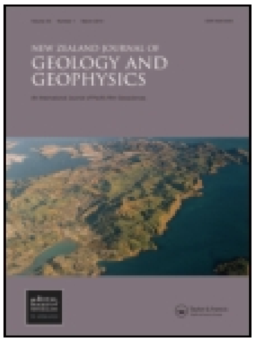

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DISTINCTION OF NEW ZEALAND BEACH, DUNE, AND RIVER SANDS BY THEIR GRAIN SIZE DISTRIBUTION CHARACTERISTICS

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ABSTRACT

The grain size distribution measures of a suite of recent beach, dune, and river sands from New Zealand and from Friedman (1961) have been studied. The population of New Zealand sands is comparable to the total population of the combined data. No single descriptive measure (e.g., skewness) can be used to discriminate sands from different environments. A linear discriminant function applied to the New Zealand sand population allows the combined use of the four descriptive measures of mean, standard deviation, skewness, and kurtosis. The function distinguishes river sands from beach and dune sands.

INTRODUCTION

A number of recent papers have discussed the criteria for the recognition of the depositional environments of modern sands (e.g., Friedman, 1961; Biederman, 1962; Shepard and Young, 1961; see also papers listed by Friedman, 1961, p. 515). The emphasis in most of these papers has been on the usefulness of grain size distribution measures for distinction of sands deposited in different environments. The results of these studies have been somewhat conflicting, but suggest that some distinction might be possible if the proper criteria could be determined and applied. The present study follows the same basic approach as previous papers, but treats the available data in a somewhat different manner to show that the measures of size distribution of modern sands are of limited value for the purpose of distinguishing environments of deposition.

The data used in this study are from two sources. One hundred and seventy-four sand samples were collected from beaches, dunes, and rivers all over New Zealand between March 1961 and July 1963. All the beach sands were collected from somewhere near the mid-tide mark; the dune sands from near the crests of dunes immediately adjacent to beaches; and the river sands from convenient localities within the boundaries of the environment. The second source of data is that presented by Friedman (1961). This information was used partly for comparative purposes and partly to allow the study of a larger suite of samples. A summary of the sources of the data is presented in Table 1. It was not possible to use

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TABLE 1—Numbers and Sources of Samples Studied in This Paper

Moment Measure	Source	Environment			Total
		Ocean Beach	Dune	River	
Mean	Friedman	78 (1)*	119 (1)	49 (5)	246
	Sevon	88	51	35	174
Standard Deviation	Friedman	43 (4)	102 (5)	49 (5)	194
	Sevon	88	51	35	174
Skewness	Friedman	78 (1)	119 (1)	59 (3)	256
	Sevon	88	51	35	174
Kurtosis	Friedman	0	71 (3)	59 (3)	130
	Sevon	88	51	35	174

*Number in brackets is the figure number from which the data were extracted.

any other published data since only Friedman's samples were treated by the same statistical approach (moments of measure).

All the samples collected were washed, dried, and split by conventional methods. Samples, 35–50 gm, were shaken for half an hour in an "Endrock" sieve shaker or for 10 minutes in a "Ro-Tap" sieve shaker through A.S.T.M. sieves using $\frac{1}{2}$ Φ intervals. Size distribution measures of mean, standard deviation, skewness, and kurtosis were calculated by the method of moments (Friedman, 1961) on the IBM 1620 digital computer in the Mobil Computer Laboratory, University of Canterbury. These measures are presented in Table 2. The *t* test and linear discriminant function calculations were also carried out on the IBM 1620 digital computer.

PRESENTATION OF THE DATA

In most previous studies of this nature the data were presented in scatter diagrams (e.g., Friedman, 1961, fig. 1, p. 517). Although such a diagram is relatively easy to read, sometimes it is very difficult to obtain any idea of the significance or lack of significance of the fields of overlap, when several different species (such as beach, dune, and river sands) are plotted on the same diagram. Because of this difficulty, the data are here presented in the form of a number of frequency polygons. The use of these frequency polygons allows easy visual appraisal of both the degree of overlap between the values of samples from different environments and the normality of the population. Some bias is introduced by the choice of interval size, but this could not be overcome by trying different intervals since I was limited to the interval size chosen by Friedman (1961) for the presentation of his data (or to some easily determined subdivision of Friedman's intervals).

