, Gold Dredging in California, by J. E. Doolittle, 1905
No. 37, Gold Dredging in California by W. B. Winston and Chas. Janin, 1910.
No. 92, Gold Placers of California by Chas. S. Haley, 1923.
No. 135, Placer Mining for Gold in California by Chas. V. Averill.

The deposits that were under investigation consisted of well-rounded pebbles, sand, clay and cobbles usually not exceeding 8 inches in diameter. The depth of the placer deposits varied; gold values were found at depths ranging from a few feet to over 300 feet. Dredging depths usually were controlled by a false bedrock of lava ash or were limited by the maximum digging depth of a particular dredge.

The black sand content of the alluvium in the California gold fields examined was comparatively low. Of the average in 8 fields, most of the black sand was magnetite, then ilmenite-hematite, with other minerals constituting the remaining fractions. These minerals included garnet, zircon quartz, epidote, and trace amounts of monazite and uranothorite. The greater percentage of the black sand was from minus 35 mesh to plus 150 mesh in size. The variety of minerals in the black sand concentrates varied from one deposit to another.

The geology 5/ of the Monterey Peninsula is in general comparable to the entire Monterey Quadrangle. The older rock types include shales, sand-stones and conglomerate overlying granite, presumably of Jurassic age. These rocks are partially obscured by sand dunes and marine and fluvial terrace material of varying thickness. The host rock of the monazite is the granite which has weathered and eroded to form the beach sands and marine placers.

The black sand minerals included magnetite, ilmenite, garnet, trace amounts of slightly radioactive zircon, and monazite. No other uranium-thorium bearing minerals were present.

Idaho and Montana Placers

Placer deposits in Idaho and Western Montana of any economic or strategic importance, because of their radioactive mineral content, are closely associated with the Idaho Batholith. The batholith is a granitic mass of late Mesozoic period covering an area of several thousand square miles in southeastern Idaho and the southwestern portion of Montana. Field reconnaissance and exploration indicated that most of the important deposits were formed under similar conditions. Radioactive minerals found in placers are usually friable and brittle.

5/ Beal, Carl H., The Geology of the Monterey Quadrangle, a thesis, September 1915, Stanford.

It is important, therefore, that after being weathered from the granitic host rock, these minerals not be transported any great distance by stream action and that a quiescent condition prevail during the period of their deposition. 6/ This condition was brought about by the formation of depressions or lake-like basins which were formed when flowing streams were obstructed either by block faulting, glacial morains, or basalt flows. An example of each type is as follows: (1) Big Creek Placers by block faulting, Bear Valley Placers by a glacial morain, and Camp Creek Placer by basalt flows. As a result the basin fill consists of successive layers of fine and coarse sand, clay and gravel. The well rounded gravel seldom exceeds 2 inches in diameter in the larger deposits.

The proportional amounts of the black sand minerals vary considerably from one deposit to another and in most cases within the individual deposits. As would be expected, this applies also to grain size.

Following is a table showing the contents in percent of the more common minerals occurring in the black sands from selected samples of 3 Idaho placer deposits.

Mineral Content of Black Sands from Selected
Samples of 3 Idaho Placers

Mineral	Pearsol Creek Placer Area Percent	Camp Creek Placers Percent	Bear Valley Placers Percent
Magnetite	0.7	29-33	10.3
Ilmenite	80.5	26-30	58.6
Garnet	1.6	0.2	20.0
Zircon	0.1	0.5-0.8	0.07
Monazite	8.4	0.1	3.6
Uranothorite	-	1.2	-
Sphene	-	10-12	1.0
Radioactive Opaques (Euxenite, samarskite, brannerite, etc.)	Tr	-	0.14-0.30

6/ J. Hoover Mackin and Dwight C. Schmidt, Reconnaissance Geology of Placer Deposits containing Radioactive Minerals in Bear Valley District, Valley County, Idaho (Trace Elements Memorandum Report 602), January 1953. J. Hoover Mackin, Reconnaissance Geology of the Monazite Placers of the Long Valley District, Valley County, Idaho (Trace Elements Memorandum Report 473), July 1952.

Wyoming Lode

The Deadwood Conglomerate, Bald Mountain Deposit in the Big Horn Mountains in Sheridan and Big Horn Counties, Wyoming, was the only monazite lode deposit drilled under the Western Radioactive Minerals program.

The Big Horn Mountains are an outlying portion of the Rocky Mountain Range. 7/ Crystalline granites and sedimentary rocks as well as glacial deposits are exposed in the area where the deposits occur. The sedimentary rocks consisting of sandstones, shales, limestone and conglomerate and known as the Deadwood Formation of Acadian (Middle Cambrian) age, overlie the granite.

The heavier concentration of monazite and other black sand minerals occurs in the soft, red conglomerate bed on or near the granite contact. The bed was characterized by well-rounded quartz pebbles and the presence of hematite and limonite.

The black sand minerals consisted of ilmenite, magnetite, hematite, limonite, garnet, monazite, and zircon. Although grinding action by drilling may have reduced grain size to some extent, over 30 percent of the monazite in the crude ore was found to be minus 200-mesh in size before the ore was crushed in the laboratory.

Alaskan Placers

The Tofty tin-belt placers in central Alaska occur along the north side of Patterson Creek which flows through an alluvial-filled valley between Rough Top Mountain and Hot Springs Dome. These peaks are composed of granitic rocks. The gravels consist of subangular to poorly rounded cobbles of quartzite, phyllite, slate, and quartz with some clay. Much of the deposits in the are are permanently frozen. In addition to gold and cassiterite, small quantities of monazite, columbite, eschynite, and ellsworthite were found.

In the Seward Peninsula, the bedrock in the Vulcan Creek-Clear Creek area, is mostly altered limestone with granitic rocks nearby. In Radium Gulch the bedrock is granitic and andesitic. In Bear Creek the rocks were found to be basic igneous with intrusions of acidic rocks and quartz veins. Only small quantities of cyrtolite, thorite, and uranothorianite were found in the placer gravels. Bear Creek bedrock samples contained small quantities of cyrtolite.

7/ Darton, N. H., Description of the Bald Mountain and Dayton Quadrangle: Geologic Atlas of the U. S.: USGS, 1906

Reconnaissance

It has been known for many years that monazite and other radioactive minerals were original constitutents of granites, gneisses and pegmatites. 8/ It was known, also, that these minerals, after being released from their host rocks by weathering and subsequent erosion, were found in varying amounts in the gravels derived from these igneous rocks. In 1905 an investigation of the black sand minerals in the Northwestern States was made by the U. S. Geological Survey. 9/ Numerous localities where monazite and other heavy black minerals had been found were catalogued in this report.

Early results of the Bureau investigations indicated that placer deposits containing the radioactive minerals in quantities of economic importance were derived from the igneous rocks located in their immediate vicinity. Reconnaissance work, to determine if the deposits were worthy of further investigation by drilling or trenching, was done in several hundred areas located within or adjacent to the Idaho Batholith and other granitic masses. The work consisted of concentrating with a gold pan gravels in stream beds, bars and benches adjacent to streams cutting igneous formations. The concentrates obtained were inspected with a 40-power pocket microscope and tested with a Geiger counter or a scintillometer to determine if the concentrates contained appreciable amounts of monazite or other radioactive minerals. In addition, if the radioactivity of the sample was greater than indicated by the amount of monazite present, a hydro-fluoric test was made for radioactive opaque minerals.

When concentrate obtained by the panning had sufficient monazite or excessive radioactivity to indicate the gravel contained one pound or more of that mineral per cubic yard, or other radioactive minerals equivalent to one pound of monazite, grab samples of gravel, weighing 50 to 100 pounds, were taken for additional testing in the field laboratory. If the field laboratory tests confirmed the results obtained by the panning, a preliminary report outlining the factors related to a possible mining operation was prepared.

The factors considered in the preliminary report include:

1. An estimate of the size and extent of gravel deposits which might be available for mining.

2. Character of material, size of gravel and type of bedrock to be expected.

8/ Waldemar Lindgren, Mineral Deposits, P. 248
9/ David T. Day and R. H. Richards, Useful Minerals in the Black Sands of Pacific Coast, Mineral Resources of the United States, 1905, pp. 1175 through 1258.

3. Accessibility and power availability.

4. Water supply and stream gradient.

5. Type of vegetation and its relationship to cost of land clearing.

6. Present use of the land, its value, and ownership.

7. Elevation of the deposit, climate to be expected, and the number of months of the year the deposit could be worked.

8. An estimate of the number of pounds of black sand per cubic yard and amount of marketable and the non-marketable black sand minerals, including gold, which might affect the economic exploitation of the deposit.

After preliminary reports had been submitted they were reviewed carefully; the deposits considered most promising were selected for more detailed investigation and sampling.

Before exploration work was begun, "Agreement for Mineral Exploration" forms were executed between Bureau of Mines and the property owners or lessees. Sampling of the placer deposits was done by churn drilling, shafting, or trenching with power equipment. All or a part of the alluvial material removed from drill holes, test pits or shafts was taken for samples. The exploration method selected varied with area and depth of the deposit, amount and type of vegetation, depth to water table, accessibility of places where the samples were to be taken.

In 1945-1947, and 1948, the U. S. Geological Survey 10/ 11/ reported finding some radioactive minerals while on reconnaissance in Alaska.

Drilling and Sampling

The purpose of the exploration was to indicate the more promising areas for private industry to develop, so therefore, no attempts were made to block out reserves by closely spaced drilling, trenching, and shaft sinkings.

