Monazite in part of the southern Atlantic Coastal Plain

By Lincoln Dryden

Trace Elements Investigations Report 566

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

IN REPLY REFER TO:

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WASHINGTON 25, D. C.

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February 13, 1956

Mr. Robert D. Nininger, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

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Sincerely yours,

John H. Eric

for W. H. Bradley
Chief Geologist

Geology and Mineralogy

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

MONAZITE IN PART OF THE SOUTHERN ATLANTIC COASTAL PLAIN*

By

Lincoln Dryden

November 1955

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* This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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By Lincoln Dryden

ABSTRACT

Sediments of the inner part of the southern Atlantic Coastal Plain have been sampled and examined for monazite. Most of the samples were collected from the Tuscaloosa formation of Cretaceous age, McBean and Barnwell formations of Eocene age, and Pleistocene deposits; a few samples were taken from other formations and from Recent stream and flood-plain sediments. Samples were split, separated in bromoform, and the heavy mineral suites were analyzed for radioactivity with a Geiger tube. The results of these analyses were converted to percentages of monazite in heavy minerals, and these percentages were used to calculate pounds of monazite per cubic yard of sediment.

A total of 456 samples was collected and has the following distribution among the sediments: 293 are from the Tuscaloosa formation, 16 are from the McBean formation, 36 are from the Barnwell formation, and 40 are from Pleistocene deposits. Less than one-fourth of the samples (107) has a tenor greater than 0.25 pound of monazite per cubic yard; the Tuscaloosa, McBean, and Barnwell formations are represented respectively by 76, 8, and 6 of these samples, and the remaining 16 came from Pleistocene deposits. Only 10 samples contain 1 pound or more of monazite per cubic yard. The richest sample had 2.1 pounds of monazite per cubic yard. Since sampling was done rapidly as reconnaissance, no estimates can be made of the resources available at the various tenors in monazite, but it is thought that these tenors have considerable lateral and vertical extent.

The monazite in these sediments presumably was derived principally from the two monazite belts in the Piedmont (Mertie, 1953), but the geographic distribution of monazite in sediments along the Coastal Plain does not suggest any particular part of one or both belts as the source, nor does it suggest the way in which monazite was transported and deposited.

All of the heavy mineral suites, except those taken from streams draining the Piedmont province, contain essentially the same association of minerals: ilmenite and leucoxene commonly make up half or more of the suite, and the rest in order of abundance includes zircon, rutile, staurolite, kyanite, sillimanite, tourmaline, and spinel. Stream and flood-plain sediments brought from the Piedmont contain these minerals plus epidote, garnet, and hornblende. Streams rising within the Coastal Plain contain the restricted suite and have more monazite in their heavy minerals than do the streams draining the Piedmont.

INTRODUCTION

The Atlantic Coastal Plain, a physiographic province extending from New York to Alabama, is bounded on the west and northwest along the Fall Line by the higher Piedmont physiographic province, and on the east by the Atlantic Ocean. It is generally less than 300 feet in altitude and is characteristically an area of plains and low hills.

The southern part of the Coastal Plain, from North Carolina to Alabama, ranges from 100 to 200 miles in width and consists mostly of low, flat, often almost featureless plains. But bordering the Fall Line is an inner belt of the Coastal Plain, 10 to 50 miles wide and higher in average altitude than the rest of the Coastal Plain. Stream erosion has progressed much further and local relief in some places reaches a maximum of about 300 feet.

The area covered in this report (fig. 1) is essentially the inner belt. In South Carolina this inner belt has about the same boundaries as the Aiken Plateau, Richland Red Hills, High Hills of Santee, and the Congaree Sand Hills described by Cooke (1936, fig. 1, p. 4, 9-11). In Georgia it corresponds to the Fall Line Hills, Fort Valley Plateau, and the Louisville Plateau of Cooke (1943, p. 3). Beyond these states the belt extends without major topographic change to its northeastern end near Wilson, N. C., and southwestward it extends to the terminus of the present work near Wetumpka, Ala. The southwestern part of the area covered in this report, particularly the part in Alabama, belongs properly to the Gulf Coastal Plain; but it is similar in geology, has furnished comparatively few samples, and is here included with the Atlantic Coastal Plain.

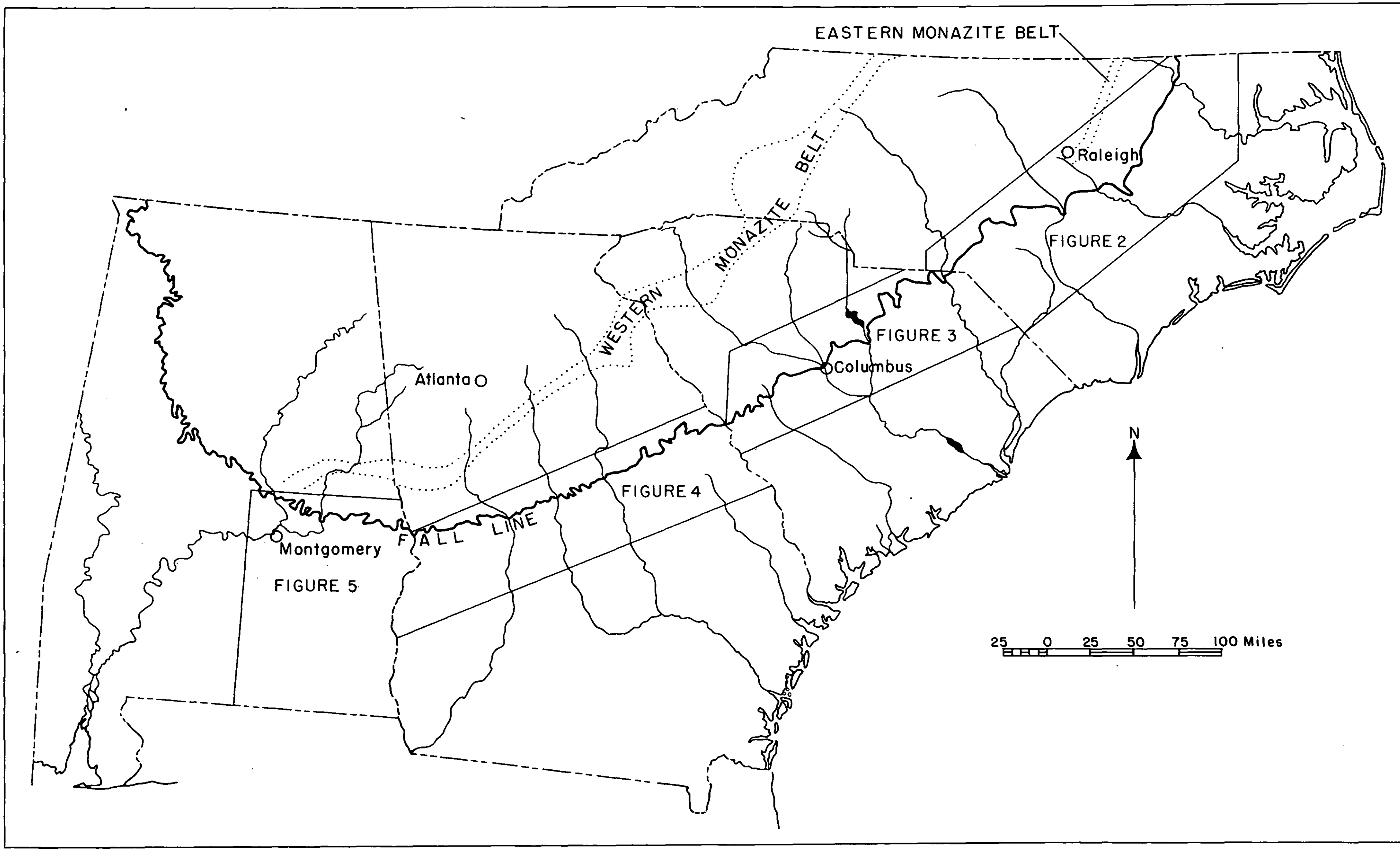

FIGURE 1-INDEX MAP SHOWING THE AREA OF REPORT, OUTLINES OF DETAILED MAPS, AND MONAZITE BELTS OF THE PIEDMONT AS MAPPED BY MERTIE (1953).

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Reconnaissance for monazite in sedimentary deposits along the Coastal Plain began in October 1952 and ended in May 1953. Most of this time was spent in a study of Pleistocene shore-line features. Clearly marked topographic features of this kind are generally confined to low altitudes and to the shoreward half or quarter of the Coastal Plain. A short time was spent in the inner half of the Coastal Plain where 60 widely spaced samples were collected and examined in the field. The results of this examination suggested that, apart from monazite deposits associated with shore-line features near the coast., the only other deposits comparatively rich in monazite were to be found in the sediments of the inner belt of the Coastal Plain near the Fall Line. The rocks of this belt were then sampled as extensively as time permitted, and a few samples were taken outside it as spot-checks. Sampling was started in March 1953 and finished in early May 1953. Samples were analyzed for monazite between May and September, and preliminary field determinations of monazite were checked at that time.

This work was done by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

The writer was assisted by G. A. Miller who collected most of the samples and helped with the laboratory work. The writer's wife, Clarissa Dryden, was associated with the work throughout and materially assisted in its completion.

GENERAL GEOLOGY

The topography which characterizes the inner belt of the Coastal Plain is developed principally on rocks of the Tuscaloosa, McBean, and Branwell formations; to a minor extent it is formed on Pleistocene deposits.

The Tuscaloosa formation of Cretaceous age is the oldest sedimentary formation of the southern Coastal Plain and lies on the crystalline rocks of the Piedmont province. It dips gently seaward and passes below successively younger Cretaceous formations in that direction. Typically, as in Alabama, the Cretaceous formations are succeeded in outcrop shoreward by successively younger Tertiary formations. But in parts of South Carolina and Georgia, the Eocene McBean and Barnwell formations are widely transgressive; the Barnwell in places overlaps all older Coastal Plain rocks and lies directly on the crystalline rocks of the Piedmont.

