THE HEAVY MINERALS OF FLORIDA BEACH AND DUNE SANDS

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ABSTRACT

The identity and proportions of heavy minerals, and in particular rutile and ilmenite, have been determined in a representative collection of beach and dune sands from Florida. The heavy minerals were concentrated by means of heavy solutions, separated into several fractions of varying magnetic properties with a Franz iso-dynamic separator, and proportion determined by means of grain counts. Sixteen minerals were identified, about eight of these (enstatite, epidote, garnet, ilmenite, rutile, kyanite, staurolite and zircon) being present in essential amounts. The so-called ilmenite of these sands proves to be an essentially amorphous material with its iron in the ferric state and hence it is chemically, but seemingly not structurally analogous to arizonite. The size distribution of the quartz sand, and heavy minerals is described in two representative occurrences.

INTRODUCTION

In February 1944 Clarence S. Ross and John B. Mertie of the United States Geological Survey made a field investigation of the rutile-ilmenite bearing sands of Florida. During the course of this investigation, fifteen samples were collected. Other samples were received from C. M. Dunham of Orlando, Florida, and one was collected by Miss Jewell J. Glass of the Survey. The detailed examination of these samples was made by the author in the petrologic laboratory of the Geological Survey in Washington, and throughout the course of the study helpful suggestions were received from Dr. Ross and other members of the Survey. The *x*-ray examinations were made by J. M. Axelrod and the analytical tests by J. J. Fahey, both members of the U. S. Geological Survey.

Two of the localities visited by Ross and Mertie are major producers of rutile, ilmenite, and zircon. The one west of Jacksonville Beach is being operated by a company affiliated with the Titanium Alloy Manufacturing Company, and the one at Vero Beach by the Riz Mineral Company. The samples collected by Ross and Mertie from the Pensacola Bay region were from areas previously investigated by the U. S. Bureau of Mines.

GEOGRAPHICAL DISTRIBUTION

Figure 1 shows the location of the eighteen Florida samples studied in the course of this investigation. They have been arbitrarily numbered from one to ten starting on the east coast with the northernmost location, extending southward down the east coast, thence northward up the west coast, and finally westward to Pensacola. Where a number of samples were collected from one general region it has seemed advisable for

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the sake of clarity to give them the same number and designate them 4*a*, 4*b*, 4*c*, etc.

Geological Occurrence

The heavy minerals of the Florida region are very sparse in the areas of Pleistocene sands back from the coast, but occur in noteworthy amounts on the beaches now bordering the shore and in the sand dunes along the coast, and some of these form commercial deposits. On the beaches, wave action has locally concentrated the heavy minerals into discontinuous lenses which range from a mere film to 3 or 4 inches in thickness. On the immediate beach these concentrations change with each recurring storm, and in places heavy minerals may constitute a large percentage of the whole. The heavy minerals in the dune deposits no doubt underwent initial concentration on the beaches, and were later picked up and redeposited by wind action. The proportion of heavy minerals is much lower in the dunes than in some of the richer beach deposits, but the large volume of the dunes makes them a more favorable commercial source of rutile and ilmenite than the beaches. The dunes are of at least two types—modern ones on the immediate coast, and older ones which lie inland at various distances. These old dunes have been reduced almost to the level of the surrounding region, so there is little topographic evidence of their presence. All the present output of rutile and ilmenite is from the old dunes, although in the past the beaches have been productive.

Location of Samples

The samples included in this study are located as follows:

Sample 1 is modern dune sand collected 4 miles south of Atlantic Beach and 150 yards inland from the beach.

Sample 2 is from ancient dunes 10 miles west of Jacksonville Beach where the sand is being worked commercially. The studies were made on a heavy mineral concentrate from the washing plant.

Sample 3 is modern dune sand collected 10 miles south of Jacksonville Beach.

Samples 4*a*, 4*b*, 4*c*, and 4*d* were collected at intervals of 2 to 3 miles starting 4½ miles south of St. Augustine Bridge and extending as far south as the south side of Matanzas Inlet. All four of these samples are wave concentrations found close to the high-tide mark.