TABLE 2—Grain-size Distribution Measures of New Zealand Beach, Dune, and River Sands Used in This Paper

BEACH

SAMPLE NUMBER	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
1	1.54	.42	.05	3.57
2	2.29	.41	-.53	7.88
3	2.50	.31	.14	4.22
4	2.13	.47	-.49	3.12
5	1.60	.52	0.00	2.76
8	2.60	.34	.56	4.25
9	2.14	.47	-.59	3.57
14	2.03	.59	-.34	2.39
16	2.17	.41	-.58	4.25
17	1.98	.41	-.25	3.07
20	2.08	.43	-.35	3.02
23	2.15	.37	-.19	3.11
26	2.27	.37	-.61	4.21
29	2.31	.38	-.37	3.55
32	2.34	.36	-.57	4.09
35	2.30	.39	-.63	3.90
38	2.28	.40	-.38	3.04
41	1.81	.76	-1.07	6.53
42	2.51	.40	-1.15	8.20
43	2.47	.37	.20	4.27
45	2.53	.46	.40	5.10
47	2.46	.42	.45	5.39
49	1.90	.56	-.63	3.57
52	.71	1.48	-.50	2.28
53	.99	1.13	-.73	3.31
54	2.31	.34	.14	4.52
64	-.90	.63	-.16	3.35
66	.42	.88	-.28	2.89
70	2.32	.68	-3.20	19.17
81	1.64	.80	-.22	2.88
82	2.22	.47	-.02	3.82
84	1.70	.67	-.73	3.96
87	1.95	.78	-2.53	10.38
88	1.42	.46	.20	3.07
93	1.88	.63	-.42	3.23
102	1.09	1.23	-.47	2.97
104	2.32	.40	-.07	2.58
105	.61	.77	.54	3.62
106	1.11	.66	.29	3.39
113	.65	.56	-.63	4.76
114	-.58	.37	1.31	6.57
142	2.60	.47	-1.67	9.13
145	2.61	.36	.10	3.94
147	1.87	.62	-.76	4.61
150	2.24	.36	.38	3.92
152	2.29	.51	-.03	3.06
153	2.74	.35	.09	3.33
159	2.72	.40	-.43	5.43
160	1.75	1.21	-.88	2.88
164	1.71	.61	-.67	5.67
168	2.38	.46	-.98	4.19
169	2.49	.45	-.62	5.98
171	2.40	.42	-.46	3.41
173	2.39	.45	-.67	3.56
175	2.50	.35	-.55	4.02
177	2.56	.31	-.55	3.64
179	2.62	.27	-.85	5.31
181	2.65	.25	-.58	4.25
183	2.53	.33	-.89	4.70
185	2.65	.24	-.73	5.06
187	2.63	.26	-.82	4.99
189	2.61	.26	-.56	3.41
191	2.70	.22	-.36	5.74
193	2.72	.20	-.51	7.72
197	2.56	.33	-1.18	6.06
199	2.61	.27	-.69	4.14
201	2.64	.25	-.77	4.58
203	2.65	.24	-.69	4.43
205	2.60	.27	-.87	4.63
207	2.56	.31	-1.12	6.19
209	2.47	.33	-.57	3.86
211	2.57	.29	-.80	5.19
213	2.58	.27	-.39	3.19
215	2.53	.27	-.21	2.45
218	2.60	.28	-.68	4.30
220	1.93	.47	.22	3.11
222	2.76	.28	-.61	7.10
223	2.78	.29	-.35	4.96
226	-1.11	.37	1.52	12.68
228	2.46	.42	-.37	3.58
254	1.78	.57	-.37	4.28
255	2.31	.55	-.88	7.75
256	2.68	.33	-.07	2.99
258	2.26	.58	-.03	2.58
259	2.34	.42	.14	3.16
261	2.21	.45	.18	2.49
263	2.25	.42	.23	3.15
265	2.34	.41	-.03	3.08