Pleistocene deposits are rather widespread in the inner belt in North Carolina and in the northeastern part of South Carolina. Northeast of Wilson, N. C., they are essentially undissected, thus forming the northeastern boundary of the inner belt. Southwestward from South Carolina they crop out farther and farther shoreward, so that they occur in very small areas or are absent in the southwestern part of the inner belt.

The geology of the inner belt and of the Coastal Plain as a whole has been described in a number of reports. Most useful in the present work are those by Stephenson (1912; 1926) and Cooke (1926; 1936; 1943) whose geologic maps were used to identify the formations sampled. A geologic map of the North Carolina Coastal Plain by Berry (1949) also was used.

The Tuscaloosa formation has afforded 293 of the 456 samples collected along the inner half of the Coastal Plain, and of the 293 samples, 76 contain more than 0.25 pound of monazite per cubic yard of rock. The lithology of the formation has been described in the reports cited; they stress its extreme variability. Typically, the formation consists largely of sand that is almost never pure enough to flow readily through the fingers but contains enough silt or clay to make it look and feel mealy. Pebbles, which are common constituents, are in places segregated in well-defined pebble beds but more generally are scattered through finer materials. Lenses of clay, locally sufficiently thick and pure to be commercially valuable, appear to be interbedded with coarser sediments. Crossbedding, lensing, and channeling are exposed in almost every outcrop.

All the other pre-Pleistocene formations are commonly well-bedded, contain pebbles or pebble beds only as rare constituents, and typically lack crossbedding, lensing, and channeling. These formations can be distinguished from the Tuscaloosa formation without difficulty.

The McBean formation of Eocene age is made up dominantly of fine- to medium-grained sand and is typically yellowish or greenish. The Barnwell formation of Eocene age is an argillaceous sand which weathers bright red and is more resistant to erosion or slumping than either the Tuscaloosa or McBean formations. Though these two Eocene formations are not nearly as extensive in outcrop as the Tuscaloosa formation, they are important in that they contain comparatively high quantities of monazite at many localities. Of the 16 samples from the McBean formation and 36 from the Barnwell formation, 8 and 6 samples respectively contained more than 0.25 pound of monazite per cubic yard of sediment.

The Pleistocene deposits consist of layers of fairly well-bedded pebbles, sand, and clay. Some of these beds, particularly those containing coarse sand and pebbles, are so much like beds of the Tuscaloosa formation that at places it is difficult or impossible to tell them apart. The writer found this especially true in unmapped outliers on the crystalline rocks of the Piedmont province. Of the 40 samples of Pleistocene sediments studied, 16 contained more than 0.25 pound of monazite per cubic yard of rock.

Other Cretaceous deposits (Black Creek, Peedee, Eutaw, Ripley, and Providence formations) were the source of 13 samples used for radioactivity analysis. Eleven samples were taken from other Tertiary sediments (Black Mingo, Wilcox, Clayton, Naheola, Nanafalia, Tuscahoma, Glendon, and Yorktown formations), and 47 specimens came from Recent deposits in streams and flood plains. Table 1 gives the distribution by state and formation.

FIELD AND LABORATORY METHODS

Sampling

Sampling within the inner belt was planned from a general knowledge that some heavy mineral suites from the Tuscaloosa formation contain significant quantities of monazite, and from field examination of 60 widespread samples. These samples confirmed reports of monazite in the Tuscaloosa formation, but they further showed that other rocks of the inner belt--notably the McBean and Barnwell formations, and Pleistocene deposits--might contain equal or larger amounts of monazite.

Sampling was carried out by reconnaissance methods along public roads and at available exposures. The rocks were identified principally by reference to published small-scale geologic maps. Topographic maps were not available; therefore, the samples lack vertical control. Most samples collected were channel samples and represent about 5 feet of thickness; no sample was taken from less than 2 feet of rock.

The sampling is not strictly representative of the rocks of the inner belt for several reasons. Sample localities are widely spaced in some areas because prevailing low relief results in an absence of natural or artificial exposures. The writer believes that the low relief is developed principally on more or less pure sand lacking other sizes of particles, thus this size of material has not been sampled as widely as it occurs. But the samples that were collected came principally from exposed sediments of sand size and avoided either clay lenses or beds of coarse pebbles. Preliminary sampling had shown that very fine or very coarse sediments were likely to contain a smaller proportion of monazite than material of predominantly sand size. Such non-representative sampling would result in reporting too much monazite in the deposits of a given large area.

Splitting and bromoform separation

Splitting and bromoform separation of collected samples were used to get a suite of heavy minerals from the minus 0.5 mm fraction of the sample suitable in size for analysis for radioactivity.

It was necessary to test a heavy mineral suite weighing at least 0.05 g. To get this amount of heavy minerals from the minus 0.5 mm fraction of the sediment studied, assuming that the minimum average tenor of the samples was 0.2 percent of heavy minerals in the minus 0.5 mm fraction, the weight of this minus 0.5 mm fraction would have to be at least 25 g. If the original sample is all sand smaller than 0.5 mm, the final split itself should weight 25 g; if a considerable part of the original sample consists of coarser material, the final split should be such a size that it will contain 25 g of minus 0.5 mm material.

Splitting was done with a Jones 8 by 10 inch splitter. The final split was screened through a 0.5 mm sieve, percentages of plus and minus fractions were estimated, and the material larger than 0.5 mm was discarded. To check the estimates, all samples with a tenor in monazite of 0.5 pound or more per cubic yard were re-split and the minus and plus 0.5 mm fractions weighed.

These check weighings revealed a systematic error in the direction of too large a percentage reported as minus 0.5 mm, and consequently too great an amount of monazite reported per cubic yard. Of the 53 samples re-split and weighed, 49 gave too high a reading for monazite. The average error is 12.5 percent. For any one sample it is impossible to correct the reported tenor in monazite unless the original sample is re-split, screened, and the minus and plus 0.5 mm fractions weighed. In table 1 all figures for monazite showing 0.5 pound or more per cubic yard have been corrected by weighing, so that the errors discussed here have been eliminated in those figures. The following samples have been corrected in the same way; North Carolina, 102A, South Carolina, 144, 193B, 205, 257, 258, 265, 289, 303, and 316; Georgia, 352 and 368.

The minus 0.5 mm fraction of the final split was weighed, the heavy minerals separated in bromoform and weighed, and the percent of heavy minerals in the fraction calculated. This result multiplied by the percent of the original sample which is minus 0.5 mm in size gives the percent of heavy minerals in the sediment. Occasional checks for total heavy minerals and for monazite made on the discarded plus 0.5 mm material showed that nearly all of it was practically free of heavy minerals and none of it contained monazite.

Determination of monazite content

The weight percentage of monazite in a heavy mineral suite was determined by radioactivity analysis. In this method the heavy mineral sample requires no special preparation, the only restriction being that its weight must be kept within certain limits. The samples were mounted in stainless steel planchets which were placed in a sample and tube holder. They were then counted using a 3.5 mg/cm^2 end window tube connected to a decimal scaler. To make the results of this type of assay comparable to determinations made by other methods, certain assumptions must be made.

The first assumption is that monazite is the one and only source of radioactivity measured. This assumption is not strictly true, but the lines of evidence used in establishing the conversion factor discussed below suggest that it can be used as an approximation. More than 100 assayed samples were examined under the microscope, and apart from monazite, no minerals known to be radioactive were recognized; about 50 of these samples in which no monazite was seen gave no appreciable radiation.

Second, in converting radiation counts into percentages of monazite and thence into pounds per cubic yard, the assumption has been made that all monazite contains an equal quantity of radioactive material per unit weight of mineral. Mertie (1953, p. 12) has shown that this quantity varies rather widely in material from narrowly restricted sources. But Hansen and Cuppels (1954, p. 20; written communication, 1955) and Hansen and White (written communication, 1954), have shown that in large alluvial placers where the distributive province of the stream covers tens of square miles, the composition of the monazite does not vary between such wide limits among samples. This appears to be the result of mechanical mixing of monazite from different sources. It is assumed that a wider and more perfect mechanical blending of monazite along ancient strands has further reduced the differences between samples, and that though the results of the radioactivity analysis cannot be strictly comparable from sample to sample, they are close enough for estimates of inferred percentages of monazite.

Third, it was assumed that all the radiation from monazite came from thorium or its decay products. But Mertie (1953, p. 12) has shown that as much as 12 percent and an average of about 7 percent of the radioactive material is uranium.

Fourth, that no heavy mineral sample was thick enough to absorb an appreciable amount of the radiation being counted. To test this assumption, 10 samples were assayed. In each case, the same heavy mineral suite was used, but the weights were successively 0.05 g, 0.1 g, 0.2 g, 0.4 g, and 0.8 g. From 0.05 g to 0.2 g, radiation counts per unit weight remained about the same but above 0.2 g the counts per unit weight decreased progressively. For the 10 samples tested, there was no significant absorption of radiation within the sample as long as the weight limit lay between 0.05 to 0.2g. Since all other heavy mineral samples were essentially similar in mineral composition (bulk density) and were kept within these weight limits, it has been assumed that no large counting error has been made through radiation absorption within the sample.

In making a count with a sample containing monazite, the total count is higher than the background; subtracting the background gives the net count. This net count, however, is a function of sample size; dividing it by the weight of the sample gives the net count per unit weight, which is a value expressing the relative proportion of monazite present.

Net counts per unit weight are comparable, so that a sample with twice the count of another contains approximately twice as high a percentage of monazite. Although they are proportional to percentages, the net counts per unit weight are not themselves percentages, and a factor must be used to convert them. The conversion factor used in this work was obtained through several methods. One was a weight percentage of monazite (and no other radioactive material) in a heavy mineral suite furnished by the Brookhaven National Laboratory, Long Island, N. Y.; their figures were checked against our own assay of the sample. Another method was to determine the net counts per unit weight of pure monazite and compare these figures with assays of suites of known composition. Another was the check of the net counts per unit weight against composition determined by grain counts under the microscope. The different methods all yielded about the same figure: the net count per unit weight multiplied by 0.7 is equal to the percentage of monazite in the heavy mineral suites from the area studied.