10/ West, W. S., Reconnaissance for Radioactive Deposits in the Northeast Part of Seward Peninsula, Alaska: U. S. Geological Survey Circular 250, 1946.

11/ West, Walter S., Reconnaissance for Radioactive Deposits in the Darby Mountains, Seward Peninsula, Alaska; U. S. Geological Survey Circular 300, 1948.

Churn drill sampling was employed at all of the larger placer deposits where the character of the terrain permitted the use of a uniform drilling grid, or pattern, and where the drill sites were readily accessible. The method was used also on some of the smaller deposits where the thickness or depth of the gravel to bedrock was too great to permit the use of test pits or shafts for obtaining samples. The depth of drilling ranged from 5 to 140 feet. In several of the deposits the depth of the monazite-bearing gravel exceeded 100 feet.

The drilling pattern for the larger areas was laid out in rectangular form on lines spaced from 800 to 1,600 feet apart. The holes were spaced from 600 to 800 feet apart on the lines. Drilling, on smaller irregularly shaped areas, was done at selected points ranging from 400 to 1,000 feet apart usually with no established pattern. The areas influenced by the holes were determined by measuring with a planimeter, the polygonal areas formed on a map of the area by using the perpendicular bisector method. Areas of influence for holes on the edges of the area were considered to extend for an arbitrary distance of about 500 feet away from a line connecting 2 adjacent holes or as far as it was considered mining could be conducted.

The churn drilling was performed under contract by privately owned drill companies at the lowest price per foot obtainable. Bids were requested for drilling both a minimum and maximum number of feet. Contractors were required to furnish all labor and equipment needed for drilling and recovering the samples. Standard, truck-mounted churn drills, equipped with heavy duty 6-inch casing and $7\frac{1}{2}$-inch drive shoes were employed. The contractors also furnished a sand pump for removing the material from the hole and a steel trough (mud box) into which the sand pump was emptied.

Standard drilling procedures were used. Sample material was recovered after each $2\frac{1}{2}$-foot drive of the casing. The material from two $2\frac{1}{2}$-foot drives was flushed from the trough into a steel pan representing one 5-foot sample. A part of each $2\frac{1}{2}$-foot sample was panned and the mineral content estimated at the drill site. This was done for the purpose of logging the hole and to control the depth of the drilling. All material panned was returned to the sample from which it was taken.

Each 5-foot sample was dried in a separate pan over an open fire and then screened to minus 1/8-inch, or minus 1/4-inch, depending on the size of the heavy minerals. The oversize was weighed, the weight recorded before the material was discarded; the undersize was dried, sacked, weighed, logged and transported to the field laboratory for concentration.

All slimes from each hole were caught in tubs, or in an open pit if the ground was tight. The total dry weight was determined by either weighing the dried slimes or by determining the dry weight of a measured volume of this material and then calculating the total weight of the slimes in the pit. A sample was taken for laboratory testing.

When the gravel deposits were shallow or inaccessible to the churn drill, sampling was done by cutting 5-foot channel samples from the sides of trenches or pits excavated either by a bulldozer or by a diesel-powered back-hoe machine. After the excavations were sampled they were filled; later the ground was leveled with a bulldozer. The equipment, with an operator, was supplied by a contractor on a rental basis if the cost of the work did not exceed $500; otherwise bids were requested for an hourly contract price. Payment for the use of the equipment was made in the manner provided by Government regulations.

Trench samples were not dried and screened in the field. Instead they were taken to a temporary field laboratory, weighed, dry weight calculated, recorded before it was wet screened and roughly concentrated on a vibrating table. The rough concentrates then were dried, sacked, and transported to the field laboratory at Spokane, Washington, for further concentration and cleaning. (The Alaskan samples were sent to the Bureau's field laboratory in Juneau for concentrating and testing.)

Samples were obtained at several properties from shafts. A few shafts were sunk in unconsolidated dredge tailings by using 5-foot sections of telescoping steel caissons ranging from 4½ to 5 feet in diameter. A 4-inch centrifugal pump, on the surface of the ground, was used to keep the shafts dry to a maximum depth of about 15 feet. At greater depths a small 1½-inch pump powered by a gasoline engine was lowered inside the caisson with precautions taken to pipe out the exhaust fumes. All material from the shaft was hoisted in a bucket by means of a power winch mounted on a truck. At some shafts all of the material was screened wet in the field to minus 16-mesh by use of a double-screen placer machine. Undersize material was transported to the field laboratory for concentration. In some instances the material hoisted was split to 1/8 of its original volume by using the alternate shovel method; 7/8 of the material was discarded. Although a larger sample was obtained and a better knowledge of the character of the material was gained by shaft sinking, costs were considerably higher and the depth which could be reached was limited. Some sand plant and dredge sampling was also done which lead to improved operations.

Processing Samples

To eliminate transportation costs on waste material, all samples taken in the field were concentrated in a field laboratory which was originally established at Hammonton, California. Concentrates from the samples were shipped to the Bureau of Mines laboratory at Mount Weather, Virginia, for analyses and determination of their monazite content. A similar field laboratory was established at Boise, Idaho, which was later transferred to Spokane, Washington, when the Special Minerals Investigation Branch began testing placer deposits in Western Montana and Idaho. The Alaskan samples were shipped to the Bureau's laboratory at Juneau for processing and analyzing.

Analyses and radiometric tests on the concentrates, made at Mount Weather, soon proved that other radioactive minerals in addition to monazite were present in some of the placer deposits. To evaluate the deposits it was necessary to develop new techniques both for use in the field and in the analytical laboratories. The methods and procedures used at the Bureau of Mines field laboratory at Boise, Idaho, and later at Spokane, Washington, for determining the amounts of the various black sand minerals in the concentrates were developed when it was noted that some concentrates were highly radioactive although they contained only trace amounts of monazite.

When the minus 1/8-inch material was received at the field laboratory, each sample was reweighed and the weight recorded. It was then dry screened on a double-deck vibrating screen equipped with 8-mesh and 16-mesh openings. This operation was carried on in a room that was separate from the main laboratory and was equipped with an exhaust fan. Respirators were supplied to the operators to decrease the dust hazard. The plus 8-mesh and the minus 8-mesh plus 16-mesh fractions were checked with a Geiger counter. If no radioactivity was noted, these fractions were weighed, logged, and discarded; otherwise they were concentrated on a laboratory jig. The minus 16-mesh fraction was passed over a 7-foot vibrating table twice to produce a rough concentrate containing all of the heavy minerals and some of the lighter sands. This concentrate then was treated on a laboratory-size vibrating table which produced a clean concentrate and a middling product which was re-run. The cleaned concentrate was dried, weighed, and the weight recorded.

Early experiments had determined that the average dry weight of one cubic yard of gravel was 2700 pounds. Since both the original dry weight of the gravel sample and the weight of black sand concentrate recovered had been recorded, the pounds of black sand per cubic yard of gravel was readily computed for each sample.

Any gold contained in the final concentrate was recovered by amalgmation; the amalgam was parted and the gold weighed. Its value in cents per cubic yard of gravel was computed if the concentrate contained more than a trace.

After the dried concentrate was mixed on a rolling cloth, a 10-gram sample was taken. The magnetite in this sample was removed with a hand magnet and weighed. Its percentage in the entire concentrate was computed. The remainder of the sample was examined with a microscope and the percentage content of ilmenite, garnet, zircon, and monazite was estimated. The zircon content in percent was also checked with ultraviolet; the fluorescence of the zircon under the short wave ultraviolet light rendered the zircon crystals easy to identify. The entire sample then was compared radiometrically, by means of a Geiger counter, with the radioactivity of a standard monazite sample of the same weight. If the concentrate contained no radioactive minerals, other than monazite, the percent of monazite in the sample could be determined by the comparative readings and the amount of monazite in pounds per cubic yard of gravel was easily calculated. If other radioactive minerals were present, the result was reported as monazite equivalent 12/ in pounds per cubic yard. 13/

Each of the concentrate samples were sacked, labeled, and shipped to the laboratory at Mount Weather, Virginia, for final analysis until that laboratory was closed and moved to the Bureau of Mines Laboratory at Raleigh, North Carolina. Later the equipment and personnel were transferred again from Raleigh to the new Bureau of Mines laboratory at Reno, Nevada. All samples then were sent to the new laboratory for final analyses. Alaskan concentrates were shipped to Reno, Nevada, for final analyses.

Soon after the investigation of the monazite-bearing placer deposits was begun, it was realized that the black sands in some of the deposits contained variable amounts of radioactive minerals other than monazite. To properly evaluate the deposits it was necessary to determine accurately the mineralogic composition of the black sands and the chemical composition of various radioactive minerals which were present in the black sands. The radioactivity of the sands was due not only to the thorium and uranium content of the monazite but also to the uranium content of radioactive minerals such as euxenite, samarskite, brannerite, thorite, and uranothorite, which were present in some deposits. Radiometric tests alone gave no evidence of the amount, or even the presence of monazite, nor can the relative amounts of thorium and uranium be determined. Chemical analyses of the black sands are necessary to determine the amounts of these elements.

When the samples were received from the field laboratory, each sample was catalogued and tested radiometrically. A composite sample then was prepared for each drill hole. This sample, thoroughly mixed, was split into 2 parts. One of these parts was combined with split parts of each composite drill hole sample to form an area composite sample. The other half of the composite

12/ Radioactivity equivalent to one pound of monazite standard containing 4.20 percent ThO_2 and 0.13 percent U_3O_8.