DUNE

SAMPLE NUMBER	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
6	2.48	.31	.02	3.43
10	2.48	.30	0.00	3.01
19	2.32	.34	.10	4.09
22	2.48	.33	.22	3.42
25	2.51	.34	.03	3.36
28	2.53	.33	.24	3.37
31	2.48	.37	.40	4.41
34	2.62	.30	.04	3.91
37	2.52	.31	.03	3.88
40	2.53	.33	-.07	3.45
44	2.48	.34	-.03	4.15
46	2.54	.31	.28	3.31
48	2.38	.36	.14	4.60
50	2.41	.30	.28	3.59
94	1.99	.53	.60	4.74
100	2.66	.30	-.23	3.44
101	2.57	.28	-.42	4.21
143	2.87	.25	.84	3.89
165	1.92	.36	.45	4.09
167	2.59	.32	-.36	4.41
170	2.84	.26	.71	4.45
172	2.72	.31	.09	3.95
174	2.73	.30	-.04	4.19
176	2.73	.28	-.10	6.36
178	2.78	.22	.63	6.08
180	2.77	.23	.32	5.92
182	2.76	.22	.39	6.12
184	2.74	.24	-.07	6.82
186	2.72	.23	-.22	5.50
188	2.71	.21	-.52	7.46
190	2.72	.21	-.34	6.90
192	2.73	.25	.01	4.52
194	2.65	.24	-.52	4.32
196	2.70	.21	-.49	5.78
198	2.64	.22	-.63	3.51
200	2.70	.21	-.27	5.92
202	2.61	.26	-.49	3.50
204	2.72	.20	-.29	6.89
206	2.77	.19	.45	6.77
208	2.80	.25	.33	4.22
210	2.65	.30	.10	3.46
212	2.75	.20	.70	8.83
214	2.70	.26	.23	6.30
216	2.64	.25	-.30	4.33
219	2.64	.24	-.67	4.95
221	2.22	.47	.13	3.99
257	2.67	.27	-.06	3.30
260	2.48	.38	0.00	2.78
262	2.28	.38	.27	3.02
264	2.34	.31	.32	3.51
266	2.36	.37	.32	3.01

RIVER

SAMPLE NUMBER	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
12	1.46	.90	-.65	4.14
58	-.02	2.08	-.20	1.75
60	.94	.98	-.26	3.06
71	1.96	.62	.63	4.65
73	1.23	.92	-.48	4.16
74	1.39	.92	-.27	4.45
75	1.78	.58	.06	3.47
77	.91	.79	.55	5.49
78	1.20	1.11	.15	3.09
83	1.13	1.16	.52	2.99
86	.54	.75	.04	5.22
91	.96	1.10	-.82	4.46
92	2.41	.41	-.41	3.64
95	2.68	.57	.68	3.49
97	2.51	.64	.53	3.09
98	1.63	.86	-.28	4.33
103	1.53	.83	-.73	4.15
108	.78	1.51	.26	2.32
109	1.33	.87	-.18	3.99
112	-.45	1.20	1.15	3.98
115	1.87	.91	.24	2.86
116	1.48	.77	.89	5.61
118	1.24	.46	.69	4.63
119	1.98	.42	.38	4.53
123	1.52	.55	.35	3.79
124	-.25	.73	.50	4.71
130	1.91	.59	.20	3.38
132	.94	.63	-.01	4.51
154	1.28	.75	.85	4.07
155	1.59	.87	-.23	3.48
157	2.11	.93	-1.12	5.84
240	1.45	.75	-.93	6.58
267	1.34	.66	-.69	4.48
268	2.42	.85	.13	2.88
269	1.21	1.18	-.38	4.14

The analysis of the data will be divided into two parts. The first part will discuss the population of each descriptive measure for the combined data of Friedman and myself and the population of each descriptive measure for my data and its relationship to the total distribution. The second part will discuss the differentiation of the New Zealand sands by means of a linear discriminant function.

GRAIN SIZE DISTRIBUTION MEASURES

Mean

Fig. 1A shows that the population of mean values for the combined data is highly skewed towards the finer sizes. Although this skewed distribution probably reflects inadequate sampling to some extent, I feel that it is largely a reflection of the tendency of the various depositional agencies to deposit sands of the finer grain sizes. This is certainly true of the dune sands, which reflect the normal transporting power of the depositing winds. This tendency is not so great in the beach sands, but the still recognisable fine grain-size bias probably reflects the greater number of beaches composed of the finer sand sizes. The relatively uniform distribution of river sand values reflects a definite lack of depositional bias for this environment. The application of a *t* test for the significance of difference between two sample means for independent samples (Croxton, 1953, p. 235) indicates that there is a significant difference between the means of the dune sands and river sands. However, the degree of overlap of the values for the different environments is so great that the descriptive measure of mean cannot be used alone to discriminate sands from the various environments.

Fig. 1B shows that although the New Zealand sands studied by the writer have a similarity in distribution of mean values to the total suite of sands (Friedman's and mine) there are some differences which may reflect either a peculiarity of New Zealand sands or incomplete sampling, probably the latter. The considerable difference between the New Zealand dune-sand distribution and the total dune-sand distribution probably reflects the fact that all of the New Zealand dune sands are from shoreline-margin dunes whereas a number of those of Friedman are from desert dunes.