Sample 5 is from ancient dunes 3 miles west of the present beach and immediately south of the city of Vero Beach. This material receives initial concentration at Vero Beach, and final treatment at Melbourne.

Samples 6*a* and 6*b* are both from wave concentrates on the beach at Fort Pierce. They were secured through the courtesy of C. M. Dunham.

Sample 7 was collected on the west coast of Florida, from a wave concentrate on the beach just south of Tampa. Sample 7 was also secured through the courtesy of C. M. Dunham.

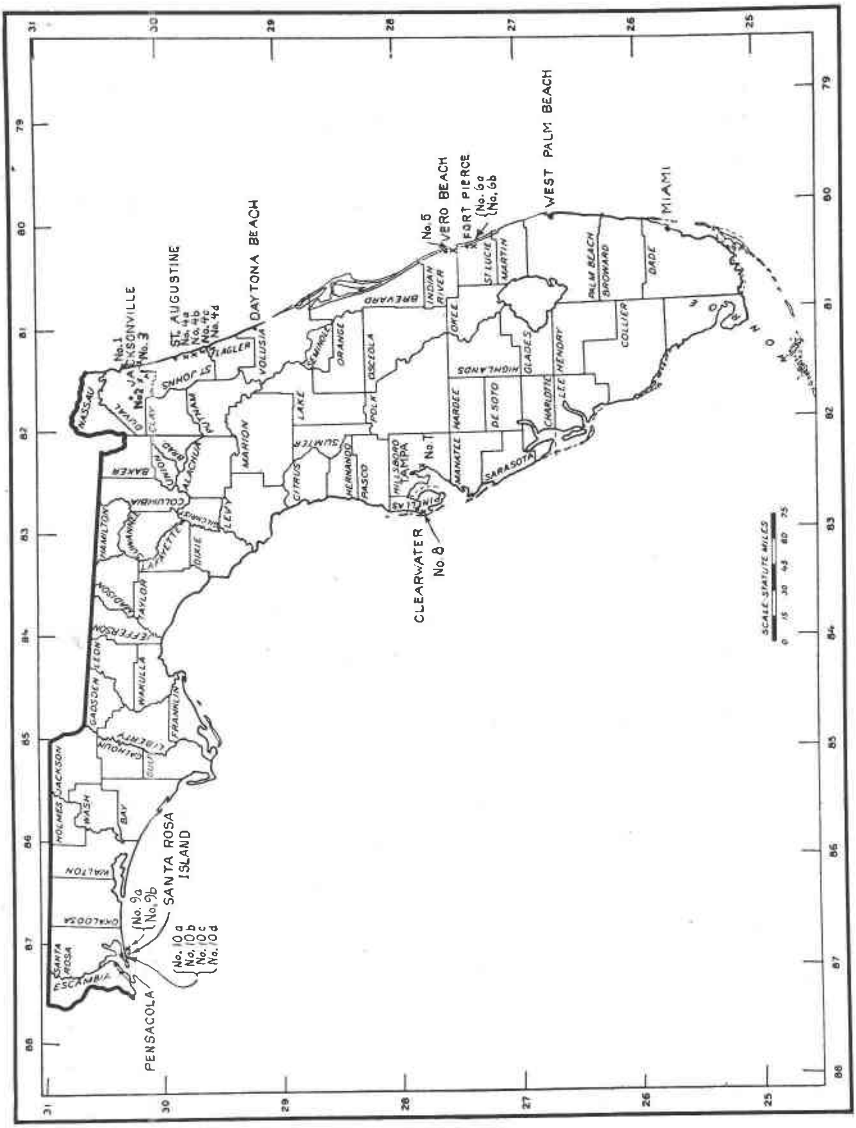
JACKSONVILLE
No.1
No.2
No.3
ST. AUGUSTINE
No.4a
No.4b
No.4c
No.4d
DAYTONA BEACH
No.5
VERO BEACH
FORT PIERCE
No.6a
No.6b
WEST PALM BEACH
MIAMI
TAMPA
No.7
CLEARWATER
No.8
SANTA ROSA ISLAND
No.9a
No.9b
No.10a
No.10b
No.10c
No.10d
PENSACOLA
SCALE-STATUTE MILES

FIG. 1

Sample 8 is from a rather sparse wave concentrate on Clearwater Beach.

