DIFFERENTIATION BETWEEN RIVER AND DUNE SAND, HUNTERS ISLAND AND VICINITY, RILEY COUNTY, KANSAS

by

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B. S., Muslim University, 1956

M. S., Muslim University, 1958

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology and Geography

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

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INTRODUCTION

Purpose of Investigation

This investigation was attempted in order to evaluate criteria that can be used to differentiate between the river and dune sediments of Hunters Island and vicinity, Riley County, Kansas. The grain size data of river and dune sands were analyzed to determine if statistically significant differences exist between the two environments of deposition. The mineral content of the river and dune sediments was determined so as to establish the source rock of these deposits.

Complete descriptions of textural and mineralogical properties of sands of different environments can aid in the understanding of the geological processes that are at work in an area. Such a study may reveal the geological agent responsible for the transportation of the sediment and the environment in which the sediment was deposited. The grain size, sorting, shape, roundness, and surface features are indicators of the agent of transportation and environment of deposition. This type of investigation is of considerable importance in searching for stratigraphic oil traps in ancient sediments, correlation between rock units, and in determining the conditions prevailing at the time of the deposition of sediment.

Geography of Area

Hunters Island and vicinity is between 39° 07' 30" and 39° 11' north latitude and between 96° 34' 40" and 96° 37' 30" west longitude. The area is bounded by the Kansas River on the east and south, Stagg Hill on the west, and Manhattan, Kansas, on the north. The area north of Hunters Island is traversed by Wildcat Creek, a tributary of the Kansas River.

Stagg Hill, which is west of Hunters Island, has a maximum elevation of 1233 feet above sea level. Moehlman Bottoms, which is southeast of Stagg Hill and southwest of Hunters Island, has an elevation less than 1020 feet. The lowest elevation of 960 feet is along the Kansas River.

The area is well connected by U.S. Highway 24, State Highway 18, and county roads. Manhattan Avenue connects Highways 24 and 18 with county roads which serve Hunters Island and Moehlman Bottoms.

The area has low relief. The dunes form irregular hummocks to relatively low gentle swells characterized by stable pedocal soils at the surface. The climate is humid continental with warm summers. The average January temperature is 32°F, and the average July temperature is 80°. Summers are modified by almost continual breezes, and winters are mild. Extreme temperatures during summer and winter are of short duration. The average annual precipitation is 32 inches (Self, 1961, p. 58, T. 4). The vegetation includes broad leaf deciduous trees and prairie grasses.

REVIEW OF LITERATURE

The study of the mineralogy and texture of a sediment may supply clues to the origin and to the environment under which the sediment was deposited. Environment has a major influence on the production, transportation, deposition, and subsequent modification of a sediment. The properties of a deposit, such as texture and structure, are important in the reconstruction of the environment of deposition.

Many workers in the field of sedimentary petrology have proposed different methods to distinguish between the several types of environments of deposition; the methods proposed by Folk (1957) and Friedman (1961) have produced some positive results.

Size Analysis

Some workers thought that grain size analysis is of considerable importance in the study of sediments. According to Pettijohn (1957, p. 15), the grain size data of a sediment are used for several purposes:

> The grain size of a clastic sediment is of considerable importance. The size of the fragments of which the rock is composed is in part the basis of subdivision into conglomerates, sandstones and shales. The size and uniformity of size or sorting is a measure of the competence and efficiency of the transporting agent. In the normal water-deposited materials, the size is in some way an index to the proximity of the source rock. Deposits of great coarseness usually have not moved far. The several agents and modes of transport lead to deposits which differ materially in their sorting and transporting ability. Turbidity flows are capable of transporting materials appreciable distances without much sorting, whereas normal air or water currents deposited some of the best sorted materials known, i.e., beach and dune sands.

Udden (1914, p. 730-732) observed that the grain size of a sediment was controlled by the conditions prevailing at the time of deposition. He called these conditions drifting, washing, and silting for water-laid deposits, and blowing, winnowing, and dusting for wind-laid deposits.

Wentworth (1931, p. 10-127) published several histograms of grain size data for several samples of sediment from different environments. These histograms show that river sand ranges between 16 mm. and 1/16 mm. (-4 Ø and 4 Ø) and is mostly unimodal. The dune sand ranges between 1 mm. and 1/16 mm. (0.0 Ø and 4 Ø) and is unimodal. The histogram is a good pictorial method, but it cannot be used to determine statistical parameters. Similarly Tanner (1940, p. 42) by an electrical method produced curves from dune and river sand to show the difference between the two sands. River sand produced concave curves, and dune sand produced convex curves. Twenhofel (1941, p. 55) observed that graphs can only suggest a possible environment and agent of deposition.

Keller (1945, p. 215) proposed that the agent and environment of deposition could be identified by the F:C (fine to coarse) ratio. Samples having larger proximate admixture to the coarse side are called coarse, and samples having larger proximate admixture to the fine side are called fine. The F:C ratio is higher in dune sand than that of beach sand.

Roundness

Roundness was considered by some workers as a criterion to distinguish the sediments of different environments. MacCarthy (1935, p. 94) found that eolian sand is more rounded than beach sand. He stated that the difference between the roundness of beach sand is more marked in coarse- and fine-grained sand than medium-grained sand.

MacCarthy and Huddle (1938, p. 73), after performing laboratory experiments, concluded that wind abrasion is one of the factors that produces rounded grains, but that the most important factor is selective sorting. Wind transports the sand by saltation. Under the action of wind, rounded grains bounce higher than angular grains; therefore, rounded grains are carried farther than the angular grains. The superior roundness of eolian sand is due to the process of shape sorting.

Beal and Shephard (1956, p. 56-60) used "roundness" as curvature or roughness of the surface. They observed that there was a consistent difference in the roundness of beach and dune sand sediments of the same area. They concluded that dune sands were more rounded than beach sands, and difference in roundness was due to selective sorting by wind.

Krumbein (1941, p. 72) suggested that roundness itself was not the only factor in selective sorting. The roundness of sand grains could be strongly modified by abrasion. He further suggested that the reconstruction of environment depends upon an interpretation of the size, roundness, mineralogical composition, surface texture, and orientation of the particles of a sediment.

Statistical Analysis of Textural Properties

Recent studies for distinguishing the sediments of different environments have been based on the statistical analysis of textural properties. Such statistical studies have produced some criteria for recognizing the environments of deposition for sediments.

Folk and Ward (1957, p. 25) studied the significance of grain size parameters of sediments of the Brazos River in Texas. In their study they observed that a sediment with a unimodal distribution should give a normal curve. Non-normal values of kurtosis and skewness indicate mixing of two or more modes. High kurtosis values indicate that the sediment was sorted in a high energy environment and later mixed with a different type of sediment. The higher the kurtosis values, the better is the sorting of the modes in their previous environment, and less effective is the sorting in the present environment. They showed that dune sands are slightly positively skewed and are leptokurtic. They concluded that kurtosis and skewness afford valuable clues to the origin of a sediment.

Mason and Folk (1958, p. 218-225) analyzed the size distribution of sand from beach, dune, and eolian flat environments at Mustang Island, Texas. They concluded that the best means for differentiating among environments was by plotting skewness against kurtosis, inasmuch as the geologic processes at work had their greatest effect on the tails of frequency curve of size distribution. Beach sands form normal curves, dune sands are positively-skewed and mesokurtic, and eolian flat sands are positively skewed and leptokurtic.

Friedman (1961, p. 523-524) studied sands from beach, river, and dune environments which were collected from different parts of the world. He found that both river and dune sands are positively-skewed. The skewness was found to be environment sensitive, and the sign of skewness was not affected by the mineralogy of the sands. He plotted skewness against kurtosis to distinguish river sand from beach and dune sand, but kurtosis values cannot be used to differentiate the depositional environment. He pointed out that dune sand was better sorted than river sand. He plotted the mean grain size against the grain size standard deviation to bring out the distinction between river and dune sands. In this plot the points for dune and river sand fell in three fields: one field for dune sand, a second field for river sand, and a third field overlapping the areas of river and dune sand. He concluded that most river and dune sands could be distinguished by textural parameters, although a wide field of overlap existed. In the field of overlap between the river and dune sands, the two sands could be distinguished by considering the standard deviation. He showed that dune sand associated with lakes has a standard deviation less than $\pm$ 0.40 ϕ, and that desert and inland dune sands have standard deviations of less than $\pm$ 0.50 ϕ, while most river sand has a standard deviation greater than $\pm$ 0.50 ϕ.

Friedman (1961, p. 524) explained that the positive skewness values of the grain size distribution were due to:

> The fact that wind and river transportation results from the unidirectional flow is believed to provide an explanation for the generally positive skewness of dune and river sands. The grain size distribution of the sand that is being transported is not known. However, the upper size limits of the grains that are carried in suspension or by saltation are governed by the competency of the medium, whereas no such limitation affects the fine particles in transport. The results of this limiting competency at the coarse-grained end of the frequency distribution curve is the lack of a 'tail' and the 'chopped off' appearance at the coarse end in comparison with normal distribution.

Passega (1957, p. 1982) used texture to distinguish the environment of deposition of river, beach and lake sediments. He selected one percentile (C) and fifty percentile, median (M) grain sizes and plotted these parameters on the semilogrithmic paper. He obtained certain patterns--oval (O) for lake, round (o) for beach, elongated () for tidal flat, and elongated but curved () with one end narrower than the other for river sediment.

Stewart (1958, p. 2586-2588) studied the sediments from San Miguel Lagoon, Baja California, Mexico.. He plotted the phi grain size standard deviation against median grain diameter. The plot shows three fields: one field for sediment deposited by river, a second field for sediment deposited by wave process, and a third field for deposition of sediment from quiet water. The median grain size diameter for river sand is coarser than 2 Ø, grain size sorting values range from 0.45 Ø to 1.25 Ø, and skewness values range from -0.47 to +0.05.

Sahu (1962, p. 47-54) studied sediments from eolian, beach, shallow marine, deltaic (river), and turbidity current deposits in Oregon and Wisconsin (U.S.). He found that the grain size standard deviation of sands from these environments progressively increases in the sequence from eolian, beach, shallow marine, deltaic (river) and turbidity currents. He derived the statistical parameters from graphs and showed that grain size standard deviations of mean size ($^{s}M_z$), variance ($^{s}\sqrt{I}^{\,2}$) and kurtosis ($^{s}K_G$) are consistent within the environment. The standard deviation of grain size skewness ($^{s}SK_I$) showed an overlap between different environments. He showed that the best results of differentiating sediments of different environments could be obtained by plotting the factor $\left\{\frac{^{s}K_G}{^{s}M_z} \cdot s(\sqrt{I}^{\,2})\right\}$ against $\sqrt{\sqrt{I}^{\,-2}}$ on log log paper. He concluded that eolian deposits have the better sorting values of grain size sorting and of uniform distribution because of constant energy and low variation through space and/or time, as wind was seldom loaded to its capacity. The near shore sediment is well-sorted, because the average fluctuation in energy was not excessive. The beach sediments are better sorted and more uniform in distribution than shallow marine deposits, because the waves pound constantly on the beach sediments. The river sediments are poorer sorted than near shore sediments, because in the river environment there is a greater fluctuation in energy through space and time. The river sediment was not distributed uniformly because of low available energy. The turbidity currents are more poorly sorted than the river deposits, because the energy fluctuation was greater and the variation in the fluidity factor through space and time was also greater than that of the river environments.

Textural Maturity

Folk (1951, p. 127-128) has defined four stages of textural maturity of sediments; these are the result of removal of clays, sorting of sand fraction and attainment of high roundness. These four stages are:

> I Immature stage. Sediment contains considerable clay and fine mica, the non-clay portion is itself poorly sorted, and the grains are angular. When the clay is winnowed out, stage II is attained.
>
> II Submature stage. Sediment contains very little or no clay, but the non-clay portion (silt, sand, or gravel) is still in itself poorly sorted and the grains are angular. As soon as the sediment becomes well-sorted, stage III is attained.
>
> III Mature stage. Sediment contains no clay and is well-sorted, but the grains are still subangular. When the grains become rounded, stage IV is attained.
>
> IV Supermature stage. Sediment contains no clay, is well-sorted, and the grains are rounded. This is the ultimate textural stage, and no further modification is possible in this cycle.

The textural maturity is important as it indicates the physical nature of environment of deposition. It gives a descriptive scale which shows the effectiveness of the environment in winnowing, sorting, and abrading the detritus supplied to it.

Heavy Minerals

Sediments are composed of three types of components which may be mixed in all proportions. These three components according to Folk (1961, p. 1) are terrigenous, allochemical, and orthochemical, and are ultimately derived from the breakdown of igneous rocks. In sediments a few minerals are important rock formers, and these minerals are transported, abraded, or precipitated. The most useful minerals for correlation are those which are derived from parent rock and have survived destruction by weathering, abrasion, or solution, and have specific gravity of more than 2.8. These minerals are called "heavy minerals." The heavy minerals rarely exceed one per cent of the rock.

When the heavy minerals are newly derived from crystalline rocks, and are incorporated into new sediment, such minerals show little abrasion. These heavy minerals are identified by their cleavage fragments and euhedral outline. In case of heavy minerals which are derived from reworked or earlier sediments, the less stable species are removed by abrasion and weathering, and the more stable varieties are rounded.

According to Milner (1962, p. 372-412) most of heavy mineral investigations have one or more of the following objectives:

1. To describe the mineral composition of a particular deposit.

2. To establish the similarity or dissimilarity of samples, generally for the purpose of geologic correlation.

3. To determine the changes in mineral composition within a series of related samples, so that factors related to the occurrence of heavy minerals may be discovered and evaluated.

4. To locate the sources or to evaluate the importance of various sources of a deposit.

5. To provide data from which the past history of a deposit may be interpreted.

6. To find an aid in exploitation of economically useful

minerals.

Bradley (1957, p. 123-125) used the volume percentage of heavy minerals to distinguish between sediments formed in marine and those found in subaerial environments. He explained that an increase in volume percentage of heavy minerals in subaerial environments was related to the work of wind. Dune sand grains are more rounded than those of river sand. Selective transportation might be related to the competency of wind with respect to volume-weight ratio. The wind has a higher competency with respect to heavy minerals.

Friedman (1961, p. 521-523) plotted mean grain size against grain size standard deviation to show the distinction between river and dune sediment. He obtained three fields: One field for river sand, a second field for dune sand, and a third field overlapping the areas of dune and river sediment. The river sediment was distinguished from the dune sediment in the overlapping area by separating light minerals from heavy minerals. He took the mean grain size ratio of quartz and that of a specific heavy mineral in the same sand, such as garnet or magnetite. The ratio of the radius of quartz to that of a specific heavy mineral is usually larger for river sands than for dune sands. Plots of ratios of mean grain size of heavy to light minerals (using phi values) against the ratio of sorting (grain size standard deviation) of heavy to light minerals show separation of river sand from dune sand.

Previous Work in the Area

Several individuals have studied different aspects of the geology of Hunters Island and its vicinity.

Beck (1949) and Moulthrop (1963) worked in Manhattan and surrounding localities. They observed that dune sand is composed of medium sand and silt. The sand consists of quartz, orthoclase, plagioclase (not subdivided), and mica (not subdivided). The mineral grains are well-rounded. The alluvium of the Kansas River near Manhattan ranges from gravel to silt and clay; the alluvium contains quartz, orthoclase, plagioclase (not subdivided), and chert. The sand and gravel fragments range from subrounded to well-rounded grains. The sand bars were deposited during flood stages where the coarsest sediment is in the lower part of the alluvium and occurs as sand and gravel, whereas the upper part is fine sand and silt.

Snow (1963) studied the sand deposit of Pleistocene Age between Manhattan and Wamego to the northeast of Hunters Island. He found that the sand deposit contains quartz, orthoclase, plagioclase (not subdivided), hornblende, and pyroxene (not subdivided). The quartz grains show more rounding than the feldspar grains. The sand deposits are poorly sorted ($\sigma = \pm 1.3\ \phi$).

Studying the mineralogy of Florena, Eskridge, Roca and lower part of Johnson shales of Permian System in Riley County, Johnson (1949) found that the light fractions consist of quartz, microcline, orthoclase and oglioclase, and the heavy fraction consists of hornblende, lamprobolite, muscovite, topaz, zircon and magnetite. In comparing Riley County tills with Permian shales, he found that tills are rich in hornblende (14.2%), epidote (17.3%) and garnet (7.6%), and that shales contain hornblende (.83%), epidote (.03%), and garnet (1.03%). Another difference is the shape of hornblende. The hornblende in tills tends to be elongated and jagged while in shale it is smoother and rounded. Tills contain 70.4 per cent quartz, and shale contains only 13.1 per cent quartz. Chalcedony is 71 per cent in shale and only 17.6 per cent in till.

Matthews (1949) determined the mineralogy of some soil and shale from Saline County, which is 80 miles west of Hunters Island. The area is traversed by Smoky Hill River, a tributary of Kansas River. He found that soil developed on the alluvial clay contains 23 per cent muscovite and 10 per cent hornblende with well developed crystals. Hornblende grains range in size from 0.125 to .074 mm. (3.0 ø to 3.75 ø). Tourmaline grains are euhedral. Zircon grains are also euhedral. Both tourmaline and zircon form 2 to 3 per cent of the heavy fraction. The soil developed on loess contains 8 per cent muscovite, 20 per cent hornblende (3.0 ø to 3.75 ø in size) and grains are rounded. Tourmaline and zircon grains are 3 to 4 per cent and are rounded.

Lill (1946) studied the glacio-fluvial terraces in Marshall and Washington Counties along the Little Blue River north of Riley County. The light minerals in the glacio-fluvial terrace deposit are quartz (75 per cent), chalcedony (8 per cent), orthoclase (3 per cent), and plagioclase (not subdivided) (4 per cent). The heavy mineral fraction consists of hornblende (3 per cent),

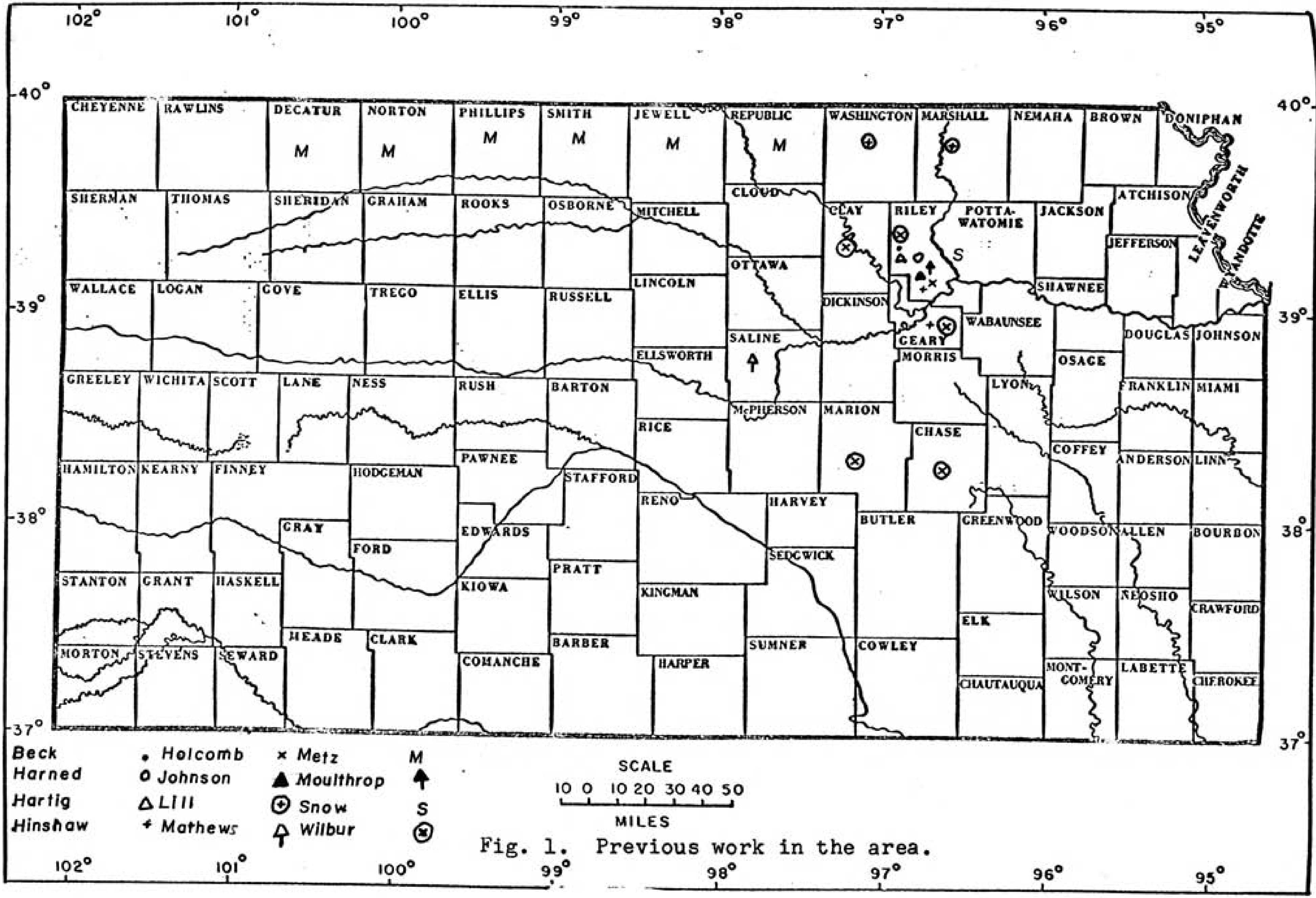

Fig. 1. Previous work in the area.

basaltic hornblende (3 per cent), epidote (18 per cent), garnet (5 per cent), muscovite (7 per cent), zircon (3 per cent), and magnetite (35 per cent). Hornblende and zircon grains are euhedral. He suggested that the Little Blue River might have contributed sediment from these terrace deposits to the Kansas River.

Harned (1940) has presented the mineral percentages in his study of the mantle rock of the Manhattan area. The mantle rock consists of 62.9 per cent quartz, 5.1 per cent orthoclase, 1.8 per cent plagioclase (not subdivided), and 24.4 per cent chalcedony in the light fraction. The heavy mineral fraction consists of 19.6 per cent hornblende, 2 per cent basaltic hornblende, 1 per cent augite, 14.6 per cent epidote, 4.5 per cent garnet, 8 per cent muscovite, 1 per cent topaz, 1.8 per cent tourmaline, 7 per cent zircon, and 18 per cent magnetite.

Seiler (1941) studied the flood plain of Kansas River between Topeka and Ogden (9 miles west of Manhattan) and observed that the sediment of the flood plain contains 55 per cent quartz, 22 per cent chalcedony, 20 per cent feldspar (not subdivided), and 3 per cent volcanic ash in the light fraction, and 32 per cent hornblende, 2 per cent augite, 1 per cent enstatite, 1 per cent hypersthene, 9 per cent muscovite, 4 per cent biotite, 11 per cent epidote, 4 per cent garnet, 8 per cent tourmaline, 3 per cent zircon, 1 per cent topaz, and 20 per cent magnetite in the heavy fraction. On the basis of average mineral percentage of the Solomon River, Saline River, Salt Creek River, and Kansas River flood plain he concluded that the tributaries are different in source and age from that of the flood plain deposit. He further stated that flood plain deposits of the Kansas River are younger in age than flood plain deposits of the Saline, Solomon, and Salt Creek Rivers.

Hinshaw (1960) determined the insoluble residue of Fort Riley limestone in Riley County. He found that the most abundant non-carbonate mineral is chert (90 per cent), and it ranges in size from .5 mm. to .08 mm. (1.0 ∅ to about 3.75 ∅). Authigenic orthoclase is 7 per cent, and it ranges in size from .6 mm to .1 mm (about .75 ∅ to about 3.25 ∅). Microcline is 2 per cent and size is .1 mm (about 2.5 ∅), albite (1 per cent), size .09 mm (about 3.5 ∅), and celestite (10 per cent), size .15 mm (about 2.75 ∅). Traces of muscovite, hornblende, tourmaline, zircon, and magnetite range from .15 mm to .07 mm (about 2.75 ∅ to about 3.75 ∅).

Hartig (1955) studied the minor petrographic constituents of some Permian rocks in Riley County. He found that limestones contain 92 per cent of chalcedony and the rest is quartz, orthoclase, and microcline. The heavy mineral fraction contains muscovite (2 per cent), biotite (2 per cent), pyrite (3 per cent), garnet (2 per cent), hematite (4 per cent), and zircon (2 per cent). In shales 90 per cent of the light fraction is chalcedony and 10 per cent includes quartz, microcline, orthoclase and plagioclase (not subdivided). The heavy mineral fraction contains muscovite (8 per cent), biotite (3 per cent), hornblende (trace), tourmaline (2 per cent), zircon (1 per cent), hematite (4 per cent), celestite (1 per cent), and magnetite (3 per cent).

Wilbur (1956) studied the limestones of the Council Grove Group of Riley and Geary Counties. He reported that limestones contain 60 per cent chalcedony, quartz (18 per cent), opal (2 per cent), microcline (1 per cent), orthoclase (6 per cent), plagioclase (not subdivided) (13 per cent) in the light mineral fraction. The heavy mineral fraction shows variation in different samples. The important heavy minerals are celestite, ranging from 60 to 90 per cent; muscovite, ranging from 40 to 70 per cent; and pyrite from 60 to 100 per cent. Hornblende, zircon, and apatite are found in traces.

Holcombe (1957) studied the petrology of the 1951 Kaw River flood deposits between Ogden and Manhattan. He reported that Hunters Island area contains 66.6 per cent quartz, 17.6 per cent chalcedony, 4.4 per cent orthoclase, 7.4 per cent plagioclase (not subdivided), 1 per cent microcline, and 0.5 per cent volcanic ash in the light fraction. The heavy mineral fraction contains 45 per cent hornblende, 5 per cent muscovite, 3 per cent garnet, 1.6 per cent tourmaline, 5.8 per cent epidote, 13.4 per cent zircon, and 11.8 per cent magnetite (ilmenite). The light mineral fraction of Wildcat Creek contains 62 per cent quartz, 26.5 per cent chalcedony, 4.0 per cent plagioclase (not subdivided), and 0.1 per cent ash. The heavy mineral fraction contains 36.3 per cent hornblende, 9.0 per cent muscovite, 5.7 per cent garnet, 4.3 per cent epidote, 13.9 per cent zircon, and 23.1 per cent magnetite (ilmenite). When the mineral percentages of the Hunters Island and Wildcat Creek areas were compared, he found that in Wildcat Creek area there is an increase of 12.3

per cent of magnetite (ilmenite), 4 per cent increase of muscovite, and 2.7 per cent increase of garnet. The Hunters Island area showed 8.9 per cent increase of hornblende, and 1.5 per cent increase of epidote. He believed that these increases in the samples indicate some influence of glacial origin or possibly incorporation of terrace deposits with 1951 flood deposits in the area.

Metz (1954) in his study of Peoria and Loveland loesses of northern Kansas found 60 per cent hornblende (including lamprobolite) and 18 per cent epidote. On the basis of hornblende-epidote assemblage he concluded that the loesses were derived from the Ogallala Formation.

