# SEDIMENTATION STUDIES IN THE SABINO CANYON AREA NEAR TUCSON, ARIZONA

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1961

## STATEMENT BY AUTHOR

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## ABSTRACT

The sediments of the Lower Sabino Canyon area near Tucson, Arizona have been transported and deposited in an arid environment, and as a result represent a departure from the typical fluvial deposit. The lack of precipitation in the region has two effects upon the sediments. Chemical weathering of the canyon slope and stream materials is almost completely lacking. As the second consequence, sediments are not transported for long distances or over long periods of time, and as a result the physical changes of the stream materials are very slight.

The slope and stream deposits are primarily sandy gravels and gravelly sands, poorly to moderately sorted, and angular to subangular. Values of the mean size, inclusive graphic standard deviation, inclusive graphic skewness, and graphic kurtosis help to illustrate the

apparent coarseness and general lack of sorting of the sediments.

Mineralogically, the sediments reflect the composition of the source rock, the Catalina gneiss. Feldspar dominates quartz while garnet is the dominant mineral of the two heavy mineral groups—garnet-magnetite and epidote-hornblende-apatite.

## TABLE OF CONTENTS

Page

## LIST OF TABLES



## LIST OF ILLUSTRATIONS

# INTRODUCTION

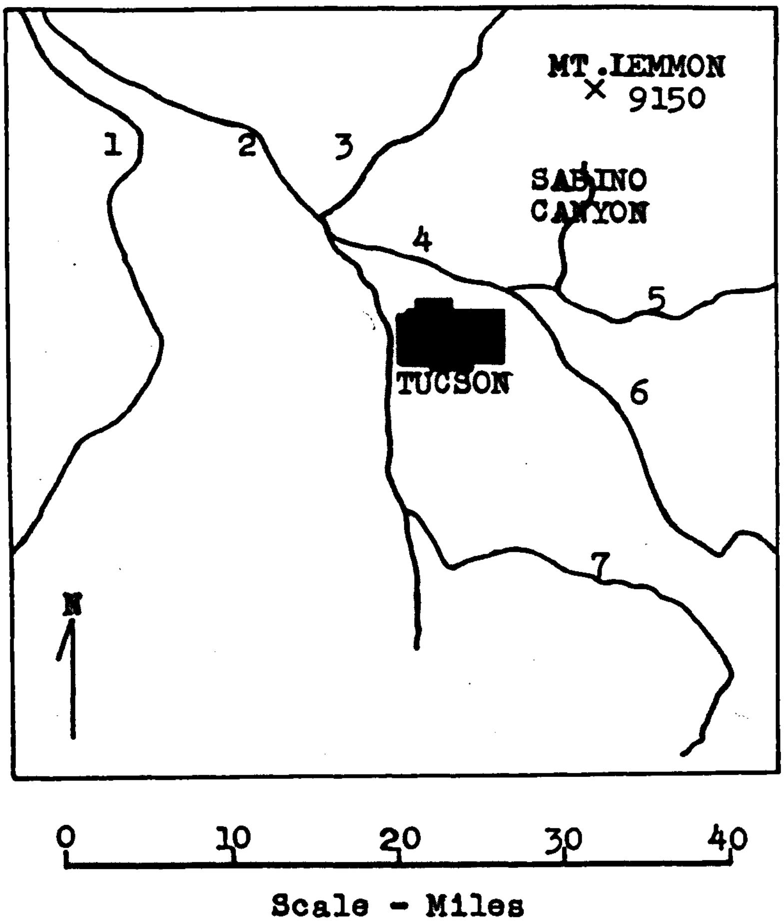
## Purpose of Investigation

The literature currently available on the geology of arid regions includes but a few papers which describe in detail the general sedimentational aspects. Several of these had their origin at the University of Arizona (Blissenbach, 1951; Voelger, 1953; Heindl, 1958), and four more are in progress or have been completed as part of the University's "Utilization of Arid Lands" project.

In the arid Southwest, much of the sediment has its origin in the mountains surrounding or adjoining the basins. The purpose of this investigation was to determine the origin, physical characteristics, and mode of transportation of the sediments in Lower Sabino Canyon, a typical arid regions canyon, located on the flank of a faulted anticlinal fold.

## Location of Area

The Lower Sabino Canyon area is located on the south flank of the Santa Catalina Mountains near Tucson, Arizona. Well known as a recreation area, it is easily reached by surfaced roads, and is only 7 miles from the eastern city limits of Tucson (Fig. 1).




**Key to Major Streams**

1. Brawly Wash
2. Santa Cruz River
3. Canada Del Oro
4. Rillito Creek
5. Tanque Verde Creek
6. Pantano Wash
7. Stream without a name

FIGURE 1. — Index Map of the Area

The area of Lower Sabino Canyon studied lies in Sections 9, 10, 14, 15, 16, 21, 22, 27, 28, 32, and 33, T. 13 S., R. 15 E., and unsurveyed areas of T. 12 S., R. 15 E., Pima County, Arizona.

## Nature of Investigation

### Field studies

A total of 124 samples were collected from the Lower Sabino Canyon area and included sediments from canyon slopes, stream channels, rapids, pools, lateral pools, terraces, and artificial dams. The stream bed samples were obtained by channeling, while the slope samples were spot samples.