Samples 9*a* and 9*b* are from wave concentrates taken along the outer beach of Santa Rosa Island, Pensacola, Florida. In this area the wave action is such that concentrates of the heavy minerals changes during each storm.

Samples 10*a* and 10*b* are from Pensacola Bay, Bureau of Mines locality No. 4, reported as situated 9.7 miles west of Camp Navarre.[1] Both samples were taken from thin lamina in the beach sand. Sample 10*a* was collected from the eastern and 10*b* from the western half of the locality.

Sample 10*c* is from Pensacola Bay, Bureau of Mines locality No. 2, 14.2 miles west of Camp Navarre. The material was collected 20 to 30 feet from the water's edge probably at or near high-tide level. The sample was concentrated from two gold-panfuls of sand.

Sample 10*d* is from a wave concentrate from Bureau of Mines locality No. 1 on East Bay, 6 miles south of Milton.

Sample 11 is from a wave concentrate from Scientists' Cliff, Chesapeake Bay, Maryland. This sample was collected by Miss Jewell J. Glass and was studied for comparative purposes.

Description of the More Important Minerals

Corundum. The sparse corundum grains, as seen under the microscope, are pale blue to colorless in the centers of the grains, bright blue around the edges. The colored parts are faintly pleochroic.

Enstatite. The enstatite is very constant in appearance throughout all the samples in which it occurs. The grains are well rounded, pale brown, and show pronounced cleavage in one direction.

Epidote. The moderately well rounded epidote grains are pleochroic, from almost colorless through pale green to strong green or brownish green. Their index of refraction indicates that they are high in ferric iron.

Garnet. The well-rounded garnet grains are violet pink; they show surprising uniformity, with an index of refraction of 1.80 in most of the grains. In sample 6*a*, however, the garnet has an index of 1.81, in sample 4*a* it varies from 1.80 to 1.81, and in sample 2 from 1.80 to 1.82. These optical properties indicate that the garnets belong to the almandite-spessartite group.

Ilmenite. The material from the Florida beach and dune sands that has commonly been assumed to be ilmenite has essentially the chemical composition of the material that has been called arizonite.[2] It contains about 53 per cent of TiO_2, and its iron is nearly all in the ferric state. Two samples (one moderately magnetic, and the other slightly magnetic) from Vero Beach and one moderately magnetic sample from the locality 10 miles west of Jacksonville Beach were examined by *x*-ray methods.

[1] War Minerals Report 141, rutile, zircon, ilmenite, kyanite: *U. S. Bureau of Mines*, 1–20 (**1943**).

[2] Palmer, Chase, Arizonite, a ferric metatitanite from a pegmatite near Hackberry, Arizona; *Am. Jour. Sci.*, *Series* 4, **28**, 353–356 (1909).

This examination indicated that all the supposed ilmenite was essentially amorphous, with only weak lines corresponding to ilmenite; hence the material is unlike the type arizonite from Arizona. Thus the relationship of the "ilmenite" of the beach and dune sands, and also of arizonite, needs more detailed study. It is interesting to note that the so-called ilmenite of Travancore is arizonite. On the other hand, x-ray examination of material concentrated from Australian sands indicates that it is ilmenite.

Hornblende. Hornblende is abundant in only one of the sands studied—that is in sample 4*c* from the locality about 10 miles south of St. Augustine. In this sample the hornblende is somewhat variable in color, but most commonly shows pleochroic colors ranging from yellow green or green to blue green. Some of the hornblende shows pale colors, but an essential proportion is nearly opaque in the direction of maximum absorption, has a high index of refraction, and no doubt is high in iron.

Kyanite. The kyanite occurs as large flat grains which are well rounded at the edges. Microscopic examination indicates that they are commonly colorless in the center and blue or green around the edges. With a hand lens the grains are colorless to blue.