FIELD PROCEDURE

The geologic map of the area was prepared from enlarged vertical aerial photographs with a scale of five inches per mile. The flight strips were flown for the U. S. Soil Conservation Department on April 22, 1939, with a scale of 2½ inches to a mile. The map area is included in the following photos:

ZA 91 93	ZA 91 125
ZA 91 94	ZA 91 126
ZA 91 95	ZA 91 127
ZA 91 96	ZA 91 128

In compilation of the map, the ruled template assembly method as described by Smith (1943, p. 163-169) was followed. Before compilation the significant contact lines were traced on the photographs. The field inspection of the photos was made to check doubtful features. The details were traced directly on the templates from the central part of each photo and half way across the sidelap and overlap areas. Later the details were transferred to the compilation sheet. After compilation of all the details, the readjustment of slight change in the course of Kansas River was adopted from topographic map of 1955. The new State Highway 18, fork of State Highway 24, and Recent Dunes were plotted. Many geologic features have been taken from Mudge and Beck (1949).

A shovel was used to collect the samples of the unconsolidated sediments. The samples were taken at a depth of 2 to 3 feet below the soil cover. Care was taken to get a sufficient quantity (500-600 grams) that was representative of the sediment.

In all, thirty-five samples were collected from the river, dunes, Illinois terrace deposits, Kansas deposit, and stream channel sand. The samples were placed in paper bags and numbers were assigned to them. The samples collected from the dune sand were marked from 1 to 20. River sand samples were marked R_1 to R_{10}. Three samples were collected from the Kansas deposit and were marked Ks_1 to Ks_3. One sample from Illinois terrace, and one from an old stream channel were collected. These samples were marked as Qgf_1 and R.C., respectively. The locations of all the samples with their assigned numbers were pin-pointed on the map (Fig. 30).

LABORATORY PROCEDURE

Grain Size Analysis

The samples were dried in an oven at 100°C for 24 hours. Each sample was reduced by quartering to 100 grams for laboratory investigation and the rest of the sample was kept for future reference.

Sixty grams of each sample were weighed on the chemical balance. The fraction was examined for aggregates. Fractions showing aggregates were crushed with the finger. A set of 8 inch Tyler screens with an interval of ¼ ∅ was used for sieving. The screens were kept in order; coarsest at the top, pan on the bottom. As the stack of screens was too large to fit in the Ro-tap, the samples were sieved in three stacks starting with the coarsest sizes. The stacks of sieves were placed in the Ro-tap mechanical shaker and agitated for 15 minutes. The fraction on each sieve was weighed on the chemical balance to the nearest 0.01 gram, and results were reduced to percentages. The fractions were retained in labelled packets for future reference.

The grade scale used is the Wentworth scale which is a logarithmic scale in which each grade limit is twice as large as the next smaller grade limit. The Phi (∅) Scale devised by Krumbein (1936) is a more convenient way of representing data. A relation between the sieve openings of U. S. Standard sieve numbers, millimeters, and phi (∅) notation is adopted from Folk (1961, p. 24) and is as follows:

U.S. Standard Sieve Numbers	Diameter in mm.	Diameter in Ø units
7	2.83	-1.50
8	2.38	-1.25
10	2.00	-1.00
12	1.68	-0.75
14	1.41	-0.50
16	1.19	-0.25
18	1.00	0.00
20	0.84	0.25
25	0.71	0.50
30	0.59	0.75
35	0.50	1.00
40	0.42	1.25
45	0.35	1.50
50	0.30	1.75
60	0.25	2.00
70	0.210	2.25
80	0.177	2.50
100	0.149	2.75
120	0.125	3.00
140	0.105	3.25
170	0.088	3.50
200	0.074	3.75
230	0.0625	4.00
270	0.0530	4.25

Statistical Analysis. It is necessary to follow certain precise measures of average size, sorting and other frequency properties when comparing the sedimentary environments quantitatively. Such properties can be determined either mathematically, by methods of moments, or graphically, by reading selected percentiles from the cumulative curves. In this study the latter method was used.

The weight of each grain size for each sample was tabulated. The cumulative weights were calculated from the weights of each grain size. The cumulative weights were then converted to cumulative percentages. The weights of each grain size were converted to individual percentages. All the calculations were made on the IBM 1620 computer. The cumulative percentages of each sample were plotted against grain size in phi units on arithmetic and probability paper. The grain size was plotted on the abscissa and cumulative percentages on the ordinate. The cumulative curves of each sample were constructed by joining the plotted points.

The statistical parameters such as mode, median, graphic mean, inclusive graphic standard deviation, inclusive graphic skewness, and graphic kurtosis were calculated from the grain size data by using the graphic formulae as described by Folk (1961, p. 43-47).

1. Mode (Mo). It is the diameter corresponding to the inflection point on the cumulative curve.

2. Median (Md). The median diameter is defined as the mid point of the distribution. It is that diameter which is larger

than the 50 per cent diameter in the distribution and smaller than the other 50 per cent. It corresponds to the 50 per cent mark on the cumulative curve.

3. Graphic Mean (M_z). The graphic mean is the best measure of the overall average size and corresponds closely to the mean as computed by methods of moments. This measure includes the central 68 per cent of the size distribution curve and is determined by the use of the following formula:

$$M_z = \frac{\phi\, 16\% + \phi\, 50\% + \phi\, 84\%}{3}$$

Here Ø 16 per cent point is considered roughly as the average size of the coarsest third of the sample, the Ø 84 per cent point as the average size of the finest third, and Ø 50 per cent point as the average of the middle third.

4. Inclusive Graphic Standard Deviation (σ_I). This is a measure of sorting. The sorting values were calculated by using Folk's formula (1961, p. 45).

$$\sigma_I = \frac{\phi\, 84\% - \phi\, 16\%}{4} + \frac{\phi\, 95\% - \phi\, 5\%}{6.6}$$

This measure includes 90 per cent of the distribution. The values are restricted to the 5 percentile and 95 percentile, as Inman (1952) has shown that data are seldom reliable beyond these limits.

The verbal limits as suggested by Folk (1961, p. 45) for the inclusive graphic standard deviation are:

σ_I	under ± 0.35 Ø	very well sorted.
	± 0.35 Ø to ± 0.50 Ø	well sorted.

$\pm$ 0.50 Ø to $\pm$ 0.71 Ø	moderately well sorted.
$\pm$ 0.71 Ø to $\pm$ 1.0 Ø	moderately sorted.
$\pm$ 1.0 Ø to $\pm$ 2.0 Ø	poorly sorted.
$\pm$ 2.0 Ø to $\pm$ 4.0 Ø	very poorly sorted.
over $\pm$ 4.0 Ø	extremely poorly sorted.

5. Inclusive Graphic Skewness (SK_I). This measure shows the lack of symmetry of the frequency distribution. The normal or symmetrical curve has a skewness of 0.00. Sediments with an excess of fine-grained particles are positively-skewed (tail toward the right), while those with an excess of coarse grains are negatively-skewed (tail toward the left). Folk (1961, p. 46) has proposed the following formula for the determination of skewness:

$$SK_I = \frac{\text{Ø}16\% + \text{Ø}84\% - 2(\text{Ø}50\%)}{2(\text{Ø}84\% - \text{Ø}16\%)} + \frac{\text{Ø}5\% + \text{Ø}95\% - 2(\text{Ø}50\%)}{2(\text{Ø}95\% - \text{Ø}5\%)}$$

This takes into account 90 per cent of the total distribution. The verbal limits as suggested by Folk (1961, p. 46) are:

+ 1.00 to + 0.30	strongly fine-skewed
+ 0.30 to + 0.10	fine-skewed
+ 0.10 to - 0.10	near-symmetrical
- 0.10 to - 0.30	coarse-skewed
- 0.30 to - 1.00	strongly coarse-skewed.

6. Graphic Kurtosis (K_G). The graphic kurtosis is the measure of sorting in the extremes compared to the sorting in the central part of the frequency distribution, or in other words, it is the relation between the sorting in the central part of the curve and the sorting of the extremes. In the normal curve the

spread between ϕ 5 and ϕ 95 percentiles should be exactly 2.44 times the spread between ϕ 25 and ϕ 75 percentiles. It is calculated by using the formula suggested by Folk (1961, p. 47).

$$K_G = \frac{\phi 95\% - \phi 5\%}{2.44\ (\phi 75\% - \phi 25\%)}$$

The verbal limits as suggested by Folk (1961, p. 47) are:

K_G less than 0.67	very platykurtic
0.67 to 0.90	platykurtic
0.90 to 1.11	mesokurtic
1.11 to 1.50	leptokurtic
1.50 to 3.00	very leptokurtic
over 3.00	extremely leptokurtic.

In natural sediments according to Folk (1961, p. 47) the K_G values range from 0.85 to 1.4; in some samples the values are as high as 3 and 4. Thus for graphic and statistical purposes the kurtosis value is normalized by using the formula $K_G' = \frac{K_G}{1 + K_G}$.

The normalized K_G' values fall between 0.40 - 0.65.

<u>Scatter Plots</u>. Scatter plots were prepared by plotting the values of each of the four grain size parameters (graphic mean, inclusive graphic standard deviation, inclusive graphic skewness, and graphic kurtosis) against each other on arithmetic graph paper. Such scatter plots show whether any regular relationship exists between two parameters, and how far they are useful in differentiating the sediments of the two different environments.

Differences will usually occur between the averages of the M_z, $\sqrt{I}$, SK_I, and K_G of dune and river sands. Such differences may result from accidents of sampling, even if no real difference existed between them. The two means were compared, and the significance between the two sets of data was determined by the "t" test.

$$t = \frac{\bar{x}_a - \bar{x}_b}{s}\sqrt{\frac{n_a \cdot n_b}{n_a - n_b}}$$

where $\bar{x}_a$ = Arithmetic mean of one set of samples.

$\bar{x}_b$ = Arithmetic mean of another set of samples.

s = Average standard deviation of two sets of values.

n_a = Total number of one set of samples.

n_b = Total number of another set of samples.

The result of the "t" test is reported in terms of probability or "P". If P value lies between 0.05 and 0.10, then there is some value between a 5 per cent and 10 per cent chance of our obtaining such differences by chance sampling of a homogenous population. This may be stated, as our experiment has shown that there are only 5 to 10 chances in 100 that an apparent difference between two sets of data could be the result of chance sampling of a similar population. By using the "t" test, only one property of any two formations can be compared at a time.

Roundness and Surface Feature Analysis

Different sizes of the river and dune sand which were separated and kept in small packets were used for a study of the roundness and surface features of the grains. One hundred grains from each grade size were examined against a black surface with a binocular microscope. Each grain was compared to a separate photograph of Powers' scale (1953, p. 118) and the percentages of grain roundness estimated. Powers' roundness (ρ) was assigned the following limits:

ρ = 0 to 1 Very angular
1 to 2 Angular
2 to 3 Sub-angular
3 to 4 Sub-rounded
4 to 5 Rounded
5 to 6 Very rounded.

The surface feature study was made by immersing the sand grains from 0.50 Ø to 2.0 Ø size in water. The percentages of grains with different surface features were estimated.

<u>Statistical</u> <u>Analysis</u>. The estimated percentages of the different limits of grain roundness were converted to cumulative percentages. The cumulative curves of roundness were drawn on arithmetic graph paper. The Powers' scale of roundness values were plotted on the abscissa and cumulative percentages on the ordinate. The cumulative curves of each sample were constructed by joining plotted points. The statistical parameters of mean roundness (MR) and roundness standard deviation (σ_ρ) were determined by the following formula of Folk (1961, p. 44-45):

$$MR = \frac{\rho 16\% + \rho 50\% + \rho 84\%}{3}$$

where MR = Mean of Powers' roundness

(ρ) = Powers' roundness

$$\sigma_\rho = \frac{\rho 84\% - \rho 16\%}{4} + \frac{\rho 95\% - \rho 5\%}{6.6}$$

where σ_{ρ} = Roundness standard deviation

ρ = Roundness.

The verbal limits for roundness sorting as suggested by Folk (1961, p. 10) are:

Roundness standard deviation under 0.60 -	very good roundness sorting
0.60 to 0.80	good roundness sorting
0.80 to 1.00	moderate roundness sorting
1.00 to 1.20	poor roundness sorting
Over 1.20	very poor roundness sorting.

Scatter Plot. A Scatter plot was prepared where the mean roundness was plotted against roundness standard deviation. This scatter plot was prepared to show the difference in the roundness of dune and river sediment. The "t" test was used to determine whether the difference in roundness of river and dune sands is significant.

Heavy Mineral Analysis

Five samples from different environments were selected for a heavy mineral analysis; one sample from dune sand, one from river sand, two from Kansas sand, and one from Illinois terrace deposit. All the different sands were first examined under the binocular microscope for coatings. Fifty grams of each sample that were smaller than 1.0 ∅ were treated with a 50 per cent solution of hydrochloric acid. After the acid treatment the samples were washed free of acid with cold water and onto a filter paper. The samples were then dried and were ready for separation into a light and heavy fraction.

The technique for separation of minerals by bromoform advocated by Milner (1962, p. 101) was followed. Bromoform is an organic compound consisting of tribrom-methane and has a specific gravity of 2.8.

The apparatus consisted of two conical type funnels with steep sides to minimize adherence of particles. A watch glass covered the upper funnel to prevent the evaporation of bromoform. The bottom of the upper funnel was fitted with a rubber tube and pinch-cock.

The upper funnel with pinch-cock was partially filled with bromoform and the stem of the funnel placed directly over a second funnel equipped with filter paper. An empty bottle was placed below the lower funnel to collect the bromoform which was filtered out during the washings. Both bottles were properly labelled as "bromoform" and "bromoform washing". Bromoform from the washing was later recovered by treating with ethyl alcohol and distilled water.

The dried and weighed sample was poured into the upper funnel containing bromoform. The bromoform was constantly stirred and later permitted to stand overnight.

After the separation of minerals was complete, the pinch-cock on the separatory funnel was released gradually, and the heavy liquid with heavy minerals was allowed to enter the second funnel with the filter paper. The heavy minerals were collected on the filter paper and bromoform in the bottle below.

The filter paper was washed three or four times with ethyl alcohol to remove all the bromoform from the grains. A new filter paper was used in the lower funnel to collect the light minerals that were floating in the bromoform. The light mineral fraction was also washed and dried.

The heavy mineral fraction included minerals with a specific gravity greater than 2.8, such as magnetite, tourmaline, topaz, apatite, zircon, biotite, and staurolite. The light mineral fraction was composed of minerals with a specific gravity less than 2.8 and included quartz, microcline, orthoclase, and some plagioclase.

After separation of heavy and light mineral fractions, the heavy mineral fraction was weighed and a weight percent was recorded. Later a portion of the heavy and light mineral fraction was permanently mounted on separate glass slides with Canada balsam.

The mineral mounts of the heavy and light fraction were examined with the petrographic microscope to determine the different minerals, their relative abundance, and physical properties, such as degree of rounding, sorting, weathering, degree of alteration, and type of inclusions. The mechanical stage was used for making a statistical traverse. One hundred counts were made on each slide at intervals of 5 mm. The mineral frequencies were expressed as a percentage of the total number of grains counted. In certain cases the oil immersion method was used to identify the minerals.

The chi square (X^2) test (Folk, 1961, p. 57-60) for the heavy minerals of dune and river sand was made to find out whether there is any significant difference between the mineralogy of the two sediments. The following formula was used to determine the chi square (X^2) value:

$$X^2 = \sum \left(\frac{D^2}{E}\right)$$

where X^2 = chi square

D^2 = square of corrected difference.

E = expected frequency.

The result of chi square test was reported in terms of probability or "P". This shows how many chances out of 100 that such differences would be obtained in random sampling of two uniform formations.

GEOLOGY OF THE AREA

Hunters Island consists of Wisconsin terrace deposits, covered at places with sand dunes of Recent Age. The individual dunes range in length from fifty meters to two hundred and fifty meters. The local relief of the dunes is about ten meters.

Two different types of sand dunes were observed: (1) Dunes covered with broad leafed deciduous trees, and (2) dunes covered with a thin cover of soil, which indicates stabilization of the dune by vegetation. West of Hunters Island is Stagg Hill, which is composed of alternating limestones and shales of the Council Grove Group of the Wolfcamp Series of the Permian System. Sand deposits of Kansan Age cap Stagg Hill. South and east of Hunters Island is the Kansas River which has sand bars of Recent Age.

Permian Rocks

The description of Wolfcamp Series of the Council Grove Group of the Permian System is adopted from Jewett (1941, p. 39-96), Parish (1952, p. 30-89), Wilbur (1956, p. 60-77), Johnson (1949, p. 25-35), and Moore, and others (1951, p. 1-132).

Foraker Limestone. The Foraker Limestone consists of three members. These three members in ascending order are Americus Limestone, Hughes Creek Shale, and Long Creek Limestone.

Americus Limestone. The Americus Limestone consists of two limestone beds separated by a bed of shale. Both limestones are hard dense, and dark gray to blue gray. They are unit-bedded but weather from blocky to platy. Both limestones contain fossil

Table 1. Generalized section of Permian and Quaternary deposits of Hunters Island and vicinity, Manhattan, Kansas, Moore and others (1952, p. 1-132).

System	Series	Group	Formation	Member	Lithology	Thickness (feet)
Quaternary	Recent		Recent Dune Sand		Sand--light gray, fine grained, unconsolidated.	8-15
			Alluvium		Sand and gravel--gray to gray brown, unconsolidated.	50
			Dune Sand		Sand--light gray, coarse to silt size particles, unconsolidated.	10-40
	Pleistocene		Upper and Lower Wisconsin Terrace Deposit		Sand--light gray, fine sand to silt size particles, unconsolidated.	60
			Illinois Terrace Deposit		Sand--dark brown, coarse sand to clay size particles, unconsolidated.	60
			Kansas Deposit		Sand--reddish brown to rusty gray, fine sand to clay size particles, loosely compacted.	6
			Unconformity			
Permian	Wolfcamp Series	Council Grove Group	Bader Limestone	Middleburg Limestone	Limestone--shale parting in middle, lower part fossiliferous.	4
				Hooser Shale	Shale--green and gray, impure limestone in the middle.	6
				Eiss Limestone	Limestone--two beds, shale parting, upper limestone gray weathers to "honeycomb", lower limestone gray argillaceous.	5
			Stearns Shale		Shale--gray, some thin limestone beds.	20

Table 1 (Cont.). Generalized section of Permian and Quaternary deposits of Hunters Island and vicinity, Manhattan, Kansas, Moore and others (1952, p. 1-132).

System	Series	Group	Formation	Member	Lithology	Thickness (feet)
Permian	Wolf-camp Series	Council Grove Group	Beattie Limestone	Morrill Limestone	Limestone--brownish to gray orange, weathers to porous.	2
				Florena Shale	Shale--gray, argillaceous, calcareous seams fossiliferous.	8
				Cottonwood Limestone	Limestone--buff, hard, fusulinid bearing.	6
			Eskridge Shale		Shale--gray, lower part varicolored, upper part calcareous, pelecypods abundant in limestone.	36
			Grenola Limestone	Neva Limestone	Limestone--buff, shale partings, limestone is fossiliferous.	16
				Salem Point Shale	Shale--gray, two shale beds, limestone parting.	8
				Burr Limestone	Limestone--tan gray, two beds, shale parting. Shale gray to dark gray.	8
				Legion Shale	Shale--light brown to gray calcareous, clayey, fossiliferous.	4
				Sallyards Limestone	Limestone--light brown to dark blue gray, fossiliferous.	2-4
			Roca Shale		Shale--gray, red and green, thin pelecypod-bearing limestones in upper part. Shale non-fossiliferous.	25

Table 1 (Cont.). Generalized section of Permian and Quaternary deposits of Hunters Island and vicinity, Manhattan, Kansas, Moore and others (1952, p. 1-132).

System	Series	Group	Formation	Member	Lithology	Thickness (feet)
Permian	Wolf-camp Series	Council Grove Group	Red Eagle Limestone	Howe Limestone	Limestone--tan to brown, unit bedded.	4
				Bennett Shale	Shale--black, carbonaceous, white brachiopods abundant.	10
				Glenrock Limestone	Limestone--gray, hard, unit bedded, fusulinids abundant.	2
			Johnson Shale		Shale--gray with argillaceous limestone beds. Limestones greyish yellow.	16
			Foraker Limestone	Long Creek Limestone	Limestone--Tan to gray orange, unit bedded, shale partings, shale partings yellowish gray and thin bedded.	8
				Hughes Creek Shale	Shale--dark gray, some limestones, upper part calcareous, and contains fusulinid tests.	40
				Americus Limestone	Limestone--two limestone beds with a shale parting, limestones, gray to blue gray, fuslinids and other fossils.	4

fragments. The upper limestone bed contains fusulinids along with other fossils. The shale parting is carbonaceous and fissile. The limestone contains chert, fibrous gypsum, traces of glauconite, and aggregates of tubular silica. The average thickness of Americus Limestone is about four feet.

Hughes Creek Shale. The Hughes Creek Shale consists of a thin bed of limestone near the top which grades laterally into yellow shale crowded with fusulinid tests. The shale is carbonaceous and contains many fusulinids at the base. The shale contains quartz, chalcedony, orthoclase, muscovite, hornblende, tourmaline, garnet, zircon, topaz, and magnetite. The average thickness is about 40 feet.

Long Creek Limestone. The Long Creek Limestone is soft and slightly dolomitic. It is unit-bedded, fine-grained and contains some shale partings. The limestone is tan to gray orange, and weathers tan. The shale partings are yellowish gray and thin-bedded. The limestone contains fusulinids. The limestone contains crystalline to amorphous celestite, tubular silica, selenitic gypsum, and chert. The average thickness is about eight feet.

Johnson Shale. The Johnson Shale is chiefly gray but contains several beds of argillaceous limestone, which range from mudstones to well laminated grayish yellow limestones; fossils are rare, chalcedony, quartz, orthoclase, muscovite, lamprobolite, tourmaline, garnet, zircon, topaz, hematite and magnetite are the non-clay minerals. The average thickness is 16 feet.

Red Eagle Limestone. The Red Eagle Limestone consists of three members. These three members in ascending order are

Glenrock Limestone, Bennett Shale, and Howe Limestone.

Glenrock Limestone. The Glenrock Limestone is hard, unit-bedded, and gray; fusulinids are abundant. The limestone contains aggregates of tubular silica, chert, rounded frosted grains of quartz and fibrous gypsum. The average thickness is about two feet.

Bennett Shale. The Bennett Shale is black and carbonaceous. A great abundance of small white brachiopods are in the black platy shale. The shale contains chalcedony, quartz, orthoclase, garnet, hematite, rutile and magnetite. The average thickness is about 10 feet.

Howe Limestone. The Howe Limestone is tan to brown, soft to hard and unit-bedded. Ostracods and brachiopods are in some units, otherwise this limestone is barren of fossils. Rounded, frosted quartz, tubular silica, celestite, fibrous gypsum and zircon are the non-clay minerals. The average thickness is about four feet.

Roca Shale. The Roca Shale is chiefly gray, red, and green. The shale contains thin pelecypod-bearing limestones in the upper part. The shale contains quartz, chalcedony, microcline, orthoclase, plagioclase, muscovite, hornblende, lamprobolite, tourmaline, garnet, zircon, and magnetite. The average thickness is about 25 feet.

Grenola Limestone. The Grenola Limestone contains five members. These members in ascending order are Sallyards Limestone, Legion Shale, Burr Limestone, Salem Point Shale, and Neva Limestone.

Sallyards Limestone. The Sallyards Limestone is light yellow-brown to dark blue-gray limestone, and has two distinct divisions. The lower division is thin-bedded, gray to yellow-brown, argillaceous limestone. It is characterized by a sparse distribution of long (0.1 mm to 3.0 mm) shell fragments, small gastropods and ostracodes. It ranges in thickness from 0.8 inch to 1.7 feet. The upper division contains abundant Osagia, high and low spired gastropods (2 mm to 3 mm high) and ostracodes. Osagia consists of algae and Ammovertella tests. Other fossils found in the Sallyards Limestone are Composita, Aviculopecten, Pseudomonotis, and myalinids. The total thickness ranges from two feet to four feet.

Legion Shale. The Legion Shale is a light brown to gray calcareous, clayey shale. The shale is soft and regularly thin-bedded and weathers blocky. Limestone beds in the shale are argillaceous and wavy bedded. The limestone beds in the shale range from two inches to eight inches. The Legion Shale contains Cavellina microfauna, Aviculopecten, Septimyalina mollusca, and Juresania brachiopod. The thickness is about four feet.

Burr Limestone. The Burr Limestone member contains two limestone beds separated by a bed of shale. The lower limestone is hard, unit-bedded, and about two feet thick. The upper limestone is fine-grained, laminated, soft and about five feet thick. The limestone is tan gray and weathers tan. The shale parting is clayey, usually calcareous, gray to dark gray, and thin-bedded. Echinoid spines, brachiopods, pelecypods, and crinoid columnal fossils are in the limestone layers. The limestone contains light gray tubular silica, chert, spongy limonite, anhedral to rounded frosted quartz, and celestite. The total thickness is eight feet.

Salem Point Shale. The Salem Point Shale contains two gray calcareous shales separated by a bed of limestone. The shale contains chalcedony, quartz, orthoclase, muscovite, hornblende, tourmaline, zircon, hematite, and magnetite. The total thickness is eight feet.

Neva Limestone. The Neva Limestone is composed of thick limestone with shale partings. In the upper part of this unit, the limestones are quite hard but become soft and honey-combed in the lower part. The interbedded shales are gray to dark gray. Echinoid spines are abundant in some units, crinoidal columnals, fusulinids, and brachiopods are other fossils in this member. Lingula and Orbiculoidea are the brachiopods in shale partings. The limestone contains light gray tubular silica, celestite, pyrite, and limonite. The average thickness is about 16 feet.

Eskridge Shale. The Eskridge Shale contains green and chocolate-colored shale bands in its lower part; the upper part of this shale is gray. The two parts are commonly separated by a calcareous zone. The upper part contains pelecypod fossils, principally Aviculopecten and Myalina. The shale contains chalcedony, quartz, orthoclase, muscovite, biotite, tourmaline, garnet, zircon, topaz, hematite and magnetite. The total thickness is about 36 feet.

Beattie Limestone. The Beattie Limestone consists of three members. These members in ascending order are Cottonwood Limestone, Florena Shale, and Morrill Limestone.

Cottonwood Limestone. The Cottonwood Limestone is unit-bedded. The limestone is buff but weathers almost white. Chert nodules project from the weathered surfaces. Fusulinids are common, Pseudofusulina emaciata is chiefly in the upper part. Brachiopods, bryozoans, echinoid spines, and crinoid columnals are other fossils in Cottonwood Limestone. The limestone contains spongy chalky chert, white chalky beekite (discoidal accretion of opaque silica replacing organic matter, generally white), white oolitic chert, tubular silica, celestite and limonite. The limestone has a uniform thickness of six feet.

Florena Shale. The Florena Shale is gray and calcareous shale. It contains myraids of little brachiopods and few other fossils. Chonetes are abundant. Shale contains chalcedony, quartz, orthoclase, lamprobolite, tourmaline, garnet, zircon, topaz, rutile and magnetite. The average thickness is about eight feet.

Morrill Limestone. The Morrill Limestone member is slightly argillaceous, brownish to gray orange and weathers tan. The limestone is unit-bedded and becomes porous and irregular after weathering. The limestone contains crystalline to amorphous, white to red celestite, aggregates of tubular silica, traces of gypsum, limonite and zircon. The average thickness is about two feet.

Stearns Shale. Stearns Shale is gray and contains thin beds of limestone. The shale has no fossils. The shale contains chalcedony, quartz, orthoclase, muscovite, garnet, zircon, topaz, hematite and magnetite. The average thickness is about 20 feet.