Field observations were also made during the 10-month sampling program. These observations concerned chiefly sediment source areas, slope angles, slope materials, canyon and stream channel widths and changes in these, sediment movement during periods of runoff, and the size of material transported during periods of rapid runoff versus periods of normal runoff.

### Laboratory studies

All of the samples were subjected to mechanical sieving to obtain particle-size distribution. Based on this data, cumulative curves were plotted on probability scale paper to obtain certain statistical parameters in order to characterize the sediments. The handling of these parameters, their meaning and results, are discussed later under SIZE ANALYSIS.

Heavy mineral separations of selected samples were made. A split of the heavy mineral crop was mounted on a petrographic slide, the grains identified, and a count made of over 300 grains to determine frequency distribution. The latter step was performed by traversing the slide with a micrometer stage.

Quartz-feldspar ratios of selected samples were obtained by counting grains mounted on 1 X 3 glass slides. The feldspars had been selectively stained using the procedure of Bailey and Stevens (1960). The large grain size of the quartz and the feldspar necessitated their mounting on larger slides in order to obtain 300 grains for counting. For this purpose, a micrometer stage mounted on plexiglas was substituted for the conventional glass stage of a binocular microscope. One half of the slide was counted first and then reversed in the holding clips of the stage to count the other half.

Binocular microscope examinations were also made of selected samples to determine the degree of angularity of the sediments.

## Acknowledgments

The writer wishes to express his appreciation to the following people for their assistance in the completion of this thesis. Joseph F.

Schreiber, Jr. suggested the problem and directed the field and laboratory studies; Stanley Buol of the Department of Agricultural Chemistry and Soils identified the soils and contributed helpful suggestions; and John F. Lance and Willard D. Pye discussed certain ideas with the writer.

Technical assistance for the paper was given by Bruce L. Miller who did the photographs.

## DESCRIPTION OF LOWER SABINO CANYON

### General Features

The overall length of Sabino Creek in the area studied is 11 miles. The upper 5.5 miles of the creek are in Sabino Canyon, while the downstream 5.5 miles wind from the mouth of Sabino Canyon (Pl. I) to the intersection with Tanque Verde Creek.

Lower Sabino Canyon does not have a uniform bottom width, but the average bottom width, from observations, appears to be about 80 feet, with narrow and wide places of less than 25 feet and more than 500 feet, respectively (Pl. II).

Slope angles are variable and range from less than 25 to 30 degrees in some areas, while in others they approach 85 degrees.

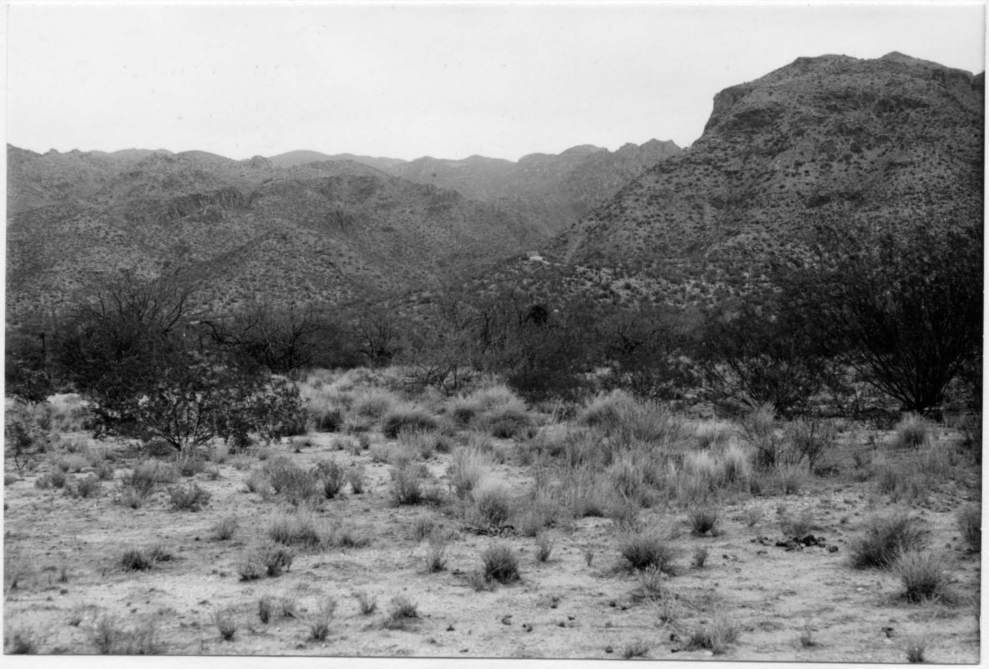
The average gradient of Sabino Creek is 180 feet per mile in the canyon, and beyond the mouth of the canyon, the average gradient is 58 feet per mile. Generally, the gradient drop is uniform along all of the creek course.