Monazite. The grains of monazite are uniformly small and well rounded. They range from colorless to pale yellow brown or greenish brown.

Rutile. Examination with a hand lens indicates that three types of rutile are present in the Florida sands—dull semi-opaque brown, transparent red, and almost black. The red rutile is dominant, the black next, and the semi-opaque brown rarest; any combination of the three may occur in the same sample. The red rutile is usually in crystals or elongate grains, while the other types show no characteristic form. Very intense transmitted light shows that most of the rutile grains that appear black, are in fact very deep red; others are red with some enclosed black pigmenting material. Even the blackest grains are dark red or brown when examined in very finely crushed fragments.

Spinel. The sparse spinel is present in bright green to blue green grains.

Staurolite. The abundant staurolite shows characteristic pleochroic colors ranging from pale reddish brown to dark brown, and commonly contains many inclusions of magnetite. In general the staurolite grains are well rounded.

Tourmaline. The tourmaline, in rounded grains or elongate crystal segments, is pleochroic, its colors ranging from pale brown to dark brown or nearly opaque.

Zircon. Two types of zircon occur in the Florida sands, one being colorless, and the other brownish. The colorless zircon occurs in small euhedral, only slightly abraded crystals, and also in well rounded grains, whereas the brownish zircon is invariably present as irregular rounded grains.

Quartz. The quartz of the Florida sands was not studied in detail, but the unusually pure white sand of the Pensacola area seemed to be a possible source of high-grade glass sand. For this reason a sample of beach sand from Santa Rosa Island, the outermost beach in the Pensacola area, was tested for iron content in the form of Fe_2O_3. The material was first separated in bromoform (sp.g. 2.87), as the grains of iron-bearing minerals form so small a proportion of the Santa Rosa Island sands, that the direct determination of the proportion of iron-bearing minerals by heavy-solution and separation by means of an electromagnet seemed the best method for approximating the iron present in the heavy minerals of the sand. A chemical analysis of an excessively large sample would be required to provide a statistically representative sample. The quartz fraction after removal of heavy minerals was analyzed for iron in the chemical laboratories of the Survey, and the Fe_2O_3 content of the magnetic heavy fraction (composed largely of ilmenite and tourmaline) was estimated as shown below:

Fraction	*Weight percentage*	*Fe_2O_3 percentage*
Light (quartz)	99.968	0.008 (by analysis)
Heavy		
a. Magnetic	0.016	0.005–0.008 (estimated as $\frac{1}{3}$ to $\frac{1}{2}$ of 0.016)
b. Non-magnetic	0.016	mostly kyanite (not analyzed)

From these data it is seen that the total Fe_2O_3 content of the beach sand before removal of the heavy magnetic minerals is between 0.013 and 0.016 per cent, and was 0.008 after their removal.

It is interesting to note that these figures are several times lower than those found by Havell and McVay[3] for the Fe_2O_3 content of the sands of the Mobile area.

The quartz forms an overwhelming proportion of the Pleistocene sand areas of Florida and was not studied in connection with the problem of rutile and ilmenite resources of the state. The proportions of quartz and heavy minerals on the present beaches varies almost foot by foot, and from day to day; therefore, samples collected from areas of local concentration give no adequate idea of the proportion of these minerals in the beach sands as a whole.

The old dune sands, which attain thicknesses of 20 feet or more and represent huge bodies of commercial ore, present a more favorable opportunity for studying the relations between quartz and heavy minerals.

[3] Havell, R. F., and McVay, T. N., Beneficiation of some Alabama glass sands: *Bull. Am. Ceramic Soc.*, **18,** no. 11, 429–431, Nov. 1939.