The limits of error in the radiation count of any sample were determined from the percentage of monazite in heavy minerals as given in table 1. For example, sample 58 has 1.4 percent of monazite in heavy minerals, which means 1.4 divided by 0.7, or net count per unit weight of 2.0. Since the weight of heavy mineral samples is not given, the error must be calculated on the assumption that any sample weighed between 0.05 g and 0.2 g. If it weighed 0.05 g, the net count was 2.0 x 0.05, or a rate of 0.10 counts per second, or a sample count of 50 in the 500-second interval used for counting each sample or background. A background count of 425 was obtained just before the sample was assayed, so the total sample and background count would have been 425 plus 50, or 475. The error in this count is 4.59 percent, and the rate is 0.95. To obtain a similar rate for the sample alone, the background value, whose rate is 0.85 ± 0.04, is subtracted from 0.95 ± 0.04, giving $0.10 \pm \sqrt{(0.0436)^2 + (0.0412)^2}$, or 0.10 ± 0.06; the counting error here is so large that the significance of the rate due to sample alone may be questioned. But if the sample weight is 0.2g, the rate for sample and background is 1.25 ± 0.05, and the rate for sample alone is 0.40 ± 0.06, the percentage error being approximately one-quarter as large as for the 0.05 g sample. These counting errors directly affect the values of percentage of monazite in heavy minerals, and the tenor of the sediment in monazite (table 1). In the 0.05 g heavy mineral sample, the value of 1.4 percent given in table 1 will vary from 0.56 to 2.24 percent, and the tenor in monazite from 0.01 to 0.05 pound per cubic yard. For the 0.2 g heavy mineral sample, corresponding figures are 1.17 to 1.63 percent, and 0.03 to 0.04 pound.

These figures show that small net counts (or small total counts for 500 seconds) mean large counting errors. Small net counts result from heavy mineral samples of small weight, from low tenor in monazite, or from both. Monazite content is, of course, the answer sought in this work, and there is no way to control it. The weight of most heavy mineral samples was kept between 0.05 g and 0.2 g. However, 62 of the 456 samples assayed weighed less than 0.05 g. They are: North Carolina 11, 17, 33, 55, 67, 69B, 77, 79, 103; South Carolina, 131, 135, 136, 140, 142, 147, 150, 155, 173, 178, 184A, 186, 187, 197, 215, 218, 227, 230B, 238, 240, 245, 258, 260, 262, 266, 283, 288, 296, 298, 300, 312, 315, 316, 318; Georgia 325, 326, 327, 333A, 335, 338B, 343, 345, 346, 349, 366, 378, 388, 389A; Alabama 395, 410, 412, 414, 417.

The counting error in analysis of these samples was so large that perhaps they should have been re-done from the beginning, so as to secure a larger heavy mineral sample for assay. However, it is precisely such samples, with unusually low percentages of heavy minerals, that are of little or no interest in the present work, for even with an average content of monazite in heavy minerals they yield low values of monazite per cubic yard. Large heavy mineral samples, containing little or no monazite, likewise are subject to large counting errors; these samples, also, are of little interest for the present report, and no attempt has been made to reduce the counting errors in either instance.

For the 107 samples with apparent tenor in monazite of 0.25 pound or more per cubic yard (table 2), the heavy minerals contain an average of 4.5 percent monazite. This gives a net count per unit weight of 6.4, and if we assume for the present calculation an average heavy mineral weight of 0.125 g, the average net count would be 0.80 count per second, or 400 counts for the 500-second interval. The total of sample and background count (assumed to be the same as above) would be 400 plus 425, or 825, and the error for this count will be 3.48 percent. The rate for the total count is 1.65 ± 0.06 and subtracting the background rate, as before, the rate for sample alone is 0.80 ± 0.07. It should be stressed that this value is an average one for the 107 samples, and the errors for this group will be smaller than for the other 349 samples.

DISTRIBUTION OF MONAZITE

The localities sampled are shown on parts of four state maps (figs. 2, 3, 4, and 5). Numbers 1 through 123 are in North Carolina, 124 through 320 in South Carolina, 321 through 389 in Georgia, and 390 through 419 in Alabama. If more than one sample was taken from the same locality, each sample has an A, B, or C added to the number. From a total of 419 localities 456 samples have been collected and analyzed.

For most sample localities shown on the figures 2, 3, 4, and 5, three numbers are given. The top one is the sample number. The middle number is the percentage of monazite in heavy minerals, and the bottom number is pounds of monazite per cubic yard of rock. Poundage was not calculated for a group of non-representative samples consisting of natural concentrates, selected parts of rock rich in heavy minerals, waste washings from quarries, and heavy mineral streaks in gutters. Tenors are calculated using 2,500 pounds as the weight of a cubic yard of sediment in place.

Relation to grain size of sediments

Relationships among grain size of the sediments, percents of heavy minerals, and percents of monazite in the heavy minerals and in the rocks are given in table 3 for 154 samples from the Tuscaloosa formation in South Carolina. Percents of heavy minerals in the minus 0.5 mm fraction increase on the average with an increase in the grain size of the sediment. For example, the top seven numbers in column three (67 samples) average 0.69 percent of heavy minerals in the minus 0.5 mm fraction, whereas the bottom seven (70 samples) average 0.42 percent. The percentage of monazite in the heavy minerals (column four) also increases in coarser grain sizes: the top seven percentages in this column average 3.48 percent , and the bottom seven average 2.68 percent. When the percent of monazite in the rock is calculated by multiplying the second, third, and fourth columns, the resulting products show large differences in percent of monazite in sediments in the various size categories. Thus, in general, the coarse-grained and fine-grained rocks seem to contain about the same proportions of this mineral. But, as appears to be the case, grains of monazite in the inner belt of the Coastal Plain are smaller than 0.5 mm. The rocks having no constituents this size will have no monazite.

The grain size and monazite content of the Tuscaloosa and other formations within the inner belt differ from that of placers in Pleistocene deposits nearer the Atlantic coast. The sand in these placers is probably all smaller than 0.5 mm in grain size with the exception of some of the sand at Trail Ridge, Clay County, Fla. Monazite grains from the Pleistocene sediments are small; 95 percent of them from one placer sample pass through a 0.125 mm sieve. Grains of monazite from the Tuscaloosa formation are larger than this. No study of their size distribution was made, but it has been observed that many of them are in the range 0.25-0.5 mm. The sands of the Pleistocene deposits, unlike those of the Tuscaloosa formation, are well-sorted and appear to have been worked and reworked. It may be that abrasion during this process diminished the size of the monazite grains; this wear and ensuing destruction may also account for the fact that monazite is less common in the Pleistocene deposits than in the Tuscaloosa, McBean, and Barnwell formations.

Geographic distribution of monazite

Monazite in the Tuscaloosa formation and other sediments sampled is thought to have been derived from monazite-bearing rocks in the Piedmont that have been shown (Mertie, 1953, pl. 1) to occur principally in an eastern and a western belt (fig. 1). The data shown on figures 2-5 do not suggest derivation from any particular part or parts of these belts, or the direction or means by which sediment was transported from them to the Coastal Plain. However, most of the samples have been examined only for the amount of contained monazite, and the data do not show whether study of the heavy mineral suites as a whole, or other lithologic studies, would reveal more closely the sources or the ways in which monazite was deposited in the Coastal Plain sediments.

North Carolina

East of a north-south line just east of Fayetteville, N. C., in the northeastern corner of the area covered by figure 2 the tenor of the sediments in monazite is comparatively low chiefly because of a low percentage of monazite in the heavy minerals. Such low percentages would not be expected if the past drainage had been similar to that of the present and if the eastern monazite belt had been yielding appreciably monazite-bearing sediment to the Coastal Plain.

The tenor of the monazite-bearing sediments generally is distinctly higher southwest of the eastern monazite belt and southwest from the longitude of Fayetteville, and some of the highest tenors are found between that community and the N. C. - S. C. state line. More than 1 pound of monazite per cubic yard is in the three samples numbered 51, 62, and 64 which are from respectively: pink to yellow, silty, fine-grained sand; silty, pebbly, arkosic sand with local beds of limonitic sandstone; and orange to olive, pebbly, silty, fine-grained sand.

South Carolina

A group of monazite-bearing samples of comparatively high tenor occurs near the northeastern corner of the area in South Carolina (fig. 3). Sample 125, although mapped as Tuscaloosa by Cooke (1936, pl. 2), was judged by the collector to be Pleistocene, because it consisted of loose, yellow, fine-grained sand. About 20 miles west of the Pee Dee River, a large number of samples contain half a pound or more of monazite; of these, number 137 is exceptionally rich in monazite. This sample is a red, silty, pebbly sand from the base of the Tuscaloosa formation. The Pee Dee River, by way of the Yadkin River, now drains one of the narrow parts of the western monazite belt. Perhaps a more easterly system of drainage existed in Tuscaloosa time and transported monazite from wider parts of the belt around the present boundary between North and South Carolina.

The tenor of monazite-bearing sediments is low in the area west of the Pee Dee River to the west side of the Lynches River; thence the tenor increases east of the Wateree River in samples 232, 212, 234, 235, and 229. Samples 238 and 271 have exceptionally high percentages of monazite in heavy minerals; sample 238 was the second highest of those tested. Westward to the Congaree River, values are rather consistently low for both percent of monazite in the heavy minerals and pounds of monazite per cubic yard of sediment.

West of the Congaree River is a large area in which there are many samples with high tenors. More detailed work should be done in this part of South Carolina, because the high monazite tenors are in three formations: the Tuscaloosa, the McBean, and the Barnwell. The Congaree and its tributaries drain the widest part of the western monazite belt, and high monazite values in nearby Coastal Plain rocks suggest a large source area for monazite and a similar drainage in the past. The McBean and Barnwell formations may have derived their monazite by erosion and re-deposition of Tuscaloosa materials.