13/ Kline, M. H., Evaluation of Monazite Placer Deposits, AEC, RMO-908 April 1952, 16 pp.

drill hole sample was divided in 2 parts. One part was ground for analytical determinations. The other was used for mineralogical examinations.

The part selected for mineralogical examination was screened and then separated into various fractions with an isodynamic separator and heavy liquids. By subsequent petrographic determinations, the percentage weights of the different minerals in the various fractions were obtained.

The part selected for analytical determinations was split as often as necessary to obtain a representative sample weighing from 200 to 300 grams. This was ground in a ball mill for 3 or 4 hours. The partly ground product of the ball mill was screened on a 100-mesh sieve. The plus 100-mesh material was then pulverized in a selected pulverizer. This procedure avoids significant scoring of the hardened steel plates in the pulverizer because most of the garnet contained in the samples is crushed to less than 100-mesh size in the ball mill.

To expedite the determination of the thorium content of the black sands new methods and procedures had to be devised; the older analytical procedures were long and yielded good results only in the most experienced hands, particularly when the samples contained only small amounts of thorium. The improved methods, developed by Kronstadt and Eberle 14/ permitted the analysis of as many as 6 samples per man-shift or at a rate about 6 times faster than that possible when any other method was used.

The procedures used were successfully employed in the analysis of samples containing from 0.05 - 0.3 percent ThO_2.

When pure monazite sands containing a high percent of ThO_2 were analyzed, the results obtained were in close agreement with the results found by the classical gravimetric method.

Standard analytical procedures were used for determining the amount of uranium in each of the composite drill hole samples.

When the ThO_2 and U_3O_8 contents of each of the mineral fractions is known, the equivalent ThO_2 for the total sample can be determined. A comparison of the radiometric, mineralogic, and chemical analyses is made on a basis of the equation:

$$\text{Equivalent } ThO_2 = \text{Chemical } ThO_2 + 4.4 \times \text{Chemical } U_3O_8.$$

14/ Kronstadt, R. and Eberle, Allan R., Analytical Procedure for the Determination of Thorium: AEC, RMO-838, 9 pp.

The factor 4.4 was determined in the laboratory by comparing the radioactivity of uranium oxide with that of thorium oxide when each is in equilibrium with its daughter products. When the analyses have been completed the volume and tonnage of each of the various minerals in a particular area can be calculated.

Calculations and Procedures

The amount of monazite per cubic yard of gravel was determined in the field laboratory by estimating with a microscope the amount of monazite in percent in the black sand concentrate recovered from each gravel sample. After the visual examination each sample concentrate was checked radiometrically and compared with a monazite standard. The gravel in the sample, as taken from the drill hole, was found by earlier tests to have an average dry weight of 2,700 pounds per cubic yard. Having weighed both the original gravel sample and the contained black sand concentrate recovered, the amount of monazite in pounds per cubic yard was readily calculated as follows:

$$\frac{2700}{\text{Dry wt. of sample}} \times \text{dry wt. of concentrate} = \text{dry wt. of black sand per cu. yd.}$$

(Weight of black sand per cu. yd.) x (estimated percent monazite) = pounds of monazite per cu. yd.

The minable depth is determined both by the character of the material encountered in the hole and by the pounds of monazite or monazite equivalent which the visual estimates and the radiometric tests indicate the gravels contain. The cut-off point was considered to be that below which the gravels contained less than one pound of monazite or monazite equivalent per cubic yard. It was considered that gravels containing less than one pound of monazite or monazite equivalent per cubic yard could not be exploited economically unless gold or some other marketable mineral was present in quantities sufficient to pay a large part of the operating expenses.

Method Used in Calculating Reserves

The amounts of each of the minerals in pounds per cubic yard for each sample were determined to the minable depth indicated for each drill hole; numerical averages of the amounts then were calculated for individual drill holes. Significant data for the deposit was obtained as follows:

Volume influence of each hole = area of influence in sq. yds. x minable depth in yds.

Pounds of mineral in volume influenced by each hole = volume of influence (cu. yds.) x calculated average mineral content in pounds per cubic yard.

Total pounds of mineral available = sum of the pounds of mineral indicated by individual holes.

$$\text{Average mineral content in pounds per cu. yd.} = \frac{\text{Total pounds of mineral available}}{\text{Total number of cubic yards in deposit}}$$

The quantities of the metals contained in the minerals were calculated on a basis of their atomic weights.

Quantities of the minerals as determined by the churn drill or test pit sampling were considered as "indicated" when the average monazite or monazite equivalent content was one pound or more per cubic yard.

When the placer deposit investigations began in 1949 one pound of monazite had a market value of approximately 13.7 cents. From 1951 to 1954 the market price was about $0.18 per pound for monazite concentrates containing 60 percent combined rare-earth oxides. During 1954 large quantities of monazite were supplied by foreign sources at a price considerably lower than was being paid to domestic producers. The discovery and development of a large deposit of bastnaesite in California further decreased the price for the combined rare-earth oxides to a point where profitable operation of the dredges for monazite alone became uneconomic. As a result the monazite dredges in Idaho were closed down on August 8, 1955, when government contracts for monazite were completed.

Conditions governing supply and demand have changed and most of the placer deposits investigated, and at one time considered capable of being exploited economically, are now considered to be strategic reserves but uneconomic in importance.

RESEARCH INVESTIGATIONS

Since the latter part of 1953, the Northwest Electrodevelopment Laboratory of the Bureau of Mines at Albany, Oregon, has conducted a series of research investigations relating to black sand minerals recovered from placers in South Central Idaho. The "Columbium-Tantalum and Black Sand Research" project was to determine the most practical method of separating Cb-Ta minerals into a marketable grade from the other black sand mineral constituents.

The "Black Sand Research" project was an investigation relating to the chemical separation of columbium-tantalum, rare earths, uranium and titanium in the several black sand minerals. A research project "Extraction of Titanium Slag from Rare Earths" 15/ was to produce a high titanium oxide slag and pig iron from the ilmenite byproduct from the sand treatment plant at Boise, Idaho.

EXPLOITATION OF DEPOSITS

The Bureau completed drilling in the Big Creek area, Valley County, Idaho September 29, 1950. In November of the same year, outside interests erected a 6-cubic foot bucket line dredge in the area and began mining the monazite bearing sands. Other interests commenced operations in the same area in 1951. Although one dredge was dismantled, 2 remaining dredges continued working until August 1955. At that time the government monazite stock pile was filled; new contracts, either with the government or private industry, were unobtainable.

At the time the gold dredges were erected in the Big Creek area, about the only change made was to decrease the size of the performations in the trommel screens. As a result of the Bureau of Mines sampling program the monazite losses were found to be high. A series of changes in the dredge flow sheet were made to improve the recovery.

Numerous changes, likewise, had to be made in the original monazite sand plant flow sheet. An increased number of high voltage separators (for recleaning purposes) and a series of magnetic induction rolls were installed. A few changes have been made in operational technique, but no major alterations have been made in the sand plant flow sheet since 1953.

In 1951 private industry became interested in the Bear Valley area and later installed a 4½ cubic foot bucket line dredge. In 1955 a second dredge with 6-cubic foot buckets was moved into Upper Bear Valley.

A pilot black sand treatment plant was installed at Boise in June 1953 and has been operated almost continuously since that date. It is equipped with large and small vibrating tables, attrition mill, laboratory size induction rolls and a laboratory size magnetic cross-belt separator. Facilities are provided for drying the black sand products.

15/ L. H. Banning, W. F. Hugert, D. E. Holter; Electric Smelting of Ilmenite Concentrates from Valley County, Idaho; Bureau of Mines Report of Investigations 5170, November 1955.

Private industry also built a new sand treatment plant at Lowman, Idaho, about 20 miles south of Bear Valley.

Several companies were granted DMEA loans for exploration of radioactive placer minerals.