The Lower Sabino area has an annual mean temperature of 68 degrees. A high temperature approaching 110 degrees, and a low near 20 degrees are the usual extremes in an average year. An average of 11 inches of precipitation falls in the region annually, with less than half

## PLATE I

## MOUTH OF SABINO CANYON

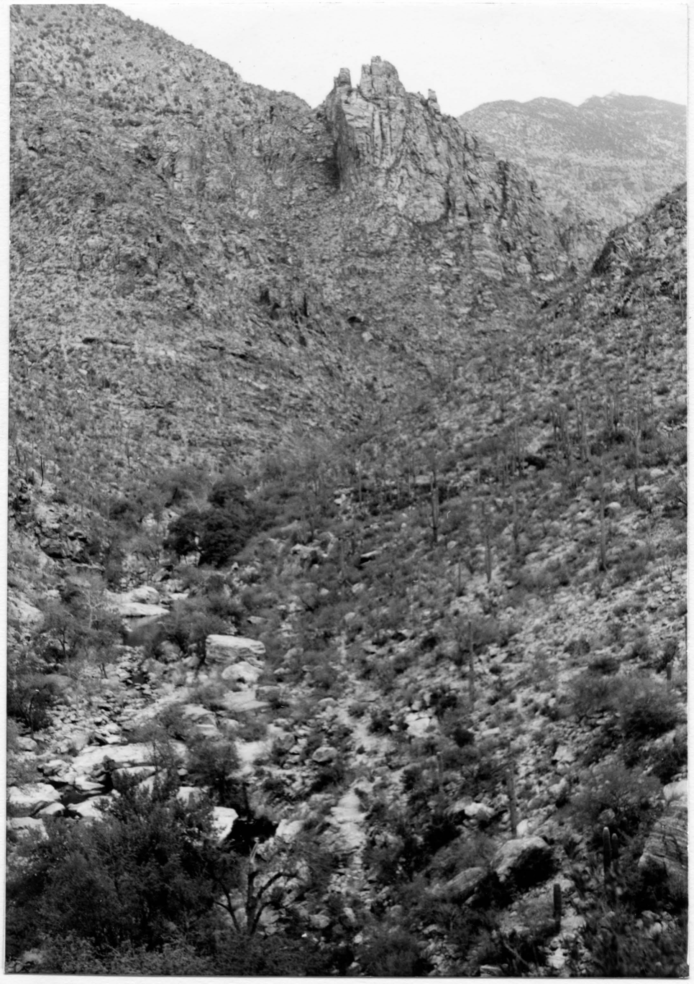
Mouth of Sabino Canyon as observed from the desert area to the south of the Santa Catalina Mountains.



## PLATE II

## GENERAL SCENE IN SABINO CANYON

Typical view of Sabino Canyon, illustrating the narrow, boulder-covered canyon bottom and the steep slopes, both characteristics of this area.



an inch being in the form of snow. Most of the rain falls during thunder-showers with as much as 1.5 to 2.0 inches falling from a single storm.

### Stream Discharge

The discharge of water in Sabino Creek is erratic because it is largely dependent upon good snow melts and large and sudden rainfalls.

For the period of this study, the United States Geological Survey Water Resources Branch records show that the largest total average discharge of water was 41.8 cubic feet per second during July 1960; of this total, 31.0 cubic feet per second was gaged on the 23d of the month. On July 22, no water flowed in measurable amounts, while on July 24, only 6.0 cubic feet per second moved by the measuring station on Sabino Creek.

The smallest monthly discharge occurred in June 1960 when a total average discharge of 0.12 cubic feet per second was recorded. All of the water moved at a daily rate of 0.01 cubic feet per second during the period from June 1 through June 12.

During a period of 128 days from September 22, 1960 to January 26, 1961, the largest daily discharge was 0.02 cubic feet per second. This period of drought was ended by a large rain storm on January 27 and 28, which brought the discharge rate up to 6.40 cubic feet per second on January 28.

This discussion indicates that most of the time Sabino Creek is dry, but even when runoff does occur it is slow to form and generally not violent in nature (Pl. III).

## General Geology

### Rock types

Lower Sabino Canyon is composed of a metamorphic rock complex called the Catalina gneiss, which includes such rock types as augen gneiss, banded augen gneiss, and gneissic granites (DuBois, 1959).

Minerals contained in the Catalina gneiss include: orthoclase, plagioclase, quartz, muscovite, biotite, garnet, magnetite, epidote, zircon, tourmaline, staurolite, ilmenite, and hematite.

Pegmatite dikes of various widths are numerous in certain portions of the area. Minerals present in the dikes include: quartz, orthoclase, plagioclase, muscovite, biotite, garnet, magnetite, ilmenite, fluorite, hornblende, augite, apatite, and topaz(?).

No other rock types, with the exception of one small diabase dike, have been noted as occurring or observed in the area studied.

### Types of weathering

Chemical weathering is almost negligible in its effects upon the rocks and slope soils of the Lower Sabino Canyon area. The

PLATE III

CHANNEL FLOW

Typical slow, shallow water moving downstream over a very narrow bedrock and boulder channel floor.

conclusions for an apparent lack of chemical attack in this region is taken from the following evidence:

1. A low to negligible calcium carbonate content at any depth in slope soils.
2. A low to negligible clay content at any depth in the slope soils.
3. A lack of alteration of feldspars in slope soils and channel deposits.
4. No apparent rounding of feldspar grains in the slope soils.

Water, heat of the sun, and growing plants, as agents of physical weathering, are the dominant rock-crumbling forces in the area studied. These agents, which operate with the assistance of sharp atmospheric changes, have also been noted as major rock-crumbling forces in the Globe area, which is 75 miles north of the Lower Sabino Canyon area (Ransome, 1903).