Bader Limestone. The Bader Limestone consists of three members. These members in ascending order are Eiss Limestone, Hooser Shale, and Middleburg Limestone.

Eiss Limestone. The Eiss Limestone member consists of two or more limestone beds separated by shale partings. The limestones are hard and unit-bedded but weather to blocky and are gray to tan gray. The shale partings are thin-bedded, clayey to silty, calcareous, and usually tan or tan gray. Pelecypods, echinoid spines, brachiopods are the common fossils in the limestone layers. The limestone contains tubular silica, beekite, red to white celestite, zircon and limonite. The average thickness is about five feet.

Hooser Shale. The Hooser Shale member consists of greenish gray shale and impure limestone. It contains chalcedony, quartz, orthoclase, muscovite, biotite, zircon, topaz and magnetite. The average thickness is about six feet.

Middleburg Limestone. The Middleburg Limestone consists of two limestones which are separated by a dark gray or black shale which is silty, calcareous and thin-bedded. The limestone is hard and unit-bedded. The limestone is gray to olive drab and usually weathers light gray. Brachiopods, pelecypods and crinoid columnals are in the basal limestone layer. The limestone contains fine, loose to aggregate, subhedral quartz grains, beekite, and traces of tubular silica. The average thickness is about four feet.

Quaternary Deposits

The Quaternary deposits in ascending order are Kansas Deposits, Illinois Terrace Deposit, Wisconsin Terrace Deposit, Dune Sand, Alluvium, and Recent Dune Sand.

Kansas Deposit. The Kansas deposit caps Stagg Hill. This deposit has an elevation of 1219 feet. It is loosely compacted, composed of fine sand to clay particles, and is reddish brown to rust gray. The deposit contains quartz, microcline, orthoclase, plagioclase (not subdivided), hornblende, tourmaline, garnet, apatite, zircon, and magnetite. The average thickness is about six feet.

Illinois Terrace Deposit. The Illinois terrace was deposited during Illinoian stage of Pleistocene Epoch. The deposit has an elevation of 1047 feet. This deposit is higher than Wisconsin terrace, is composed of coarse sand to clay, and is dark brown. Quartz, orthoclase, plagioclase (not subdivided), biotite, hornblende, lamprobolite, garnet, and magnetite are the non-clay minerals composing the deposit. The average thickness is about 60 feet.

Wisconsin Terrace Deposit. The Wisconsin terrace was deposited during Wisconsinan stage of the Pleistocene Epoch and underlies Kansas River valley, forming a broad level surface a few feet above the present flood plain. The deposit has an elevation of 1010 feet. This deposit is composed of fine sand to silt. The lower part of the terrace consists of coarse sand and gravel lenses. The deposit is light gray. It contains quartz, microcline, orthoclase, plagioclase (not subdivided), hornblende, garnet, zircon, and magnetite. The average thickness is about 60 feet.

Dune Sand. The Dune Sand is loosely compacted. The Dune Sand is light gray and is composed of coarse sand to silt. It contains quartz, microcline, orthoclase, plagioclase (not subdivided), hornblende, lamprobolite, epidote, tourmaline, garnet, apatite, zircon, and magnetite. The dunes range in heighth from 10 to 40 feet.

Alluvium. The Alluvium is gray to brown and is composed of gravel to silt. The coarse sediment is in the lower part of the Alluvium and occurs as sand and gravel bars. The upper part of the Alluvium is composed of fine sand and silt. The Alluvium contains chalcedony, quartz, orthoclase, plagioclase (not subdivided), muscovite, biotite, hornblende, lamprobolite, epidote, garnet, apatite, zircon, and magnetite. The average thickness is about 50 feet.

Recent Dune Sand. The Recent Dunes were deposited during the 1951 flood. These dunes are light gray and are composed of particles ranging from fine sand to silt. The Recent Dune Sand contains quartz, microcline, plagioclase (not subdivided), hornblende, lamprobolite, tourmaline, zircon, apatite, and magnetite. The dunes range in thickness from 8 to 15 feet.

DIFFERENTIATION OF RIVER AND DUNE SAND

Grain Size

The cumulative curves of river sand fall in region A, and the cumulative curves of dune sand fall in region B of Figure 2. Region C in the same figure indicates an overlapping of region A and B. Except in the region C, the cumulative curves of the river and dune sand show complete separation. The figure also indicates that the river sand is coarser than dune sand.

Statistical Parameters. The statistical parameters were calculated graphically.

Mode (Mo). The values of mode obtained from the frequency curves (Figs. 10-16) for river, dune, stream, and Kansas sand are in Table 2.

The river sediment is bimodal and polymodal. Sample R_9 is bimodal, and the rest of the samples are polymodal. The primary mode of samples R_4 and R_{10} lies in medium sand, and the primary mode for the rest of the samples lies in coarse sand. The secondary mode of all the samples lies in the coarse sand. Other modes do not show a regular arrangement. The dune sediment is unimodal to polymodal. Sample 1 is unimodal. Samples 2, 3, 5, 6, 7, 9, 16, 17, and 20 are bimodal, and samples 4, 8, 10, 11, 12, 13, 14, 15, 18, and 19 are polymodal. The primary mode of samples 1, 3, 5, and 8 lies in medium sand. The primary mode of samples 2, 4, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 lies in fine sand, and the primary mode for sample 6 lies in very fine sand. The secondary mode for samples 9 and 19 lies in

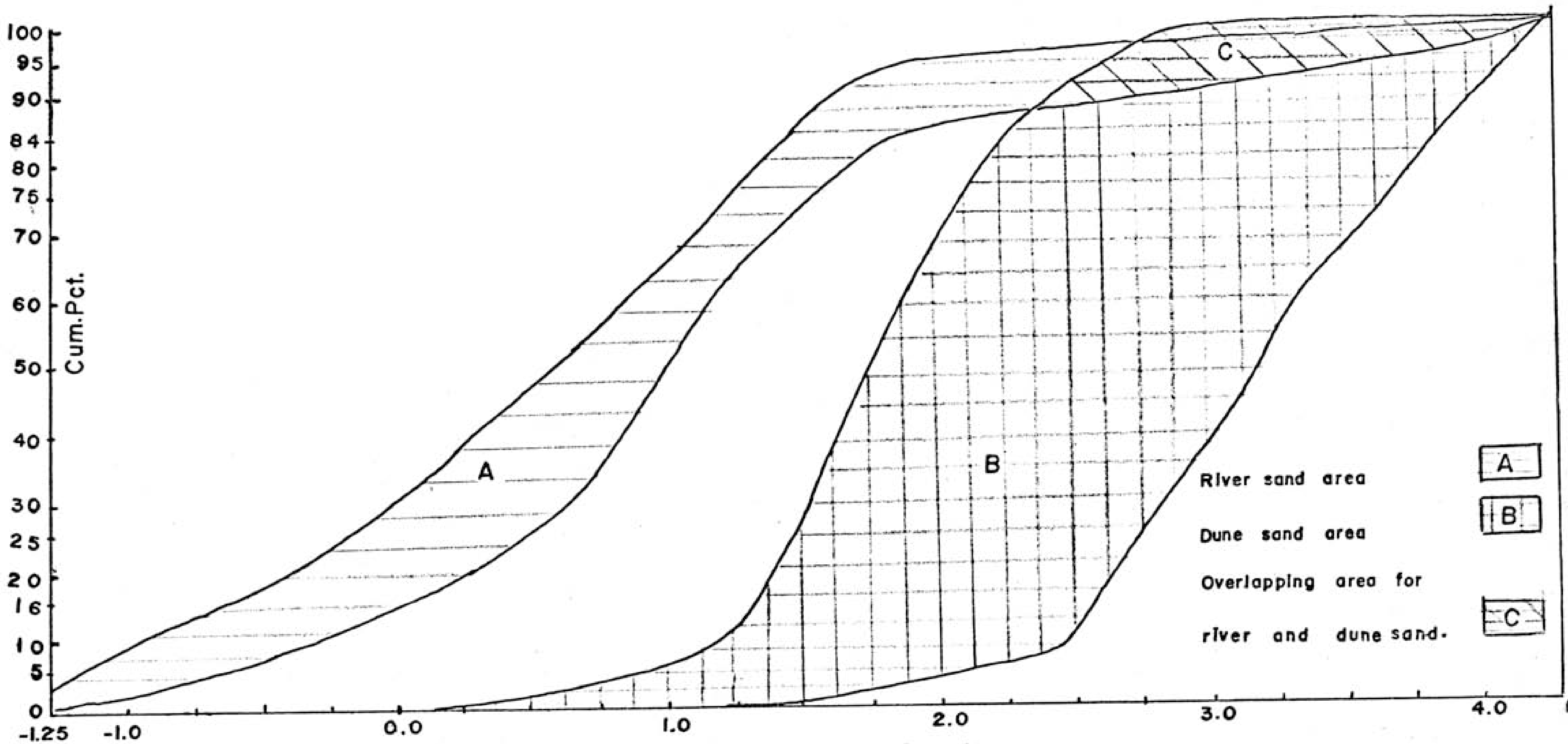

Fig. 2. Total spread of cumulative grain size frequency curves of river and dune sand.

Table 2. Phi modal values of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
R_1	0.87, 2.63, 3.13	1	1.63	R.C.	1.37, 3.87	Ks_3	2.87, 0.87
R_2	0.87, 0.37, 1.37, -0.37, -1.13, 2.63	2	2.1, 2.63				
R_3	0.87, 0.37, -0.37	3	1.87, 2.63				
R_4	1.37, 0.87, 0.37, -0.37	4	2.13, 2.63, 3.13, 0.63				
R_5	0.87, 0.37, -0.37, -1.13	5	1.87, 2.63				
R_6	0.87, 0.37, -0.37, 3.12	6	3.13, 2.63				
R_7	0.87, 0.37, -0.37, 2.37 3.13	7	2.38, 2.87				
R_8	0.87, 0.37, -0.37, 2.37, 3.13	8	1.63, 2.63, 3.13				
R_9	0.87, 0.37	9	2.63, 3.12				
R_{10}	1.37, 0.87, 0.37, -0.37, 3.13	10	2.63, 2.13, 3.13, 3.87				
		11	2.63, 2.13, 3.13, 3.87				
		12	2.63, 2.13, 3.13, 3.87				
		13	2.63, 2.13, 3.13, 3.87				
		14	2.63, 2.13, 3.13				
		15	2.63, 2.13, 3.13, 3.87				

Table 2 (concl.). Phi modal values of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
		16	2.63, 2.13				
		17	2.63, 2.13				
		18	2.63, 2.13, 3.13, 3.87				
		19	2.63, 3.13, 2.13, 3.87				
		20	2.63, 2.13				

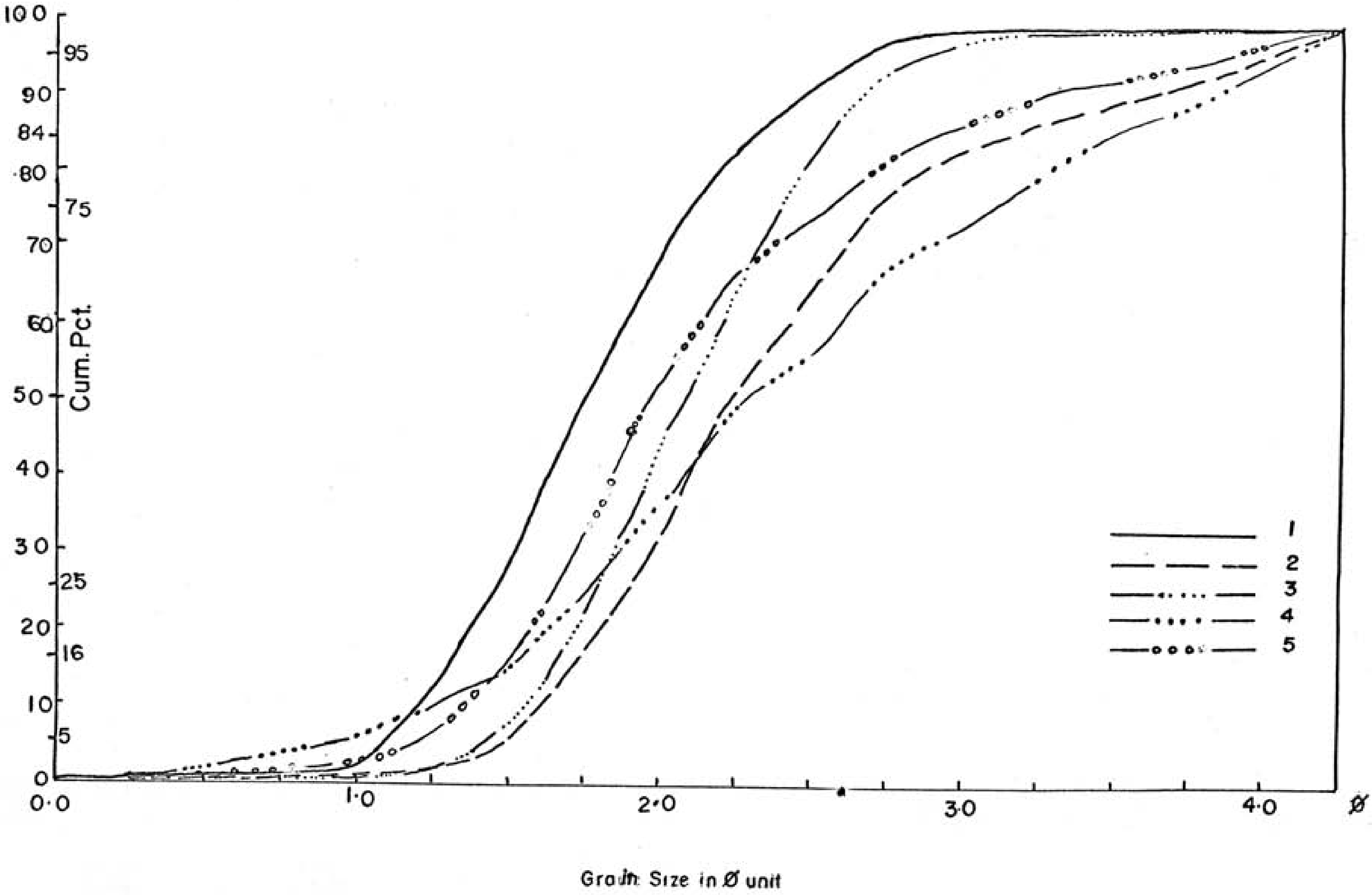

Fig. 3. Cumulative grain size frequency of dune sand.

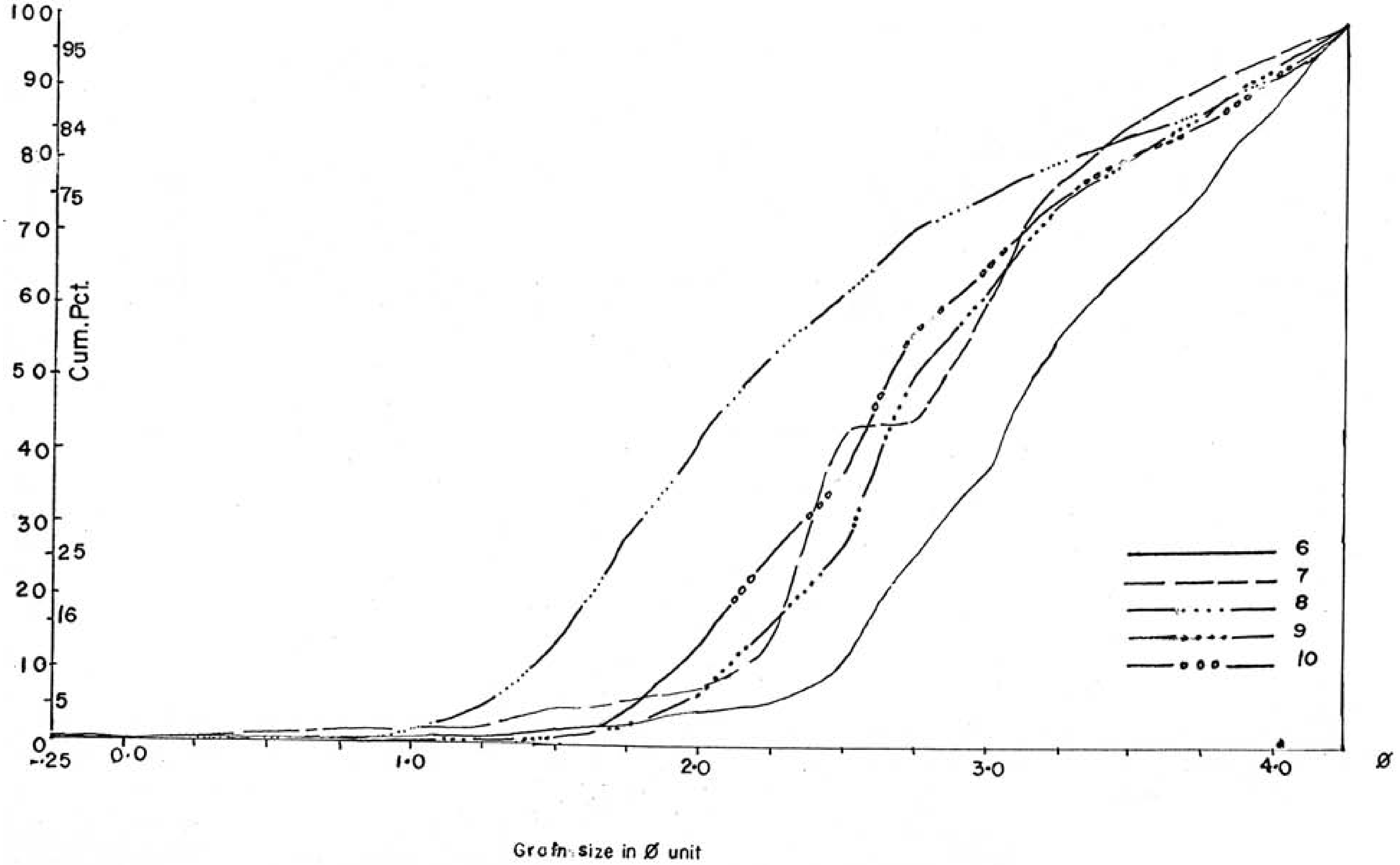

Fig. 4. Cumulative grain size frequency of dune sand.

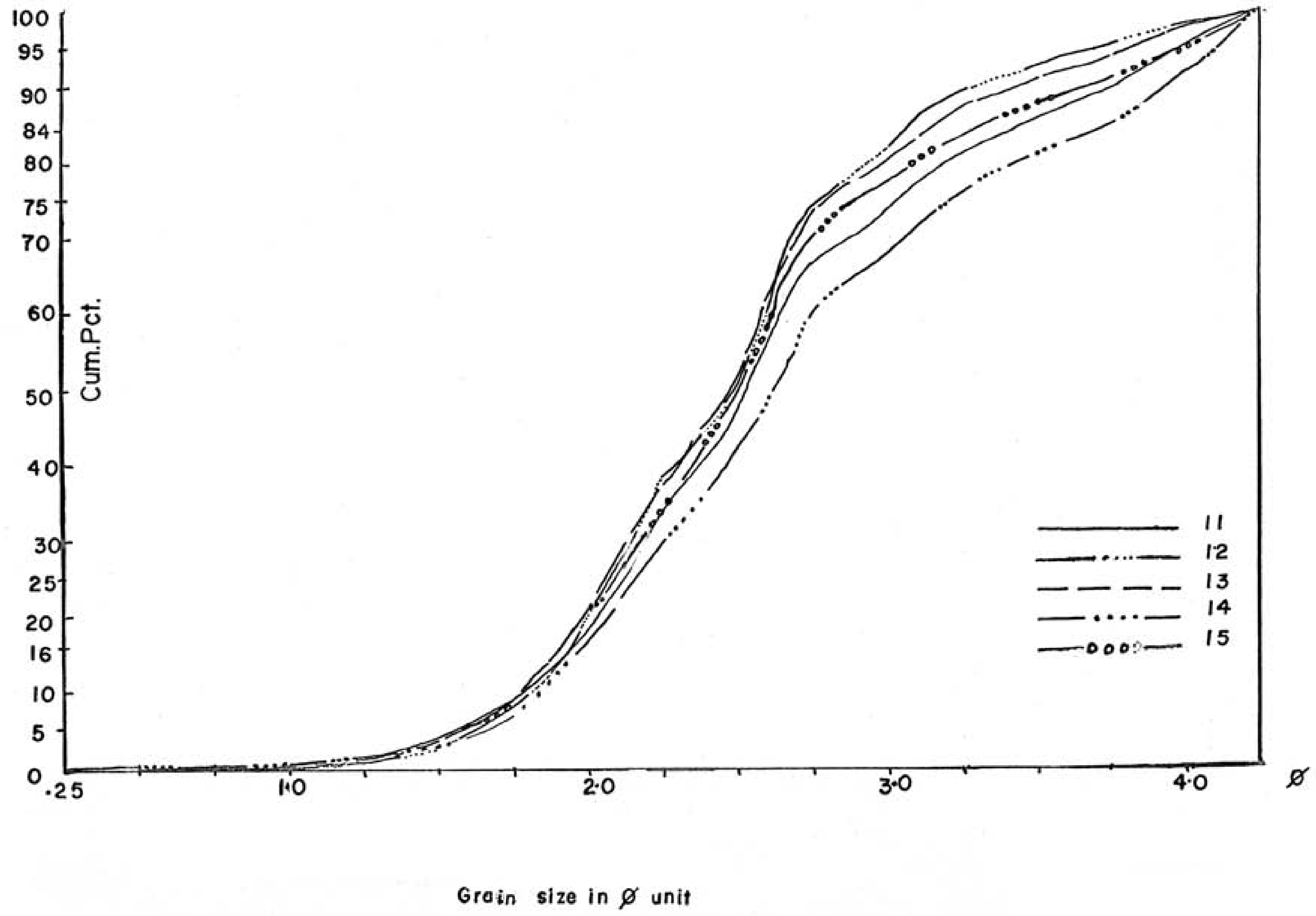

Fig. 5. Cumulative grain size frequency of dune sand.

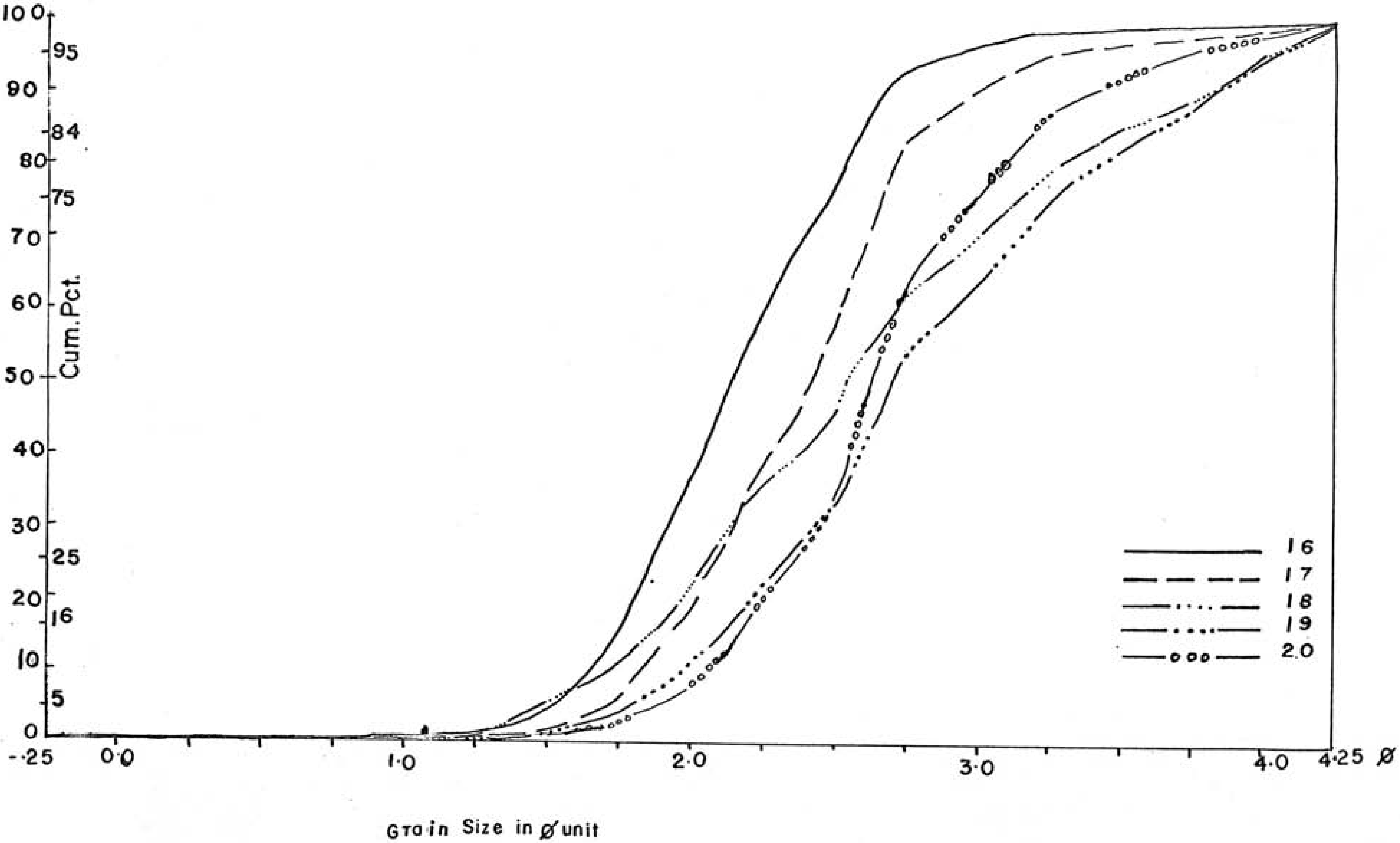

Fig. 6. Cumulative grain size frequency of dune sand.