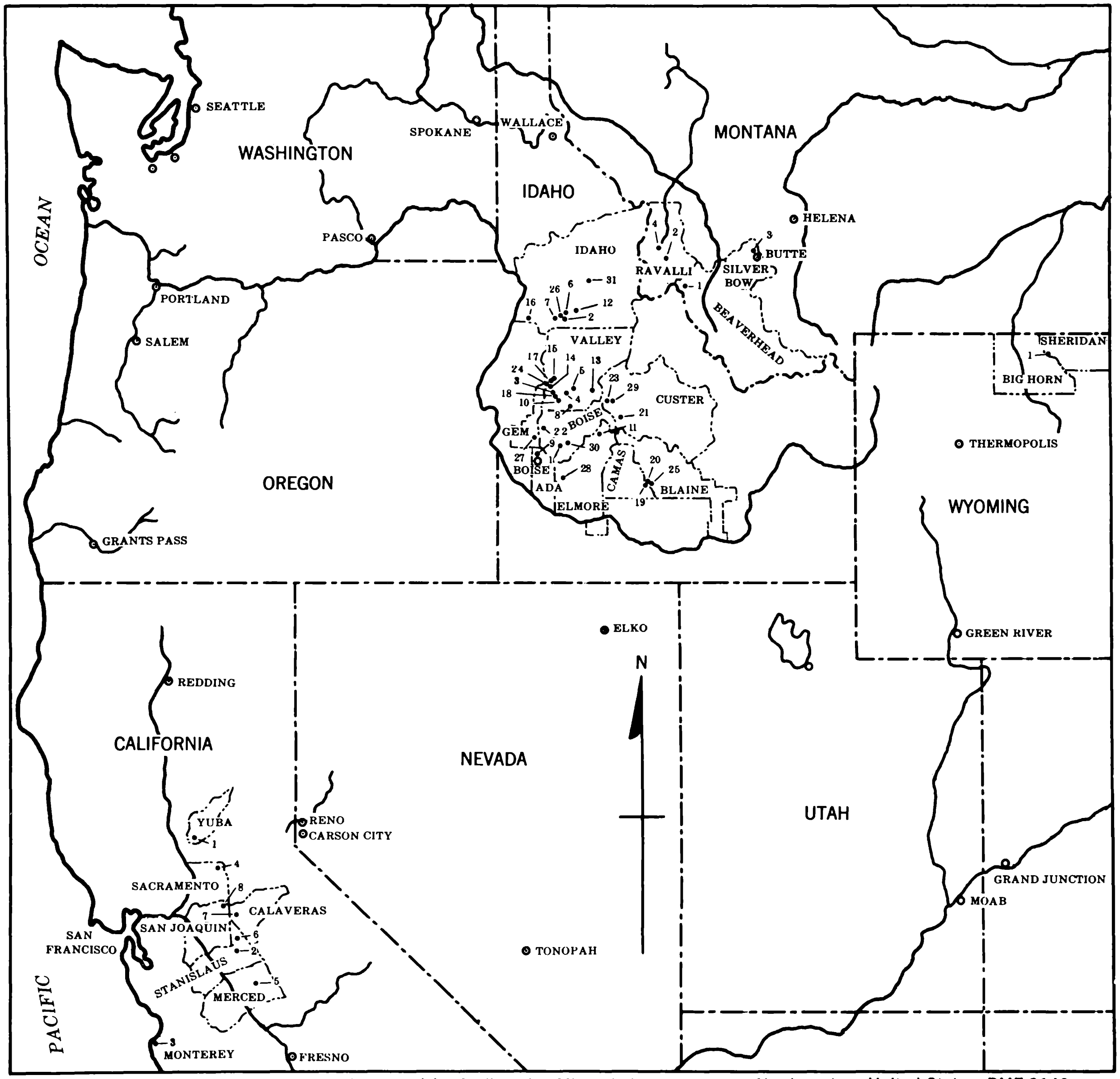
CONCLUSIONS

1. The Thorium and Radioactive Black Mineral Exploration Program conducted by the Bureau of Mines for the Atomic Energy Commission has apparently resulted in making this country self-sufficient in monazite as far as future requirements can now be determined. The deposits are not presently competitive with richer foreign deposits containing monazite of high ThO_2 content than domestic ores, but they constitue strategic reserves that can be utilized if necessary.

2. Substantial tonnages of columbium-tantalum-uranium bearing minerals were developed that are presently being mined.

3. Appreciable quantities of uranothorite and yttrium-thulium-bearing sphene were found associated in 2 deposits. They represent an important stategic reserve of uranium, thorium, yttrium, thulium, and titanium.

APPENDIX I



CALIFORNIA

1 Hammonton Placer Deposit, Yuba County
2 Waterford Placer Deposit, Stanislaus County
3 Beach Sands, Monterey Peninsula, Monterey
4 Folsom Field, American River, Sacramento County
5 thru 8 Placer Deposits of the Merced, Stanislaus, Calaveras and Mokelumne Rivers of California

IDAHO

1 Boise Basin, Boise County
2 Secesh Meadows Placer Area, Idaho County
3 Big Creek Placers, Valley County
4 Scott Valley and Horsethief Basin Placers, Valley County
5 thru 9 Stolle Meadows, Kelly Meadows, Squaw Meadows, Peace Valley and Dry Creek of Central Idaho
10 Clear Creek Placers, Valley County
11 Alexander Flats, Elmore County
12 Warren Meadows, Idaho County
13 Bear Valley Placers, Valley County
14 Pearsol Creek Placer Area, Valley County
15 Gold Fork Placer Areas, Valley County
16 Grouse Creek Placer Area, Idaho County
17 Beaver Creek Placer Area, Valley County
18 Corral Creek Placer Area, Valley County
19 Camp Creek Placer Area, Blaine and Camas Counties
20 Rock Creek Placer Area, Blaine County
21 Gold Creek and Williams Creek Placer Area, Custer County
22 Garden Valley Placer Area, Boise County
23 Meadow Creek and Valley Creek Placer Area, Custer County
24 West Mountain Placer Area, Valley County
25 Poverty Flats, Reed Creek and Dead Sheep Creek Placer Areas, Blaine County
26 Lake Creek Placer Area, Idaho County
27 Johnson Creek Placer Area, Gem County
28 Mud Flats Placer Area, Elmore County
29 Kelly Creek and Stanley Creek Placer Areas, Custer County
30 Rabbit Creek Placer Area, Boise County
31 Elk City Placers, Idaho County

MONTANA

1 Trail Creek Placers, Beaverhead County
2 Rye Creek Placer Area, Ravalli County
3 Price and Powder Gulch Placer Areas, Silver Bow County
4 Victor and McCalla Placer Area, Ravalli County

WYOMING

1 Deadwood Conglomerate, Bald Mountain Deposit, Sheridan and Big Horn Counties

100 0 100 200
Scale, miles

Figure 1. -- Index Map of Placer Deposits tested for Radioactive Minerals in Western and Northwestern United States. RME-3140

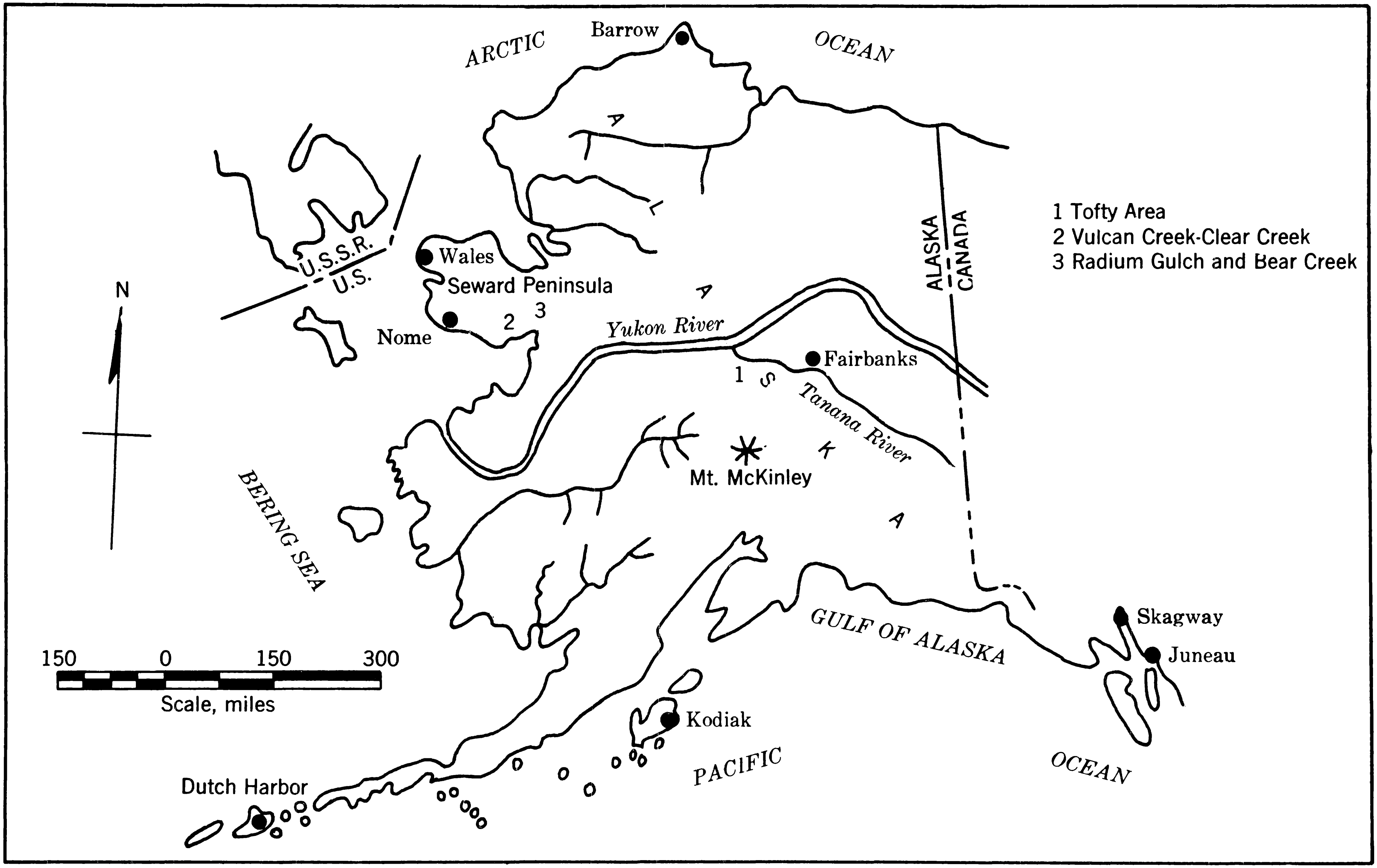


Figure 2. -- Index Map of Alaska. RME-3140

GS-20
765

PART II - SOUTHEASTERN UNITED STATES

By: Milton H. Marshall 16/

INTRODUCTION

The Southeastern Radioactive Minerals Program of the Bureau of Mines was initiated in late 1951. Funds for this work, terminated June 30, 1955, were provided by the Division of Raw Materials of the U. S. Atomic Energy Commission.