TABLE 1. WEIGHT PERCENTAGE OF HEAVY MINERALS IN FLORIDA SANDS

No.	Locality	Occurrence	Apatite	Corundum	Enstatite	Epidote	Garnet	Hornblende	Ilmenite	Kyanite	Magnetite	Monazite	Rutile	Sphene	Spinel	Staurolite	Tourmaline	Zircon
1	4 mi. South of Atlantic Beach	Modern Dune Sand			4	30	2	4	29	2	Tr.		9	Tr.		9	1	8
2	West of Jacksonville Beach	Heads from Washing Plant			24	11	1	1	26	3	Tr.	Tr.	5	1		21	6	3
3	South of Jacksonville Beach	Present Dune Sand	Tr.	Tr.	3	21	2	1	38	3	Tr.		14	Tr.		7	5	7
4*a*	South of St. Augustine	Beach Sand		Tr.	1	8	4	Tr.	38	1	Tr.	Tr.	19	Tr.	Tr.	2	Tr.	27
4*b*	South of St. Augustine	Beach Sand			8	24	1	3	34		Tr.		14	Tr.		2	2	12
4*c*	South of St. Augustine	Beach Sand			12	44	Tr.	15	19	Tr.	Tr.		6			Tr.	5	Tr.
4*d*	Matanzas Inlet	Beach Sand		Tr.	3	3	8		51	2	Tr.	Tr.	15		Tr.	5	1	10
5	Vero Beach	Rough concentrate Melbourne Plant		2	2	3	2		36	1	Tr.	Tr.	27	Tr.		20	Tr.	6
6*a*	Fort Pierce	Beach Sand		Tr.	2	4	3		26	Tr.	Tr.		24	Tr.		28	1	12
6*b*	Fort Pierce	Beach Sand		1	3	Tr.	Tr.	Tr.	28	Tr.			28		Tr.	27	2	10
7	Tampa	Beach Sand			5	3	5	Tr.	26	8		Tr.	22	Tr.	Tr.	14	2	15
8	Clearwater	Beach Sand				1	17	1	23				1			47	10	1
9*a*	Santa Rosa Is.	Beach Sand		Tr.	1		Tr.		15	12			7	Tr.	Tr.	18	2	43
9*b*	Santa Rosa Is.	Beach Sand		Tr.	1		Tr.	Tr.	19	45	Tr.	Tr.	9	Tr.	Tr.	22	5	Tr.
10*a*	Pensacola Bay	Beach Sand			1			Tr.	14	35	Tr.		16		Tr.	29	1	4
10*b*	Pensacola Bay	Beach Sand			Tr.			Tr.	9	40	Tr.		8	Tr.		38	2	1
10*c*	Pensacola Bay	Panned Beach Sand			1				8	35	Tr.	Tr.	5	1		40	2	9
10*d*	Pensacola Bay	Beach Sand			Tr.				23	30	Tr.	Tr.	7	1	Tr.	34	3	2
11	Chesapeake Bay, Maryland	Beach Sand		Tr.	1	Tr.	3		39	1	25		11	Tr.	Tr.	11	Tr.	8

At the locality about 10 miles west of Jacksonville Beach, the proportion of heavy minerals was determined in three samples. A low-grade white sand near the bottom of the deposit contained 6.14 per cent of heavy minerals. Two more representative samples contained 12.1 and 19.2 per cent, respectively. The ilmenite in these 3 heavy fractions amounted to 1.6, 3.3, and 4.2 per cent, and the rutile 0.3, 0.6 and about 1.0 per cent of the entire samples.

The quartz from the old dune deposit about 10 miles west of Jacksonville Beach is sub-angular to sub-rounded in shape, but is very rarely well rounded. The sands from the old dune at Vero Beach are sub-rounded, with many more well rounded grains than in those at the locality west of Jacksonville Beach. The modern beach sand from the locality 10 miles south of St. Augustine is sub-angular to sub-rounded with well-rounded grains very rare. The sand from Santa Rosa Island is the coarsest-grained sand examined, as nearly all of the quartz grains range between 0.6 to 0.3 millimeters in diameter (between 28 and 6 meshes per inch). The grains are sub-rounded to well rounded in form.

Distribution of Minerals

The accompanying table shows the percentages of the minerals in the heavy-mineral fraction of each sample examined. From its study definite trends may be observed in the occurrence and abundance of some of the minerals in relation to the geographic location of the samples. These trends will be pointed out for the individual minerals and then discussed in relation to one another.