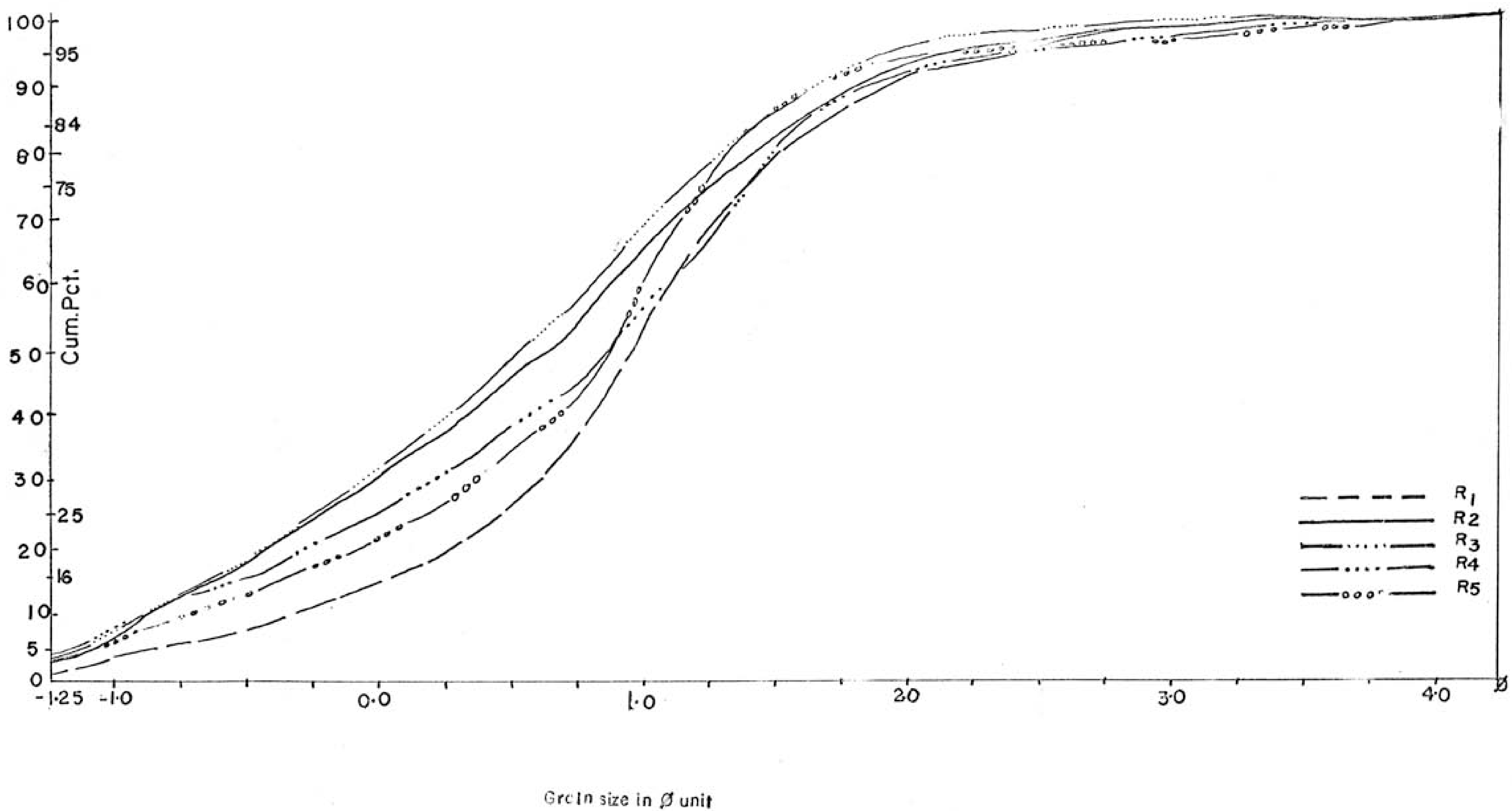

Fig. 7. Cumulative grain size frequency of river sand.

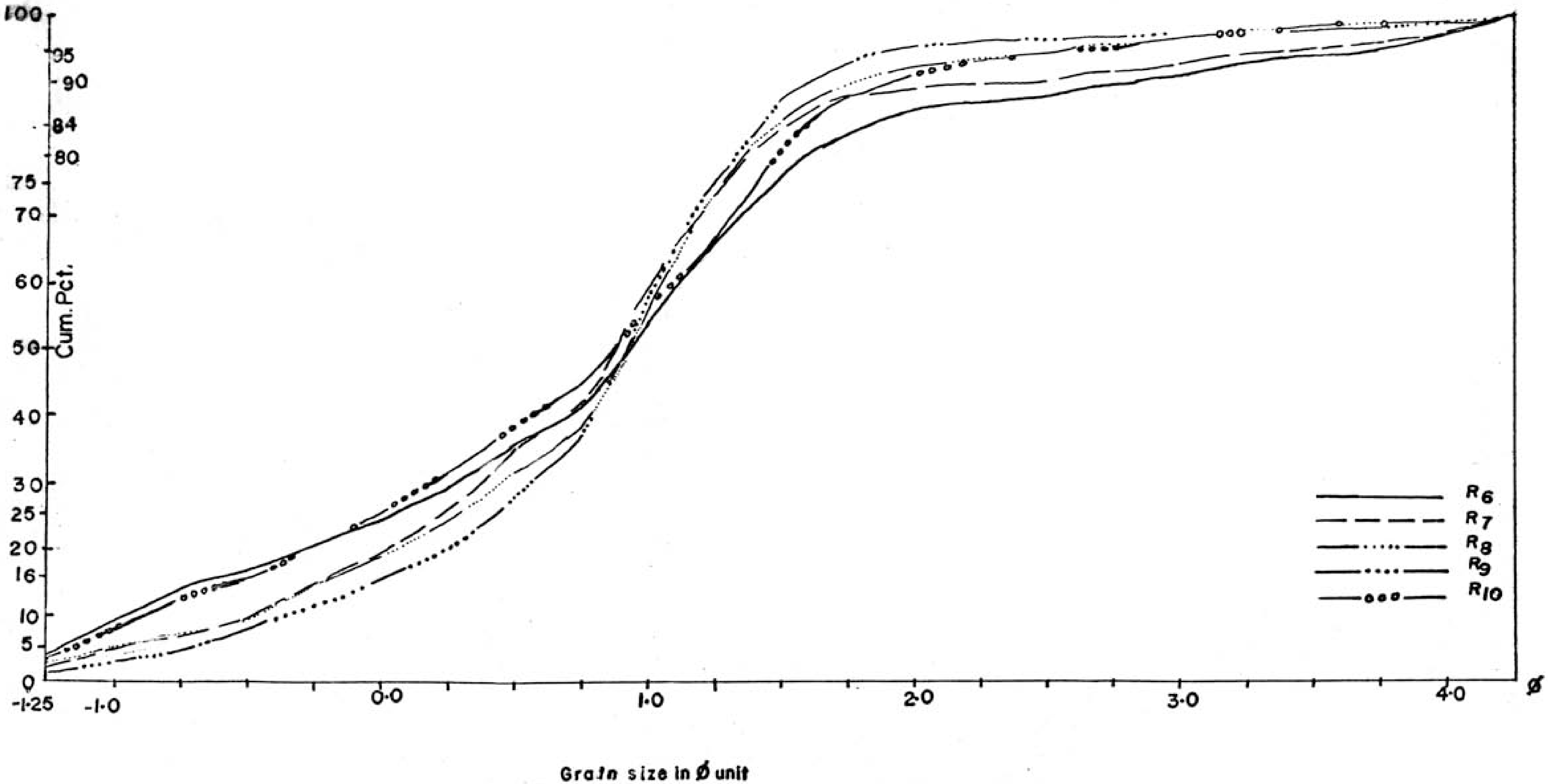

Fig. 8. Cumulative grain size frequency of river sand.

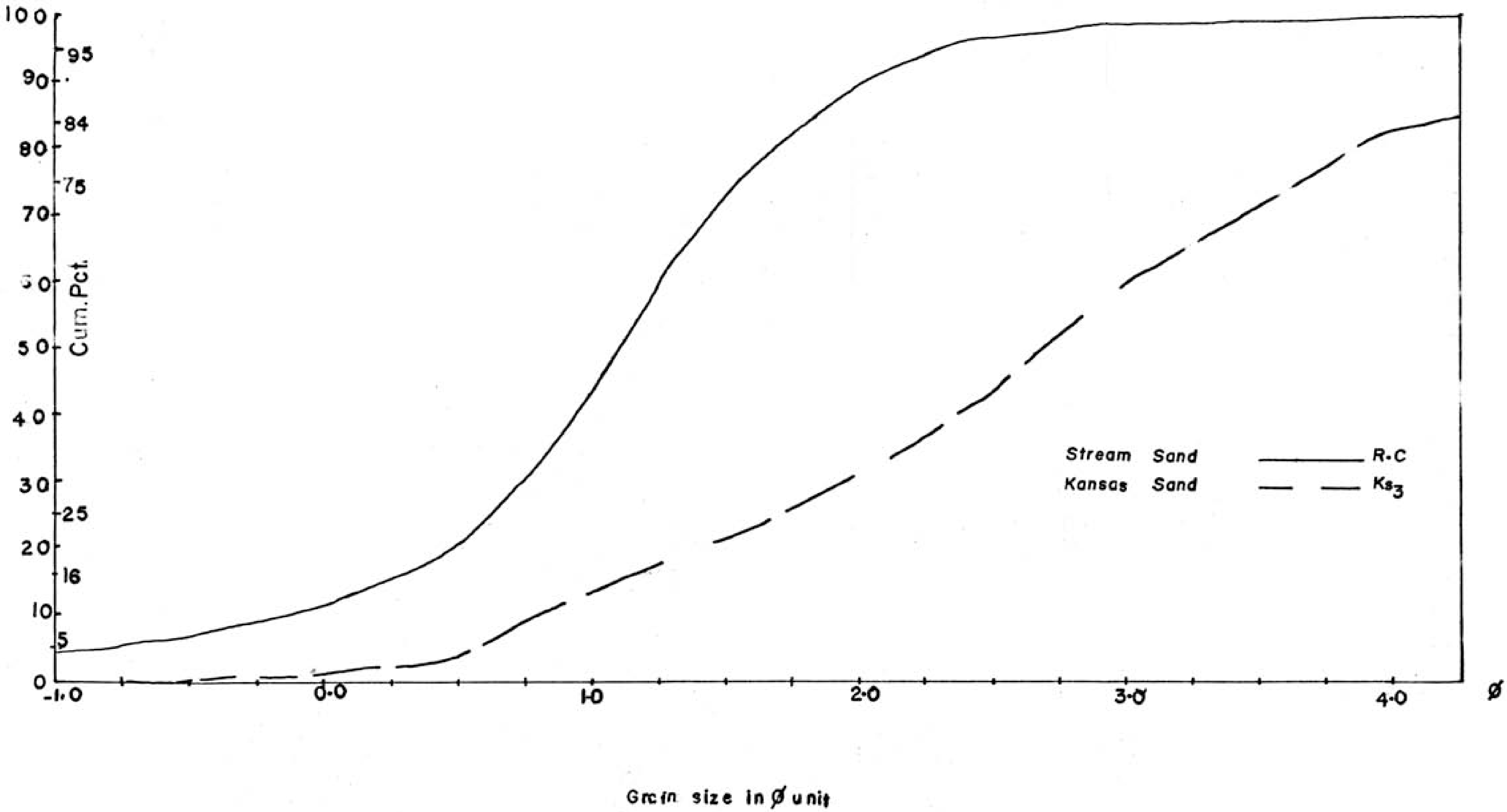

Fig. 9. Cumulative grain size frequency of stream and Kansan sand.

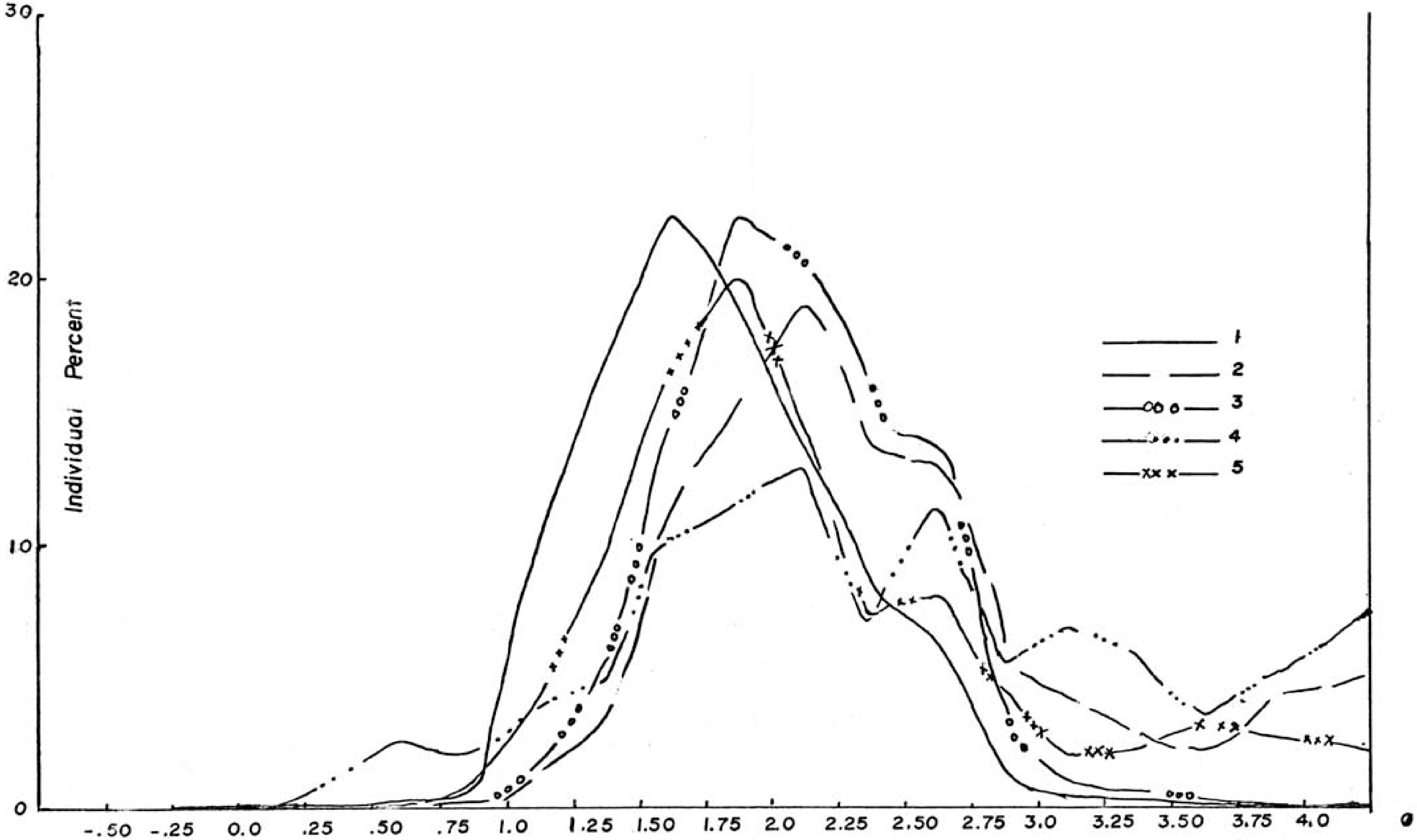

Fig. 10. Grain size frequency distribution of dune sand.

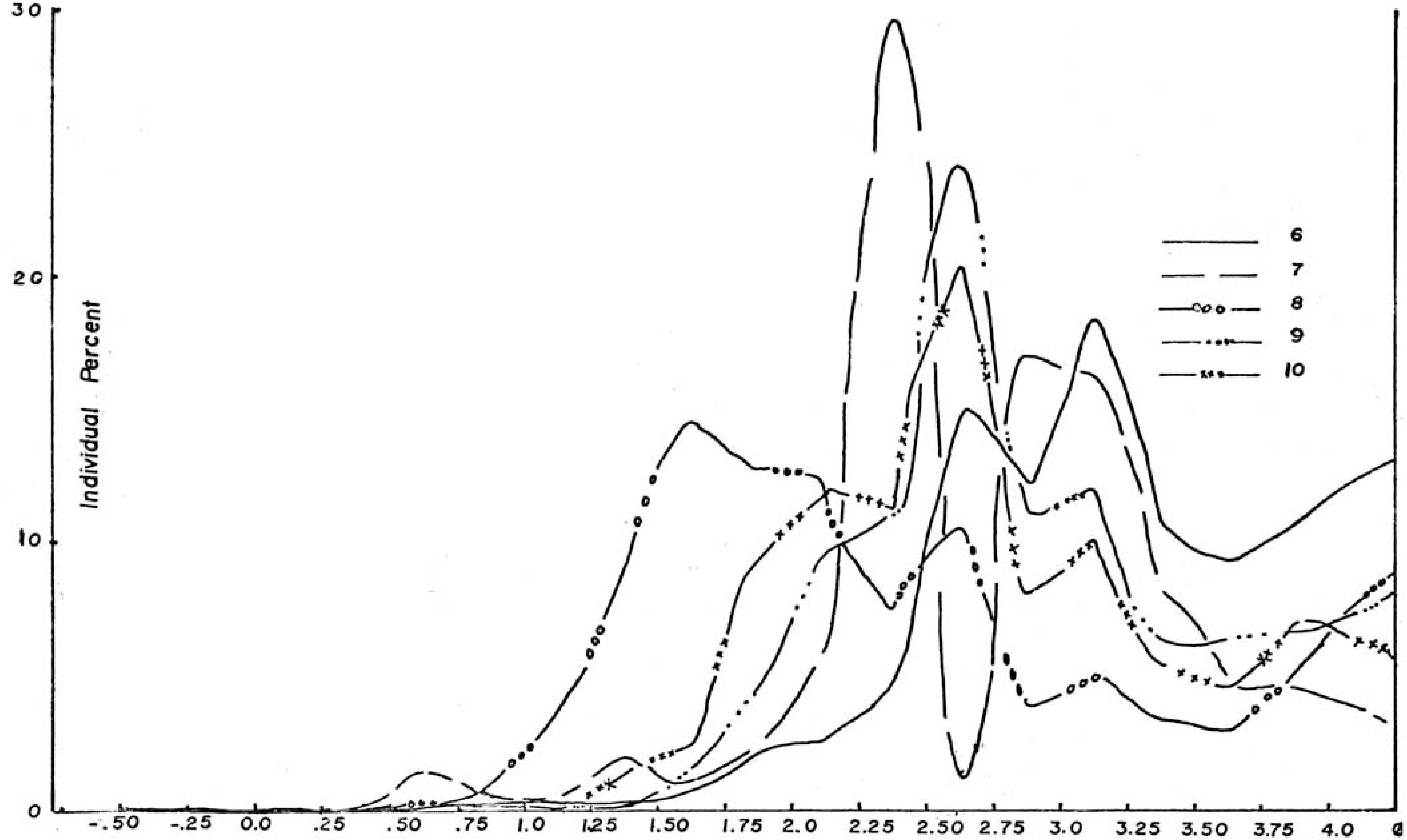

Fig. 11. Grain size frequency distribution of dune sand.

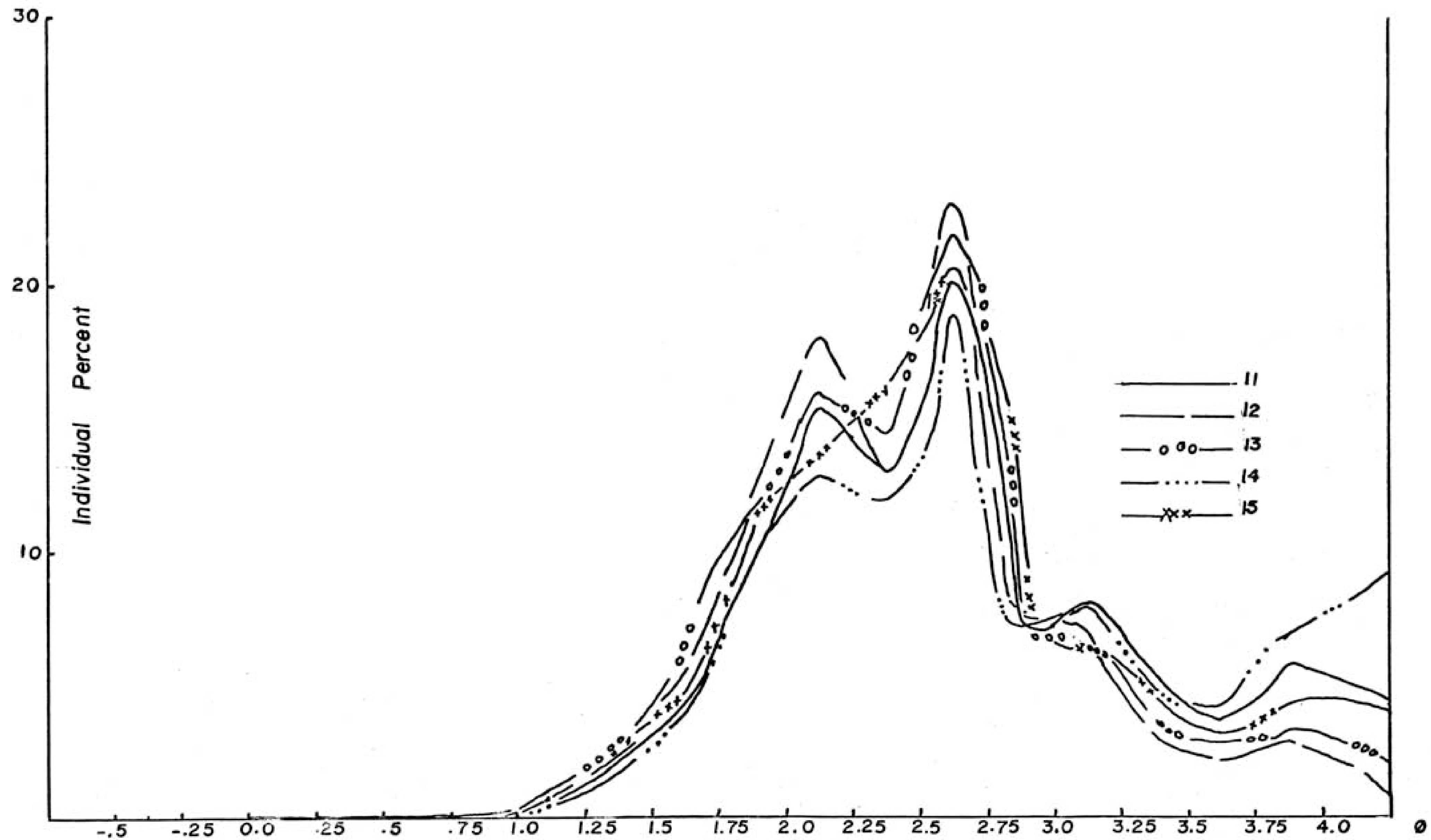

Fig. 12. Grain size frequency distribution of dune sand.

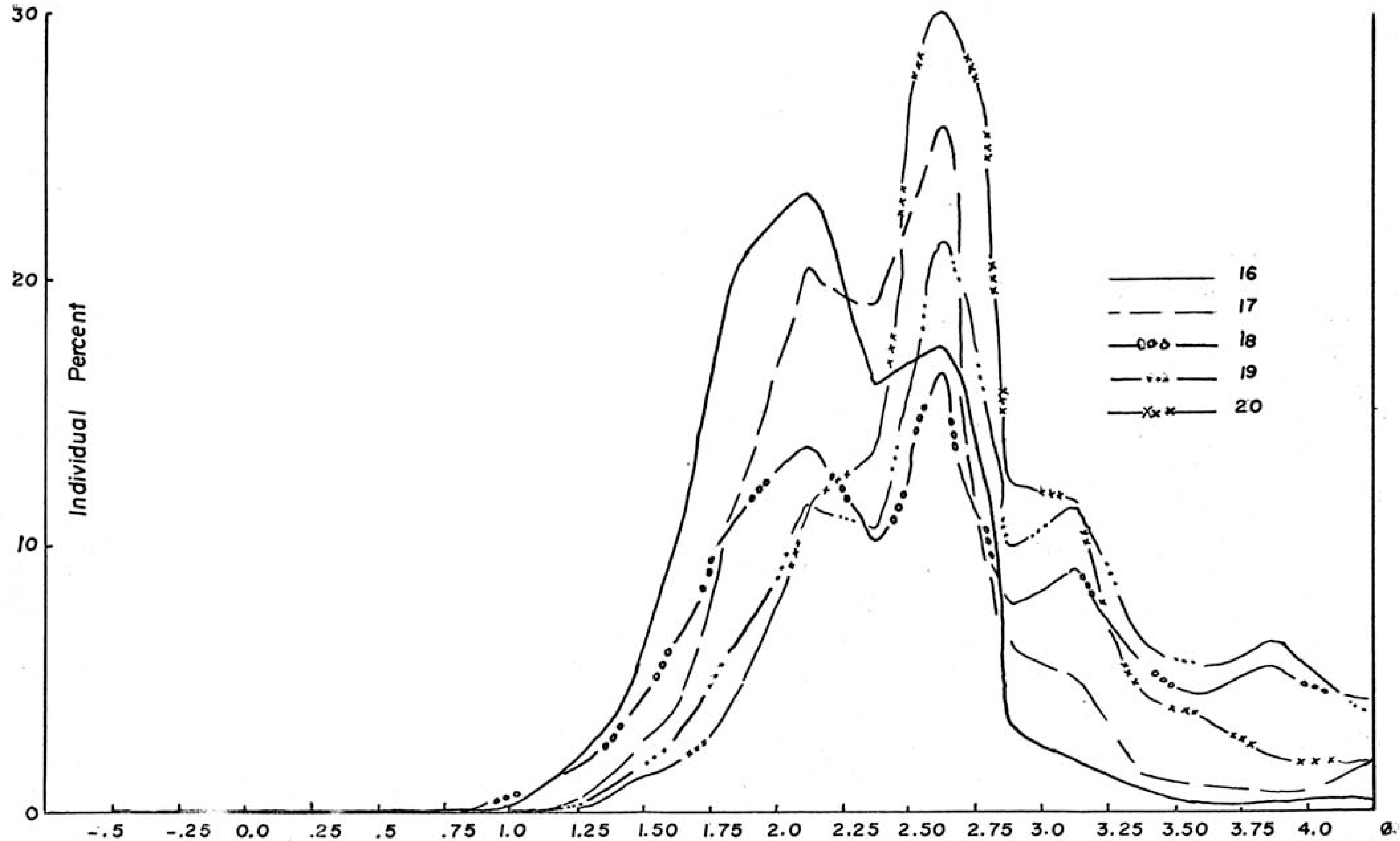

Fig. 13. Grain size frequency distribution of dune sand.

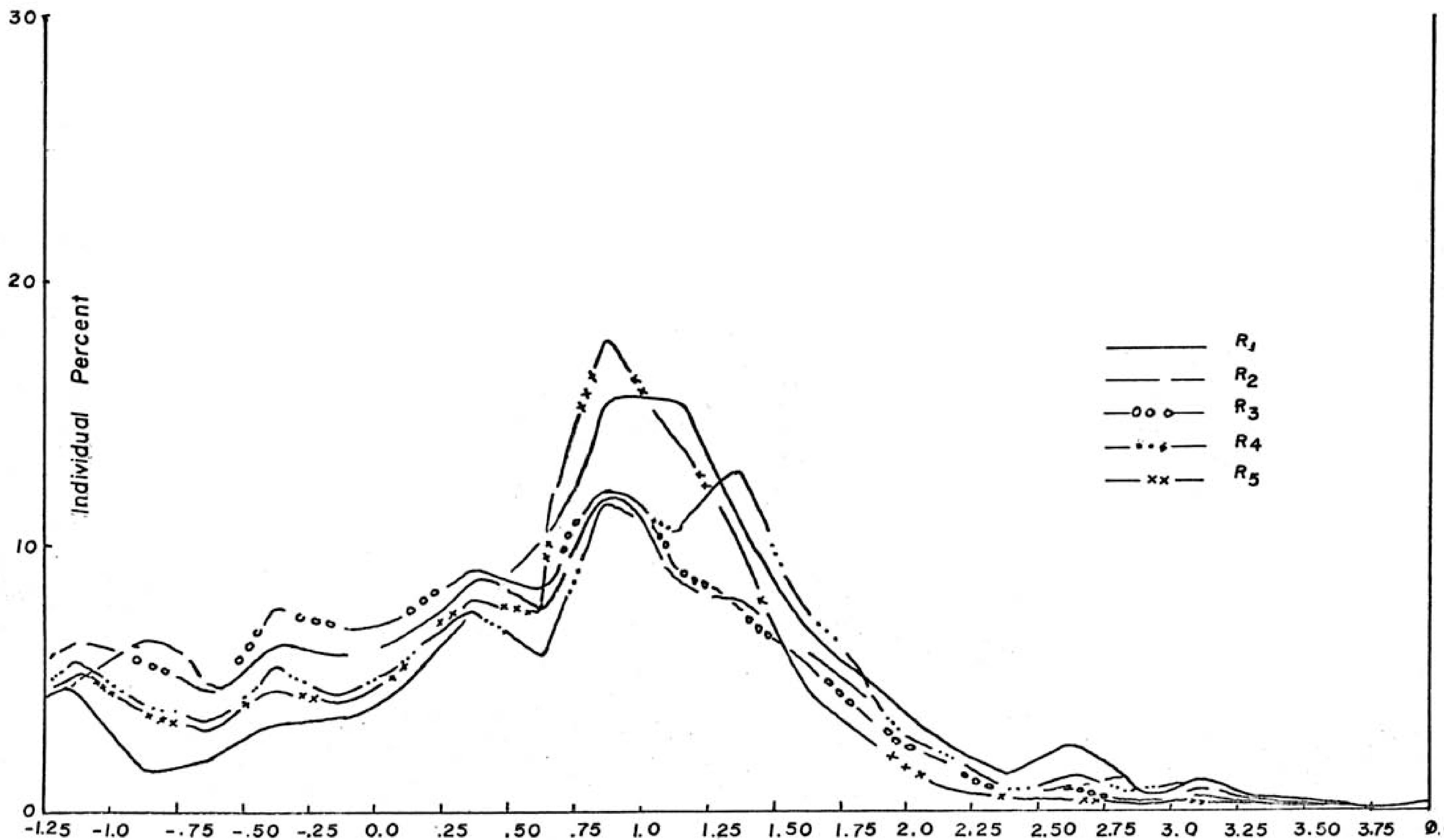

Fig. 14. Grain size frequency distribution of river sand.