After India had restricted exports of monazite in 1946 and Brazil in 1951 it was logical to look again to the Southeastern States for monazite where records show that monazite placer mining began in 1886 17/ and that shipments of monazite were made annually from 1887 to 1911 18/ with a peak of 1,573,000 pounds of monazite sand shipped in 1895.

The objectives for exploration in the southeast were: (1) to determine if there were monazite deposits in the region of sufficient tenor and volume to warrant exploitation by private interests under existing economic conditions; and (2) to obtain information as to the location of potential commercial sources of monazite.

SUMMARY

A total of 10 exploration projects for monazite were completed in the Southeastern States, namely, 5 in North Carolina, 4 in South Carolina, and one along the Southeast Atlantic Coast.

Of the 10 projects, 8 were reported jointly by the Bureau of Mines and the Geological Survey to the A. E. C., and 2 were reported by the Bureau alone. All areas were designated by the U. S. Geological Survey for exploration by the Bureau of Mines.

The first 3 projects, namely Knob Creek, Buffalo Creek and Sandy Run were selected for initial consideration due to favorable past production history and reports of monazite being in these areas.

16/ Mining Engineer, Bureau of Mines, Norris, Tennessee.

17/ Pratt, J. H., Zircon, Monazite and other Minerals used in the Production of Chemical Compounds Employed in the Manufacturing of Lighting Apparatus, North Carolina Geological and Economic Survey, Bull. 25, 1916, p. 52.

18/ Houk, L. G., Monazite Sand, U. S. Bureau of Mines, I. C. 7233, Feb. 1943, pp. 11-15.

The next 5 projects, namely, South Muddy and Silver Creeks, First Broad River and its Tributaries, Junction of the North Tyger with the Middle Tyger River, Rabon and Generostee Creeks, and Broad River and Thicketty Creek were carried out in large flood plains. The Hollow Creek project was the result of an individual reconnoitering the Southeast for dredgable gravels and from encouraging preliminary sampling work. The last project was conducted on the Southeast Atlantic ocean beaches.

Thirteen deposits, namely, Knob Creek, Buffalo Creek, Sandy Run Creek, South Muddy Creek, Silver Creek, First Broad River, Broad River, Thicketty Creek, Tyger River, Rabon Creek, Big Generostee Creek, Hollow Creek, and Hilton Head Island were estimated to have reserves of black-sand minerals.

Six areas, South Muddy Creek, Silver Creek, Tyger River, Thicketty Creek, Rabon Creek, and Big Generostee Creek were estimated to have inferred reserves of black-sand minerals.

The total indicated and inferred black-sand reserves of the areas are shown below:

Cubic yards	Short tons			
of gravel	Monazite	Ilmenite	Rutile	Zircon
353,950,000	126,660	1,275,250	237,120	351,710

The indicated and inferred reserves of monazite were estimated to have 685 tons of U_3O_8 and 6,640 tons of ThO_2.

During the Hollow Creek exploration, 4 holes were also drilled on Horse Creek, a parallel stream tributary to the Savannah River 10 miles upstream from Hollow Creek. The results of the 4 holes formed the basis for approval of a DMEA financed exploration program which resulted in the blocking out of a large volume of minable monazite-bearing alluvium. As a result, Marine Minerals, Inc., was established to develop and exploit these deposits.

FIELD INVESTIGATIONS

Projects

Exploration for monazite in the Southeastern States began late in November 1951. The Knob Creek area of North Carolina was chosen by the Bureau and Survey as the area to start the program because monazite was known to be present and there was evidence of old mining operations for monazite in the area. The drilling for monazite in the southeastern area was completed late in August 1954.

The individual projects, listed below, are keyed to the Index Map in the appendix:

Published North Carolina Reports
(For sale by Office of Technical Services, Department of Commerce, Washington 25, D. C.)

Index Map
Key No.

1. Knob Creek Monazite Placer, Cleveland County, RME-3112
2. Buffalo Creek Monazite Placer, Cleveland and Lincoln Counties, RME-3113
3. Sandy Run Creek Monazite Placer, Rutherford County, RME-3114
4, 5 and 6. Monazite Placers on South Muddy Creek, McDowell County, and Silver Creek, Burke County, RME-3115
7. Monazite Placer on the First Broad River and its Tributaries, Cleveland County, RME-3116

Published South Carolina Reports
(For sale by Office of Technical Services, Department of Commerce, Washington 25, D. C.)

10 and 11. Monazite Placer at the Junction of the North Tyger River with the Middle Tyger River, Spartenburg County, RME-3117

12 and 13. Monazite Placers on Rabon Creek, Laurens County, and Big Generostee Creek, Anderson County, RME-3118
8 and 9. Monazite Placers at the Broad River and Thicketty Creek, Cherokee County, RME-3126
14 and 15. Hollow Creek Monazite Placer, Aiken County, RME-3127

Unpublished South Atlantic Coast Report

16 and 17. Monazite Bearing Beach Sands of the South Atlantic Coast

General Geology and Mineralogy

The southeastern coastal states, with the exception of Florida, essentially begin and radiate east and south from the Southern Appalachian Mountains seaward to the Atlantic Ocean and Gulf of Mexico.

The general features of the Southeast were influenced by a mountain building disturbance that took place in late Paleozoic time. The mountains of western North and South Carolina, northern Georgia, and east-central Alabama are the highest in the east, but are mere erosional remnants of this orogency. Today, evidence of profound erosion may also be observed in the consequent peneplanation of the east flank of the ancestral mountains. The resulting peneplain, or Piedmont as it is called, extends quite distinctly as an upland province of low relief parallel and adjacent to the remnant mountains from northern Virginia southwestward into east-central Alabama. In North Carolina, the Piedmont reaches a maximum width of 125 miles, but elsewhere averages 60 to 80 miles in width. Since the end of Paleozoic time, the Appalachians and Piedmont, have stood as positive areas. This land mass contributed constituents of their complex rock assemblages to later encroaching Mesozoic and Cenezoic seas. Terrestrial derived materials incorporated into the clastic (Cretaceous and Tertiary) sediments eventually resulted in the formation of the Atlantic and Gulf Coastal Plains.

Inland Features

Monazite is found in outcropping plutonic rocks as a narrow indistinct area in the inner southeastern Piedmont. As little detailed geologic mapping has been done on the crystalline rocks of this section, the geology is not thoroughly known. Outcrops are infrequent, and deep residual weathering further complicates delineation. Fortunately, the adjacent and paralleling southern Appalachian are the main watershead for a large part of the Southeast. Headwaters of most major river systems traverse the known area of monazite-bearing bedrock, and under suitable conditions, form placers.

The mineral monazite is resistant to chemical alteration but is readily reduced by attrition 19/. If conditions are not favorable for initial enrichment, as valley-head placers, the mineral rapidly disseminates in stream sands and gravels.

In cases where streams carrying monazite flowed into ancient seas, some concentration undoubtedly took place near the deltas and adjacent shore line. As sedimentation and weathering processes continued, the heavy minerals were subjected to repeated cycles of concentration and dissemination. The placers below the Fall Line is an example where concentrations of monazite are found due to weathering of once overlapping formations. Evidence of concentration by more recent seas may be observed in the Pleistocene shore features of the lower coastal plains. Today, evidence of concentration by present seas is noticeable along the coastal shore in the features of the Southeast Atlantic Ocean Beaches.

19/ Faul, H., Nuclear Geology, John Wiley & Sons, 1954, p. 103

Coastal Features

Small amounts of monazite are carried in the sediment load of rivers that traverse areas of original bedrock sources and/or areas of secondary enrichment. At the deltas, marine forces of the Atlantic Ocean and Gulf of Mexico hinder immediate deposition. The mineral, with other heavier resistates, are transported for great distances by offshore currents. Wave action along the shorelines further distributes the terrestrial material. Strong currents during storms aided by severe winds have probably been instrumental in promoting present monazite-bearing beach placers. Placers so formed are erratic in size and distribution, but essentially lie seaward and parallel to the adjacent shore line feature present at the time of concentration. Undoubtedly, some of the earlier formed deposits have been buried by subsequent storms, but recent placers are found associated with the present ocean beach. Where winds have been predominately strong, exposed marine concentrations have been re-deposited in the troughs of beach dunes. Peculiarly positioned deposits sometime are found as a result.

Description of Deposits

All deposits explored and herein briefly described were located in the southeastern states of North Carolina, South Carolina, and Florida. The network of primary, secondary and farm roads throughout these states generally rendered some part of each deposit accessible by motor vehicle. Within the limits of the deposit, the seasonable amounts of precipitation (40-50 inches) and vegetation was the controlling factor of further accessibility.

The physical features of deposits explored were generally consistent in a particular phase of investigation. The deposits were so chosen in the headwater and higher flood plain activity to fall within certain limits of estimated tons of reserves.

A wide variation in the descriptive characteristics of the material in the deposits was immediately made apparent, and persisted through the duration of the project. The condition is thought to be due to: (1) to variance in the assemblage of outcrop constituents in the rocks comprising the deposit, and (2) to the consequent environmental conditions affecting deposition. Such variation is normal and expected owing to the nature of the deposit.

For example, the character of the alluvium contained in the deposits tested during the headwater investigations were variable.