Samples with comparatively little monazite characterize that part of South Carolina between the rich area west of the Congaree River and the State boundary with Georgia. In this large expanse only locality 314 is outstanding for monazite, but a few other places (samples 279, 303, and 313) have about 0.5 pound of monazite per cubic yard. Sediments in this southwestern part of South Carolina contain less monazite than those in any area of comparable size sampled in the present work.

Georgia

Samples (fig. 4) from the Tuscaloosa formation in Georgia contain about the same amount of monazite per cubic yard as do samples from the same formation in South Carolina; the tenors are about 0.3 and 0.25 pound respectively. Northeast of the Ogeechee River only two samples from the Tuscaloosa formation, nos. 321 and 325, have more than the average amount of monazite.

The distribution of monazite in Georgia, apart from this northeastern section, has no distinctive pattern. Only two samples, nos. 377 and 386, contain more than a pound of monazite per cubic yard. Number 377, from the Tuscaloosa formation, is a pink to orange silty sand, with 98 percent passing through the 0.5 mm sieve. Sample 386, which contains 2.10 pounds of monazite per cubic yard, comes from the base of the Tuscaloosa and is the richest sample taken. When the sample was collected some of the larger pebbles in the pebbly sand were excluded from the sampling. It is estimated that the monazite content of a more representative sample would be less than 2 pounds but would still be unusually high. Sample 359, although containing less than a pound of monazite per cubic yard of sediment, has the highest percentage of monazite in heavy minerals (11.9 percent) found in the present work.

Alabama

The 17 samples of the Tuscaloosa formation taken in Alabama (fig. 5) have an average monazite content of only 0.1 pound per cubic yard. This relatively low tenor is due in part to a low percentage of monazite in the heavy minerals. The samples from Alabama average only 2 percent monazite in the heavy minerals, whereas the 154 samples from the Tuscaloosa formation in South Carolina average 3 percent. It is difficult to explain such low content, since all samples lie comparatively close to a wide part of Mertie's (1953) western monazite belt. Further, monazite content decreases westward in Alabama, despite the fact that such samples as 390, 391, and 392 come from very close to the overlapped end of the monazite belt. Possible explanations for low monazite content in these samples include: low average tenor in monazite among the rocks in the southwestern part of the western monazite belt; and this part of the monazite belt may have been covered during Tuscaloosa time, initially, perhaps, by the lowest beds of the formation itself.

Grade and size of placers

Sediments containing 1 percent of heavy minerals or more possibly might be called placers because they have a concentration of heavy minerals well above the average for Coastal Plain sediments. Of the 456 samples examined, only 34 contain between 1 and 2 percent of heavy minerals, and only 5 contain 2 percent or more. Monazite is usually present as only a few percent of the heavy minerals; in 154 samples of the Tuscaloosa formation in South Carolina, for example, it averages 3 percent, and the two highest values found in the present work are 11.9 and 10.1 percent. In terms of monazite content of rock, the 154 South Carolina samples from the Tuscaloosa formation average about 0.25 pound per cubic yard, and the two samples with 11.9 and 10.1 percent of monazite in heavy minerals contain about 0.8 pound per cubic yard.

The location of all samples with a content of 0.25 pound or more is given in detail in table 2. The richest sample examined gave 2.1 pounds per cubic yard; richer ones might be found by additional investigations.

Some of the samples reported here are possibly of commercial or near-commercial grade, but additional field and laboratory work will be necessary to establish reliable figures for tonnage.

The data given on the maps and in the tables are discrete values, pertaining only to the samples from the localities indicated. They do not imply that the monazite content shown for two localities is maintained between them, or that the content between them is an average of the two values. That values may be more or less constant between two localities is suggested by data from samples 321 and 322. The heavy mineral suite of sample 321 is almost all staurolite. Sample 322, taken about 5 miles away, shows a similar high percentage of staurolite. These two samples are the only ones with this exceptionally heavy mineral suite, and the implication is that the high staurolite tenor may be widespread in this area. By extension, the monazite tenor may behave in similar fashion, though there are no specific data to support this assumption.

There are few localities that give information about vertical distribution of the monazite. One of the best is locality 314 (Barnwell formation, South Carolina). Sample 314C was taken 15 feet above 314B; the two have almost identical percentages of monazite and both have high tenors in monazite. Another locality where the samples have almost the same percentages of monazite is 337 (McBean formation, Georgia) where sample 337A was taken 20 feet stratigraphically higher than 337B. Sample 337A is finer grained than 337B and has a somewhat higher percentage of heavy minerals; consequently, it has a higher monazite tenor. At these two localities and at other places the vertical continuity of monazite tenors between the samples has not been proved, but there is no reason to assume that such tenors are restricted to the sampled intervals only. However, samples 118, North Carolina, and 128, South Carolina (both from the Tuscaloosa formation), are about 50 feet apart stratigraphically, but their tenors in monazite are quite different.

Samples have been collected from both Pliestocene and Tuscaloosa sediments (nos. 72, 81, 87, 89, 101, 102, 106, and 112) at the same localities, and the paired samples are usually quite similar with respect to amount of contained monazite. This suggests that the Pleistocene material is made up in large part of reworked Tuscaloosa formation.

The data given above and on the maps suggest considerable vertical and lateral extent of high monazite tenors at certain localities and suggest that such values are maintained between some closely-spaced localities.

Promising areas for further work are outlined in figures 2 to 5, and in the discussion of geographic distribution. The formations which unconformably overlie the Tuscaloosa formation and which presumably are made up in considerable part of reworked material from the Tuscaloosa formation are particularly promising. The 5 samples of the McBean formation in South Carolina have an average tenor of 0.7 pound monazite per cubic yard. These formations probably have their highest tenors near the contact with the Tuscaloosa formation; and presumably, because of their regular bedding, such high content would continue laterally for a considerable distance.

Monazite in Recent stream sediments and flood plains

Essentially one heavy mineral suite characterizes all the formations sampled for this report. The only different suite, containing epidote, hornblende, and garnet in addition to the usual heavy minerals, is found in the sediments and flood plains of streams that drain the Piedmont province. The monazite content is different for the two suites of heavy minerals. Of ten alluvial deposits sampled in South Carolina along streams that flow from the Piedmont into and across the Coastal Plain, the average suite of heavy minerals contained only 0.25 percent of monazite. No monazite was in 6 of the 10 samples. Streams that head within the Coastal Plain were sampled at 8 places and have an average of 3.7 percent of monazite in the heavy mineral fraction. The poorest sample contains 1.3 percent of monazite in the heavy fraction.

There are many possible reasons for this difference in monazite content. One may be the method of collecting. Most of the streams that drain the Piedmont province are large, are bordered by swamp, and are difficult to sample. At many places samples from these streams represent sediments deposited during overbank floods and might not contain monazite. However, this explanation seems inadequate, since samples from streams rising in the Piedmont actually contain a higher proportion of heavy minerals than samples from streams that flow only in the Coastal Plain. The ratio is 2.7 percent to 1.3 percent. Another possibility is that some monazite-poor streams from the Piedmont do not reach and drain monazite-bearing rocks. Of the 10 samples examined, however, 6 came from rivers forming the Wateree-Congaree system, which drains the widest part of the western monazite belt. Whatever the explanation for lack of monazite, it is clear that the larger streams from the Piedmont are not receiving a very high proportion of their sediment locally from the Tuscaloosa and other monazite-bearing formations of the Coastal Plain.

OTHER MINERAL PRODUCTS

Other minerals and materials associated with monazite may be salable as coproducts or byproducts under favorable circumstances. The most salable commodities are sand and gravel, the titanium-bearing minerals, zircon, and the high-alumina minerals.

Sand and gravel are widely mined in operations that range in size from small pits supplying local road material to quarries reported to produce several thousand tons a day. None of the samples showing highest percentages of monazite in the heavy minerals came from quarries, but a high content of monazite might make it possible to work ground for sand, gravel, and monazite where it is currently uneconomical to mine for sand and gravel alone.

The titanium-bearing minerals ilmenite, leucoxene, and rutile are the most important industrial minerals in the sediments, and their value to industry depends upon the quantity of contained titania. Estimates were made of the quantity of titanium-bearing minerals in the heavy fractions of 12 samples from the Tuscaloosa formation (nos. 51, 62, 64, 137, 157, 170, 193B, 334A, 350, 359, 368, and 386) in North Carolina, South Carolina, and Georgia. They were chosen because they generally have a higher percentage of monazite than average, the percent of opaques (dominantly ilmenite and leucoxene) varied from 41 to 78 and averaged 55.5. Rutile made up 2.3 to 11.7 percent of the heavy minerals and averaged 5.1 percent. No determinations of titanium dioxide were made in connection with this work.

Zircon averaged 20.5 percent and ranged in abundance from 9.0 percent to 32.6 percent of the heavy fraction in the same 12 samples.

The high-alumina minerals include kyanite, sillimanite, and staurolite, and all range widely in their percent distribution in these 12 samples. Staurolite made up 0.3 to 13.7 percent of the heavy minerals in the 12 samples and averaged 2.8 percent. Kyanite and sillimanite together form less than 2 percent of the heavy minerals in eight samples but are 5.5, 10.1, 9.5, and 7.5 of the heavy fraction in the other samples.

A sample from the Barnwell formation in South Carolina and a sample from Pleistocene sediments in North Carolina show the same minerals in percentages not very different from those given for the 12 from the Tuscaloosa formation.

Deposits whose income will derive from several coproducts appear to be the only source of monazite along the inner belt of the Coastal Plain. Deposits economically dependent only on monazite will not be found there.