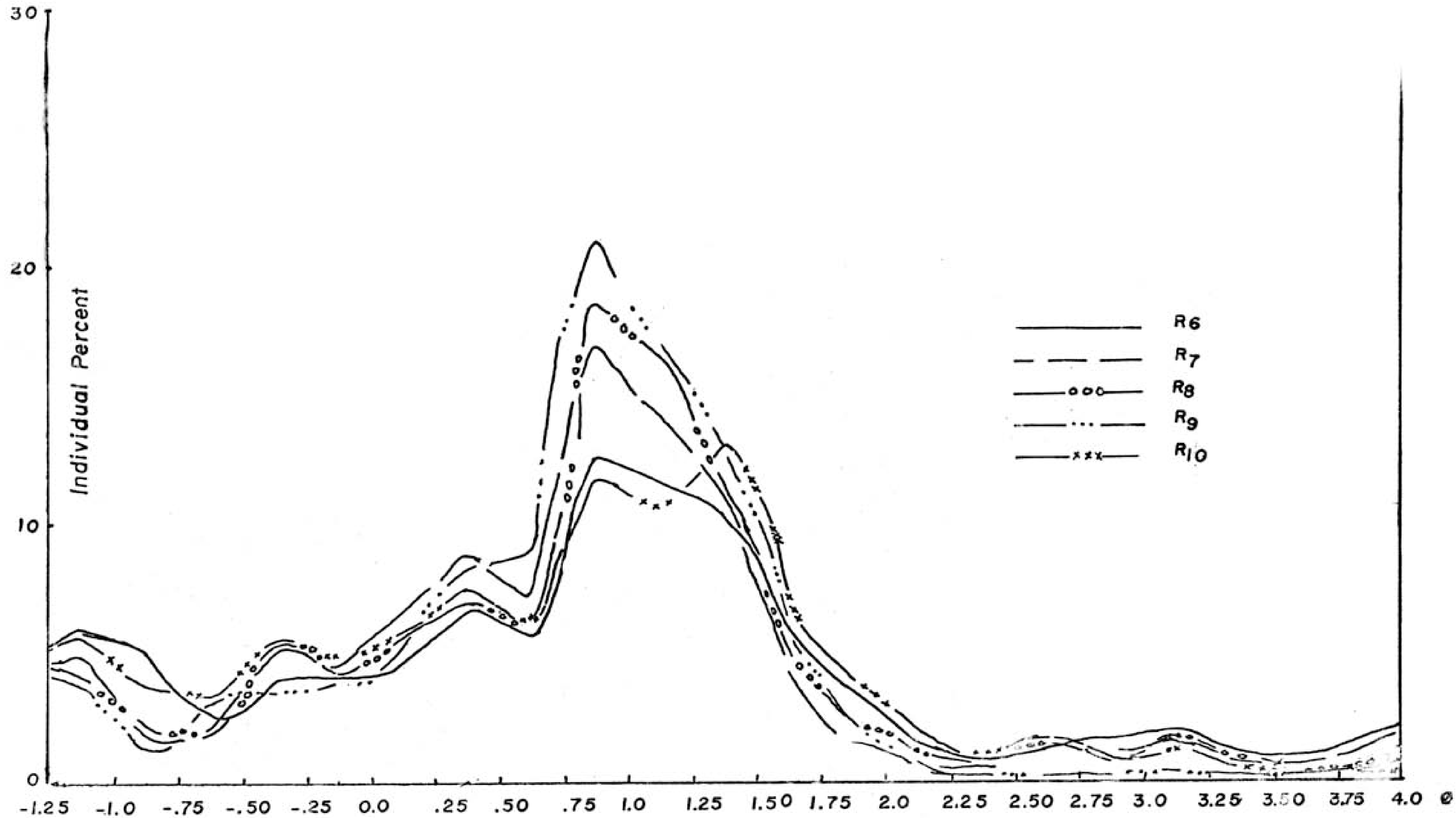

Fig. 15. Grain size frequency distribution of river sand.

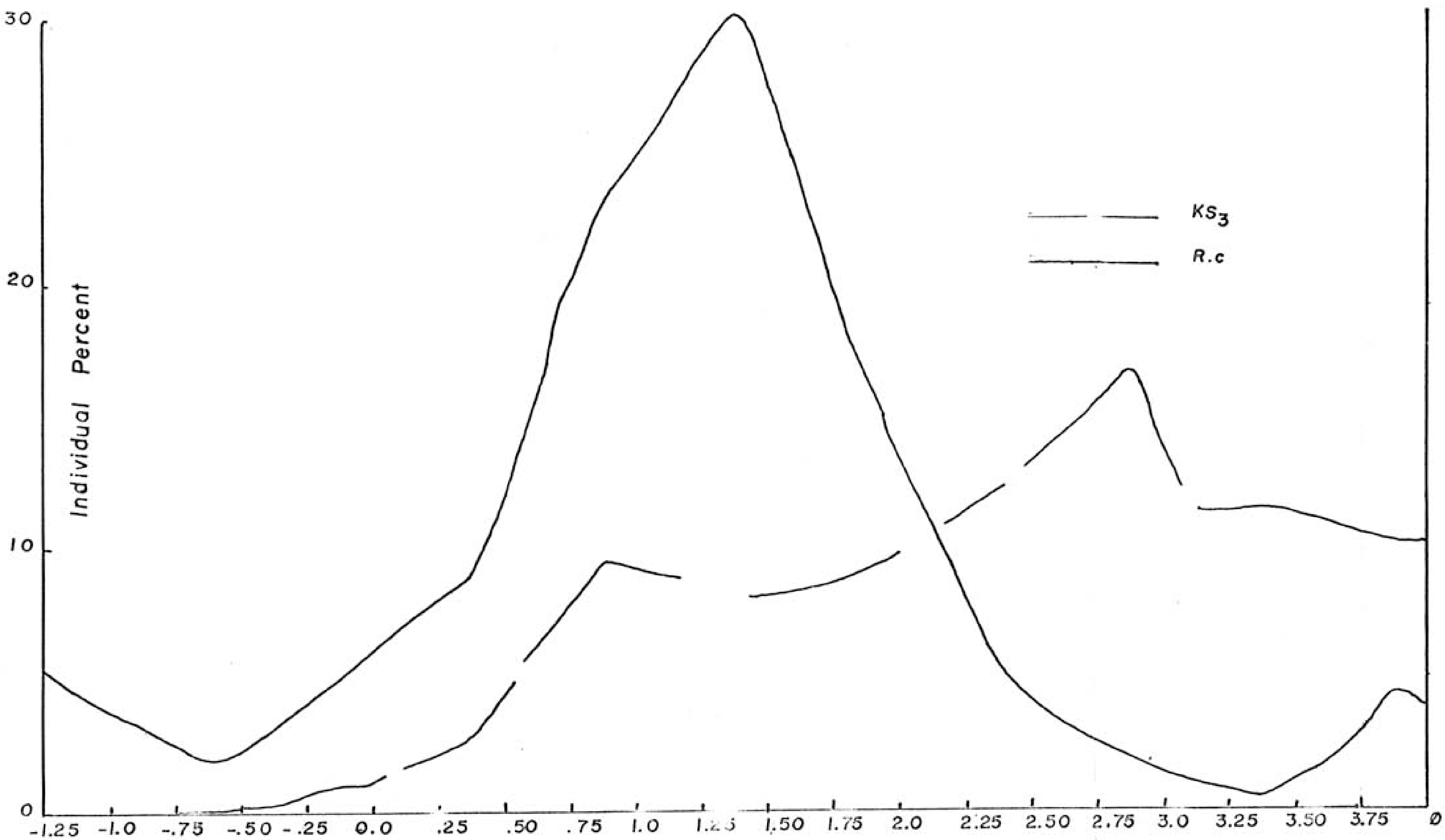

Fig. 16. Grain size frequency distribution of stream and Kansan sand.

very fine sand. In the rest of the samples, except sample 1 which is unimodal, the secondary mode lies in fine sand. Other modes in polymodal samples lie in very fine sand. The stream sand is bimodal. The primary mode lies in medium sand, and secondary mode lies in very fine sand. The Kansas sand is also bimodal. The primary mode lies in fine sand and secondary mode in medium sand.

Median (Md). The median diameters of river, dune, stream, and Kansas sand are in Table 3.

Table 3. Phi median diameter values of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
R_1	0.97	1	1.78	R.C.	1.20	Ks_3	2.70
R_2	0.65	2	2.23				
R_3	0.53	3	2.08				
R_4	0.88	4	2.28				
R_5	0.88	5	1.95				
R_6	0.98	6	3.15				
R_7	0.88	7	2.82				
R_8	0.93	8	2.18				
R_9	0.93	9	2.75				
R_{10}	0.88	10	2.19				
		11	2.54				
		12	2.5				
		13	2.5				
		14	2.6				

Table 3 (concl.). Phi median diameter values of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
		15	2.51				
		16	2.15				
		17	2.31				
		18	2.53				
		19	2.68				
		20	2.63				

The average median diameter of river and dune sand is 0.84 Ø and 2.41 Ø respectively. This shows that median for river sand lies in coarse sand, and median for dune sand lies in fine sand.

Graphic Mean (M_z). The values of graphic mean for river, dune, stream and Kansas sand are in Table 4.

Table 4. Phi values of graphic mean of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
R_1	0.99	1	1.79	R.C.	1.40	Ks_3	2.78
R_2	0.51	2	2.35				
R_3	0.44	3	2.09				
R_4	0.67	4	2.44				
R_5	0.66	5	2.10				
R_6	0.75	6	3.20				
R_7	0.42	7	2.84				
R_8	0.74	8	2.42				
R_9	0.79	9	2.79				

Table 4 (concl.). Phi values of graphic mean of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
R_{10}	0.65	10	2.61				
		11	2.64				
		12	2.49				
		13	2.5				
		14	2.80				
		15	2.55				
		16	2.20				
		17	2.17				
		18	2.61				
		19	2.78				
		20	2.64				

The mean of river sand samples R_1 and R_9 lies in coarse sand. The mean of sample R_6 lies in granule, and the mean of the rest of the samples lies in very coarse sand. The mean of dune sand sample 1 lies in medium sand, while the mean of the other samples lies in fine sand. The mean of stream and Kansas sand lies in medium and fine sand, respectively. The average mean of river sand is 0.661 ϕ, and the average mean of dune sand is 2.5 ϕ. The standard deviations of means of river and dune sands are $\pm$ 0.019 and $\pm$ 0.028, respectively. A "t" test was applied to the means of river and dune sand. A "t" value of 191.5 was obtained with 28 degrees of freedom and probability of less than 0.001. The result indicates that the means of the two sands are significantly different.

Inclusive Graphic Standard Deviation (σ_I). The values of inclusive graphic standard deviation are given in Table 5.

Table 5. Phi values of inclusive graphic standard deviation of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
R_1	± 0.71	1	± 0.46	R.C.	± 0.62	Ks_3	± 1.30
R_2	± 0.41	2	± 0.70				
R_3	± 0.32	3	± 0.42				
R_4	± 0.96	4	± 0.94				
R_5	± 0.49	5	± 0.73				
R_6	± 1.09	6	± 0.71				
R_7	± 0.75	7	± 0.93				
R_8	± 0.55	8	± 0.91				
R_9	± 0.50	9	± 0.61				
R_{10}	± 0.96	10	± 0.72				
		11	± 0.72				
		12	± 0.58				
		13	± 0.63				
		14	± 0.80				
		15	± 0.77				
		16	± 0.20				
		17	± 0.42				
		18	± 0.76				
		19	± 0.68				
		20	± 0.52				

The average standard deviation of the grain size of the river sand is 0.67 ∅ (moderately well sorted). The standard deviation ranges between 0.32 ∅ (very well sorted) and 1.09 ∅ (poorly sorted). The average standard deviation for dune sand is 0.66 ∅ (moderately well sorted). The sorting ($\sqrt{I}$) values range between 0.20 ∅ (very well sorted) and 0.94 ∅ (moderately well sorted). The standard deviations of $\sqrt{I}$ of river and dune sands are ± 0.23 and ± 0.22, respectively. A "t" test was applied and "t" value of 1.125, 28 degrees of freedom, and probability of 0.27 was obtained. The result indicates that the sorting of the two sediments is not significantly different. The standard deviation for stream and Kansas sand is 0.62 ∅ (moderately well sorted) and 1.30 ∅ (poorly sorted), respectively.

Inclusive Graphic Skewness (SK_I). The grain skewness values are given in Table 6.

Table 6. Inclusive graphic skewness values of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
R_1	-0.22	1	+0.12	R.C.	-0.23	Ks_3	-0.06
R_2	-0.74	2	+0.20				
R_3	-0.59	3	+0.17				
R_4	-0.33	4	+0.19				
R_5	-0.26	5	+0.04				
R_6	-0.49	6	-0.07				
R_7	-0.32	7	-0.14				
R_8	-0.29	8	+0.55				

Table 6 (concl.). Inclusive graphic skewness values of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Sample No.	Stream sand	Sample No.	Kansas sand
R_9	-0.26	9	+0.25				
R_{10}	-0.32	10	+0.11				
		11	+0.19				
		12	-0.07				
		13	+0.09				
		14	+0.24				
		15	+0.05				
		16	+0.15				
		17	+0.21				
		18	+0.14				
		19	+0.27				
		20	+0.09				

The average skewness of the river sand is -0.38 and is strongly coarse-skewed. The average skewness of dune sand is +0.13 and is fine-skewed. Dune sand samples 6, 7, and 12 are slightly negatively skewed. The standard deviations of river and dune sand skewness are ± 0.17 to ± 0.10, respectively. A "t" test was applied to the skewness values of the two sediments. A "t" value of 4.7, 28 degrees of freedom, and probability of less than 0.001 was obtained. The result indicates that there is a real difference between the skewness of the two sediments. The stream sand is strongly coarse-skewed, and Kansas sand is slightly negatively skewed.

Graphic Kurtosis (K_G). The kurtosis values determined graphically are given in Table 7.

Table 7. Graphic kurtosis values of river, dune, stream, and Kansas sand samples.

Sample No.	River sand	Sample No.	Dune sand	Stream sand	Kansas sand
R_1	0.70	1	1.03	0.66	0.75
R_2	0.46	2	1.01		
R_3	0.38	3	0.97		
R_4	0.37	4	0.95		
R_5	0.57	5	1.21		
R_6	1.36	6	0.89		
R_7	1.35	7	0.54		
R_8	0.62	8	0.96		
R_9	1.00	9	1.48		
R_{10}	0.37	10	2.30		
		11	1.07		
		12	0.12		
		13	1.29		
		14	0.94		
		15	0.65		
		16	0.44		
		17	1.10		
		18	0.96		
		19	2.40		
		20	1.12		

The average kurtosis of river sand is 0.71 (platykurtic); the range in kurtosis value is from 0.37 (very platykurtic) to 1.36 (leptokurtic). The average kurtosis of dune sand is 1.07 (mesokurtic); the range in kurtosis of dune sand is 0.12 (platykurtic) to 2.4 (very leptokurtic). The standard deviations of river and dune sand kurtosis are $\pm$ 0.36 and $\pm$ 0.54 respectively. A "t" test was applied to the kurtosis values of the two sediments. A "t" value of 1.61, 28 degrees of freedom, and probability of 0.11 was obtained. The result indicates that kurtosis of two sediments may be significant. More samples are required for further investigation. The stream sand is 0.66 (very leptokurtic). The kurtosis value for stream and Kansas sand is 0.66 (very platykurtic) and 0.75 (platykurtic), respectively.

The textural parameters of different sands are summarized in Table 8.

Table 8. Summary of statistical parameters of river, dune, stream, and Kansas sand.

	River sand	Dune sand	Stream sand	Kansas sand
Mo	Bimodal and polymodal	Unimodal to polymodal	Bimodal	Bimodal
Md	Average 0.84Ø	Average 2.41Ø	1.20Ø	2.70Ø
M_z	Average 0.66Ø	Average 2.50Ø	1.40Ø	2.78Ø
σ_I	Average ±0.67Ø	Average ±0.66Ø	±0.62Ø	±1.30Ø
SK_I	Average -0.38	Average +0.13	-0.23	-0.06
K_G	Average +0.71	Average 1.07	0.66	0.75

River sand: coarse sand, bimodal and polymodal, moderately well-sorted, negatively skewed and platykurtic.

Dune sand: fine sand, unimodal to polymodal, moderately well-sorted, positively skewed, and mesokurtic.

Stream sand: coarse sand, bimodal, moderately sorted, negatively skewed and platykurtic.

Kansas sand: fine sand, bimodal, poorly sorted, nearly symmetrical and platykurtic.

Scatter Plots. Scatter plots were prepared by plotting each of the four grain size parameters against each other--mean, standard deviation, skewness, and kurtosis. Such scatter plots show whether any relationship exists between two parameters, and how far they are useful in differentiating the sediments of the two different environments.

Mean Grain Size Versus Grain Size Skewness. In Fig. 17 grain size skewness is plotted against the mean grain size in phi units. The river sand is negatively skewed, and dune sand, except samples 6, 7, and 12, is positively skewed. The mean of the dune sand lies in fine sand, while mean of river sand lies in coarse sand. The plot shows a separation of the sediments. Stream sand is negatively skewed with mean in medium sand. The Kansas sand is nearly symmetrical with mean in fine sand.

Grain Size Skewness Versus Grain Size Kurtosis. In Fig. 18 grain size skewness is plotted against grain size kurtosis. Kurtosis shows a wider spread of points for river sand. The points of dune sand are crowded. The river sand is negatively skewed and kurtosis ranges from very platykurtic to leptokurtic. The dune sand, except samples 6, 7, and 12 (negatively skewed), is

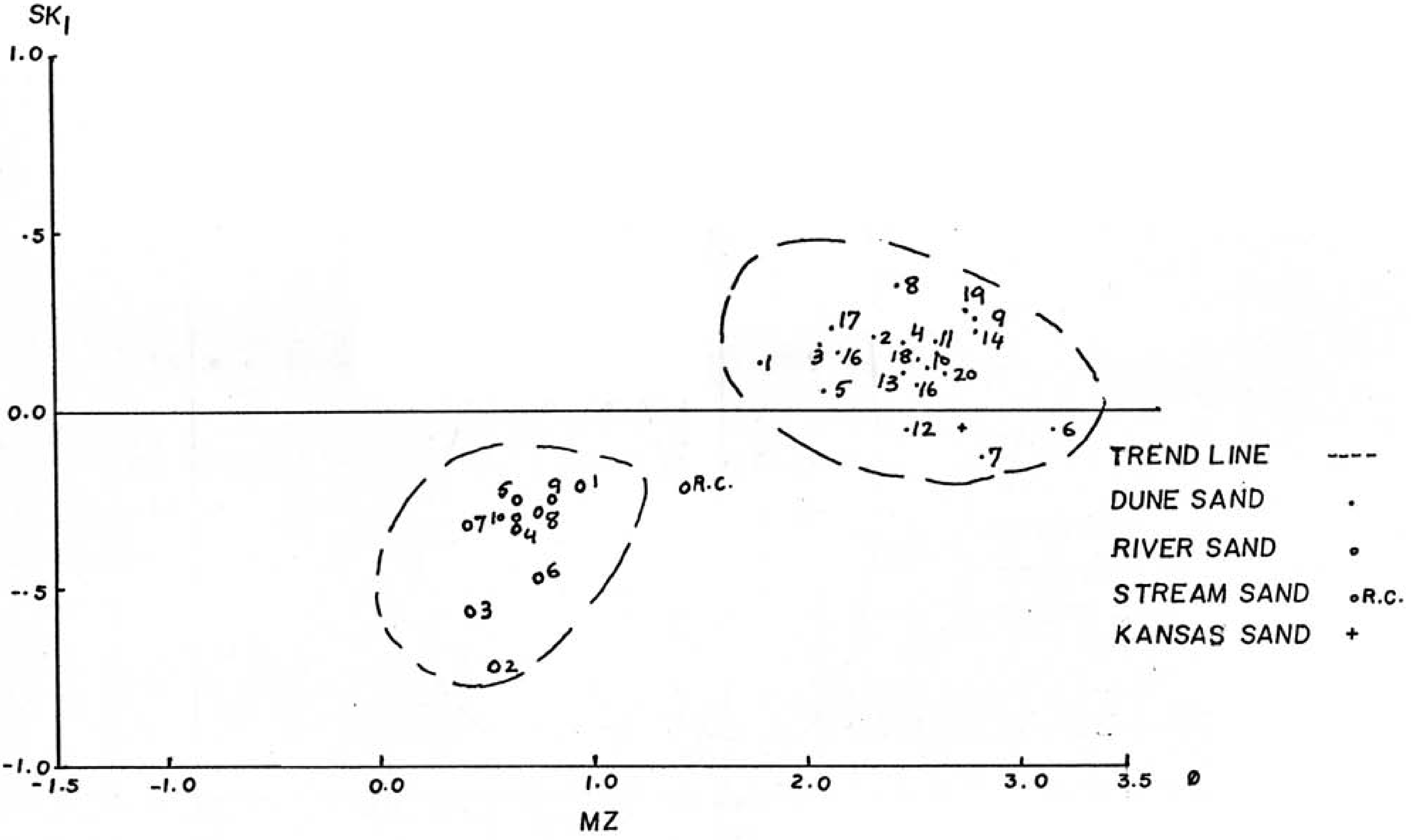

Fig. 17. MEAN GRAIN SIZE VS SKEWNESS

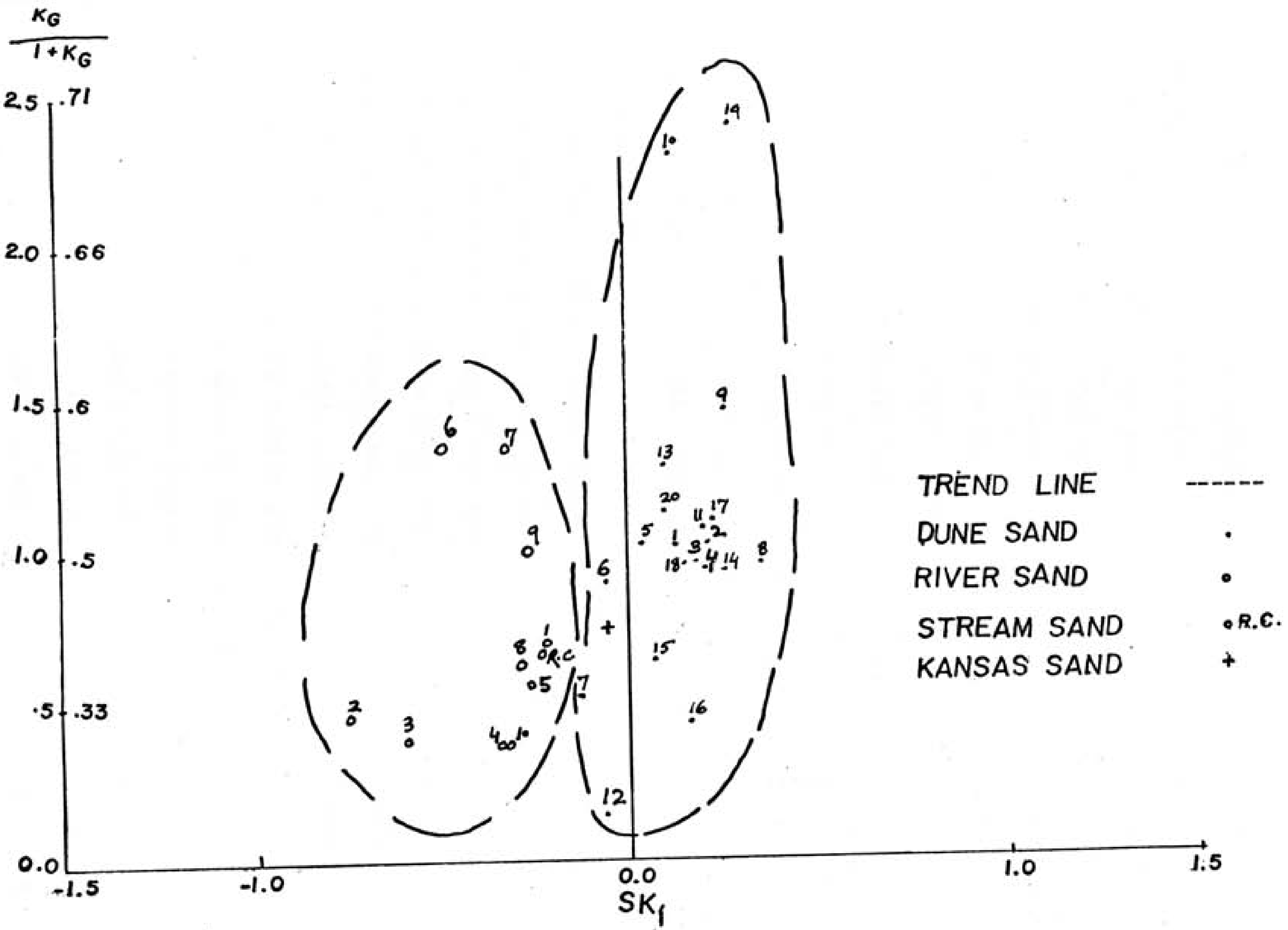

Fig. 18. SKEWNESS VS KURTOSIS

positively skewed. The kurtosis ranges from platykurtic to very leptokurtic. There is a complete separation of the two sediments. Stream sand is negatively skewed and platykurtic. The Kansas sand is nearly symmetrical and platykurtic.

Grain Size Standard Deviation Versus Grain Size Skewness. In Fig. 19 the grain size values of skewness are plotted against those of standard deviation. River sand is negatively skewed, and sorting ranges between very well-sorted to poorly sorted. The dune sand, except samples 6, 7, and 12 (negatively skewed), is positively skewed. The sorting values of dune sand range between very well sorted to moderately sorted. The sediments show a complete separation. Stream sand is negatively skewed and moderately sorted. The Kansas sand is nearly symmetrical and poorly sorted.