Deposit	Percent Gravel	Gravel and sand	Gravel and clay	Sand	Sand and clay	Clay
Knob Creek	-	3	26	-	35	26
Buffalo Creek	-	13	22	-	40	25
Sandy Run Creek	19	19	3	-	27	32

Likewise, the variation in the frequency of four heavy minerals in selected samples from the deposits is shown as follows:

Deposit	Percent mineral in concentrate Rutile	Ilmenite	Zircon	Monazite
Knob Creek	-	9.8	0.9	11.5
Buffalo Creek	2.6	18.2	.5	3.4
Sandy Run Creek	5.4	34.3	0.5	6.1*

*Monazite-xenotine

For comparison, the character of alluvium for three deposits included in the higher flood plain phase of investigations is:

Deposit	Percent Gravel	Gravel and sand	Gravel and clay	Sand	Sand and clay	Clay
South Muddy Creek	24	9	15	-	22	30
Thicketty Creek	-	40	-	10	50	-
Tyger River	2	-	-	43	55	-

The frequency of four heavy minerals in selected concentrates is:

Deposit	Percent mineral in concentrate Rutile	Ilmenite	Zircon	Monazite
South Muddy Creek	0.3	23.0	8.0	6.4
Thicketty Creek	4.2	42.0	0.3	5.2
Tyger River	1.4	32.5	8.5	7.2

Admittedly, the three higher flood plain type deposits are widely scattered, but deposits close enough to be considered a single mining operation are as variable. Each deposit is perhaps best described by its own individual characteristics.

Reconnaissance

The preliminary examination 20-21/ of an area began with panning river gravel or beach sand taken from selected spots considered to be promising for the concentration of monazite. This step established the heavy mineral relationships between different sections of a given area and/or between different areas.

Inland, a quick and reliable way to determine mineral relationships was by panning the "short side" of solid stream bars. A surface concentration is generally found at such places owing to the action of the stream which, in flowing over the bar, carries the lighter minerals downstream and deposits the heavier minerals among the pebbles frequently exposed on the short side of the bar.

Beaches have similar characteristic points whereby rapid evaluation was possible. The line formed by trash deposited along a beach at high tide level was the key spot to begin preliminary examinations. The trash or debris acts as riffles (similar to exposed pebbles of stream bars) behind which the wave and wind blown heavy minerals may accumulate. The minerals thereby collected at the high tide strand line may be visible as a dark narrow ribbon 2 - 3 feet wide along the beach parallel to the shore. Unlike solid stream bars which are relatively permanent, beaches are constantly altered. A "dark show" may be completely obscured by a thin mantle of white sand.

A shovel or hand auger sample to ground water level was standard practice in both bar and beach examination. Where feasible, the depth of sample extended below the water level. Shovel or hand auger samples from nearby flood plains, or a vertical channel sample from a stream bank, supplemented initial bar derived information in river examinations. In beach examinations, shovel or auger samples from inlying beach dunes or believed embayments frequently assisted in determining the economic feasibility of additional investigation.

A small hand screen, having 1/8-inch openings to 14-mesh for river sampling and smaller mesh for beach sampling, was used to separate the oversize from the fines. A rough percent 22/ was obtained by measuring the two volumes. The undersize was carefully panned and observed with a 40X microscope. A determination has been made that a teaspoon of monazite obtained from a level 16-inch pan of gravel is equivalent to $2\frac{1}{2}$ pounds of monazite per cubic yard of gravel. The same rule holds for beach examinations. Indications of radioactivity was noted by the aid of a portable Geiger counter.

20/ Kline, M. H., Evaluation of Monazite Placer Deposits, AEC Rept. RMO-908, April 1952, p. 3.

21/ Griffith, R. F., Development of Monazite Exploration Techniques Improves U. S. Rare Earth and Thorium Supply, Mining Engineering, Oct. 1955, pp. 930-932.

22/ Work cited in footnote 20, p. 4.

If the counter registered good radioactivity, several 75 to 200-pound samples were obtained for careful analysis at the laboratory.

Admittedly, the points selected for initial examinations were generally four times as high in monazite content, as the deposit the selected points represent. Experience has shown though, if monazite is not found at such points in at least interesting quantity, the area has a low economic potential.

The need for an extensive reconnaissance project was realized as another result of the Hollow Creek discovery. In the Fall of 1952, a widespread sampling program was started 23/ that covered parts of 5 southeastern States.

Airborne surveys 24-25/ flown by the Geological Survey along the South Atlantic and Gulf shore line, assisted the exploration program by pointing out areas of higher-than-average radioactivity.

The reconnaissance investigations had three objectives. The first was to establish the identity, amount, and relation of monazite to other heavy minerals in a sample from a selected point. The second was to provide an indication of what heavy minerals might be expected in a particular area or drainage basin. The third was to determine whether or not monazite existed in gravel deposits of untested streams and in untested sand deposits of coastal features which were worthy of additional attention.

The first phase of reconnaissance tested the sediments of the lower Atlantic Coastal Plain from North Carolina southward into Florida. A continuation of the first phase of reconnaissance tested the present Gulf and Atlantic shore line of North and South Carolina, Georgia, and Florida, but was restricted to the easily accessible features. The second phase of reconnaissance tested the higher Gulf-Atlantic Coastal Plain sediments below and adjacent to the Fall Line, where similar conditions may exist as in the Aiken County, South Carolina field. The third and final phase of reconnaissance was conducted in the Blue Ridge province of the Southern Appalachians when the A.E.C. expressed interest in radioactive black minerals. A few streams in the mountains of North Carolina and Georgia were found to contain these minerals, but only in trace amounts. The reconnaissance project was concluded in Spring of 1954.

23/ Marshall, M. H., Reconnaissance for Monazite and Radioactive Black Minerals in Southeastern United States, October 1952 to April 1954. Report to Branch of Rare and Precious Metals, June 1955, 103 pp. unpublished.

24/ Moxham, R. H., and Johnson, R. W., Airbone Radioactivity Survey of the Atlantic Ocean Beach, Virginia to Florida, U. S. Geological Survey Trace Elements Memo. Rept. 644, 1953.

25/ Mensehke, J. L, Moxham, R. H., and Bortner, T. E., Airborne Radioactivity Survey of the Gulf of Mexico Between Sanibel Island and Caladesi Island, Florida, U.S. Geological Survey Trace Elements Memo. Rept. 678, 1953

Many heretofore unreported monazite-bearing sites were found as the result of the Fall Line reconnaissance. Sampling results, however, indicated the percentage ratio of monazite contained in the heavy mineral concentrate to be below normally acceptable limits for profitable extraction unless markets could be found for the sand and gravel recovered as a byproduct.

Drilling and Sampling 26-27/

The next step (after heavy mineral relationships were obtained) involved more detailed sampling to bedrock or cut-off points, usually below the ground water level. This required the use of casing and generally some source of power such as churn or jet-drilling equipment. Drill patterns were designed to indicate only the more promising areas for private industry to develop. Drill holes were spaced at intervals of two hundred feet or more in a line, according to the terrain and the size of the deposit. Distances between lines were governed by the objective and accessibility.

Churn drilling equipment was used in detailed examinations of all river deposits. Standard truck mounted, churn drill, 6 inch casing, and 7-3/8 inch drive shoes were employed. Drives of $2\frac{1}{2}$ feet were made before bailing, due to relatively even heavy mineral distribution in monazite-bearing placers. The bailer contents from two drives were combined into one 5-foot sample unless stratigraphic changes made this interval inadvisable.

A six-inch core was left in the casing at all times thereby holding "run ins" to a minimum. This was determined by careful measurement of core rise during drilling and bailing. A sample containing a "run in" was discarded. The condition was reduced by maintaining a high water column in the casing and completing each drive in consolidated material where possible. Holes were usually bottomed in bedrock or saprolite.

Part of each sample was panned and its mineral content estimated at the drill site and returned to the original sample. The samples were then dried in pans over an open fire in the field and screened to minus $\frac{1}{4}$-inch. The oversize was weighed, examined, and discarded. The undersize was weighed, sacked, and shipped in the field laboratory.

26/ Work cited in footnote 20 (page 35) pp. 6-9
27/ Work cited in footnote 21 (page 35) p. 931

Jet drilling equipment [28] was used in detailed examination of all beach deposits. A standard, truck mounted, core drill with hydraulic feed was used. The jetting arrangement consisted essentially of an EX rod recessed about 6 inches from the bit and within an NX rod. The NX rod acted as the casing and enclosed the jetted material carried to the surface. The hole was drilled without interruption. Circulation was momentarily halted when the rod chuck was raised for each stroke or run. Sampling was a continuous process and demanded close cooperation between driller and sampler. Prior to beginning a hole, several tubs were arranged within the radius of the circulent discharge hose. When drilling started, the sampler held the hose over the first tub and continuously caught the return water carrying the jetted material in a small wooden bowl. At approximately 10-second intervals, the material accumulated in the bowl was dumped into the tub and new material caught and visually scanned. The instant a change in color or composition of the jetted material was noted: (1) the hose was shifted to a new tub; (2) the sampler asked and received from the driller the depth; and (3) the sampler continued the rapid collect-discharge scanning with the bowl. The sampler mentally retained the depths at which a change in facies occurred while drilling was in progress. He then entered this information after the hole was completed on the drill hole log and described the material of each sample thereby collected.

Excess water was carefully decanted from the tubs containing each sample and emptied into individual buckets. A tag with the hole, sample number, and interval was fastened to the bucket handle. When all samples had been thus processed, the buckets were sent to a site where the material was dried in pans over an open fire. The sample was then sacked, weighed, and readied for shipment to the field laboratory for further examination.