Standard Deviation

Fig. 2A shows that the population of standard deviation values for the combined data is approximately normal with a skewness towards the larger values. There is a pronounced bimodality which reflects the strongly developed and different modes of the values from the dune and beach samples. The extremely wide range of values for the beach sands excludes the possibility of using standard deviation as a single means of distinguishing beach sands from dune sands. The values of standard deviation for river sands are spread over a wide range, but are absent in the area of smaller values where most of the dune sand values occur. This suggests that the river environment does not normally develop the high degree of sorting that occurs in the dune environment. The *t* test for significance of difference of means indicates a significant difference between the mean

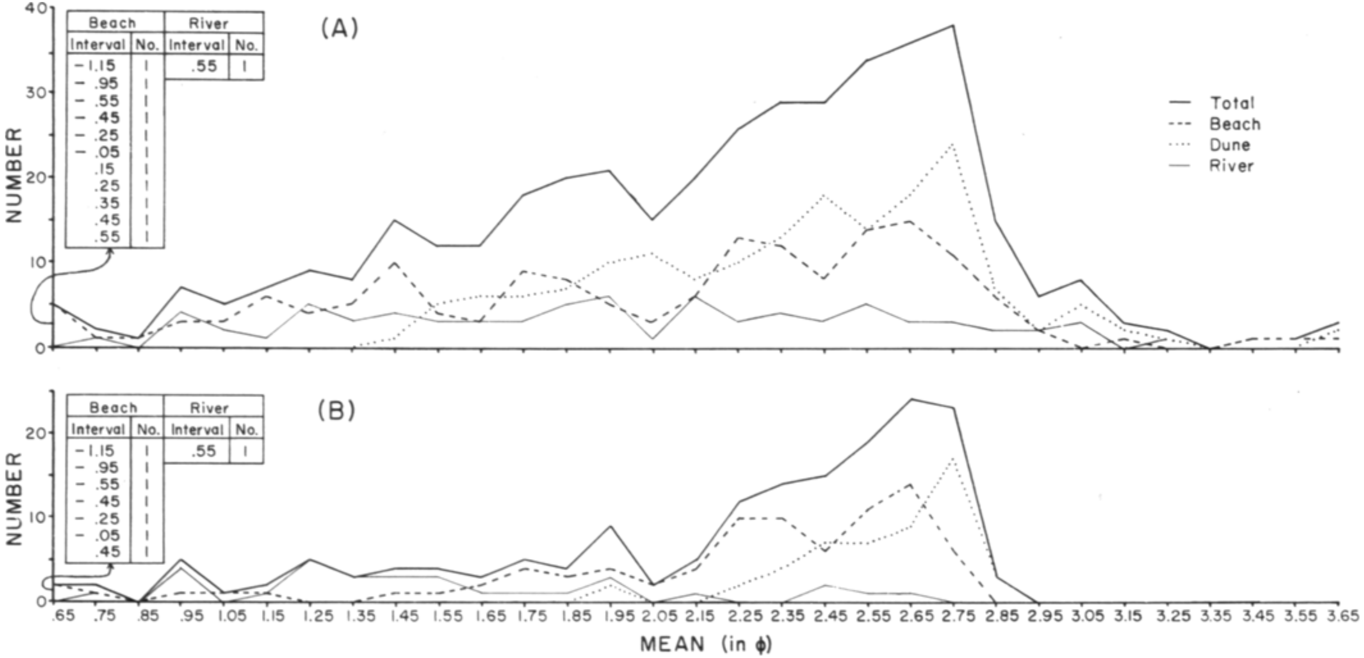

FIG. 1—Frequency polygons of the mean values for beach, dune, and river sands for (A) the combined data of this investigation and that of Friedman (1961) and (B) the data from New Zealand sands only.