Enstatite. The distribution of enstatite is highly irregular, but in general the mineral is less abundant in the Santa Rosa Island and Pensacola Bay samples than elsewhere.

Epidote. Epidote shows the same trend as enstatite, but more emphatically. It is abundant on the north part of the east coast as far south as St. Augustine, becomes decidedly scarcer farther south along the east coast and in the Tampa area, and disappears entirely in the Pensacola Bay area.

Garnet. The percentage of garnet in the Florida beach and dune sands is extremely variable. On the east coast it is present in quantities ranging from a trace to 8 per cent of the heavy minerals. On the west coast at Clearwater Beach it reaches its peak of 17 per cent, but on Santa Rosa Island it drops back to a trace. No garnet was found in any of the four samples from Pensacola Bay.

Hornblende. Only one sample, that from about ten miles south of St. Augustine shows a noteworthy amount of hornblende.

Ilmenite. "Ilmenite" is irregular in abundance but shows a drop in quantity in the Pensacola Bay and Santa Rosa Island localities.

Kyanite. This mineral is a very minor constituent in all the samples with the exception of those from the Pensacola Bay area where it is very abundant. In this area the lowest percentage of kyanite, 12 per cent in one of the Santa Rosa Island samples, is more than four and one-half times as great as the highest percentage of this mineral in any one of the other samples.

Magnetite. Magnetite is rare in all the Florida sands and shows no observable distribution trend. In contrast, the sample from Chesapeake Bay, Maryland, is high in magnetite, whose abundance indicates that this sand is much nearer its source than are the Florida sands and has undergone a minimum of oxidation.

Rutile. The proportion of rutile in the sands shows a tendency to vary directly as the ilmenite. On the east coast epidote and rutile tend to vary inversely, while in the same region the ilmenite is abundant but variable. Sample 4*c*, however, is an exception inasmuch as both the rutile and ilmenite decrease in abundance while the epidote increases to 44.2 per cent.

Staurolite. With the exception of sample 2, staurolite shows a tendency to decrease on the east coast as far south as Matanzas inlet. In the next sample, from Vero Beach, its percentage rises sharply and it is fairly to very abundant in the remainder of the samples.

Zircon. No trends are evident in the distribution of zircon in the various samples; however, at both St. Augustine and Santa Rosa Island extreme variations in the zircon content of the sand occur within comparatively short distances. The mineral is subject to intense local concentration rather than a gradual concentration over a large area.

The significance of these trends is not altogether clear. A larger number of samples would have served to counterbalance the effects of local conditions of concentration. The study of many more samples collected at reasonably regular intervals over the whole coast line would have been highly desirable. The samples studied, however, disclose the characteristic heavy minerals in areas so far from the crystalline source rocks that transportation over long distances and repeated reworking have eliminated all but the most resistant materials. The study also shows the essential proportions of economically important minerals, rutile, zircon, and ilmenite in an area that is a major source of these essential minerals.

Grain Size

Time did not permit complete analyses of grain size in all the samples; however, samples 3 and 5, which represent the two sands of present commercial value, were screened and their grain sizes were plotted against the weight percentage, as shown in Figs. 2 and 3. In both figures the percentages of different grain sizes of the heavy minerals and of the