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Table 1. --Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain. _/

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
NORTH CAROLINA						
Tuscaloosa formation						
7B	40	0.9	0.4	0.3	0.001	0.03
10	35	0.75	0.26	0.8	.002	0.05
18	85	1.5	1.3	0.5	.007	0.18
19	90	0.4	0.36	0.0	.00	0.00
20	75	0.5	0.38	0.0	.00	0.00
21	83	0.3	0.25	0.0	.00	0.00
22	60	1.3	0.78	0.2	.002	0.05
23	85	0.04	0.03	0.0	.00	0.00
24	50	0.25	0.13	0.2	.0003	0.01
26	93	0.21	0.2	0.4	.001	0.03
27	45	0.11	0.05	0.0	.00	0.00
28	72	1.85	1.33	0.1	.002	0.05
30	90	0.08	0.07	1.2	.0008	0.02
31	65	1.1	0.7	0.0	.00	0.00
33	95	0.08	0.07	3.2	.002	0.05
34	40	0.4	0.16	0.4	.0006	0.02
35	59	0.02	0.01	0.0	.00	0.00
37	80	0.38	0.3	0.8	.003	0.08
38	45	0.53	0.24	0.4	.001	0.03
39	55	0.31	0.17	1.8	.002	0.05

_/ Dashes indicate value not determined

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
41	65	0.18	0.12	0.4	.0004	0.01
42	94	0.25	0.24	1.9	.005	0.12
44	90	0.2	0.18	0.6	.001	0.03
45	80	0.09	0.07	0.8	.0006	0.01
46	75	0.16	0.12	0.5	.0006	0.02
47	50	1.1	0.55	2.9	.016	0.4
48	73	0.4	0.29	8.4	.24	0.61
50	60	0.5	0.3	0.7	.002	0.05
51	99	1.0	1.0	7.3	.07	1.81
52	50	0.22	0.11	5.9	.007	0.18
53	30	0.25	0.08	1.2	.0009	0.02
54	65	0.32	0.21	0.5	.001	0.03
58	65	0.13	0.09	1.4	.001	0.03
59	65	0.35	0.12	3.1	.004	0.1
60	40	0.55	0.22	2.7	.006	0.15
61	65	0.2	0.13	2.7	.004	0.1
62	51	1.0	0.51	8.8	.05	1.13
63	75	0.25	0.19	4.9	.009	0.23
64	30	2.3	0.70	8.9	.06	1.55
65	94	0.29	0.27	2.3	.006	0.15
66	80	0.2	0.16	2.5	.004	0.1
67	89	0.06	0.05	1.6	.0008	0.02
68	45	0.23	0.1	2.6	.003	0.08
69A	94	0.15	0.14	0.0	.00	0.00

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
70	75	0.23	0.17	3.3	.006	0.15
71	45	0.38	0.17	1.8	.003	0.08
72B	75	0.4	0.3	1.7	.005	0.13
74	65	0.24	0.15	3.8	.006	0.14
75	98	0.17	0.17	1.5	.003	0.08
76	80	0.52	0.42	1.3	.005	0.13
77	45	0.1	0.05	3.7	.002	0.05
79	50	0.26	0.13	1.9	.003	0.06
80	70	0.54	0.38	3.3	.01	0.25
81B	70	0.8	0.56	2.9	.02	0.4
83	80	0.44	0.35	2.2	.008	0.2
84	85	0.27	0.23	1.8	.004	0.1
85	85	0.38	0.32	0.3	.0009	0.02
86	70	0.8	0.56	1.6	.009	0.25
87B	75	0.7	0.5	3.0	.02	0.38
89A	30	0.43	0.13	2.9	.004	0.09
90	50	0.25	0.12	2.7	.003	0.08
93	25	0.37	0.09	6.1	.006	0.15
94	55	0.2	0.07	5.4	.004	0.1
95	35	0.4	0.14	0.0	.00	0.00
97	70	0.2	0.14	3.3	.005	0.13
99	80	0.28	0.22	2.0	.004	0.1
100A	40	0.7	0.3	1.4	.004	0.1
101A	90	0.27	0.24	2.3	.006	0.15

Table 1. --Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
102A	65	0.32	0.21	6.0	.13	0.33
103	40	0.16	0.06	1.4	.0008	0.02
104	65	0.7	0.45	1.3	.006	0.15
105	50	0.13	0.07	2.1	.0002	0.04
106A	75	0.47	0.35	3.3	.01	0.3
107	70	0.1	0.07	1.8	.001	0.04
108	65	0.4	0.26	1.3	.003	0.09
111	80	0.2	0.16	1.5	.002	0.06
112B	65	0.36	0.23	1.2	.003	0.08
113	94	0.13	0.12	3.0	.004	0.1
114	70	0.38	0.27	2.7	.007	0.18
115	70	0.34	0.24	6.9	.02	0.43
116	98	---	---	2.0	---	---
117	60	0.9	0.54	3.4	.02	0.48
118	88	0.32	0.28	0.8	.002	0.05
119	70	0.27	0.19	2.1	.004	0.1
120	70	0.4	0.28	1.1	.003	0.08
			Black Creek formation			
56	94	1.1	1.0	0.6	.006	0.16
110	55	0.12	0.8	0.0	.00	0.00
122	95	0.6	0.6	0.9	.006	0.14

Table 1. --Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentages of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediments (lbs.)
			Yorktown formation			
4	35	0.74	0.26	0.1	.0004	0.01
11	70	0.07	0.05	2.8	.001	0.03
14	40	0.32	0.13	2.0	.003	0.07
17	40	0.25	0.1	1.2	.001	0.03
			Pleistocene deposits			
43	84	0.3	0.25	1.4	.004	0.09
49	70	0.63	0.44	1.1	.005	0.12
55	80	0.11	0.09	3.4	.003	0.08
72A	94	0.5	0.47	2.2	.01	0.25
73	64	0.5	0.32	1.5	.005	0.12
78	52	1.0	0.52	4.2	.02	0.55
81A	70	0.78	0.55	2.1	.01	0.29
82	42	1.0	0.42	3.2	.01	0.35
87A	60	0.5	0.3	2.5	.008	0.19
88	84	0.62	0.52	2.8	.02	0.38
89B	80	0.72	0.58	3.0	.02	0.42
91	50	0.46	0.23	0.8	.002	0.05
92A	20	0.36	0.07	1.9	.001	0.03
92D	35	0.35	0.12	0.1	.0001	0.00
96	65	0.6	0.39	6.7	.03	0.65
98	60	0.8	0.48	3.0	.01	0.35
101B	91	1.0	0.91	2.9	.03	0.68
102B	75	0.58	0.43	2.9	.01	0.31

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample <0.5 mm in size	Heavy minerals in <0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
106B	78	0.52	0.41	2.4	.01	0.25
109	40	0.29	0.11	0.0	.00	0.00
112A	75	0.3	0.23	0.4	.0009	0.02
121	35	0.4	0.14	0.0	.00	0.00
Stream sediments and miscellaneous samples						
1	---	---	---	0.2	---	---
2	---	---	---	1.3	---	---
3	---	---	---	0.3	---	---
5	---	---	---	0.3	---	---
6	92	4.95	4.55	0.2	---	---
7A	---	---	---	1.0	---	---
8	---	---	---	3.6	---	---
9	89	4.0	3.6	0.3	---	---
12	---	---	---	2.1	---	---
13	82	0.33	0.27	0.8	---	---
15	---	---	---	1.8	---	---
16	---	---	---	1.0	---	---
25	---	---	---	1.0	---	---
29	---	---	---	0.2	---	---
32	---	---	---	0.7	---	---
36	96	1.6	1.5	0.0	---	---
40	80	0.15	0.12	0.0	---	---
57	40	1.2	0.5	0.9	---	---

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample <0.5 mm in size	Heavy minerals in <0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
69B	96	0.2	0.2	6.0	---	---
92B	69	2.95	2.0	1.5	---	---
92C	77	1.9	1.47	0.4	---	---
100B	70	0.6	0.4	0.9	---	---
123	98	0.7	0.7	2.5	---	---
SOUTH CAROLINA						
Tuscaloosa formation						
124	85	0.28	0.24	6.7	.02	0.4
125*	87	0.93	0.81	6.2	.05	1.25
126	82	0.43	0.35	4.8	.02	0.43
127	45	0.6	0.27	3.1	.008	0.2
128	30	0.72	0.22	2.0	.004	0.1
129	40	0.28	0.11	1.1	.001	0.03
130	55	0.63	0.35	5.1	.02	0.43
131	65	0.19	0.12	3.0	.004	0.1
132A	70	0.4	0.28	2.8	.007	0.18
132B	53	0.45	0.25	3.9	.01	0.25
133	50	0.37	0.19	2.9	.006	0.15
134	78	0.5	0.4	2.0	.008	0.2
135	35	0.7	0.25	2.5	.006	0.16
136	80	0.14	0.11	7.7	.008	0.2
137	64	1.9	1.22	5.5	.07	1.68

*Collected from loose, yellow, fine-grained sand thought to be a Pleistocene deposit in an area mapped by Cooke (1936, pl. 2) as the Tuscaloosa formation of Cretaceous age.