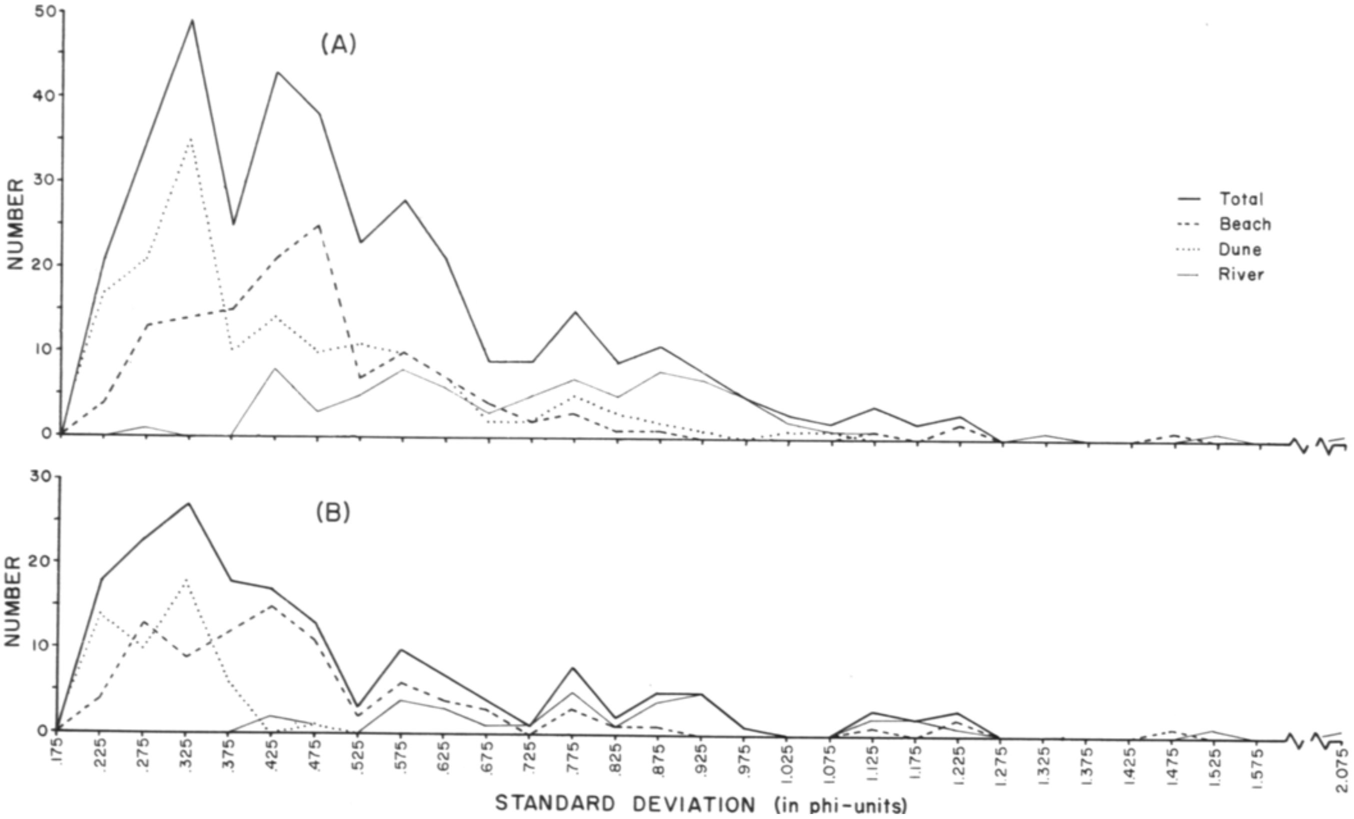

FIG. 2—Frequency polygons of the standard deviation values for beach, dune, and river sands for (A) the combined data of this investigation and that of Friedman (1961) and (B) the data from New Zealand sands only.

values of standard deviation for all environments, but the large amount of overlap of values from different environments severely limits the use of this difference.

Fig. 2B shows that the distribution of values for New Zealand sands is very similar to that of the combined data and thus must be representative of the total population of sands. The differences in mean values of standard deviation for the different environments is even more marked in the New Zealand sands than in the combined data. This suggests that more complete sampling on a world-wide scale might tend to bring the mean values of standard deviation for the total population even closer together.

Skewness

Fig. 3A shows that the population of skewness values for the combined data has a normal distribution and is composed of significantly different elements. The following conclusions can be drawn from Figs. 3A and 3B and are supported by *t* tests.

1. The population of skewness values of the New Zealand sands is similar to the total population, but does not have the same proportion of negative values as does the total population.

2. In both the New Zealand sand population and the total population there no difference in the mean values of skewness for dune and river sands, but there is a significant and practical difference in mean values between beach sands and dune and river sands.

3. The differences in distributions of values for the different environments between the New Zealand sand population and the total population suggests that more complete sampling might give rise to an even more distinctive difference between the mean skewness values of the beach sands and the dune and river sands.

The reasons for the strong differences in skewness between the dune and beach sands have been adequately discussed elsewhere (Friedman, 1961; Sevon, 1966).

Kurtosis

Figs. 4A and 4B show that both populations are very similar, that the distributions tend towards normality with some skewness towards the larger values and that there is no practical difference in kurtosis values between the three environments.