The area around Shelby, North Carolina, was selected for initial consideration due to the past production history and individuals reporting the occurrence of monazite in this area. Three deposits, Knob Creek, Buffalo Creek, and Sandy Run, in the vicinity were recommended in the first phase of the program for exploration by the Geological Survey. Drilling began in October 1951, and continued through the early winter of 1951-1952. The field season was planned to avoid destruction of summer crops.

In each case, the areas were selected because: (1) they are the first sizable flood plains downstream from the headwaters, (2) each had been mined for monazite, and (3) because a different type of source rock was predominant in each area.

28/ Thoenen, J. R., and Warne, J. D. Titanium Minerals in Central and Northeastern Florida, U. S. Bur. Mines Rept. Inv. 4515, 1949, 62 pp.

During the winter of 1952-1953, the second phase of the exploratory program was carried out. Five monazite projects, namely, South Muddy Creek and Silver Creek, First Broad River and its tributaries, Junction of North Tyger River with the Middle Tyger River, Rabon Creek and Generostee Creek, and Broad River and Thicketty Creek, were carried out. Larger flood plains (10 to 20 million cubic yards) in the general monazite belt were thought likely to contain favorable quantities of monazite due to the tributary flood plains which had been mined at the turn of the century.

Previous experience indicated that tenors of large flood plain deposits could be correctly inferred over large areas by analysis of churn-drill hole results from a few carefully chosen locations.

Accordingly, ten larger flood plains in North and South Carolina were designated by the survey for exploration by the Bureau.

Exploration in parts of North Carolina, South Carolina, and Florida resulted in 639 holes being drilled with a total footage of 12,596 feet. The drilling began in October 1951 and was completed in August 1954. Sixteen individual areas were explored with churn drill equipment. The remaining two areas were explored with jet-drill equipment. A total of 2,220 samples were collected with an approximate weighted average core recovery of 62.7 percent.

Prospecting in parts of North Carolina, South Carolina, Georgia, Florida, and Alabama resulted in 368 sites being sampled. Prospecting began in October 1952 and was completed March 1954. Eighty-eight sites were sampled by jet drill equipment, with an approximate total footage of 1,873 feet. The remaining 280 sites were sampled by hand auger and prospector's pan.

Processing Samples in Field Laboratory

The field laboratory served a twofold purpose for preliminary examinations; the first proved a suitable guide for exploration; the second provided a concentrated sample suitable for detailed radiometric, mineralogical, and chemical determinations. A field laboratory was maintained at Shelby, North Carolina during the headwater, high flood plain, and Fall Line drilling. The laboratory was maintained in Raleigh, North Carolina during the Atlantic beaches investigation.

Flowsheet 1, in the appendix, shows the flow of sample through the field laboratory.

Samples received at the field laboratory were first sorted and weighed to the nearest pound. The desirable weight of a sample for concentration varied with the heavy mineral content. If the weight of the heavy mineral concentrate was estimated to exceed 1.5 pounds, the sample was split, and the split discarded, otherwise, the entire sample was processed. River samples were sifted through a nest of 3 screens having quarter-inch, eighth-inch, and tenth-inch openings. Weights of material retained on the screens were recorded. Beach samples were sifted through a screen with sixteenth-inch openings which excluded trash such as shell fragements and vegetation. This was discarded without weighing.

The sample was next concentrated on a laboratory scale vibrating table fed by a hydraulic cone classifier. A large sample was observed to "clean up" easier than a small one. This knowledge also influenced the decision of splitting the sample. Initial tabling excluded the majority of the quartz. Consequent and final tabling endeavored to split the epidote "band" in the "middling area" which produced a final concentrate of 3.0+ specific gravity. The tabled concentrate was then dried, sacked, and weighed to the nearest gram.

In preparing the heavy mineral concentrate for field laboratory estimation, two samples were taken. One sample was used only to estimate the percent of monazite. The other sample was used in estimating all heavy minerals in the concentrate.

The first sample was prepared for estimating the percent of monazite in the concentrate. The concentrate was thoroughly mixed and split to obtain a sample which weighed slightly less than 0.4 pound. Such weight corresponded to weight of standard samples. A paper envelope identical to the envelopes containing the known monazite standards was labeled with the weight and sample number. The sample, after being weighed, was poured into the labeled envelope and set aside for future use.

The balance of the concentrate was remixed, spread, and a representative sample of approximately ten grams obtained. The ten-gram sample obtained was poured on a flat surface, spread to grain thickness and a hand magnet passed back and forth to remove the magnetite. The weight of magnetite removed was noted and returned to the unused portion of concentrate. The ten-gram sample, minus magnetite, was once more mixed and spread slightly to obtain a sample for microscopic examination. This was accomplished by taking a pinch from the center of the spread sample and placing the "pinched" material in a pan or watch glass. A second pinch was likewise taken from the center of the spread sample, but normal to the first. This also was placed in the pan or watch glass. The balance of the sample was resacked and returned later to the unused portion of the heavy mineral concentrate. The "pinch" sample was placed in the 36X field of a steroscopic microscope and examined. Identification of each mineral was determined by utilizing basic optical properties observed. An elementary grain count was made to determine the frequency of each mineral. The zircon content was further checked with a short-wave mineralight.

The monazite content was additionally determined by comparing the previously prepared (first sample) sample with known standards. Ideally, the standards contained pure monazite from the area in which the samples to be compared originated. Each standard was packaged to a definite volume and weighed .030, .050, .100, .200, .300, and .400 pound, respectively. To compensate for variances of count during a testing period, a check reading was obtained for one minute from both sides of each envelope containing the standard. The average reading for each standard was noted. This check was made twice each day comparisons were estimated. For an unknown, an average reading from both sides of the envelope containing the unknown was taken. The unknown sample was made to conform to the same shape and density as that of the standard. By knowing the background count, purity, weight, and MR/HR of the standard, the percent of monazite contained in each unknown sample was determined by the interpolation of its weight and Geiger counter readings. The radioactivity of zircon was taken into account. After the percentages of heavy minerals were calculated, the tested sample was likewise poured back into the sack containing the unused portion of the concentrate.

Testing and Analytical Methods

Petrographic Analysis 29/

The sample, received from the field laboratory, was generally a table concentrate weighing approximately 500 grams. It was split to provide about 50 grams for analysis. This portion was weighed on an analytical balance and the magnetite then removed with a hand magnet. The sample was next screened into 4 fractions, plus 60, plus 100, plus 200, and minus 200-mesh. Each screen fraction was considered separately, but treated the same, throughout the analysis.

The first fraction (plus 60-mesh) was placed in an isodynamic separator with the tilt set at 12° and the amperage adjusted to 0.2 amp. The separator divided the fraction into 2 parts, the magnetic and nonmagnetic.

29/ Submitted by the Southern Experiment Station, U. S. Bureau of Mines, Tuscaloosa, Alabama.

The magnetic part was weighed, the net radioactivity determined with a qualitative scaler type Geiger counter, and the approximate percentages of minerals obtained by visual inspection under a binocular scope.

The nonmagnetic part was returned to the isodynamic separator. With a tilt setting of 12° and the amperage increased to 0.3 amp., a separation was made. The magnetic part of this separation was tested in the same manner as the magnetic part of the first separation.

The nonmagnetic part of this separation was returned to the isodynamic separator and with the tilt set at 12° and the amerpage increased to 0.4 amp., further separation was made.

The magnetic part of this separation was sink-floated with Clerici solution in order to obtain a high concentration of xenotime and radioactive blacks. The sink portion was weighed on an analytical balance and the net radioactivity determined. In order to determine more accurately the approximate percentages of radioactive blacks in the sink portion, hydrofluoric acid was added and this portion placed under infrared lamps for 5 minutes. During this reaction a green coating formed on the uranium-bearing minerals which readily distinguished them from other black minerals present in this portion. Visual estimates of the percentages of the different minerals was then made under the binocular scope. The float portion of the heavy minerals separation was tested in the same manner as the magnetic part of the first and second fractions.

The nonmagnetic part of the third separation was returned to the isodynamic separator. With the tilt set at 3° and the amperage increased to 0.55 amp., this part was separated into a magnetic and a nonmagnetic part.

The magnetic part of this separation was then sink-floated with Clerici solution to obtain a high concentration of monazite. The sink portion was accurately weighed and the net radioactivity determined with the Geiger counter. This portion was then split, using a microsplitter, to obtain an amount usuable for grain counting. The split portion was immersed in oil having an index of refraction of 1.87, and the percentages of monazite and other minerals present determined by grain count.

The nonmagnetic part and the float portion of the magnetic part were tested as the magnetic part of the first and second separations.

This entire procedure was repeated for each of the remaining fractions.

Radiometric Analysis 30/

The Rare Materials Branch was largely concerned with the evaluation of thorium-bearing samples, and reported the radio-assays in terms of percent ThO_2 equivalent. As a thorium-bearing material which was both in equilibrium and free of uranium was not available, a factor for converting radioactivity, expressed in counts per minute, to percent ThO_2 equivalent, was determined.

Chemical Analysis 31-32/

The percent ThO_2 in the monazite was also determined chemically as a check and for comparison of results obtained from other methods of analyzing.