Mean Grain Size Versus Grain Size Standard Deviation. In Fig. 20 the mean grain size is plotted against the grain size standard deviation. The river sand shows a spread of the points, while the points of dune sand are concentrated. Dune sand is better sorted than river sand. The plot shows a complete separation of the two sediments. The stream sand is moderately sorted with mean grain size in medium sand. The Kansas sand is poorly sorted and mean grain size in fine sand.

Mean Grain Size Versus Kurtosis. In Fig. 21 the mean grain size is plotted against grain size kurtosis. River sand with its mean grain size in coarse sand shows a wide spread of its points. Points of dune sand are crowded. Both sands occupy two separate fields in the plot. The mean of stream sand lies in medium sand, and the stream sand is platykurtic. The mean of Kansas sand lies

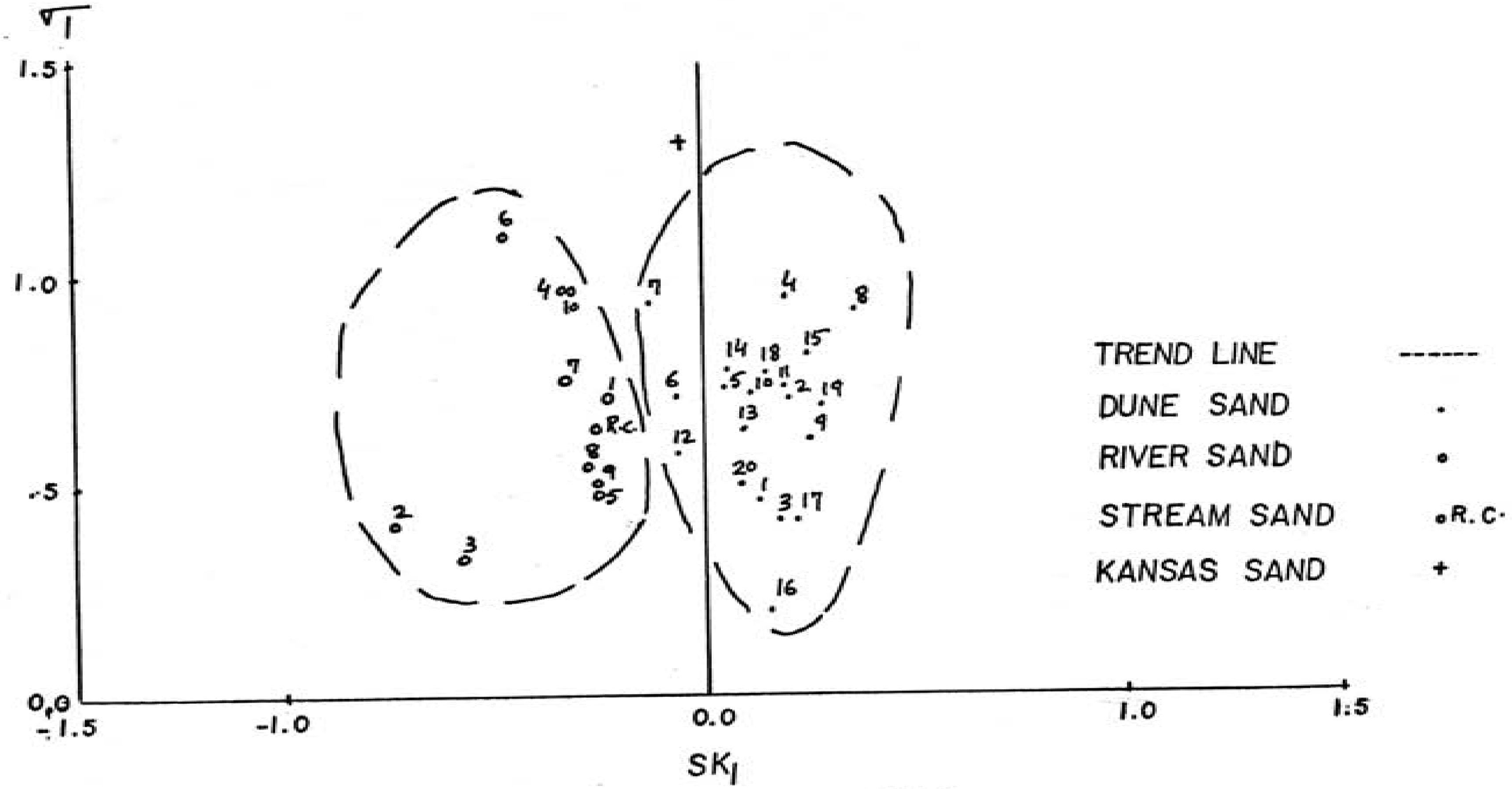

Fig. 19. STANDARD DEVIATION VS SKEWNESS

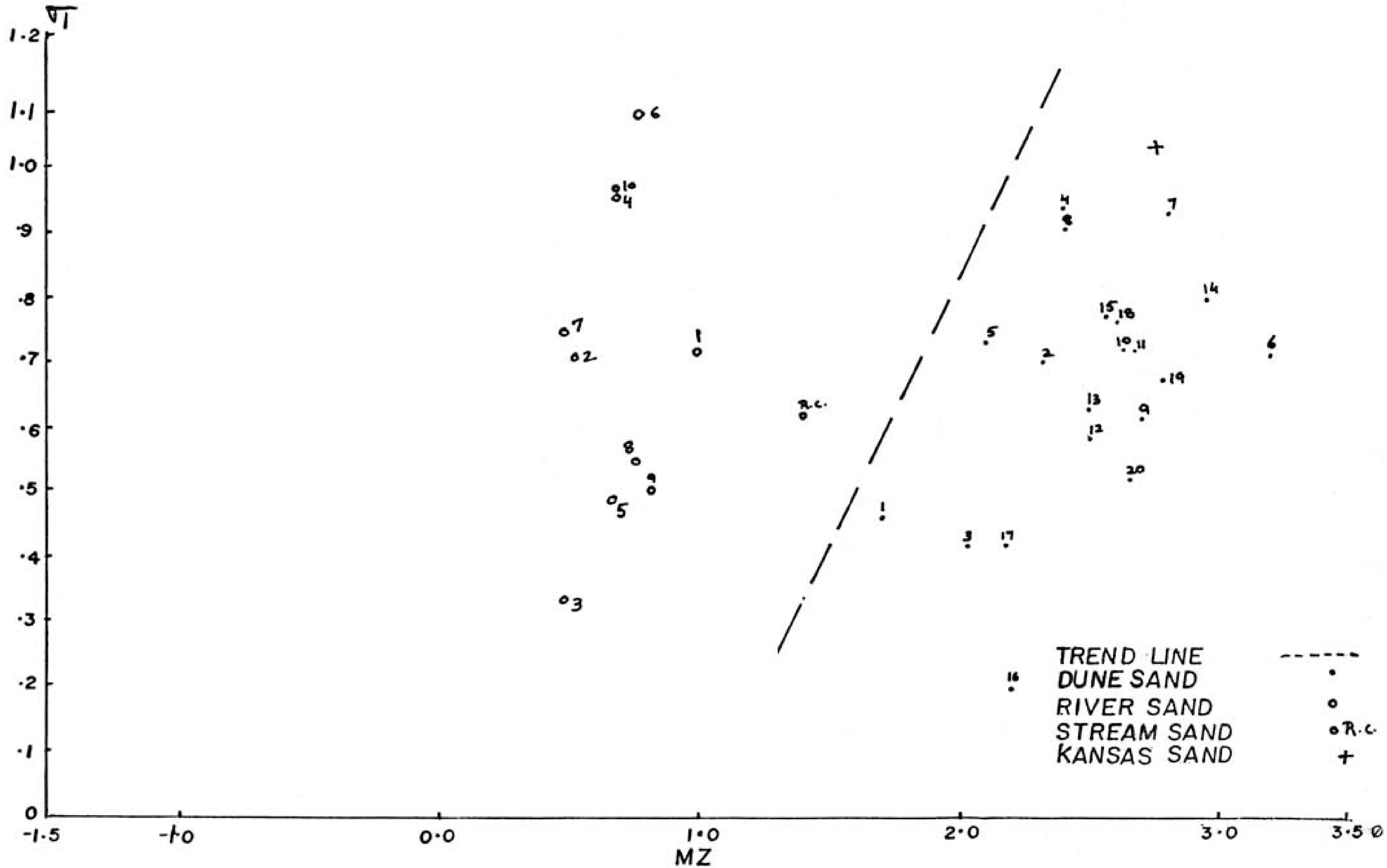

Fig. 20. MEAN GRAIN SIZE VS STANDARD DEVIATION

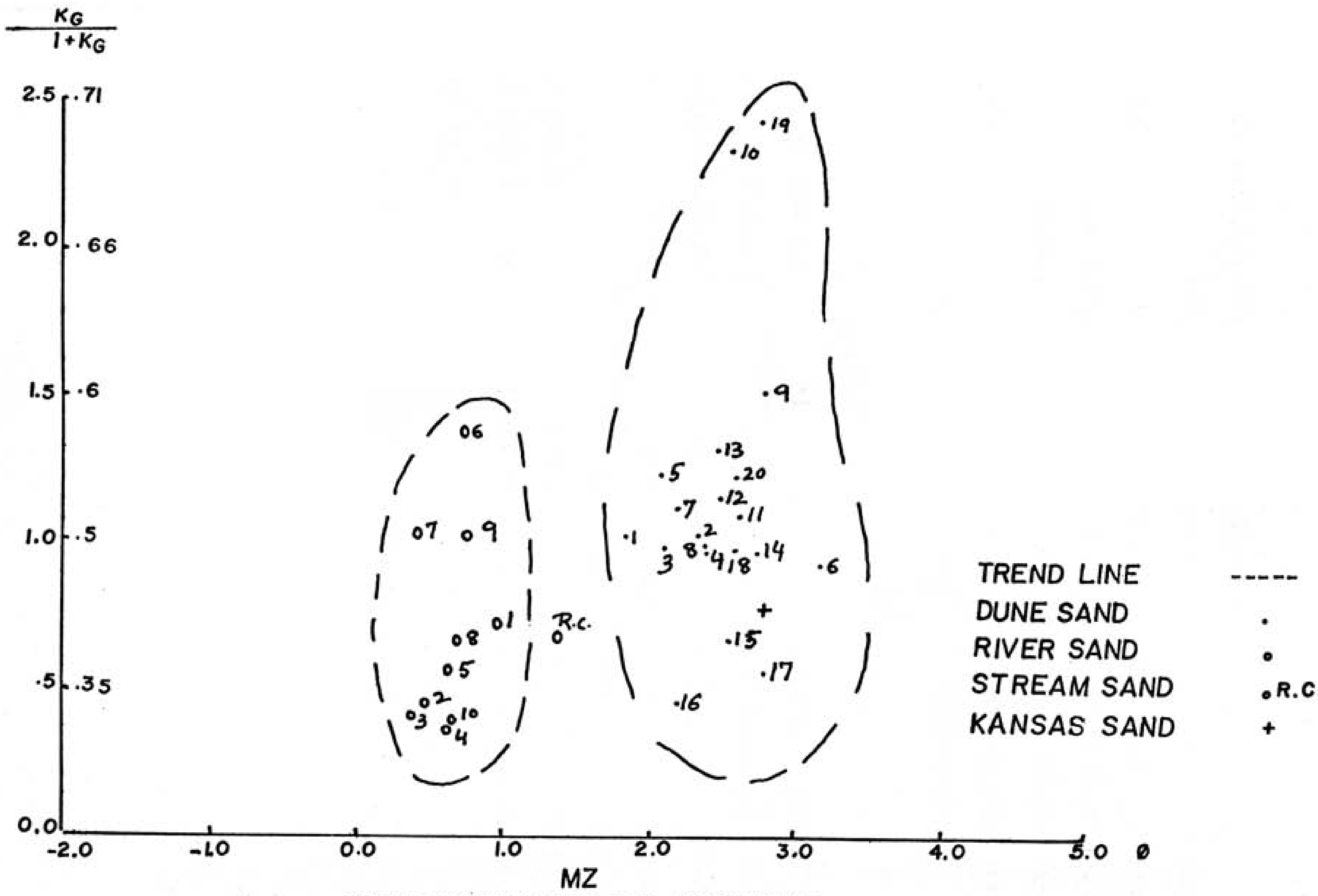

Fig. 21. MEAN GRAIN SIZE VS KURTOSIS

in fine sand and Kansas sand is platykurtic.

Grain Size Standard Deviation Versus Grain Size Kurtosis. In Fig. 22 the grain size standard deviation is plotted against the grain size kurtosis. This plot does not show a separation of the two sands. The points for river sand are mixed with points of dune sand. The stream sand is moderately sorted and platykurtic. The Kansas sand is poorly sorted and platykurtic.

Roundness

The examination of the roundness cumulative curves (Figs. 23-28) of river and dune sand shows that the roundness of the grains of the river sand ranges from very angular to well-rounded. The grains of the dune sand range from angular to well-rounded.

Statistical Parameters. The mean roundness (MR) and roundness standard deviation of the different samples of river and dune sand were calculated graphically. These values are in Table 9.

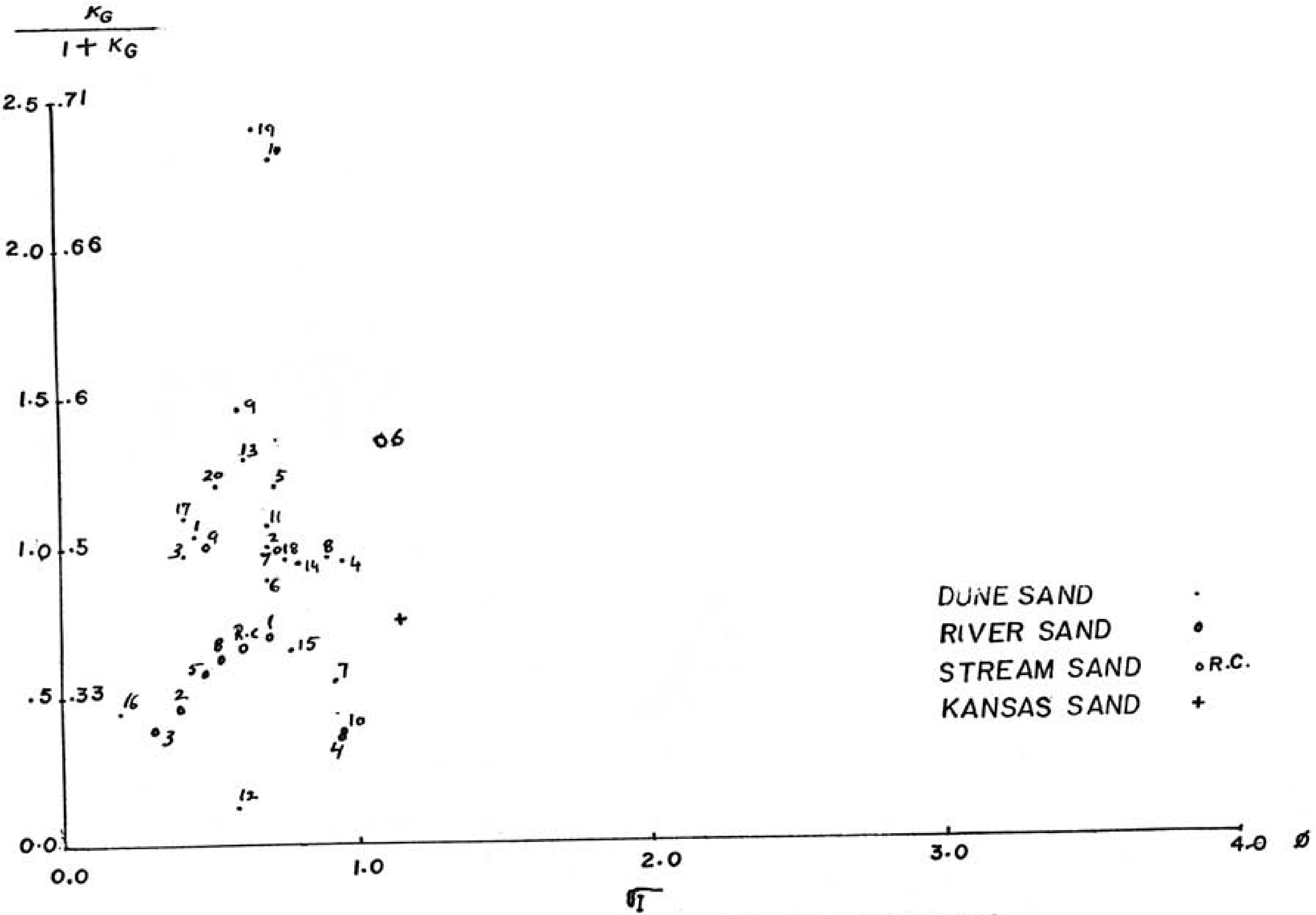

Fig. 22. STANDARD DEVIATION VS KURTOSIS

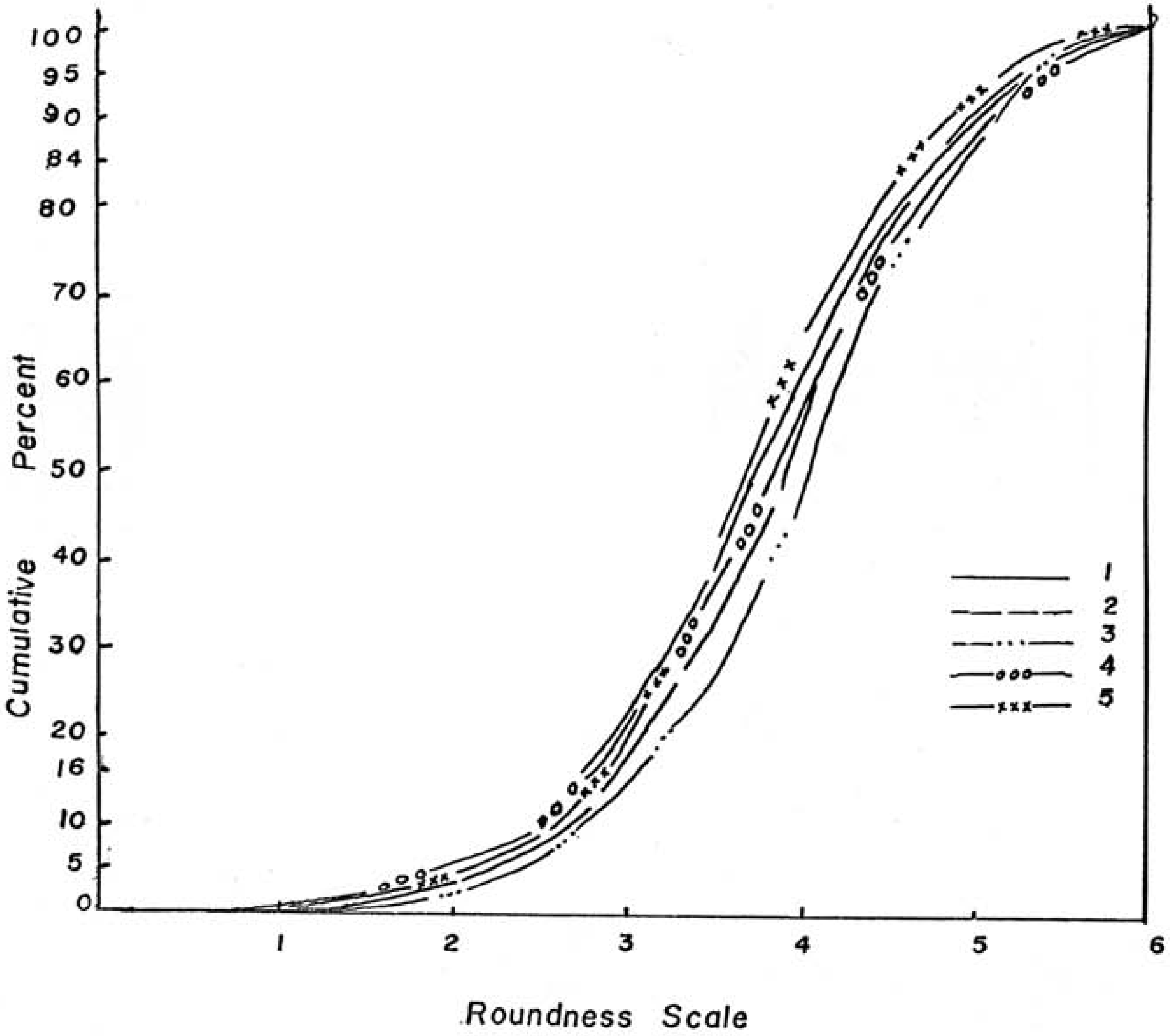

Fig. 23. Cumulative roundness frequency of dune sand.

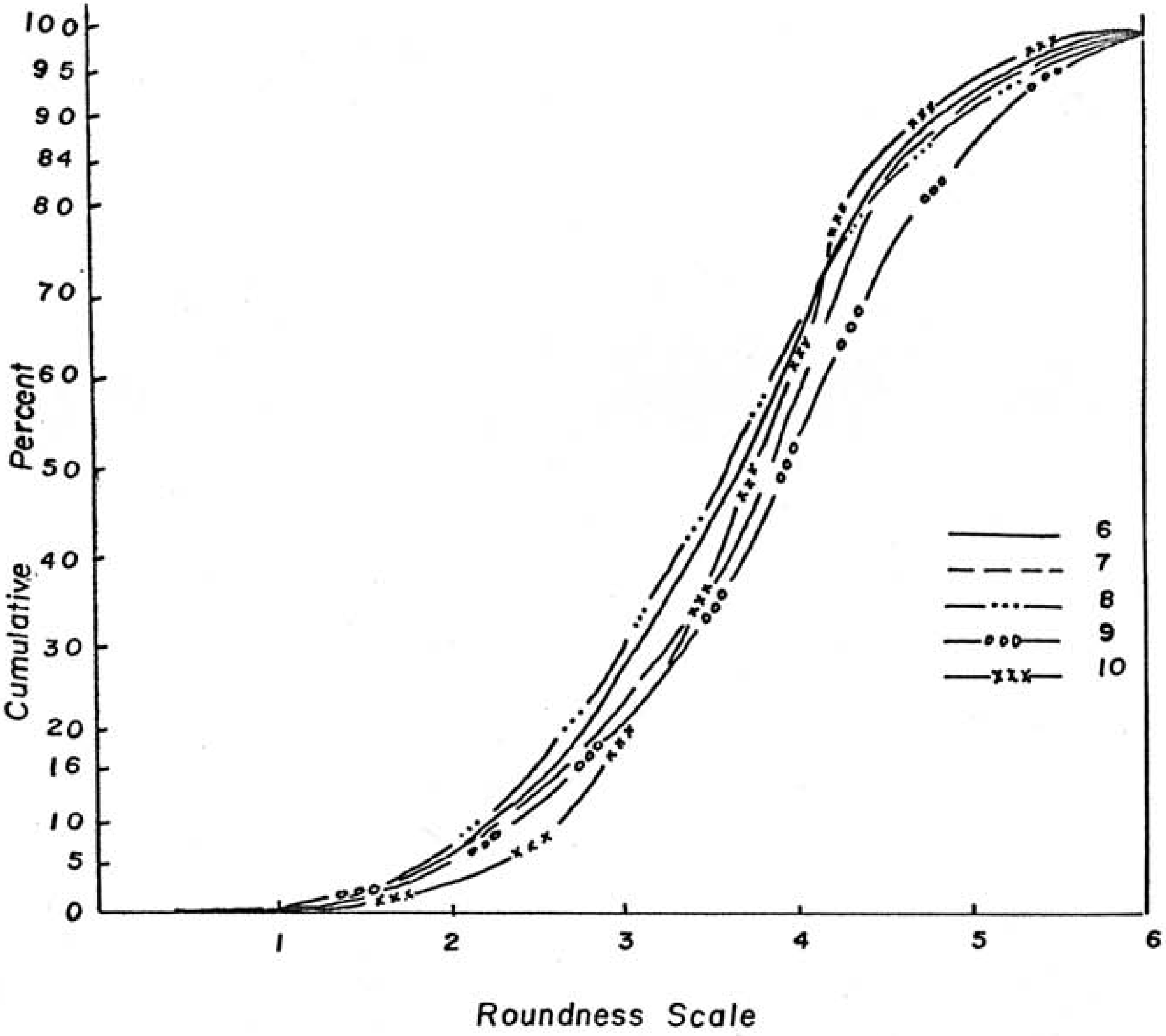

Fig. 24. Cumulative roundness frequency of dune sand.

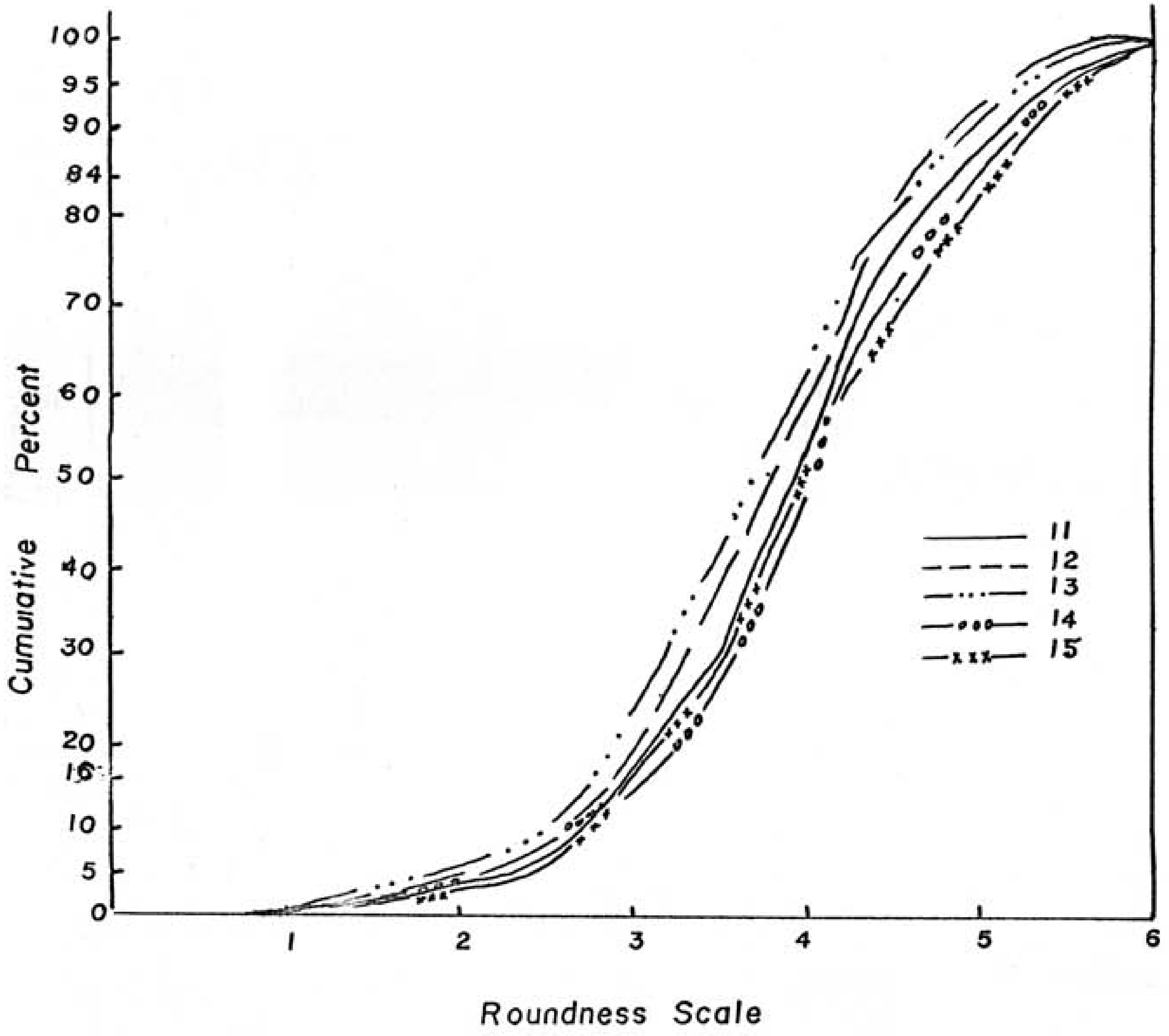

Fig. 25. Cumulative roundness frequency of dune sand.