LINEAR DISCRIMINANT FUNCTION

Because the study of the various populations of individual descriptive measures does not yield any good distinctions between the three environments studied and because the two-variable approach used by Friedman (1961) does not give well defined distinctions in all cases, I applied a linear discriminant functions to the New Zealand sand data. This function allows all four descriptive measures to be considered at the same time for the purposes of discrimination. The approach used is that discussed by

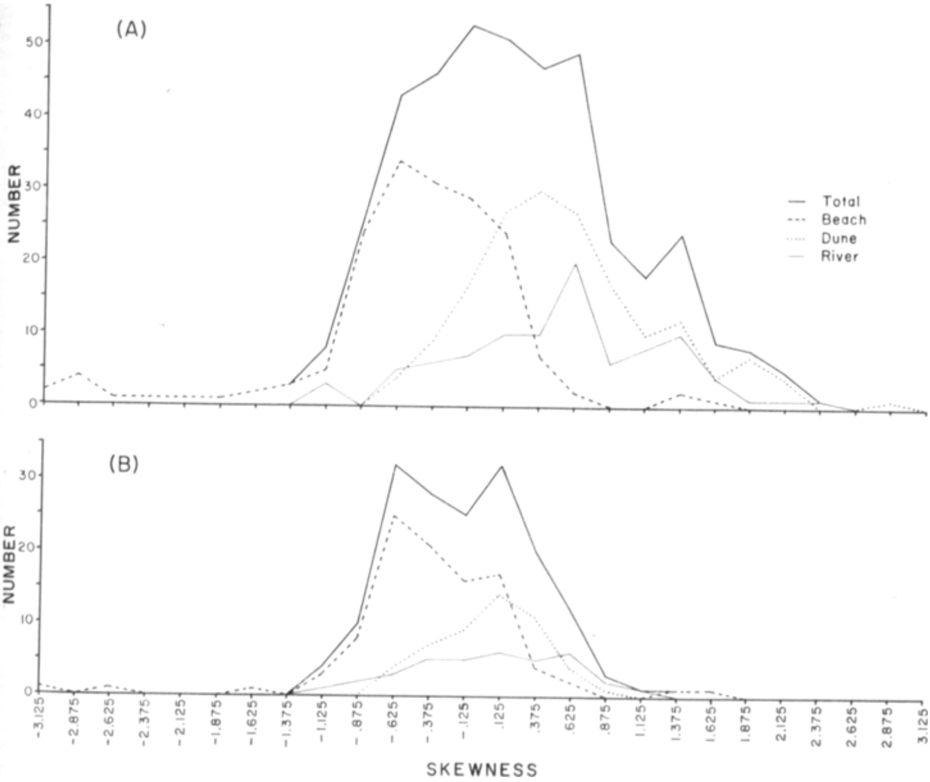

FIG. 3—Frequency polygons of the skewness values for beach, dune, and river sands for (A) the combined data of this investigation and that of Friedman (1961) and (B) the data from New Zealand sands only.

Miller and Kahn (1962, p. 276). I was not able to apply this function to the total population of values since the data presented in Friedman's paper could not be correlated. The procedure followed was that of determining a discriminant function for samples from two environments and then applying the function to the sample data. The resulting '*R*' values were used to make the frequency polygons presented in Fig. 5. A separate function was determined for each of the following environmental combinations: beach and dune, beach and river, and dune and river.

I have also determined discriminant functions for the same environmental combinations using all possible combinations of two and three variables, but, since the result of this work showed less discrimination than the function using four variables, these functions and their related frequency polygons are not presented here. The results of this study did emphasise, however, that whereas one particular variable may be critical in the distinction of any two environments, the same variable may not be critical in the distinction of two other environments. For example, standard deviation is