EXPLOITATION OF DEPOSITS

During the Hollow Creek exploration program, 4 prospect holes were drilled by the Bureau of Mines on lower Horse Creek. Encouraging results from this work prompted an outside interest to further explore the large Horse Creek area with Bureau of Mines assistance. Early in 1952, 9 additional holes were drilled on lower Horse Creek and 8 on upper Horse Creek by this interest. The results of this drilling indicated the better ground was upstream.

Consequently, a Defense Minerals Exploration Administration loan application, submitted by other outside interests was approved. During the winter and spring of 1952-53, a number of churn-drill holes and several check shafts were completed on upper Horse Creek. The results of this work showed that the Horse Creek deposit contains a large volume of dredgable material having a large quantity of monazite and quantities of other black-sand minerals.

The results of this work encouraged the establishment of mining operations, Marine Minerals, Incorporated.

30/ Work cited in footnote 29 (page 41)

31/ See footnote 29. The method was successfully employed at Mount Weather, Virginia, and Raleigh, North Carolina stations and is a revision of Kronstadt, R., and Eberle, H.R., Analytical Procedure for the Determination of Thorium, RMO-838, 1952, 9 pp

32/ This procedure follows, with only minor variations, the method of Sill and Peterson, Bureau of Mines, Salt Lake City.

CONCLUSIONS

At this time the deposits explored are of strategic value rather than commercial. However, in the course of the Hollow Creek exploration program, 4 prospect holes drilled in lower Horse Creek area by the Bureau were encouraging. This lead to additional holes being drilled in the same area and others drilled in the upper Horse Creek area. Additional holes on a DMEA project were drilled in the upper area, and eventually this lead to the formation of a mining operation, Marine Minerals, Incorporated.

APPENDIX II

Table of Contents

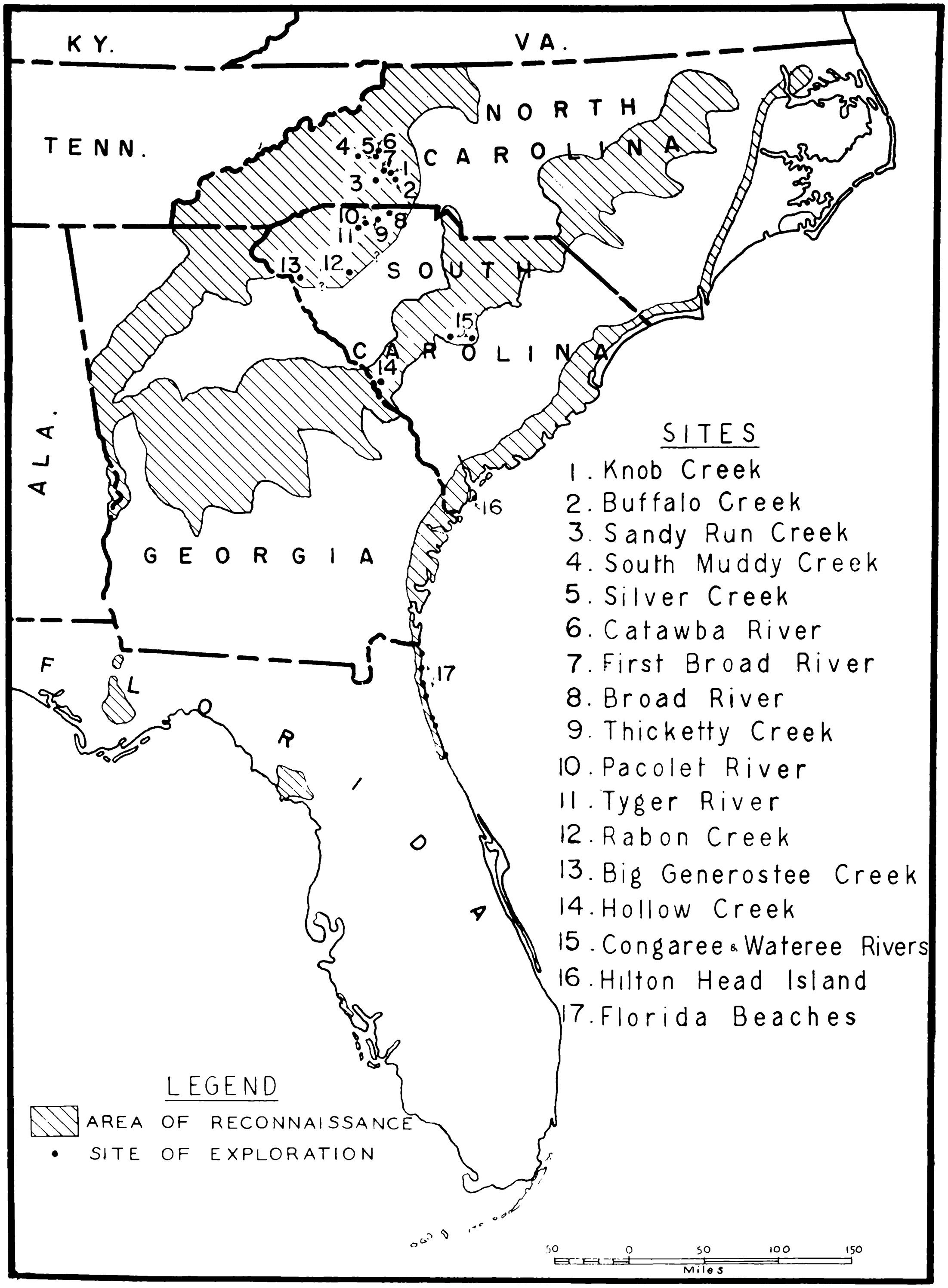
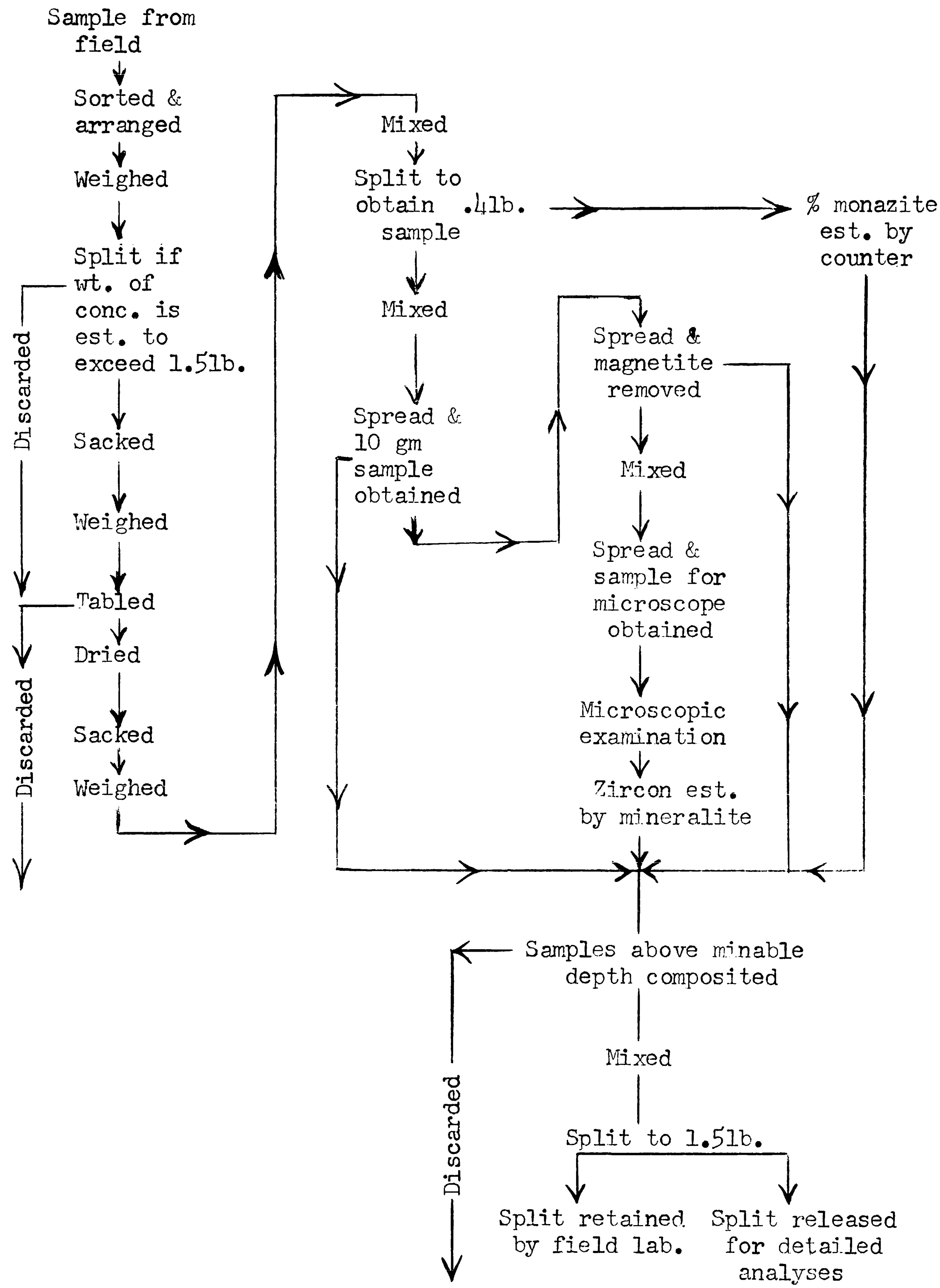


Figure 1 - Index map showing area of reconnaissance and sites of exploration in southeastern United States



Flowsheet 1. - Flowsheet of sample through field laboratory