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
138	50	0.7	0.4	0.9	.004	0.10
139	50	0.21	0.11	3.7	.004	0.1
140	50	0.18	0.09	3.4	.003	0.08
141	85	0.76	0.65	0.7	.005	0.13
142	75	0.16	0.12	1.3	.002	0.04
143	35	0.81	0.29	0.2	.0006	0.02
144	37	0.68	0.25	5.7	.01	0.35
145	65	0.37	0.24	4.9	.01	0.3
146	35	0.43	0.15	1.8	.003	0.08
148	70	0.19	0.13	1.3	.002	0.05
149	94	0.25	0.24	2.8	.007	0.17
150	94	0.08	0.08	2.8	.002	0.05
151	40	2.66	1.1	0.6	.006	0.15
152	55	0.7	0.38	2.5	.009	0.23
153	40	0.27	0.11	2.2	.002	0.05
154	60	0.3	0.18	3.0	.005	0.13
155	71	0.65	0.46	5.8	.03	0.68
156	78	0.66	0.52	4.3	.02	0.55
157	78	0.82	0.64	3.9	.03	0.63
158	50	0.57	0.29	1.6	.005	0.13
159	60	0.5	0.3	2.5	.007	0.18
160	45	0.19	0.09	4.7	.004	0.10
161	55	0.22	0.12	2.8	.004	0.10
162	60	0.4	0.24	2.1	.005	0.13

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
163	60	0.43	0.26	0.3	.0007	0.02
164	41	1.4	0.58	3.4	.02	0.50
165	80	0.25	0.2	1.6	.003	0.08
166	55	0.28	0.15	3.4	.005	0.13
168	40	1.23	0.5	1.9	.01	0.25
169	83	0.5	0.27	3.9	.11	0.26
170	47	0.9	0.42	6.1	.03	0.65
171	70	0.29	0.2	0.2	.0005	0.01
172	65	0.28	0.18	4.1	.007	0.18
173	50	0.15	0.08	5.8	.005	0.13
174	50	0.34	0.17	2.5	.004	0.10
175	75	0.42	0.31	5.6	.02	0.45
176	30	0.45	0.14	0.4	.0006	0.02
177	50	1.2	0.6	1.5	.009	0.23
178	85	0.08	0.07	0.6	.0004	0.01
179	70	0.5	0.35	0.9	.003	0.08
180	85	0.02	0.02	0.6	.0001	0.00
181	40	2.82	1.13	0.9	.01	0.25
184B	40	0.17	0.07	3.7	.003	0.08
185	90	0.5	0.45	4.2	.02	0.48
186	96	0.11	0.11	6.4	.007	0.18
187	60	0.14	0.08	1.3	.001	0.03
188	34	0.4	0.14	1.3	.002	0.05
189	25	1.25	0.31	5.5	.02	0.42

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample <0.5 mm in size	Heavy minerals in <0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
190	65	0.08	0.05	0.1	.00	0.00
191	75	0.34	0.26	0.6	.001	0.04
192	50	0.5	0.25	1.3	.003	0.08
193B	32	1.1	0.35	4.5	.16	0.40
193C	64	0.23	0.15	1.8	.003	0.08
194	57	0.5	0.29	2.4	.007	0.18
196	80	0.9	0.72	4.1	.03	0.75
197	72	0.4	0.3	0.0	.00	0.00
198	85	0.3	0.26	0.4	.001	0.03
199B	90	0.05	0.05	0.0	.00	0.00
200	94	0.09	0.08	0.4	.0003	0.01
202	50	0.65	0.33	0.4	.001	0.03
203	65	0.08	0.05	0.0	.00	0.00
204	50	0.2	0.1	0.4	.0004	0.01
205	53	1.53	0.81	2.3	.02	0.48
207	55	1.2	0.66	1.4	.009	0.23
208	45	0.52	0.23	4.8	.01	0.28
209	50	0.28	0.14	0.9	.001	0.03
210	40	0.94	0.38	1.5	.006	0.15
211	65	0.39	0.25	4.8	.01	0.3
212	43	0.9	0.38	5.8	.02	0.55
213	65	0.34	0.22	2.3	.005	0.13
214	75	0.23	0.18	1.3	.002	0.05
215	100	0.4	0.4	0.7	.003	0.08

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
221	79	0.5	0.4	3.1	.01	0.3
222	80	0.23	0.19	4.1	.007	0.18
223	74	0.52	0.39	2.5	.01	0.25
224	70	0.24	0.17	2.9	.005	0.13
225	35	0.57	0.2	7.0	.01	0.35
226	70	0.5	0.35	0.9	.003	0.08
227	65	0.1	0.065	7.7	.005	0.13
229	79	2.3	1.8	1.5	.03	0.68
230B	50	0.11	0.06	2.5	.002	0.05
231	55	0.27	0.12	1.8	.002	0.05
232	60	0.65	0.39	6.9	.027	0.68
233	75	0.18	0.14	1.1	.002	0.05
234	58	0.72	0.42	8.6	.04	0.91
235	65	0.77	0.50	4.2	.02	0.53
236	36	1.5	0.54	6.9	.37	0.93
237	89	0.01	0.01	4.5	.0005	0.01
238	65	0.5	0.33	10.1	.03	0.83
240	35	0.5	0.18	2.8	.005	0.13
241	65	0.8	0.52	2.6	.01	0.33
242	45	0.42	0.19	3.1	.006	0.15
243	40	1.79	0.72	0.9	.007	0.18
244	45	1.35	0.61	0.6	.004	0.1
245	60	0.7	0.42	0.8	.003	0.08
247	85	0.24	0.2	1.9	.004	0.1

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
248A	80	0.5	0.4	0.0	.00	0.00
249	89	0.5	0.45	0.2	.001	0.03
250	67	0.57	0.38	5.8	.22	0.55
251	60	0.13	0.08	3.1	.002	0.05
252	88	0.5	0.44	3.5	.02	0.38
253	80	0.17	0.14	4.3	.006	0.15
256	50	0.3	0.15	2.1	.003	0.08
257	57	0.6	0.34	5.2	.02	0.45
258	55	0.5	0.28	5.7	.02	0.40
259	60	0.4	0.24	4.6	.01	0.28
260	70	0.5	0.35	2.7	.01	0.23
262	50	0.4	0.2	4.2	.008	0.2
264	55	0.8	0.44	2.5	.01	0.28
265	45	0.6	0.27	7.0	.02	0.48
266	80	0.5	0.40	7.0	.03	0.70
267	40	0.5	0.2	0.0	.00	0.00
268	84	1.8	1.5	0.1	.001	0.03
269	80	0.6	0.48	3.6	.02	0.45
271	33	0.85	0.28	9.1	.03	0.65
273	50	0.19	0.1	3.4	.003	0.08
276	85	0.5	0.43	3.6	.02	0.40
277	82	1.1	0.9	3.9	.04	0.88
280	50	0.63	0.32	2.5	.008	0.2
285	65	1.43	0.86	0.9	.007	0.18

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample ∠ 0.5 mm in size	Heavy minerals in ∠ 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
286	75	0.33	0.25	3.6	.009	0.23
287	95	0.2	0. 2	0.6	.001	0.03
291	70	0.33	0.23	2.5	.006	0.15
293	70	0.52	0.36	3.8	.01	0.35
298	62	0.5	0.31	0.1	.0004	0.01
300	30	0.5	0.15	4.6	.007	0.18
303	40	0.5	0.2	8.4	.02	0.48
304A	94	0.25	0.25	0.0	.00	0.00
306	15	1.1	0.17	2.1	.004	0.09
309	60	0.2	0.12	0.6	.0007	0.02
312	25	0.25	0.06	3.1	.002	0.05
314A	21	0.26	0.055	3.4	.002	0.04
317	40	0.43	0.17	1.3	.002	0.05
318	50	0.5	0.25	2.1	.005	0.13
319	60	0.3	0.18	0.7	.001	0.03
320	60	0.65	0.39	1.7	.007	0.18
			Black Creek formation			
218	94	0.02	0.014	1.9	.0003	0.01
219	89	0.73	0.65	0.6	.004	0.10
			Peedee formation			
217	78	0.47	0.36	0.0	.00	0.00
			Black Mingo formation			
272	60	0.5	0.3	2.2	.007	0.17

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample ∠ 0.5 mm in size	Heavy minerals in ∠ 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
			McBean formation			
289	82	0.6	0.49	3.9	.02	0.48
290	45	0.8	0.36	9.1	.03	0.83
302	56	2.3	1.3	5.3	.07	1.73
315	40	0.4	0.16	0.5	.0008	0.02
316	57	0.5	0.29	5.8	.02	0.43
			Barnwell formation			
278	60	0.8	0.48	3.9	.02	0.48
281	85	0.13	0.11	1.7	.002	0.05
282	80	0.1	0.08	2.0	.002	0.04
283	65	0.07	0.05	0.8	.0003	0.01
288	78	0.5	0.39	1.4	.005	0.13
295	40	0.48	0.2	2.7	.005	0.13
296A	93	0.27	0.25	3.7	.009	0.23
297	80	0.5	0.4	1.6	.006	0.16
301	75	0.8	0.62	1.8	.01	0.28
305	55	0.44	0.24	0.8	.002	0.05
310	40	0.5	0.2	5.4	.01	0.28
311	50	0.4	0.2	3.4	.007	0.18
314B	27	3.3	0.9	8.3	.08	1.87
314C	68	0.6	0.41	8.1	.03	0.83

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
			Pleistocene deposits			
147	60	0.17	0.1	5.3	.005	0.13
184A	20	0.4	0.1	0.8	.0009	0.02
193A	50	0.68	0.34	4.3	.02	0.38
195	75	0.5	0.38	1.8	.007	0.18
199A	40	1.8	0.72	1.2	.009	0.21
201	70	0.25	0.18	0.0	.00	0.00
206	75	0.51	0.38	0.7	.003	0.08
216	74	0.5	0.37	0.7	.002	0.05
220	73	0.31	0.23	1.1	.002	0.05
230A	90	0.57	0.5	1.3	.007	0.16
246A	98	0.6	0.6	0.6	.004	0.10
246B	98	1.35	1.35	0.6	.009	0.21
261	40	0.7	0.28	3.6	.01	0.25
279	80	0.52	0.42	4.2	.02	0.45
292	15	0.44	0.07	2.1	.001	0.03
296B	90	0.5	0.45	2.9	.01	0.33
304B	75	0.5	0.38	1.4	.005	0.13
313	67	0.7	0.47	4.6	.02	0.55
			Stream sediments and miscellaneous samples			
167	05	2.3	0.12	0.0	---	---
182	--	1.4	---	1.0	---	---
183	76	3.0	2.3	0.0	---	---
228	95	2.5	2.4	0.0	---	---