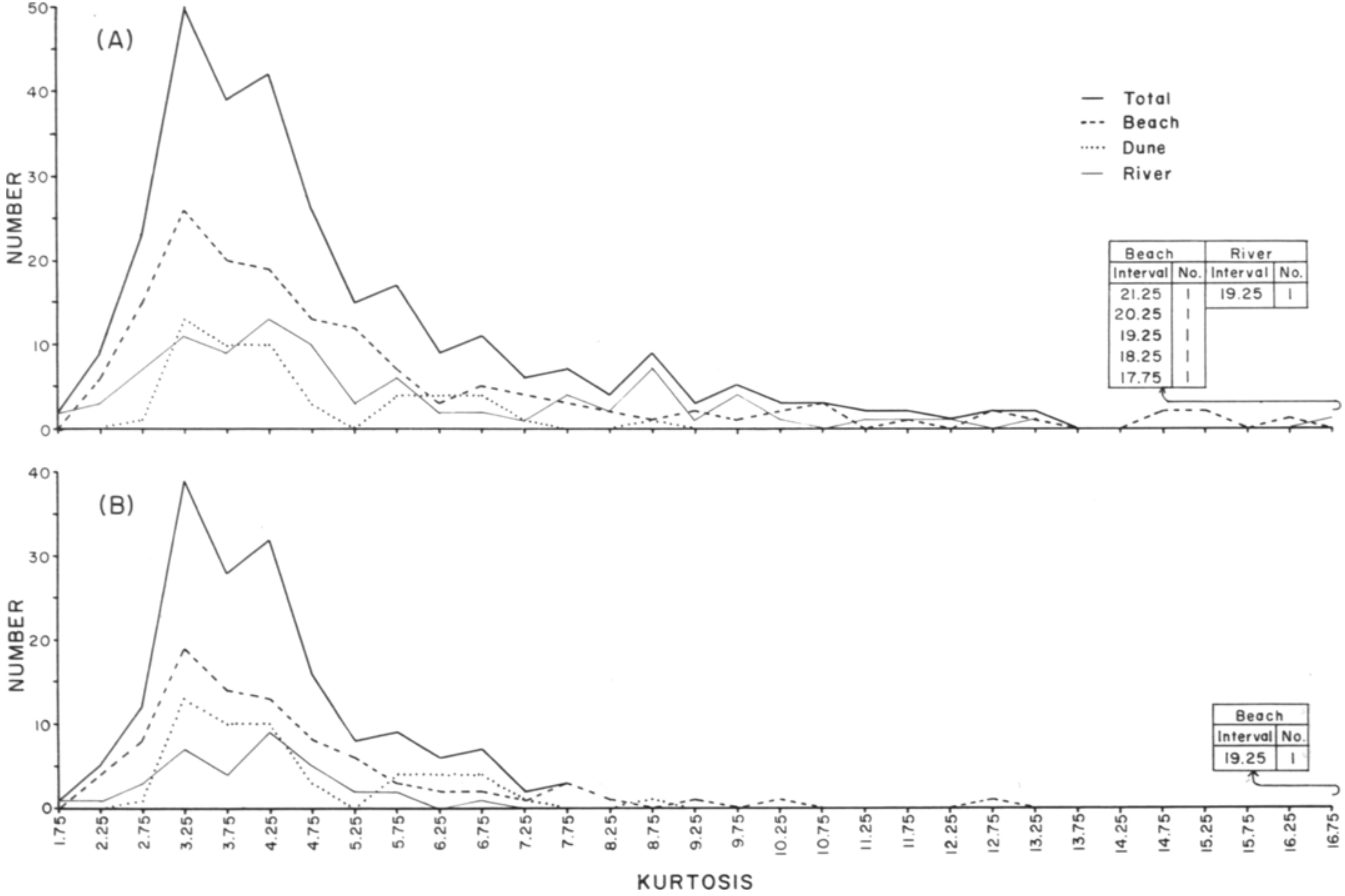

FIG. 4—Frequency polygons of the kurtosis values for beach, dune, and river sands for (A) the combined data of this investigation and that of Friedman (1961) and (B) the data from New Zealand sands only.

critical in the distinction of dune and river sands, but is of little value in the distinction of beach and dune sands.

Fig. 5A shows that the linear discriminant function based on the available data gives no positive discrimination between beach and dune sands within the range of the main bulk of sands from both environments. It does appear that values of *R* greater than 0·025 would indicate beach sands on the basis of New Zealand sand data.

Fig. 5B shows a good separation of the R values for beach and river sands and although there is considerable overlap of values some safety could be assured in assuming that all samples with positive *R* values are beach sands when this function is applied to New Zealand sands.

Fig. 5C shows a marked distinction between the *R* values of dune and river sands from the New Zealand suite. Values of *R* between 0·14 and 0·17 are in a field of overlap, but values outside these may be used with some confidence to discriminate between New Zealand dune and river sands.

TABLE 3—Linear Discriminant Functions (*R*) for Use in the Distinction of (A) Beach and Dune, (B) Beach and River, and (C) Dune and River Sands by Means of Their Grain Size Distribution Characteristics.

(A)

$$R = -0{\cdot}0662M + 0{\cdot}02842SD - 0{\cdot}00672Sk + 0{\cdot}00399K$$

(B)

$$R = 0{\cdot}00152M - 0{\cdot}04371SD - 0{\cdot}00624Sk + 0{\cdot}00375K$$

(C)

$$R = 0{\cdot}04601M - 0{\cdot}04993SD + 0{\cdot}00976Sk + 0{\cdot}01920K$$

NOTE—*M* = Mean (in Φ); *SD* = Standard Deviation (in phi-units); *Sk* = Skewness; *K* = Kurtosis.