Soil types

The slope soils in the canyon are severely eroded, non-calcic, brown soils grading into lithosols (Buol, personal communication, 1961).

A good A soil zone is not developed in the area. This situation is probably the result of a stripping effect caused by the erosive power of rapidly moving runoff water. The B soil zone contains up to 15 percent clay, but in general, clay is completely lacking or occurs in negligible amounts in about 90 percent of the horizon. At an average depth of 1 foot from the surface, a C soil zone is encountered, and is composed of angular rock fragments of various sizes.

## THE SEDIMENTS OF THE CANYON

### Area of Deposition

#### Slope

The slope deposits are composed of various materials ranging in size from coarse silt to 10-foot boulders (Pl. IV). Some deposits of soils are also found in the area, but these are not common or large. The particles of the soil horizon range in size from medium silt to very fine gravel.

The larger sizes are composed of rock fragments and mineral grains such as, quartz, orthoclase, plagioclase, and muscovite. Minor amounts of biotite, garnet, and magnetite have also been observed in the slope materials, but only in places where the underlying bedrock contains these minerals.

#### Channel

The stream channel deposits are extremely variable in size range and volume. Some stretches of the channel are completely covered with large rounded boulders but with very little sand (Pl. V); at the other extreme, the channel contains mostly sand. The typical

## PLATE IV

## SLOPE MATERIAL

Slope material covering an area having a slope of 35 degrees. Note the various sizes and typical angularity of the sediment.

## PLATE V

## BOULDER-COVERED STREAM CHANNEL

A view of the channel of Sabino Creek near stream ford 9 illustrating the rounded boulders covering the stream bed, a characteristic of the Lower Sabino Canyon area. Note the lack of sand deposits in or adjacent to the channel.

channel deposit consists of very fine gravel and very coarse and coarse sand with included or bordering boulders. The large boulders show the best rounding probably because of a major amount of abrasion by flowing water, and a minor amount of actual movement. Deposits of fine gravel and coarse sand contain angular fragments for the most part.

The deposits of stream rapids are generally found at the inlets and outlets of pools in the Sabino Creek channel (Pl. VI). The deposits are composed of very coarse sands with some deposits being heavily contaminated with very fine gravel and water-worn boulders.

Many pools of various sizes and shapes are located along the entire course of Sabino Creek within the canyon, and all are good depositional basins for sediments. The deposits are largely composed of very coarse sand with included amounts of very fine gravel and minor amounts of coarse sand. The apparent decrease in the amount of larger sized materials in pools appears to be caused by entrapment in a depression as a result of a sudden loss of water velocity as the transporting water enters from a narrow rapids region.

A few small, shallow lateral pools which branch from the main channel of Sabino Creek are minor depositional areas. Commonly these bodies of water are formed behind natural dams such as, sand and boulder deposits (Pl. VII), tree roots, and bedrock outcrops. During periods of evaporation, these pools are the first to stagnate and dry up. The sediments in lateral pools are very coarse sand and coarse sand

PLATE VI

RAPIDS AND POOL AREA

Small rapids on downstream side of a pool which is formed within barriers of bedrock. Note the large size of the boulders that line the pool perimeter.

## PLATE VII

## A LATERAL POOL

A stagnant lateral pool upstream from stream ford 4 which has formed behind a boulder and sand dam. The main stream channel is moving from left to right behind the large, massive boulder.

with minor amounts of very fine gravel and medium sand included in the deposits. A decrease in size of the particles is probably the result of deposition in a quiet, restricted body of water during the stages of large, flooding runoffs.

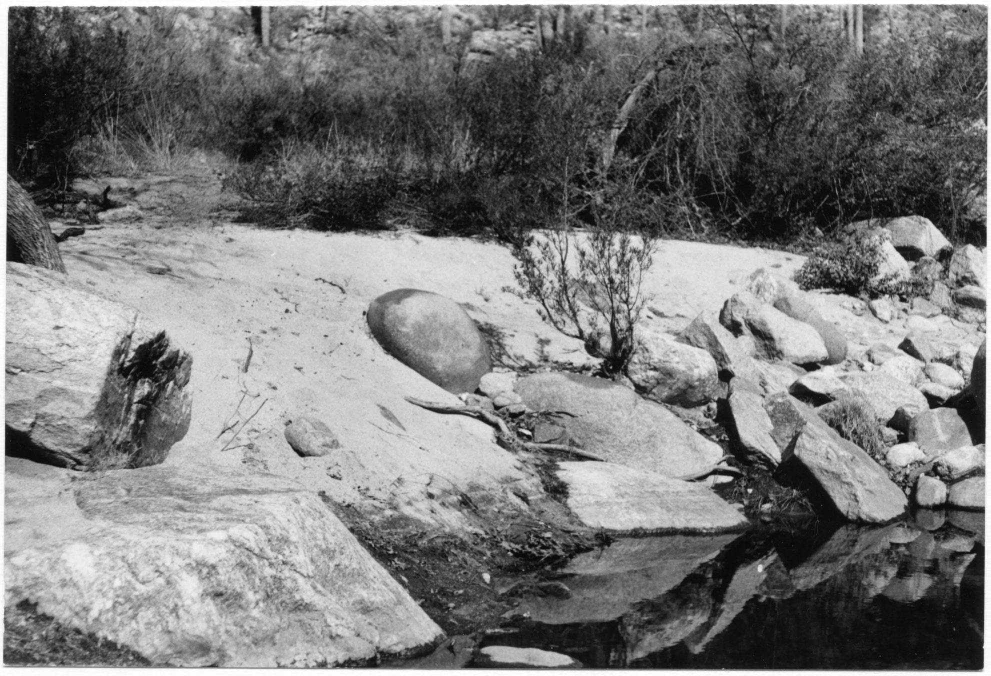
All of the deposits in the various depositional areas of the channel contain the same types of materials. Orthoclase, plagioclase, rock fragments, quartz, and muscovite are the major constituents in channel sediments, while biotite, garnet, magnetite, epidote, hornblende, and apatite occur in minor quantities.