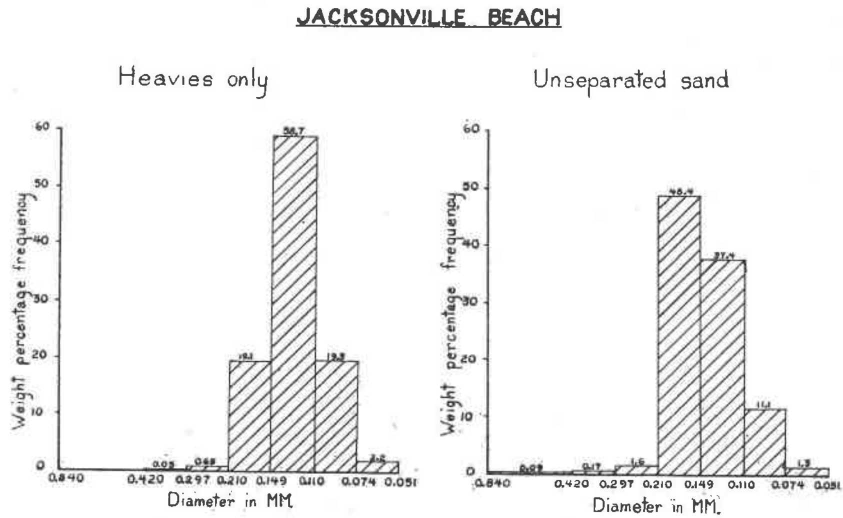

FIG. 2

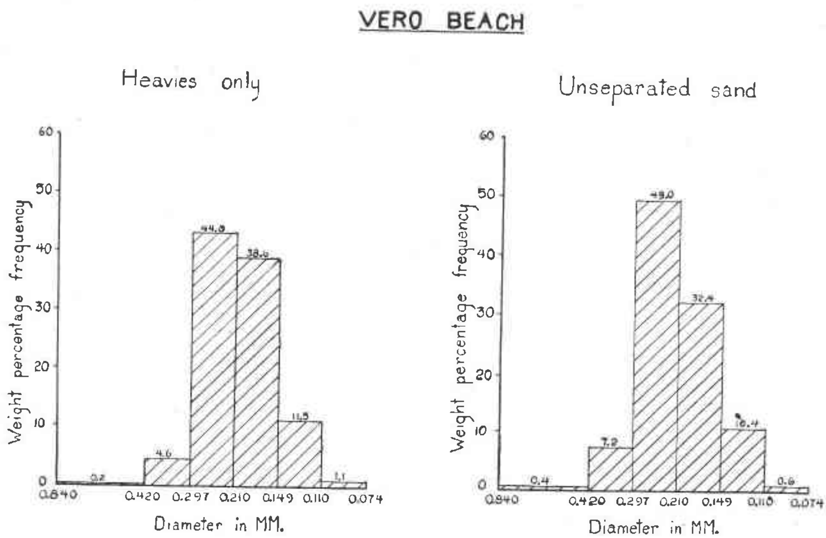

FIG. 3

unseparated sand are represented by diagrams. Comparison of the diagrams representing heavy minerals and unseparated sand shows that at both localities the quartz occurs in coarser grains than do the heavy minerals; also that the Jacksonville Beach sand is not only finer grained than the Vero Beach sand, but is also much more regular in grain size. In the heavy minerals of the Vero Beach sample 98.7 per cent of the grains are between 0.420 mm. and 0.110 mm. in diameter—an interval of 0.310 mm. In the unseparated sand 99.0 per cent of the grains lie within this interval. At Jacksonville Beach 97.1 per cent of the heavy minerals and 97.9 per cent of the unseparated sand has a diameter of 0.210 to 0.074 mm., an interval of 0.136 mm.

Laboratory Procedure

Each sample was first treated with dilute hydrochloric acid (1:1) to remove all carbonate material. This also removed collophane where it was present. The heavy minerals were then separated from the quartz in bromoform. Next, the heavy minerals were magnetically separated into three fractions with a Franz iso-dynamic separator, the magnetite having been removed first with a hand magnet. The presence of opaque rutile caused some difficulty, but it was found by experimentation with commercial concentrates that both the opaque and non-opaque rutile could be separated from the ilmenite by using a current of 0.45 amps in the separator; consequently, the first magnetic separation of each sample was made at 0.45 amperes, all the opaque material in the magnetic fraction being recorded as ilmenite and all the opaque material in the non-magnetic fraction being recorded as rutile. The essential correctness of this assumption is confirmed by the titanium content (92 per cent or over) of the commercial concentrates, which are essentially similar to the concentrates made in this laboratory.

The non-magnetic fraction at 0.45 amps was then separated by using 1.4 amps, thus dividing the heavy minerals into three fractions. Each of the fractions was then studied microscopically, the minerals identified, and grain counts made. Approximately 500 grains were counted in addition to any contaminating minerals. After grain countings, corrections were made for specific gravity of each mineral and the weight percentages calculated.