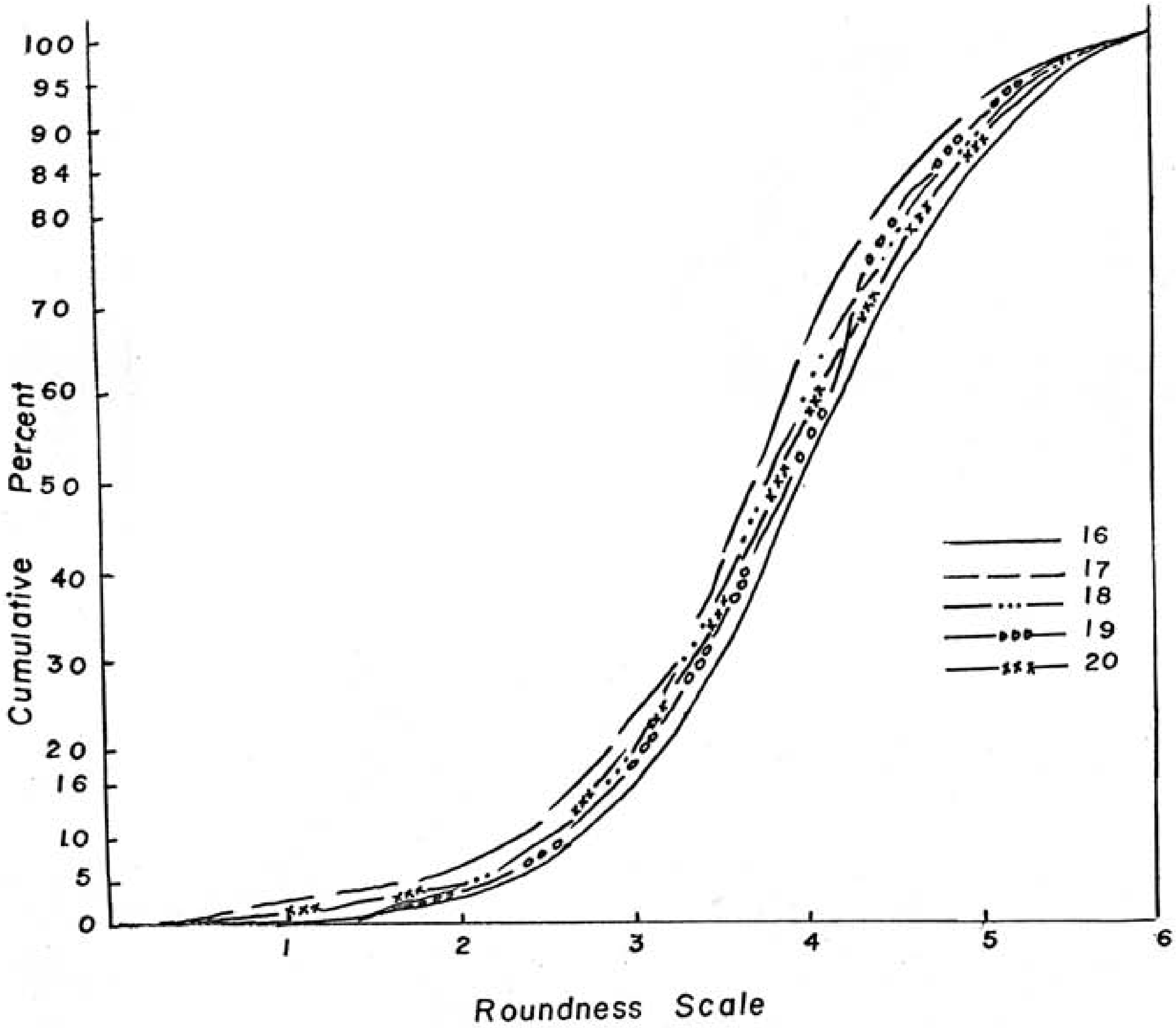

Fig. 26. Cumulative roundness frequency of dune sand.

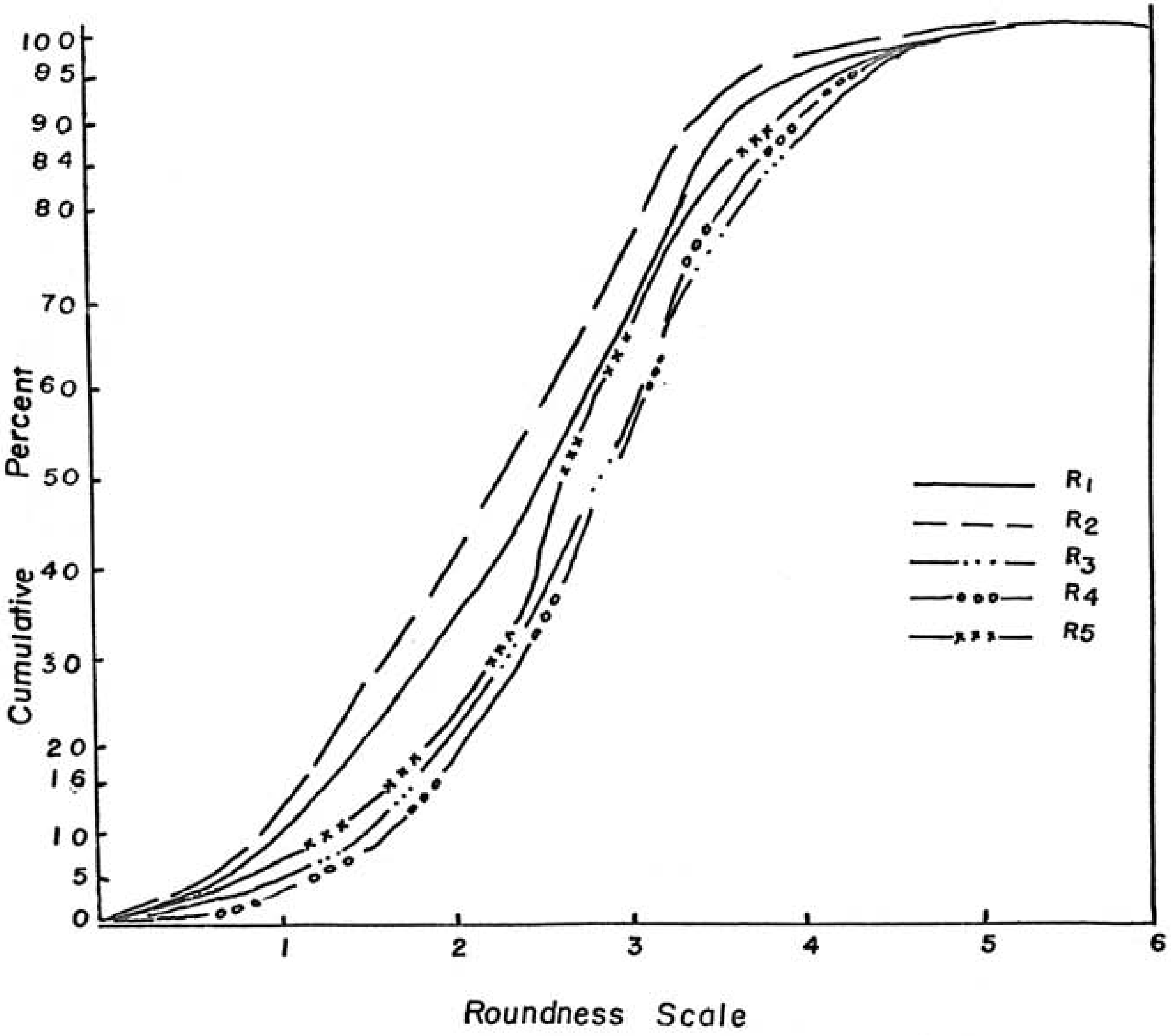

Fig. 27. Cumulative roundness frequency of river sand.

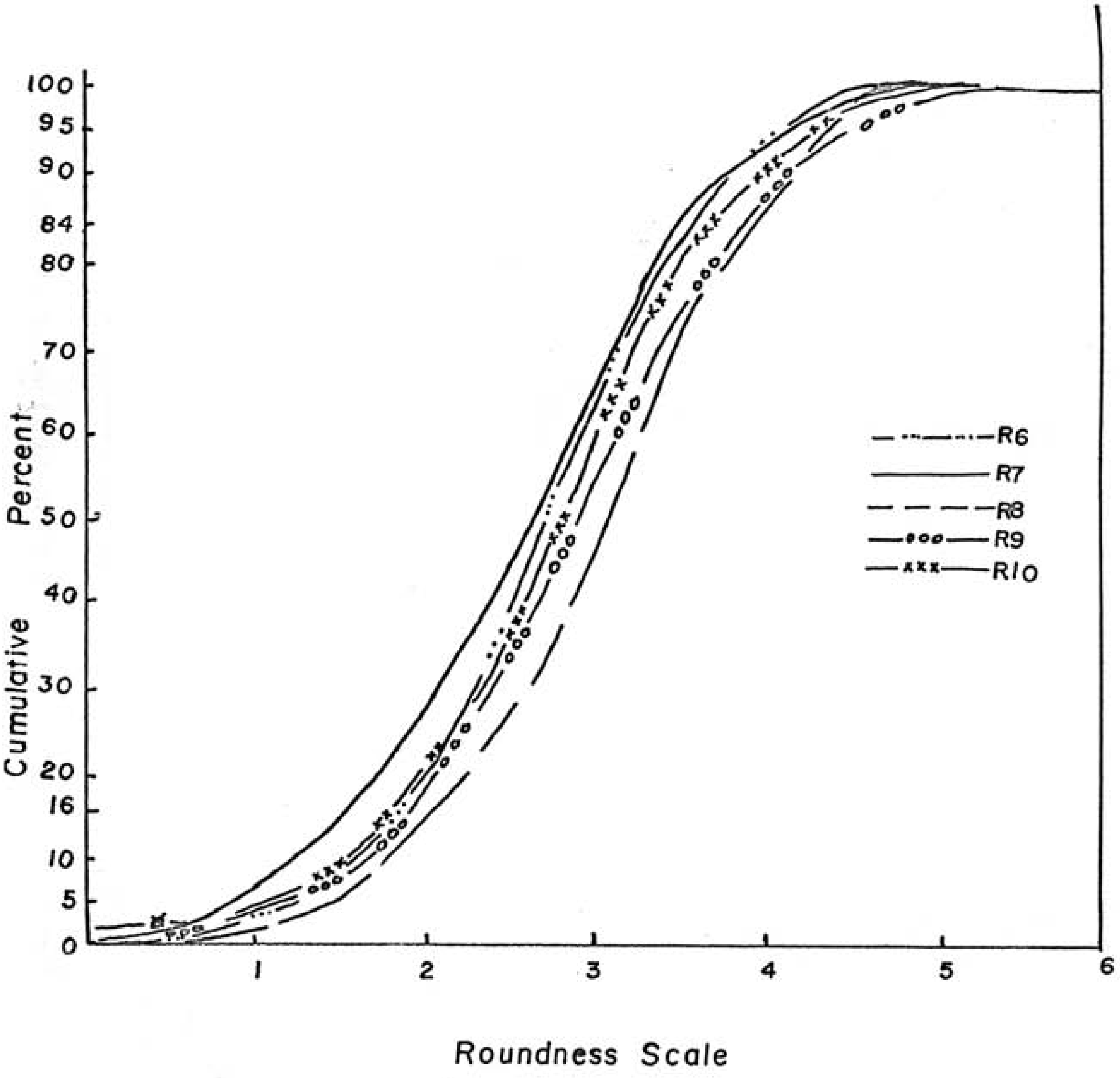

Fig. 28. Cumulative roundness frequency of river sand.

Table 9. Mean roundness values of river and dune sand samples.

Sample No.	River sand	Sample No.	Dune sand
R_1	2.30 ρ	1	3.70 ρ
R_2	2.58 ρ	2	3.98 ρ
R_3	2.83 ρ	3	3.88 ρ
R_4	2.90 ρ	4	3.80 ρ
R_5	2.70 ρ	5	3.90 ρ
R_6	2.68 ρ	6	3.68 ρ
R_7	2.59 ρ	7	3.70 ρ
R_8	2.81 ρ	8	3.54 ρ
R_9	2.86 ρ	9	3.80 ρ
R_{10}	2.78 ρ	10	3.70 ρ
		11	3.90 ρ
		12	3.70 ρ
		13	3.98 ρ
		14	4.00 ρ
		15	3.90 ρ
		16	3.98 ρ
		17	3.33 ρ
		18	3.70 ρ
		19	3.90 ρ
		20	3.81 ρ

The average mean roundness of river sand is 2.7ρ (sub-angular), and the average mean roundness of dune sand is 3.79 (sub-rounded). The standard deviations of river and dune sand mean roundness are ± 0.16 and ± 0.47. A "t" test was applied to

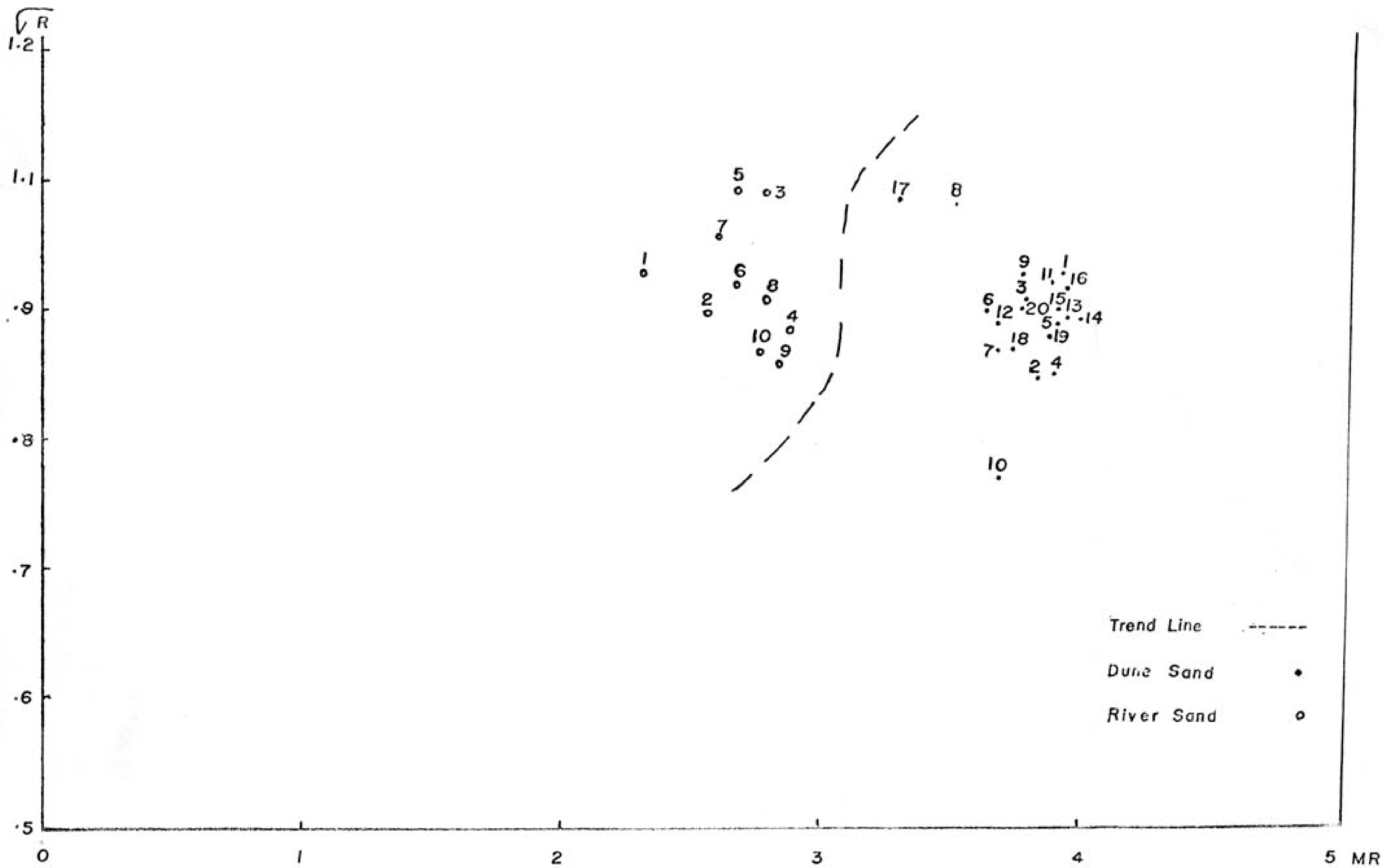

Fig. 29. MEAN ROUNDNESS VS ROUNDNESS STANDARD DEVIATION

the mean roundness values of the two sediments. A "t" value of 8.00, 28 degrees of freedom, and probability of less than 0.001 was obtained. The result indicates that there is a real difference between the mean roundness of the two sediments.

Roundness Standard Deviation. The values of roundness standard deviation of river and dune sand are in Table 10.

Table 10. Roundness standard deviation of river and dune sand samples.

Sample No.	River sand	Sample No.	Dune sand
R_1	± 0.92	1	± 0.88
R_2	± 0.90	2	± 0.93
R_3	± 1.00	3	± 0.85
R_4	± 0.89	4	± 0.91
R_5	± 1.09	5	± 0.85
R_6	± 0.92	6	± 0.90
R_7	± 0.96	7	± 0.87
R_8	± 0.91	8	± 0.97
R_9	± 0.86	9	± 0.93
R_{10}	± 0.87	10	± 0.77
		11	± 0.92
		12	± 0.89
		13	± 0.88
		14	± 0.88
		15	± 0.96
		16	± 0.92
		17	± 0.98
		18	± 0.87
		19	± 0.88
		20	± 0.90

The roundness standard deviation values for river sand ranges between σ_ρ 0.86 (moderate roundness sorting) and 1.09 (poor roundness sorting). The average roundness sorting value for river sand is σ_ρ 0.93 (moderate roundness sorting). The roundness standard deviation values for dune sand ranges between σ_ρ 0.77 (good roundness sorting) to σ_ρ 0.98 (moderate roundness sorting). The average roundness sorting value for dune sand is σ_ρ 0.90 (moderate roundness sorting). The standard deviations of river and dune sand roundness standard deviation (σ_ρ) are ±0.02 and ±0.30, respectively. A "t" test was applied to the roundness standard deviation values of the two sediments. A "t" value of 0.45, 28 degrees of freedom, and probability of more than 0.50 was obtained. The result indicates that there is no significant difference in the roundness standard deviation of the two sediments.

Scatter Plot. In Fig. 29 the mean roundness is plotted against roundness standard deviation. There is a complete separation between the two sediments. The dune sand shows better roundness sorting than the river sand.

Surface Features

The surface features are independent of size, shape, or roundness but are of genetic significance. The estimated percentage of the different types of surface features studied in river and dune sand are in Table 11.

Table 11. Surface features of river and dune sand.

	Frosted	Polished	Dull
River sand	23%	65%	12%
Dune sand	75%	15%	10%

Heavy Mineral Analysis

The heavy mineral analysis was made to determine the mineral content of river (one random sample), dune (one random sample), Illinois terrace sand (Qgf_1), and two Kansas sands (Ks_1, and Ks_3). The percentage by weight of heavy mineral fraction for the different samples is:

River sand	=	0.5 per cent
Dune sand	=	1.1 per cent
Kansas sand (Ks_1)	=	0.65 per cent
Kansas sand (Ks_3)	=	0.89 per cent
Illinois terrace sand (Qgf_1)	=	2.0 per cent

About 99 per cent of the fraction analyzed was composed of light minerals, and 1.0 per cent was composed of heavy minerals.

Light Minerals. The light minerals which form the light fraction of the different samples are quartz, orthoclase, microcline, plagioclase (not subdivided), and chert. The percentage of the different minerals calculated by count method are given in Table 12.

Table 12. Percentage of light minerals of river, dune, Illinois, and Kansas sand.

	Quartz	Orthoclase	Microcline	Plagioclase	Chert
River sand	56	20	8	12	4
Dune sand	47	28	7	15	3
Kansas sand (Ks_1)	60	20	12	8	-
Kansas sand (Ks_3)	67	15	9	9	-
Illinois terrace sand (Ψgf_1)	77	13	6	4	-

Quartz. Ordinary quartz averages 80 to 90 per cent of the different samples. The ordinary quartz is characterized by straight to slightly undulose extinction. The different varieties of quartz observed include quartz with water-filled vacuoles, quartz with microlites, quartz with rutile needles, and quartz without any inclusions. The quartz grains range in size from 0.5 mm to 0.06 mm (1.0 ϕ to 4 ϕ). In dune sand a majority of grains are subrounded to rounded. In Kansas River sand and Kansas sand the grains are subangular to rounded. Quartz grains of the Illinois terrace sand are angular. Reworked quartz was also observed in these sediments.

Chert. Detrital chert was observed in dune, river, and Kansas sand. The chert grains are about 0.2 mm (about 2.25 ϕ) and are subrounded. Chert grains are microcrystalline quartz; they form less than five per cent of the light fraction.

Feldspar. Feldspar makes up from 20 to 40 per cent of the light fraction of the different sands. Members of the feldspar group which were identified are orthoclase, microcline, and plagioclase (probably oligoclase). The grain size of the orthoclase ranges from 0.4 mm to 0.05 mm (about 1.25 Ø to 4.25 Ø). Orthoclase grains show more rounding in the dune and river sands than in other sands. Orthoclase is identified from quartz by its low birefrengence, cloudiness due to bubbles, sign (biaxial negative), refractive index, and by its slight pinkish tinge.

Microcline forms six to 12 per cent of the light minerals. Microcline grains are subangular to subrounded; they range in size from 0.3 mm to 0.04 mm (1.75 Ø to about 4.5 Ø). Microcline is identified by its grid polysynthetic twining. Microcline is also altered by vacuolization.

Plagioclase forms less than 15 per cent of the light minerals. The grains are subangular to subrounded and range in size between 0.4 mm to 0.06 mm (1.25 Ø to 4.0 Ø). The plagioclase is identified by polysynthetic twining. A few grains were identified as oligoclase by oil immersion method.

<u>Heavy Minerals</u>. One hundred grains were counted on the heavy mineral slides by the use of mechanical stage. The mineral frequencies are reported as percentages of the total number of grains counted. The minerals in the different sands are hornblende, lamprobolite, garnet, tourmaline, epidote, biotite, muscovite, apatite, zircon, magnetite (ilmenite) and staurolite.

The percentages of heavy minerals are given in Table 13.

Table 13. Percentage of heavy minerals of river, dune, Illinois, and Kansas sand.

	River sand	Dune sand	Kansas sand Ks_1	Kansas sand Ks_3	Illinois terrace sand
Hornblende	36	42	30	29	27
Lamprobolite	3	4	3	4	3
Garnet	12	10	10	7	8
Tourmaline	7	8	15	8	8
Epidote	11	8	7	11	9
Biotite	--	--	6	6	5
Muscovite	3	--	5	6	8
Apatite	3	4	3	5	3
Zircon	5	6	6	6	5
Magnetite (ilmenite)	15	14	15	18	24
Staurolite	5	4	--	--	--

Hornblende. Hornblende is abundant in all the different sands. It forms more than 30 per cent of the heavy fraction in river and dune sand. Green and brown varieties are in all the sands. The green variety is in larger proportion than the brown variety. The hornblende grains range in size from 0.5 mm to 0.05 mm (1.0 ϕ to about 4.25 ϕ). The hornblende grains show more rounding in dune, river and Kansas sand. In these sands the hornblende grains are sub-rounded to rounded. The grains in Illinoian terrace sand are subangular to sub-rounded. Hornblende is identified by its shape, pleochorism, extinction, and sign.

Lamprobolite. Lamprobolite is a variety of hornblende and occurs as prismatic grains. The grains are 0.3 mm in size (1.75 ϕ). Lamprobolite was identified by its brown color, straight extinction and pleochorism. It forms less than five per cent of the heavy mineral fraction.

Garnet. Two varieties of garnet, pink and colorless, were observed in all the different sands. Garnet grains are angular to subangular. The grains are about 0.3 mm (1.75 Ø) in size. There are two types of garnet, with inclusions and without inclusions. The garnet was identified by its high refractive index and isotropic character. Garnet forms from seven to 12 per cent of the heavy mineral fractions in the different sands.

Tourmaline. The light brown variety of tourmaline is in all the sands. The tourmaline grains are sub-rounded to rounded. The grains range in size from 0.4 mm to 0.1 mm (approx. 1.25 Ø to 3.25 Ø). Tourmaline was identified by its pleochorism, parallel extinction and sign. Grains are translucent, with or without inclusion, and free from decomposition.

Epidote. Epidote grains are subangular to sub-rounded. The grains are pale yellowish green in color with an optic axis interference figure. The grains range in size from 0.4 mm to 0.2 mm (approx. 1.25 Ø to 2.25 Ø).

Biotite. Biotite grains are minor constituents in Kansas and Illinois sands. Biotite occurs as yellowish brown rounded grains of about 0.3 mm (1.75 Ø) in diameter. The grains are non-pleochroic, as they lie with (001) in the plane of the slide. Biotite grains show pseudo uniaxial interference figures.

Muscovite. A few grains of muscovite were observed in the river, Kansas, and Illinois sands. The grains are sub-rounded, about 0.3 mm (1.75 Ø) in diameter. Muscovite was identified by its interference color, 2 V, and negative sign.

Apatite. Only a few grains of apatite were observed in all the sands. The grains are angular to sub-rounded. The size is about 0.07 mm (3.75 ∅). Apatite was identified by its prismatic shape, colorless grains with high relief and weak birefregence. Dune and river sand contain a few typical, egg-shaped detrital grains.

Zircon. Zircon represents a small percentage of heavy minerals. The colorless variety is found in all the sands; it occurs as subangular to sub-rounded grains. Prismatic crystals with pyramidal terminations are common. Zircon grains range in size from 0.1 mm to 0.06 mm (3.25 ∅ to 4 ∅). Zircon was identified by high relief, high order interference color, parallel extinction, and many inclusions.

Magnetite. Magnetite and ilmenite are included under this heading. Rounded to irregularly shaped grains were observed in different sands. Magnetite grains range in size between 0.1 mm to 0.03 mm (approx. 3.25 ∅ to 4.75 ∅). A high percentage of magnetite is found in Illinois terrace sand. The grains are black opaque.

Staurolite. A few grains of staurolite were observed in the river and dune sands. The grains are sub-rounded, about 0.2 mm (approx. 2.25 ∅) in size. Grains are pale yellow with many inclusions.