Terrace

Terrace deposits are common, especially in some of the wider stretches of the canyon, and occur adjacent to large pools (Pl. VIII). This relationship between the pools and terraces appears to bring out the fact that the terrace deposits are probably the result of flood stage deposition by Sabino Creek.

Coarse the medium sand makes up the terrace deposits. Small amounts of very coarse sand and very fine gravel are included in some terraces, but this situation is exceptional.

The prevalent materials in these deposits are orthoclase, plagioclase, and muscovite, with minor amounts of quartz and biotite. The occurrence of muscovite in major amounts in terraces is a distinguishing feature in separating this type of deposit from a channel



deposit through mineralogical means. Heavy minerals such as, epidote, garnet, apatite, and magnetite occur as disseminated grains in all terrace deposits but are found in small amounts.

Artificial dam

Nine concrete stream fords, 3 small concrete dams, and 1 large concrete dam interrupt the course of Sabino Creek. These artificial stream barriers have trapped much material on their upstream side (Pl. IX), and therefore are major depositional areas in the Lower Sabino Canyon area.

The material deposited behind the dams is composed of all sizes of sediments with very fine gravel and very coarse sand dominating.

PLATE IX

STREAM FORD TRAPPING SEDIMENTS

The stream ford is trapping material on its upstream side (right) so that the downstream side (left) is relatively barren of sand.

## SIZE ANALYSIS

All of the slope materials from Lower Sabino Canyon that were studied are classified as sandy gravels and gravelly sands. The average slope deposit contains over 48 percent very fine gravel.

The sediments of Sabino Creek are rather coarse in nature with over 90 percent being sandy gravel and gravelly sand while the remaining materials are composed of slightly gravelly sand. No major deposits of materials with a size of a fine sand or less were observed along the entire length of the stream course.

Typical histograms and cumulative curves (Figs. 2 and 3) illustrate the large grain size and degree of sorting. The curves and histograms represent all types of deposits in and adjacent to the Sabino Creek channel (Fig. 4).

In analyzing the sediments, four statistical parameters were used. They are the mean size ($M_Z$), inclusive graphic standard deviation ($\sigma_I$), inclusive graphic skewness ($Sk_I$), and graphic kurtosis ($K_G$). These parameters were adapted from the work of Inman (1952) and Folk and Ward (1957). These parameters make use of a greater portion of the cumulative curve than do the older quartile measures of Krumbein