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
239A	98	3.4	3.4	0.0	---	---
239B	98	4.8	4.8	0.0	---	---
248B	94	1.3	---	1.3	---	---
254	94	2.5	2.4	0.1	---	---
255	89	2.6	2.3	0.0	---	---
263	---	2.6	---	2.1	---	---
270	20	---	---	4.7	---	---
274	85	1.7	1.4	0.8	---	---
275	97	3.0	3.0	0.5	---	---
284	---	---	---	9.0	---	---
294	88	0.75	0.65	2.8	---	---
299	99	---	---	3.6	---	---
307	40	1.3	0.52	3.4	---	---
308	99	0.5	0.5	2.9	---	---
			GEORGIA			
			Tuscaloosa formation			
321	55	8.7	4.8	1.4	.66	1.65
322	75	0.7	0.52	0.0	.00	0.00
323	40	0.9	0.36	1.8	.006	0.16
325	70	0.5	0.35	4.2	.01	0.37
327	60	0.4	0.24	3.7	.009	0.22
329	75	0.08	0.06	0.0	.00	0.00
332	70	0.5	0.35	0.0	.00	0.00

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
334A	25	0.5	0.125	7.6	.01	0.24
335	96	0.3	0.3	1.4	.004	0.10
350A	78	0.51	0.4	3.3	.01	0.32
350B	46	1.4	0.65	3.6	.02	0.58
351	50	0.45	0.22	2.5	.006	0.15
352	73	0.5	0.37	4.9	.02	0.45
353	65	1.0	0.65	1.5	.01	0.25
354	50	0.33	0.17	5.3	.009	0.22
356	60	0.7	0.4	1.8	.007	0.17
357	45	0.33	0.15	3.0	.005	0.11
358	45	0.8	0.4	0.0	.00	0.00
359	41	0.63	0.26	11.9	.03	0.78
361	50	0.34	0.17	3.0	.005	0.12
368	38	1.5	0.57	2.8	.02	0.40
370	85	0.34	0.29	2.6	.008	0.19
371	60	0.24	0.14	5.8	.008	0.20
372	94	0.19	0.18	6.2	.01	0.28
373	30	1.6	0.48	2.5	.01	0.30
374	55	0.2	0.11	2.2	.002	0.06
375B	75	0.28	0.21	2.4	.005	0.12
277	98	0.75	0.74	5.6	.04	1.05
378	40	0.5	0.2	2.5	.005	0.12
379	80	0.27	0.22	0.8	.002	0.05
380B	70	0.48	0.34	3.0	.01	0.25

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
380A	70	0.24	0.17	6.6	.01	0.28
381	65	0.38	0.246	3.2	.008	0.19
382	70	0.32	0.22	4.6	.01	0.25
383	60	0.65	0.33	2.2	.007	0.18
384	70	0.5	0.35	2.7	.01	0.24
385	50	1.55	0.78	1.1	.008	0.20
386	45	1.9	0.86	9.7	.08	2.10
387	60	0.3	0.18	1.5	.003	0.07
388	84	0.5	0.4	1.8	.007	0.18
			Wilcox formation			
389B	94	0.4	0.4	0.0	.00	0.00
			McBean formation			
333A	72	0.35	0.25	1.0	.003	0.06
334B	80	0.25	0.2	7.4	.01	0.37
337A	78	0.6	0.46	2.0	.009	0.23
337B	52	0.4	0.2	2.2	.004	0.11
339	85	0.5	0.43	2.1	.009	0.22
341	96	0.27	0.26	0.5	.001	0.03
342	60	0.48	0.29	1.5	.004	0.11
348B	96	0.6	0.58	2.3	.01	0.30
349	95	0.5	0.5	2.7	.01	0.34
362	40	0.58	0.23	0.8	.002	0.05
389A	90	0.4	0.36	2.8	.01	0.25

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
			Barnwell formation			
324	84	0.18	0.15	1.3	.002	0.05
330	85	0.08	0.06	0.9	.0005	0.01
331	97	0.4	0.4	1.0	.004	0.10
333B	89	0.16	0.14	2.5	.004	0.09
334C	79	0.3	0.24	0.0	.00	0.00
336	25	0.5	0.125	0.4	.0005	0.01
338B	75	0.3	0.23	2.8	.007	0.16
340	50	0.3	0.15	1.5	.002	0.05
343	50	0.13	0.07	2.7	.002	0.05
345	94	0.5	0.5	0.1	.0007	0.02
346	94	0.16	0.15	2.2	.003	0.08
347	91	0.5	0.45	1.2	.006	0.14
348A	30	0.3	0.09	1.9	.002	0.04
360	75	0.27	0.2	2.2	.005	0.10
363	70	0.32	0.22	1.4	.003	0.08
364	95	0.25	0.25	0.9	.002	0.05
365	92	0.36	0.33	3.6	.01	0.30
366	92	0.23	0.2	0.7	.001	0.03
367	92	0.25	0.23	1.4	.003	0.08
369	92	0.13	0.12	1.1	.001	0.03
375A	90	0.1	0.07	1.3	.0009	0.02
376	82	0.2	0.16	1.4	.002	0.05

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Continued.

Sample number	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediments (lbs.)
			Stream sediments and miscellaneous samples			
326	55	---	---	0.7	---	---
328	94	1.0	0.9	1.8	---	---
338A	85	1.7	1.5	0.4	---	---
344	96	1.0	0.96	0.4	---	---
355	88	---	---	1.2	---	---
			ALABAMA			
			Tuscaloosa formation			
390	50	0.5	0.25	1.4	.004	0.09
391	84	0.54	0.45	0.6	.003	0.07
392	79	0.13	0.10	0.5	.0005	0.01
393	57	0.5	0.29	3.5	.01	0.25
394	40	0.4	0.16	0.7	.001	0.03
395	45	0.5	0.25	1.4	.004	0.09
396	89	0.09	0.08	0.0	.00	0.00
397	78	0.4	0.31	2.5	.008	0.20
398	40	0.78	0.31	0.6	.002	0.05
400	35	0.33	0.11	2.2	.002	0.06
401	65	0.6	0.4	0.7	.003	0.07
405	50	0.2	0.10	3.8	.004	0.10
406	40	0.31	0.12	4.1	.005	0.12
407	65	0.34	0.22	3.6	.008	0.20
408	50	0.47	0.24	1.4	.003	0.08
409	40	0.49	0.2	2.3	.005	0.11
410	50	0.5	0.25	3.0	.008	0.19

Table 1.--Distribution of monazite among the heavy minerals and sediments in part of the southern Atlantic Coastal Plain--Concluded.

Sample number	Percentage of sample $<$ 0.5 mm in size	Heavy minerals in $<$ 0.5 mm size (percent)	Heavy minerals in rock (percent)	Monazite in heavy minerals (percent)	Monazite in sediment (percent)	Monazite per cubic yard of sediment (lbs.)
			Eutaw formation			
402	85	0.5	0.4	2.2	.009	0.22
403	94	0.57	0.54	0.7	.004	0.10
404	78	0.44	0.34	1.1	.004	0.09
411	68	0.15	0.10	2.0	.002	0.05
			Ripley formation			
412	40	0.06	0.024	2.5	.0006	0.01
			Providence formation			
413	84	0.3	0.25	1.3	.003	0.08
414	84	0.5	0.4	1.5	.006	0.15
			Clayton formation			
416	95	0.19	0.18	1.0	.002	0.05
			Naheola formation			
415	90	0.5	0.45	0.0	.00	0.00
			Nanafalia formation			
417	90	0.5	0.45	1.4	.006	0.16
			Tuscahoma formation			
418	84	0.45	0.38	0.6	.002	0.05
			Glendon formation			
419	58	1.6	0.93	1.6	.02	0.37
			Stream sediments and miscellaneous samples			
399	20	0.65	0.13	0.2	---	---

Table 2.--Location of samples having an apparent monazite content of 0.25 pound or more per cubic yard of rock.

Sample number	Location
	NORTH CAROLINA
47	Harnett County; N. C. Route 210, 0.1 mile north of Upper Little River crossing.
48	Harnett County; N. C. Route 87, 0.5 mile by road north of Olivia.
51	Moore County; U. S. Route 1, 2.5 miles by road southwest of Lee County line.
64	Harnett County; N. C. Route 210. 0.4 mile by road north of Cumberland County line.
72A	Moore County; U. S. Route 1, about 2 miles by road northeast of Aberdeen.
78	Moore County; U. S. Route 501, 3.5 miles by road north of Hoke County line.
80	Moore County; U. S. Route 1, 0.8 mile south of Pinebluff.
81A 81B	Richmond County; U. S. Route 1, 1.3 miles by road southwest of Hoffman.
82	Richmond County; U. S. Route 1, 1.6 miles by road southwest of Moore County line.
86	Hoke County; U. S. Route 15A, 0.9 mile by road northeast of Raeford.
87B	Scotland County; U. S. Route 501, 14.6 miles by road north of junction with U. S. Route 15A north of Laurinburg.
88	Richmond County; U. S. Route 1, 0.7 mile by road west of junction with N. C. Route 77 south of Hoffman.
89B	Richmond County; U. S. Route 1, 3.0 miles by road west of junction with N. C. Route 77 south of Hoffman.
96	Richmond County; U. S. Route 1, 5.9 miles by road southwest of junction with N. C. south of Hoffman.
98	Scotland County; U. S. Route 501, 11.1 miles by road north of junction with U. S. Route 15A north of Laurinburg.
101B	Scotland County: U. S. Route 501, 8.0 miles by road north of junction with U. S. Route 15A north of Laurinburg.
102A 102B	Richmond County; U. S. Route 74, 0.5 miles by road east of junction with N. C. Route 381 east of Hamlet.
106A 106B	Scotland County; U. S. Route 74, 0.7 miles by road southeast of Richmond County line.
115	Richmond County; N. C. Route 38, 0.6 miles by road north of South Carolina line.
117	Richmond County; U. S. Route 1, 0.4 mile by road northeast of South Carolina line.