The linear discriminant functions are presented in Table 3 and may be readily used by inserting known values in place of the appropriate word (e.g., known value for skewness) and performing the necessary multiplication. A comparison of the obtained *R* value with the appropriate polygons in Fig. 5 should give some indication as to what was the environment of deposition of the sand. Since the New Zealand sand suite upon which this study was made is comparable to the total population of sands examined, cautious use of these functions to discriminate sands outside New Zealand may be justified.

SUMMARY AND CONCLUSIONS

1. Although some differences are present, the population of measures of size distribution of New Zealand sands is basically similar to a total population of values obtained by combining the data of this paper with those published by Friedman in 1961.

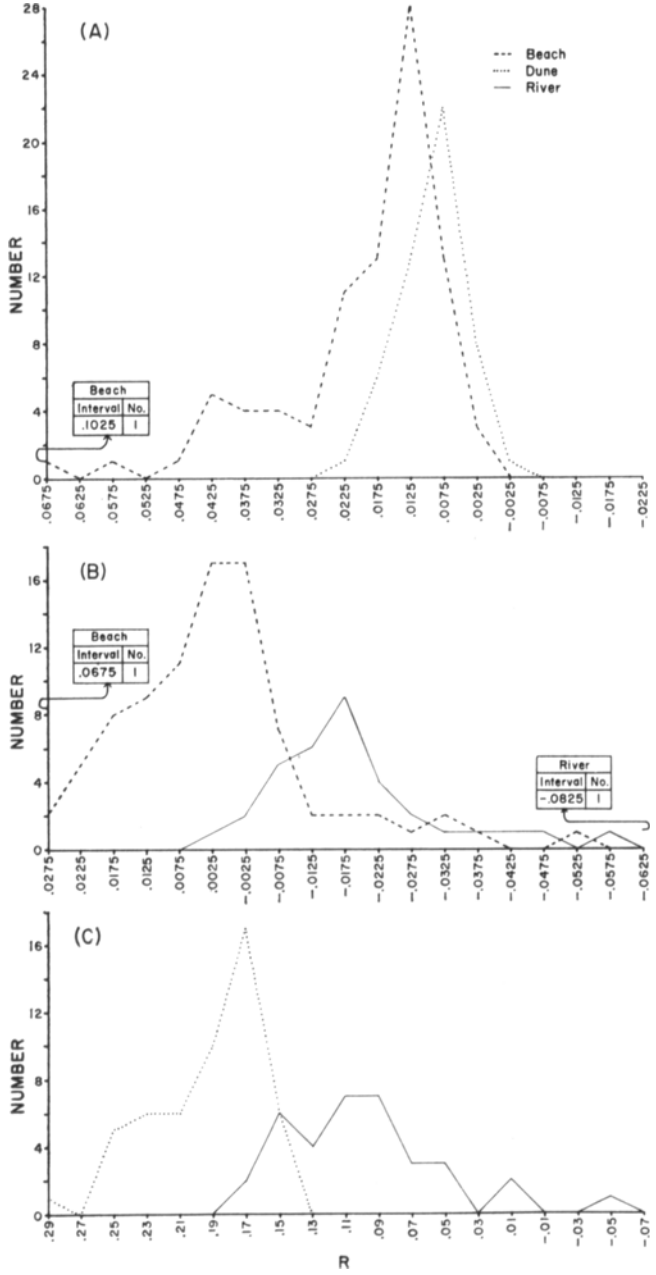

FIG. 5—Frequency polygons of the "*R*" values obtained by applying a four-variable linear discriminant function (Table 2) to New Zealand samples of (A) beach and dune sands, (B) beach and river sands, and (C) dune and river sands.

2. Although there tend to be some differences between the descriptive measures of sands from the beach, dune, and river environments, these differences are not sufficiently consistent for any one measure, such as skewness, to be relied upon to discriminate a sediment from a particular environment.

3. Linear discriminant functions determined for all combinations of two, three, and four size distribution measures indicate that a four-variable discriminant function can be used to distinguish river sands from beach and dune sands.

4. The present study suggests that the determination of a linear discriminant function based on a large suite of samples (1,000–2,000) from all over the world might be of considerable value in attempting to distinguish the environment of deposition of ancient sands.

5. With more and more data available on the size distributions of sediments from other environments of deposition than those studied, the linear discriminant function might prove to be very useful in discriminating a variety of depositional environments by measures of size distribution.

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