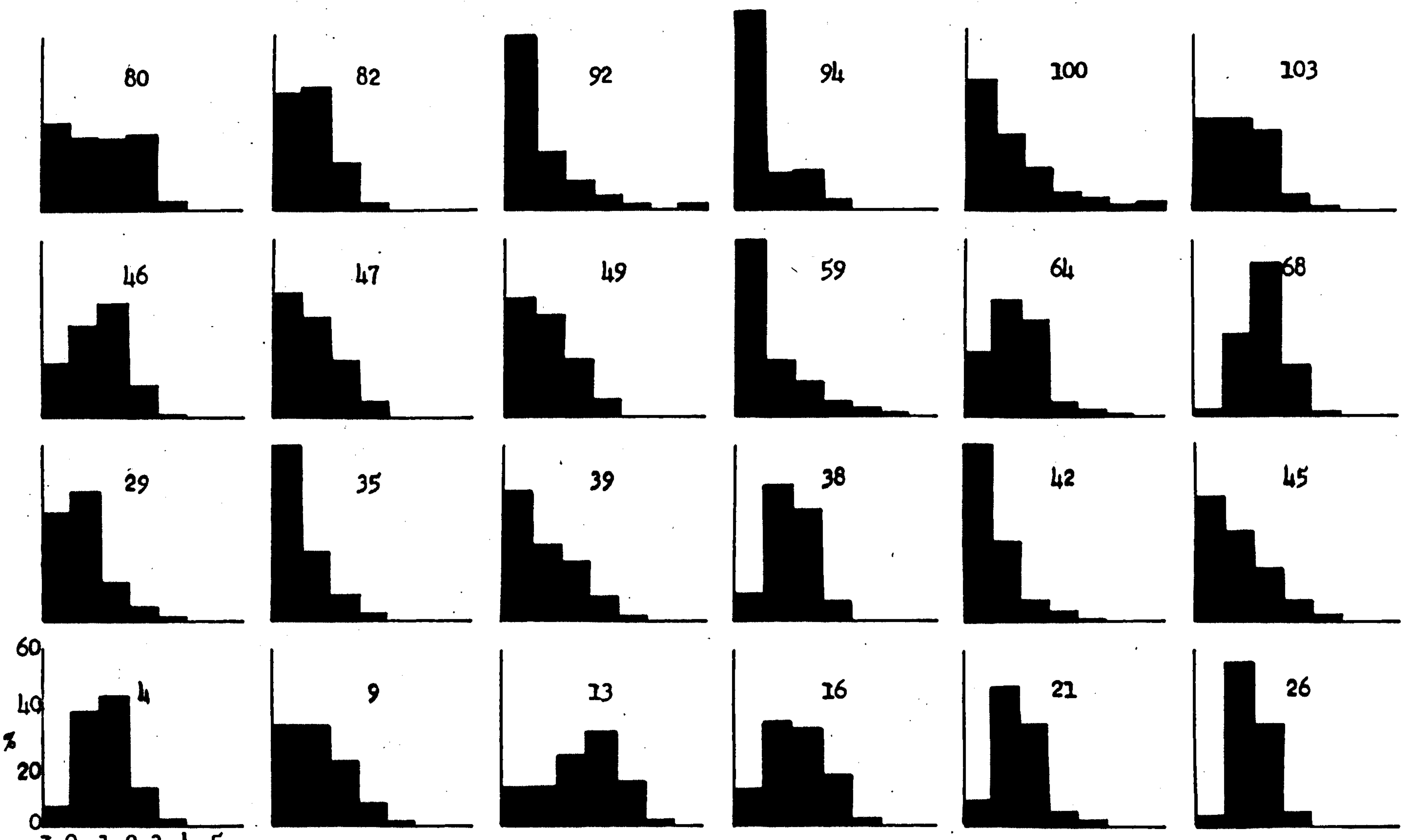



FIGURE 2. — Typical Histograms

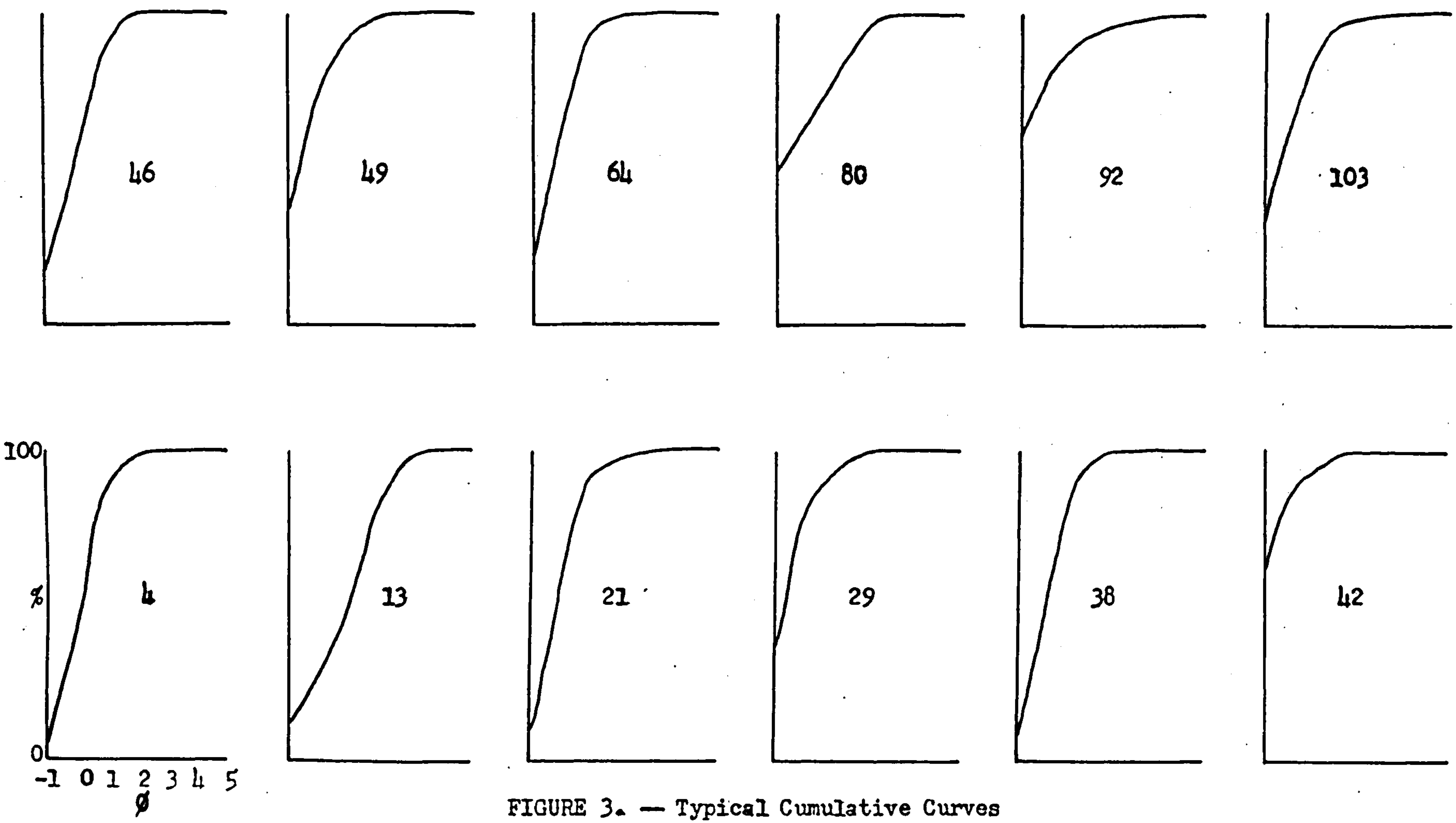



FIGURE 3. — Typical Cumulative Curves

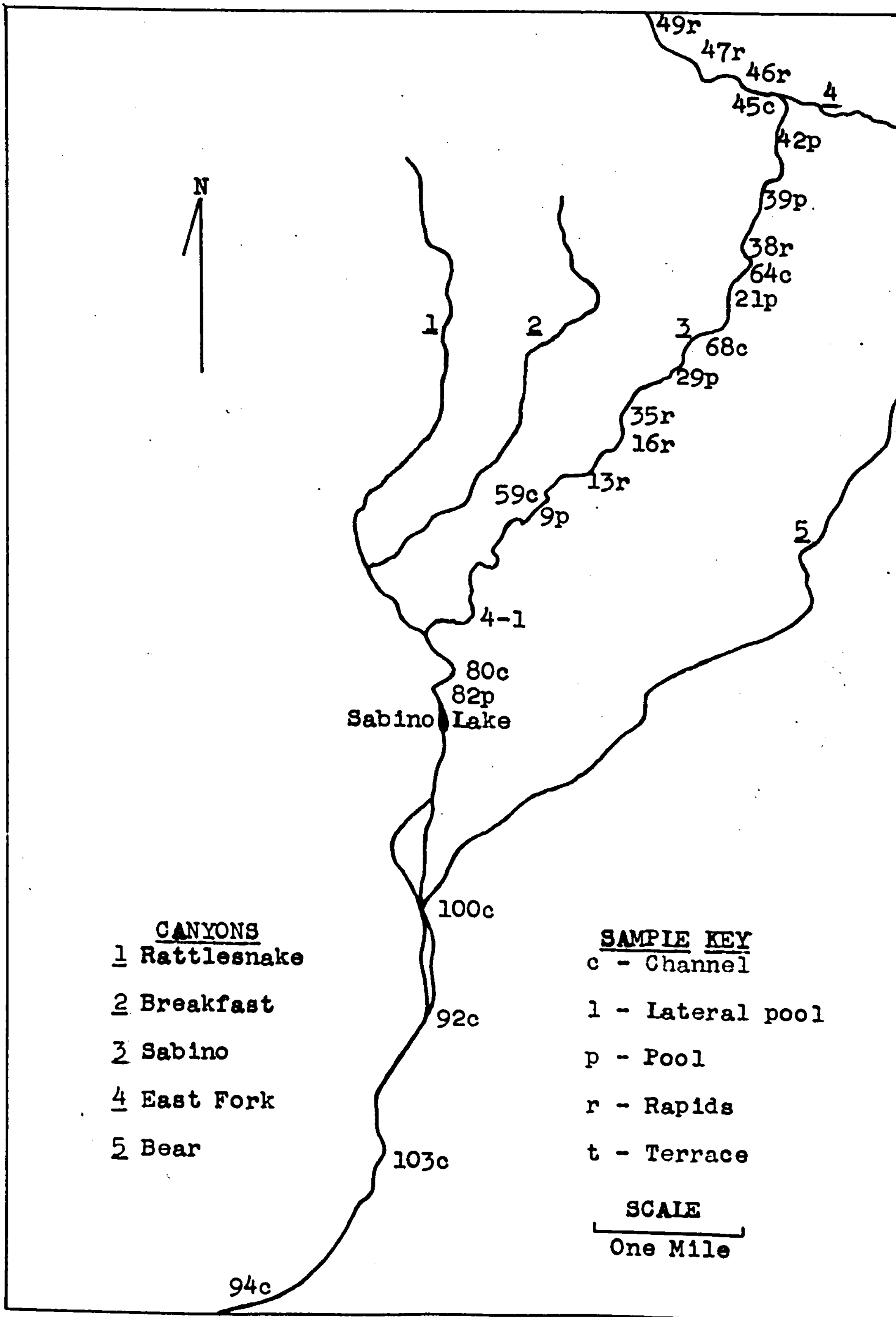



FIGURE 4. — Typical Sample Locations on Sabino Creek

and Pettijohn (1938). The phi ($\phi$) values at 5, 16, 25, 50, 75, 84, and 95 percentiles were read from the cumulative curve and substituted in the following formulae:

Mean Size:

$$M_z = \frac{P_{16} + P_{50} + P_{84}}{3}$$

Inclusive Graphic Standard Deviation:

$$\sigma_I = \frac{P_{84} - P_{16}}{4} + \frac{P_{95} - P_5}{6.6}$$

Inclusive Graphic Skewness:

$$Sk_I = \frac{P_{84} + P_{16} - 2(P_{50})}{2(P_{84} - P_{16})} + \frac{P_{95} + P_5 - 2(P_{50})}{2(P_{95} - P_5)}$$

Graphic Kurtosis:

$$K_G = \frac{P_{95} - P_5}{2.44(P_{75} - P_{25})}.$$

The phi scale of Krumbein and Pettijohn (1938) is used since these values are easier to manipulate in computations than millimeter values. A phi value is equal to: $-\log_2 \text{dia}_{mm}$. Corresponding phi-millimeter units are listed below:

$-2\phi = 4.000$ mm.