Table 2.--Location of samples having an apparent monazite content of 0.25 pound or more per cubic yard of rock--Continued.

Sample number	Location
	SOUTH CAROLINA
124	Marlboro County; S. C. Route 383, 1.1 miles by road southwest of junction with S. C. Route 79, southwest of Gibson, N. C.
125	Marlboro County, S. C. Route 38, 0.6 mile by road south of North Carolina line.
126	Marlboro County; S. C. Route 77, 1.3 miles south of North Carolina line.
130	Chesterfield County; U. S. Route 52, 6.5 miles by road north of junction with U. S. Route 1.
132B	Chesterfield County; S. C. Route 9, 4.1 miles by road east of Pageland.
137	Chesterfield County; S. C. Route 102, 1.3 miles by road southeast of junction with by-pass S. C. Route 9 at Chesterfield.
144 145	Marlboro County; S. C. Route 38, 2.6 miles by road northwest of junction with S. C. Route 383, east of Cheraw.
155	Chesterfield County; U. S. Route 1, 0.9 mile by road southwest of junction with U. S. Route 52 south of Cheraw.
156	Chesterfield County; U. S. Route 1, 4.1 miles by road south of junction with U. S. Route 52 south of Cheraw.
157	Chesterfield County; S. C. Route 102, 5.8 miles by road northwest of Patrick.
164	Lancaster County; S. C. Route 265, 0.6 mile by road west-southwest of junction with S. C. Route 903 northeast of Kershaw.
168	Chesterfield County; S. C. Route 903, 1.4 miles by road northwest of junction with S. C. Route 151 south of Jefferson.
169	Chesterfield County; S. C. Route 85, 3.6 miles by road southwest of junction with S. C. Route 109.
170	Chesterfield County; S. C. Route 102, 4.0 miles by road northwest of Patrick.
175	Chesterfield County; U. S. Route 52, 4.7 miles by road south of junction with U. S. Route 1 at Cheraw.
181	Marlboro County; S. C. Route 9, 2.1 miles by road east-southeast of junction with U. S. Route 15 near Bennettsville.
185	Chesterfield County; S. C. Route 102, 0.3 mile by road south of Patrick.
189	Chesterfield County; U. S. Route 1, 3.4 miles by road northeast of junction with S. C. Route 85 near McBee.

Table 2.--Location of samples having an apparent monazite content of 0.25 pound or more per cubic yard of rock--Continued.

Sample number	Location
193A 193B	Chesterfield County: S. C. Route 151, 0.7 mile by road northwest of McBee.
196	Chesterfield County; S. C. Route 102, 4.4 miles by road south of Patrick.
205	Darlington County; S. C. Route 102, 3.8 miles by road south of Chesterfield County line.
208	Chesterfield County; U. S. Route 1, 2.0 miles south of McBee.
211	Kershaw County; U. S. Route 1, 2.4 miles by road southwest of Cassatt.
212	Kershaw County; U. S. Route 1, 5.1 miles by road southwest of Bethune.
221	Lee County; S. C. Route 341, 3.0 miles by road southeast of Kershaw County line.
223	Kershaw County; U. S. Route 1, 3.9 miles by road northeast of junction with S. C. Route 34 east of Camden.
225	Kershaw County; U. S. Route 601, 8.4 miles by road south of Westville.
229	Kershaw County; U. S. Route 521, 0.9 mile by road south of Camden.
232	Lee County; S. C. Route 34, 6.3 miles by road east of Kershaw County line.
234	Kershaw County; S. C. Route 34, 6.8 miles by road east-southeast from junction with U. S. Route 1 east of Camden.
235	Kershaw County; S. C. Route 34, 3.9 miles by road east-southeast from junction with U. S. Route 1 east of Camden.
236	Kershaw County; U. S. Route 601, 1.4 miles by road south of junction with U. S. Route 1 west of Camden.
238	Kershaw County; U. S. Route 1, 1.7 miles by road northeast of Blaney.
241	Richland County; U. S. Route 1, 0.4 mile by road southwest of Pontiac.
250	Kershaw County; U. S. Route 601, 6.7 miles by road south of junction with S. C. Route 12.
252	Richland County; U. S. Route 1, 1.7 miles by road northeast of Dentsville.
257	Richland County; U. S. Route 601, 3.0 miles by road north of junction with U. S. Route 76.
258	Richland County; S. C. Route 262, 4.8 miles by road west of junction with U. S. Route 601.
259	Richland County; S. C. Route 262, 12.4 miles by road west of junction with U. S. Route 601.

Table 2.--Location of samples having an apparent monazite content of 0.25 pound or more per cubic yard of rock--Continued.

Sample number	Location
261	Richland County; near University of South Carolina, Columbia.
264	Lexington County; U. S. Route 1, 14.4 miles by road east of junction with S. C. Route 245 near Leesville.
265	Lexington County; S. C Route 215, 7.1 miles by road northeast of junction with S. C. Route 6 at Edmund.
266	Richland County; Quarry of Southeastern Sand Company, off U. S. Route 321 about 6 miles by road from junction with S. C. Route 215 southwest of Columbia.
269	Richland County; U. S. Route 76, 12.2 miles by road east of junction with U. S. Route 1 at Columbia.
271	Richland County; U. S. Route 76, 6.9 miles by road east of Lykesland.
276	Lexington County; U. S. Route 321, 2.7 miles by road south of junction with U. S. Route 21 south of Columbia.
277	Lexington County; S. C. Route 215, 2.8 miles by road northeast of junction with S. C. Route 6 at Edmund.
278	Lexington County; S. C. Routes 6 and 215; 0.4 mile by road south of their junction at Edmund.
279	Lexington County; U. S. Route 178, 6.6 miles by road southeast of junction with S. C. Route 391 east of Batesburg.
289	Lexington County; U. S. Route 321, 2.7 miles by road south of the Gaston fire tower.
290	Calhoun County; Near U. S. Route 21, 0.05 mile south of Beaver Creek, about 20 miles south-southeast of Columbia.
293	Aiken County; S. C. Route 391, 0.6 mile by road north of junction with S. C. Route 39 south of Leesville.
296B	Aiken County; S. C. Route 19, 3.5 miles by road southeast of Edgefield County line.
301	Aiken County; S. C. Route 39, 2.3 miles by road northwest of junction with the Scott-Seivern road, near Wagener.
302	Lexington County; Junction of U. S. Route 321 and S. C. Route 3, 1.1 miles by road south of Swansea.
303	Aiken County; U. S. Route 1, 0.6 mile by road north of Shaw's Creek, about 4 miles north of Aiken.
310	Aiken County: S. C. Route 215, 2.8 miles by road east of junction with U. S. Route 78 east of Aiken.

Table 2. --Location of samples having an apparent monazite content of 0.25 pound or more per cubic yard of rock--Continued.

Sample number	Location
313	Aiken County; Scott-Seivern Road, 0.9 mile by road southwest of the South Fork of the Edisto River.
314 B 314C	Aiken County; Scott-Seivern Road, at crossing of the South Fork of the Edisto River.
316	Orangeburg County; U. S. Route 321, 1.1 miles by road south of North
	GEORIGA
321	McDuffie County; Ga. Route 12, 4.5 miles by road west of Thomson.
325	McDuffie County; Ga. Route 17, 9.8 miles by road north of Wrens.
334B	Jefferson County; Reedy Creek, about 2 miles northeast of Mathews.
348B	Washington County; Ga. Route 24, 2.8 miles by road west of Sandersville.
349	Washington County; Ga.. Route 24, 3.1 miles by road west of Sandersville, at creek crossing.
350A 350B	Baldwin County;; Ga. Route 24, 7.9 miles by road southeast of junction with Ga. Route 22 east of Milledgeville.
352	Baldwin County; Ga. Route 24, 4.2 miles by road southeast of junction with Ga. Route 22 east of Milledgeville.
353	Baldwin County; about 4 miles southwest of Hardwick.
359	Bibb County; Ga. Route 49, 5.8 miles by road northeast of Macon.
365	Jefferson County; Ga. Route 78, about 1 mile northeast of Wadley, at creek crossing.
368	Wilkinson County; Ga. Route 18, 0.6 mile by road north of junction with Ga. Route 57.
372	Bibb County; U. S. Route 80, 2.3 miles by road east of Lizella.
373	Crawford County; Ga. Route 128, at Flint River crossing southwest of Roberta.
377	Taylor County; Ga. Route 137, 4.5 miles by road northeast of Butler.
380A 380B	Talbot County; Ga. Route 96, 2.8 miles by road east of Junction City.
382	Talbot County; at junction of U. S. Route 80 and Ga. Route 41 west of Geneva.
389A	Randolph County; Ga. Route 266, 4.5 miles by road southwest of Cuthbert.

Table 2--Location of samples having an apparent monazite content of 0.25 pound or more per cubic yard of rock--Concluded.

Sample number	Location
	ALABAMA
393	Elmore County; Ala. Route 14, 5.4 miles by road east of junction with Ala. Route 11 at Wetumpka.
419	Houston County; U. S. Route 231, 11.2 miles by road north of the Florida State line.

Table 3.--Relation of grain size, percent of heavy minerals, and percent of monazite in heavy minerals.

Number of samples	Percentage of sample < 0.5 mm in size	Heavy minerals in < 0.5 mm fraction (percent)	Monazite in heavy minerals (percent)
2	25-29	0.75	4.30
6	30-34	0.67	3.64
7	35-39	0.74	3.80
14	40-44	1.02	2.29
7	45-49	0.60	4.20
20	50-54	0.47	2.40
11	55-59	0.58	3.76
17	60-64	0.47	2.50
13	65-69	0.45	3.80
11	70-74	0.45	2.10
11	75-79	0.60	2.43
13	80-84	0.57	3.57
12	85-89	0.36	2.52
6	90-94	0.20	1.70
4	95-99	0.30	2.63