The chi square (X^2) test was applied to the heavy minerals of river and dune sand to find out if a real difference exists in their mineral composition. The X^2 value obtained was 0.125 with two degrees of freedom and probability more than 0.50. The "P" value is insignificant. It shows that there are more than five chances in ten that the difference between the heavy minerals of the river and dune sand are by chance, i.e., there is no difference in the mineral composition of the two sediments.

CONCLUSIONS

Certain conclusions are drawn as to what statistical parameters of texture may be used to differentiate the river from the dune sands of Hunters Island and vicinity, Riley, County, Kansas.

1. The river sand is coarser than the dune sand. The average mean grain size of river sand is 0.66 ∅ (coarse sand), and the average mean grain size of dune sand is 2.5 ∅ (fine sand). Using the "t" test a probability of less than 0.001 was obtained which shows that a real difference exists between the means of the two sediments. This difference in grain size may be because the wind has selective power of transportation and carries only sand and silt, which results in the deposition of fine-grained sediment by wind. Rivers do not have the selective power of transportation; they carry sediment of a wider range of grain size, and this results in the deposition of coarser sediment.

2. The sand of Kansas River is negatively skewed (coarsely skewed). The skewness values of dune sand indicate that dune sand, except samples 6, 7, and 12 (which are slightly negatively skewed), is positively skewed (finely skewed). The negative skewness of the river sand may be due to the lower velocity in the area of deposition which enables the river to drop the coarser sediment and continue to carry the finer sediment in suspension. Because the wind has a selective power of transportation, it carries sand and silt in suspension or by saltation, and gives rise to positive skewness. The slightly negative skewness of samples 6, 7, and 12 may be due to some contribution of coarser

sediment from some nearby source.

3. Mean grain size and grain size skewness are the two statistical parameters which can be used to differentiate between the river and the dune sands of Hunters Island and vicinity. The results of the "t" test for the two parameters (probability of less than 0.001) indicate that a real difference exists between their mean and their skewness values. The grain size standard deviation (σ_I) and grain size kurtosis cannot be used to differentiate between the river and dune sediments. The "t" test for the grain size standard deviation (σ_I) (probability of 0.27) indicates that there is no significant difference between the grain size standard deviation (σ_I) of the two sediments. The "t" test for the grain size kurtosis (probability of 0.11) indicates that there may be some real difference between the grain size kurtosis of the two sediments, but more samples are required for further investigation before a conclusion can be reached.

4. It has been observed that when mean grain size is plotted against grain size skewness or any of these two parameters are plotted against grain size standard deviation or grain size kurtosis, the plots show a separation between the river and dune sediments; but when the grain size standard deviation is plotted against grain size kurtosis, the plot does not show any separation of the two sediments. This also points out that grain size skewness and mean grain size parameters can be used to differentiate between the river and dune sands of Hunters Island and vicinity.

Examination of the heavy mineral analysis (Table 13) shows that river sand has a hornblende-epidote assemblage with 36 per cent of hornblende and 11 per cent of epidote. Other evidence such as sorting which ranges from $\pm 0.32\ \phi$ to $\pm 1.09\ \phi$, and presence of frosted grains points out that Kansas River sand is probably derived from eolian deposits. The Republican River, Solomon River, Saline River, and Blue River transport sediment from the eolian deposits of northcentral Kansas to the Kansas River. Moreover, the eolian deposits along the Kansas River also contribute sediment. The eolian deposits are well-sorted and well-rounded. The sediment supplied has undergone one or two sedimentary cycles of erosion, and this is responsible for the sorting and roundness of the river sand.

Pebbles and granules of limestone and chert and other minerals in the sand grains are probably supplied by the surrounding Permian rocks. Moreover, magnetite, apatite, and zircon, of two different sizes, 0.1 mm. and 0.06 mm. ($3.25\ \phi$ and $4.0\ \phi$), are indicative of contributions from an older sedimentary source. Bimodal and polymodal character of the sediment indicates that sediments which were sorted in two different energy environments were later mixed, and the present environment is less effective in its sorting.

The heavy minerals of the dune sand in Table 13 show a hornblende-epidote assemblage with 42 per cent hornblende and 8 per cent epidote. Other evidences, such as sorting which ranges from $\pm 0.20\ \phi$ to $\pm 0.94\ \phi$, presence of polished and frosted grains, bimodal and polymodal character of the sediment, and two different sizes of magnetite, apatite, and zircon, indicate that the sediment was derived from the Kansas River sand. The prevailing winds in the area which are southwest to northeast play an important role in transporting sediment from the Kansas River and depositing it in Hunters Island and vicinity. Sediment is also contributed to the wind deposits from the surrounding Permian Rocks, Illinois and Wisconsin terrace deposits. The Recent dune sand was deposited after the flood of 1951.

The grain size statistical parameters may be applied to differentiate the river and dune sands of ancient sediments. Mean grain size and grain size skewness are the two statistical parameters which may prove to be the most valuable for identifying ancient river and dune sands.

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Assistant Professor Page C. Twiss, major instructor, for his helpful suggestions, counsel, and guidance in the preparation of this thesis. Thanks are also expressed to Professor Joseph R. Chelikowsky, Head of Geology and Geography, Professor Henry V. Beck, and Assistant Professor Huber Self for their helpful cooperation.

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APPENDIX

Table 14. Weights in grams of grain sizes for dune sand.

Ø	1	2	3	4	5	6	7	8	9	10
-1.25	-	-	-	-	-	-	-	-	-	-
-1.00	-	-	-	-	-	-	-	-	-	-
-0.75	-	-	-	-	-	-	-	-	-	-
-0.50	-	-	-	-	-	-	-	-	-	-
-0.25	-	-	-	-	-	0.007	-	-	-	-
0.00	0.055	-	-	-	-	0.006	-	-	-	-
0.25	0.158	0.010	0.010	0.020	0.021	0.013	0.003	0.007	-	0.022
0.50	0.200	0.015	0.015	0.855	0.060	0.024	0.001	0.021	-	0.034
0.75	0.220	0.035	0.035	1.470	0.742	0.185	0.994	0.296	0.007	0.079
1.00	0.320	0.085	0.065	1.300	0.702	0.118	0.330	0.579	0.027	0.154
1.25	5.300	1.000	1.000	2.420	2.658	0.238	0.223	1.927	0.129	0.348
1.50	9.100	2.060	3.200	3.100	10.004	0.182	1.356	5.345	0.295	0.798
1.75	12.100	7.010	8.515	6.275	12.014	0.554	0.655	8.746	0.924	1.424
2.00	10.300	9.200	13.100	7.275	8.509	1.189	1.250	7.485	2.772	5.604
2.25	7.350	11.500	12.100	8.125	4.305	1.446	3.984	7.485	5.759	7.209
2.50	4.370	8.100	9.050	4.550	4.848	2.529	18.494	4.531	6.500	6.695
2.75	3.500	7.965	8.000	7.129	2.758	9.012	0.714	6.114	14.413	11.989
3.00	0.560	3.225	2.000	3.335	2.212	7.264	10.554	2.339	6.604	4.754
3.25	0.350	2.325	0.600	4.295	1.235	11.129	10.144	3.056	7.224	5.989
3.50	0.335	1.595	0.300	3.600	1.242	6.472	5.330	1.954	3.826	3.362
3.75	0.010	1.230	0.200	2.220	1.745	5.612	3.012	1.826	3.586	2.834
4.00	0.031	2.550	0.135	3.140	1.483	6.554	2.970	2.959	3.919	4.164
Pan	0.051	2.580	0.335	4.124		7.544	2.321	4.624	3.448	3.779

Table 14 (concl.). Weights in grams of grain sizes for dune sand.

Ø	11	12	13	14	15	16	17	18	19	20
-1.25	-	-	-	-	-	-	-	-	-	-
-1.00	-	-	-	-	-	-	-	-	-	-
-0.75	-	-	-	-	-	-	-	-	-	-
-0.50	-	-	-	-	-	-	-	-	-	-
-0.25	-	-	-	-	-	0.019	-	0.027	-	0.026
0.00	-	-	-	-	-	0.024	-	0.029	-	0.018
0.25	-	-	-	0.013	-	0.025	0.010	0.057	-	0.015
0.50	0.015	0.003	-	0.017	0.007	0.035	0.012	0.060	0.007	0.020
0.75	0.064	0.014	0.004	0.042	0.067	0.072	0.041	0.094	0.019	0.032
1.00	0.174	0.109	0.219	0.164	0.204	0.172	0.112	0.246	0.061	0.092
1.25	0.559	0.367	0.612	0.444	0.582	0.564	0.194	0.571	0.189	0.192
1.50	1.604	1.201	1.464	1.029	1.376	2.042	0.779	1.729	0.669	0.489
1.75	2.676	3.074	3.216	2.401	2.754	6.100	2.422	3.784	1.734	1.112
2.00	5.732	7.259	6.812	5.839	7.149	12.571	7.115	6.754	4.114	3.049
2.25	9.304	10.669	9.669	7.689	7.919	13.862	12.120	8.254	6.758	7.524
2.50	7.684	7.489	8.532	7.109	9.564	9.623	11.289	6.019	6.388	8.174
2.75	12.104	13.694	13.207	11.324	12.304	10.454	15.204	9.914	12.859	18.279
3.00	4.324	4.539	4.099	4.294	4.087	1.906	3.919	4.726	5.926	7.424
3.25	4.494	4.314	4.344	4.880	3.927	1.107	3.064	5.534	6.981	6.944
3.50	3.004	1.984	2.169	2.844	2.339	0.329	0.834	3.202	3.991	2.704
3.75	2.214	1.574	1.689	2.599	1.834	0.203	0.604	2.739	3.324	2.144
4.00	3.509	1.719	2.122	4.139	2.716	0.219	0.576	3.304	3.992	1.292
Pan	2.859	1.064	1.659	4.912	2.654	0.294	0.786	2.759	2.789	1.116

Table 15. Weights in grams of grain sizes for river, stream, and Kansas sand samples.

Ø	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R.C.	Ks_3
-1.25	-	1.347	1.119	1.466	0.665	1.859	-	0.631	-	2.253	-	-
-1.00	2.630	2.906	3.879	3.890	3.127	4.503	2.873	2.543	2.370	3.103	1.694	-
-0.75	0.982	3.864	3.471	2.736	2.212	3.059	0.923	1.488	0.800	2.735		
-0.50	1.141	2.722	2.784	2.075	1.877	1.520	1.450	1.195	2.023	2.074	0.836	0.044
-0.25	1.964	4.317	4.782	3.622	2.624	2.270	3.030	3.460	2.140	3.620		
0.00	2.007	3.542	4.457	3.207	2.530	2.265	2.688	3.468	2.385	3.207	1.896	0.489
0.25	2.927	4.042	4.502	3.720	3.162	2.595	3.707	2.955	3.073	3.720		
0.50	4.396	5.275	5.652	4.847	4.962	3.995	5.112	4.560	5.280	4.840	3.449	1.159
0.75	5.984	4.482	5.144	3.832	4.572	3.200	4.050	3.937	5.600	3.822		
1.00	9.399	7.207	7.458	7.820	10.669	7.565	9.885	11.345	13.365	7.820	9.014	3.974
1.25	9.302	5.267	5.537	7.067	8.782	6.860	8.297	10.043	10.895	7.062		
1.50	6.526	4.805	4.892	8.682	6.347	6.365	6.112	6.890	8.163	8.682	11.796	3.554
1.75	4.334	3.667	3.467	5.103	2.937	3.680	2.557	3.180	3.515	5.100		
2.00	2.694	2.540	2.187	2.714	1.427	1.985	0.860	1.570	1.300	2.714	6.579	3.879
2.25	1.737	1.579	1.224	1.396	0.600	0.990	0.463	0.900	0.508	1.391		
2.50	1.004	0.759	0.537	0.612	0.272	0.505	0.293	0.485	0.245	0.610	2.559	5.107
2.75	1.484	0.915	0.576	0.850	0.443	1.010	0.743	0.895	0.270	0.850		
3.00	0.424	0.322	0.207	0.530	0.332	0.830	0.653	0.530	0.150	0.520	0.829	6.999
3.25	0.526	0.352	0.222	0.832	0.562	1.283	0.953	0.753	0.322	0.932		
3.50	0.156	0.142	0.067	0.370	0.337	0.577	0.415	0.315	0.250	0.270	0.234	4.859
3.75	0.116	0.112	0.047	0.261	0.297	0.563	0.380	0.235	0.170	0.261		
4.00	0.164	0.132	0.067	0.272	0.422	0.850	0.575	0.250	0.238	0.272	0.186	4.736
Pan	0.344	0.202	0.147	0.462	0.804	2.180	2.123	0.395	0.815	0.442	0.224	7.448

Table 16. Phi percentile values for dune sand.

Sample No.	5%	16%	25%	50%	75%	84%	95%
1	1.10	1.33	1.47	1.75	2.08	2.28	2.63
2	1.50	1.74	1.76	2.23	2.75	3.08	3.96
3	1.44	1.68	1.80	2.08	2.40	2.53	2.84
4	0.95	1.55	1.76	2.28	3.10	3.45	4.06
5	1.20	1.50	1.65	1.95	2.52	2.85	3.80
6	2.13	2.58	2.75	3.15	3.71	3.89	4.15
7	1.55	2.28	2.35	2.83	3.18	3.43	3.95
8	1.25	1.55	1.70	2.18	2.98	3.53	4.08
9	1.90	2.23	2.45	2.75	3.04	3.46	4.03
10	1.78	2.05	2.25	2.19	3.23	3.60	4.06
11	1.58	1.96	2.14	2.54	3.05	3.43	3.98
12	1.60	1.94	2.08	2.50	2.79	3.05	3.70
13	1.58	1.91	2.06	2.50	2.76	3.11	3.79
14	1.68	1.95	2.18	2.60	3.22	3.73	4.10
15	1.08	1.89	2.09	2.51	2.90	3.28	3.98
16	1.52	1.78	1.14	2.15	2.49	2.59	2.88
17	1.71	2.00	2.10	2.31	2.66	2.76	3.23
18	1.48	1.88	2.05	2.54	3.13	3.44	3.98
19	1.78	2.13	2.31	2.69	3.23	3.55	3.98
20	1.85	2.16	2.35	2.63	3.22	3.55	3.98

Table 17. Phi percentile values for river, stream, and Kansas sand samples.

Sample No.	5%	16%	25%	50%	75%	84%	95%
R_1	-0.88	0.08	0.46	0.98	1.43	1.93	2.53
R_2	-1.08	-0.59	-0.25	0.65	1.28	1.58	2.53
R_3	-1.13	-0.63	-0.26	0.53	1.16	1.43	2.23
R_4	-1.15	-0.46	-0.01	0.88	1.43	1.61	2.63
R_5	-1.08	-0.34	0.18	0.88	1.25	1.45	2.58
R_6	-1.20	0.58	0.05	0.98	1.48	1.88	3.75
R_7	-0.94	-0.15	0.25	0.88	1.30	1.56	3.60
R_8	-1.05	-0.19	0.28	0.93	1.28	1.50	2.58
R_9	-0.75	0.02	0.42	0.92	1.25	1.43	1.80
R_{10}	-1.15	-0.46	-0.01	-0.87	1.42	1.61	2.62
R.C.	-0.70	0.26	0.56	1.20	1.60	1.77	2.38
Ks_3	-0.57	1.20	1.70	2.70	3.70	4.20	4.25

Table 18. Phi statistical parameter values of dune sand.

Sample No.	Mo	Md	M_z	σ_G	σ_I	SK_G	SK_I	K_G	K_G'
1	1.63	1.78	1.79	±0.48	±0.46	+0.11	+0.12	1.03	0.50
2	2.1, 2.63	2.23	2.35	±0.67	±0.70	+0.27	+0.20	1.01	0.50
3	1.87, 2.63	2.08	2.09	±0.43	±0.42	+0.58	+0.17	0.97	0.48
4	2.13, 2.63, 3.13, 0.63	2.28	2.44	±0.95	±0.94	+0.23	+0.19	0.95	0.48
5	1.87, 2.63	1.95	2.10	±0.68	±0.73	+0.33	+0.04	1.21	0.54
6	3.13, 2.63	3.15	3.20	±0.65	±0.71	+0.14	-0.077	0.89	0.47
7	2.38, 2.87	2.82	2.84	±0.58	±0.93	+0.45	-0.14	0.54	0.35
8	1.63, 2.63, 3.13	2.18	2.42	±0.98	±0.91	+0.36	+0.35	0.96	0.48
9	2.63, 3.12	2.75	2.79	±0.59	±0.61	+0.10	+0.25	1.48	0.59
10	2.63, 2.13, 3.13, 3.87	2.19	2.61	±0.78	±0.72	+0.82	+0.11	2.30	0.69
11	2.63, 2.13, 3.13, 3.87	2.54	2.64	±0.73	±0.72	+0.20	+0.19	1.07	0.51
12	2.63, 2.13, 3.13, 3.87	2.50	2.49	±0.55	±0.58	-0.002	-0.07	0.12	0.10
13	2.63, 2.13, 3.13, 3.87	2.50	2.50	±0.60	±0.63	+0.02	+0.09	1.29	0.56
14	2.63, 2.13, 3.13	2.60	2.80	±0.89	±0.80	+0.26	+0.24	0.94	0.48
15	2.63, 2.13, 3.13, 3.87	2.51	2.55	±0.69	±0.77	+0.09	+0.05	0.65	0.39
16	2.63, 2.13	2.15	2.20	±0.35	±0.20	+0.24	+0.15	0.44	0.30
17	2.63, 2.13	2.31	2.17	±0.40	±0.42	+0.07	+0.21	1.10	0.52
18	2.63, 2.13, 3.13, 3.87	2.53	2.61	±0.78	±0.76	+0.16	+0.14	0.96	0.48
19	2.63, 3.13, 2.13, 3.87	2.68	2.78	±0.70	±0.68	+0.21	+0.27	2.40	0.69
20	2.63 , 2.13	2.63	2.64	±0.50	±0.52	+0.01	+0.09	1.12	0.54

Table 19. Phi statistical parameter values of river, stream, and Kansas sands.

Sample No.	Mo	Md	M_z	$\sqrt{G}$	$\sqrt{I}$	SK_G	SK_I	K_G	K_G'
R_1	0.87, 2.63, 3.13	0.98	0.99	±0.93	±0.71	+0.026	-0.22	0.70	0.41
R_2	0.87, 0.37, 1.37, -0.37, -1.13, 2.63	0.65	0.51	±0.50	±0.41	-0.87	-0.74	0.46	0.31
R_3	0.87, 0.37, -0.37	0.53	0.44	±0.40	±0.32	-1.25	-0.59	0.38	0.27
R_4	1.37, 0.87, 0.37, -0.37	0.88	0.67	±0.75	±0.96	-0.28	-0.33	0.37	0.27
R_5	0.87, 0.37, -0.37, -1.13	0.88	0.66	±0.55	±0.49	-0.03	-0.26	0.57	0.36
R_6	0.87, 0.37, -0.37, 3.12	0.98	0.75	±0.65	±1.09	-0.38	-0.49	1.36	0.57
R_7	0.87, 0.37, -0.37, 2.37, 3.13	0.88	0.42	±0.70	±0.75	-0.026	-0.32	1.35	0.57
R_8	0.87, 0.37, -0.37, 2.37, 3.13	0.93	0.74	±0.65	±0.55	-0.12	-0.29	0.62	0.38
R_9	0.87, 0.37	0.93	0.79	±0.70	±0.50	-0.28	-0.26	1.00	0.99
R_{10}	1.37, 0.87, 0.37, -0.37, 3.13	0.88	0.65	±0.75	±0.96	-0.27	-0.32	0.37	0.27
R.C.	1.37, 3.87	1.20	1.40	±0.75	±0.62	-0.48	-0.23	0.66	0.39
Ks_3	2.87, 0.87	2.70	2.78	±1.50	±1.30	0.00	-0.06	0.75	0.45

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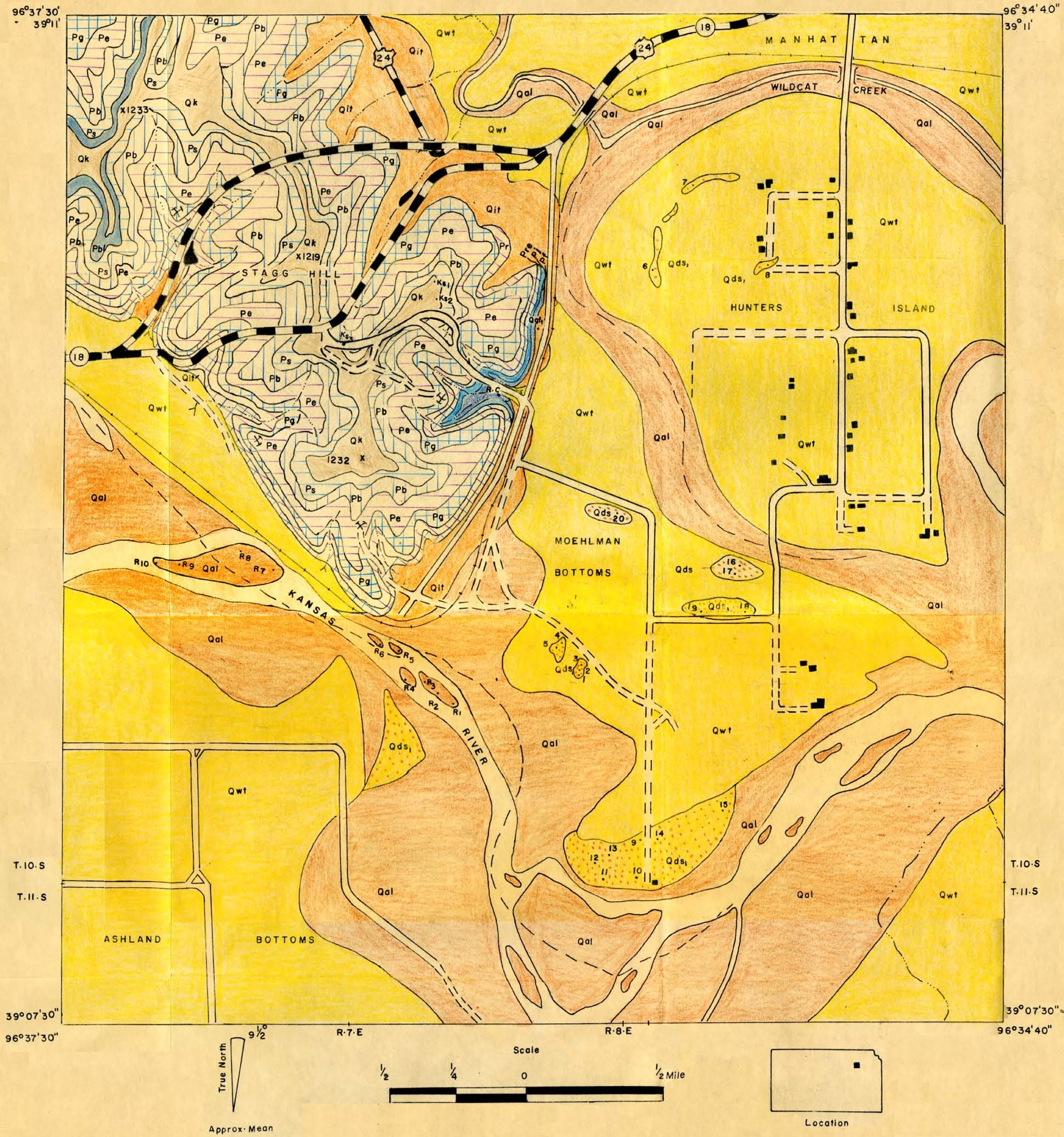

Fig. 30

EXPLANATION

Quarternary System

Qds	Recent Dune Sand
Qal	Alluvium
Qds1	Dune Sand
Qwt	Wisconsin Terrace Deposit
Qit	Illinois Terrace Deposit
Qk	Kansas Deposit

Unconformity

Permian System — Wolfcamp Series — Council Grove Group

Pbl	Bader Limestone
Ps	Stearns Shale
Pb	Beattie Limestone
Pe	Eskridge Shale
Pg	Grenola Limestone
Pr	Roca Shale
Pre	Red Eagle Limestone
Pj	Johnson Shale
Pf	Foraker Limestone

Geologic Contact
Highway
U.S. Route
State Route
County Road
Unimproved Dirt Road
Railroad
Bench Mark
Abandoned Quarry
Stream
Intermittent Stream
Pond
Bridge
Buildings
Old River Channel

GEOLOGIC MAP OF
HUNTERS ISLAND AND VICINITY
RILEY COUNTY, KANSAS.

Modified after Mudge, M.R, and Beck, H.V., 1948-49.

by Athar Husain, 1963.

Supervised by P.C.Twiss.

Department of Geology and Geography

Kansas State University.

DIFFERENTIATION BETWEEN RIVER AND DUNE SAND,
HUNTERS ISLAND AND VICINITY, RILEY COUNTY, KANSAS

by

ATHAR HUSAIN

B. S., Muslim University, 1956

M. S., Muslim University, 1958

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology and Geography

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

In this study an attempt has been made to determine if the grain size data show any significant differences between the river and dune sands from Hunters Island and vicinity, Riley County, Kansas. Dried samples of the two environments of deposition were seived using $\frac{1}{4}$ Ø intervals. Cumulative curves were constructed from grain and roundness data, and the grain size and roundness statistical parameters were determined graphically using Folk's (1961, p. 40-47) formulae.

The Kansas River sand consists of moderately well-sorted, bimodal to polymodal, negatively skewed, and platykurtic coarse sand (average mean grain size is 0.66 Ø, average σ_I is ±0.67 Ø, average grain size skewness is -0.38, and average grain size graphic kurtosis is 0.71). The dune sand consists of moderately well-sorted, bimodal to polymodal, positively skewed, and mesokurtic fine sand (average mean grain size is 2.5 Ø, average σ_I is ±0.66 Ø, average grain size skewness is +0.13, and grain size graphic kurtosis is 1.07). The "P" values for mean grain size and grain size skewness of the river and dune sands are less than 0.001 which indicate that these two parameters can be used to differentiate between the two environments of deposition. Plots of mean grain size against grain size skewness and any one of these two parameters against grain size standard deviation and grain size kurtosis show the two sands fall into two separate fields in the graph.

The river sand is subangular with moderate roundness sorting (average mean roundness 2.7ρ, average σ_ρ of ±0.92). The dune sand is subrounded with moderate roundness sorting (average mean roundness is 3.79, average $\sqrt{\sigma}$ is ± 0.90). The "P" value for mean roundness is 0.001 which indicates that the difference in mean roundness of the two sediments is significant. A plot of mean roundness against roundness standard deviation separates the two sediments into two separate fields in the graph.

The Kansas River sand consists of large quantities of quartz in the sand and silt size grains and small quantities of granules of limestone and chert. The dune deposits have been derived by removal of the fine particles from the Kansas River sand. The negative skewness of the Kansas River sand is caused by the granules of limestone and chert. The positive skewness of dune sand is caused by removal of the fine particles from the Kansas River sand. The hornblende-epidote assemblage of river and dune sediment indicates that both the sands have been derived from the same source. The immediate source of the river sand is the eölian deposits of northcentral Kansas and the Dakota Sandstone. The immediate source of the dune sand is the Kansas River sand. Both sediments are also affected locally by outcropping rocks and soils as indicated by the bimodality and polymodality, and the two sizes (3.25 ϕ and 4 ϕ) of hornblende, zircon, apatite, and magnetite.