$-1\phi = 2.000$ mm.

0ø = 1.000 mm.

1ø = 0.500 mm.

2ø = 0.250 mm.

3ø = 0.125 mm.

4ø = 0.063 mm.

5ø = 0.031 mm.

6ø = 0.016 mm.

The coarseness of the sediments in the area is illustrated by the negative phi values of the mean size. The majority of all the sediments shows a mean phi range from 1.00 to -1.95, with only 3 samples studied having a value greater than plus 1.00 phi. A typical mean size was not established for any of the different types of deposits. Uniformity of sediment types appears to be the case in Lower Sabino Canyon sedimentary deposits.

The following verbal limits have been set by Folk and Ward (1957) to describe the sorting expressed by inclusive graphic standard deviation:

| $\sigma_I$ Value | Sorting |
|---|---|
| Under 0.35 | Very Well Sorted |
| 0.35-0.50 | Well Sorted |
| 0.50-1.00 | Moderately Sorted |
| 1.00-2.00 | Poorly Sorted |

| $\sigma_I$ Value | Sorting |
|---|---|
| 2.00-4.00 | Very Poorly Sorted |
| 4.00-Higher | Extremely Poorly Sorted |

The standard deviation values obtained from the sediment studies show that poor to moderate sorting is characteristic of all of the deposits of the area. Over 57 percent are poorly sorted, while over 42 percent are moderately sorted, with one sample being well sorted. The best sorting was 0.37, and the worst sorting had a value of 1.98. None of the deposits have a characteristic sorting value.

The full significance of skewness and kurtosis values in sediment studies has not been realized. Many writers believe these parameters to have environmental significance; therefore, they are included for future reference (Appendix II).

Skewness is a measure of the symmetry of a size distribution curve, and may be either positive or negative. If the skewness value is positive, the tail of the curve is in small diameter material; but, if the value is negative, the long tail of the curve is in the coarse sediments. The average skewness value obtained in the study is 0.08, with an extreme high of 0.35 and an extreme low of -0.18.

The kurtosis values are a measure of the peakedness of a size distribution curve, with values greater than 1.00 indicating a curve with a high, relatively thin central peak, and with values less than 1.00

indicating a curve having a large, broad, square-shouldered central peak. In Sabino Canyon materials, the average kurtosis value is 1.02 with a high value of 1.28 and a low value of 0.71.

## Angularity Studies

The slope materials and stream deposits have similar features of angularity in almost all of the area studied. With the exception of some channel deposits near the Sabino Creek-Tanque Verde Creek intersection, all sediments are angular to subangular. The only particles not showing angular features are subrounded grains in the previously mentioned channel deposits near the mouth of Sabino Creek.

The lack of rounding of the sediments in transport appears to indicate that, even though Sabino Creek is a mountain stream, the short distance of transport makes abrasion and chemical weathering almost completely ineffective. This feature of the Lower Sabino Canyon area opposes the findings of Plumley (1948) in his work on streams of the Black Hills of South Dakota, which are in a sub-humid environment.

Boulders in all sections of the channel are subrounded to rounded, but this appears to be the result of abrasion and wear by moving sediments and a minor amount of movement in the channel. Studies have been started recently to determine how, when, and how much these boulders are transported, if at all.

## Mineral Analyses

All deposits of the area contain the light minerals, feldspar, quartz, and mica, and the heavy minerals, garnet, magnetite, and epidote. The average sediment contains about 65 percent feldspar, 30 percent quartz, 3.5 percent mica, and 1.5 percent heavy minerals.

All of the light minerals are angular to subangular along the entire course of Sabino Creek, except near its mouth, where the feldspars and quartz show some subrounding.

The heavy minerals observed and investigated during the study are described in detail.

Apatite. Colorless, euhedral to anhedral, angular to subangular grains, no pitting, fracturing, or etching; occurs primarily in the 3Ø and 4Ø fractions, and makes up over 4 percent of the heavy minerals studied.

Biotite. Mottled brown to black, subhedral to anhedral, angular grains, alteration lacking, except in a few grains where chlorite had formed along the edges of the grains; common in all sediments of the area, especially in the 3Ø and 4Ø fractions.

Epidote. Yellowish-green, subhedral to anhedral, angular grains, some inclusions, no pitting, fracturing, or etching; has a size range from 2Ø to 4Ø, and is third in abundance in the heavy minerals.

Garnet. Reddish-brown to pale pink, euhedral to anhedral, angular grains, no inclusions, pitting, fracturing, or etching; has a size range of 0Ø to 4Ø with most grains in the 2Ø fraction, and is the most common of the heavy minerals in the area, occurring as disseminated grains and concentrations in very fine gravel and very coarse sand (Pl. X).

Hornblende. Greenish-brown to green, anhedral, angular to subangular grains, no pitting or etching, but cleavage fractures common; occurs in large amounts in 1Ø and 2Ø fractions of almost all deposits.

Magnetite/Ilmenite. Metallic black, euhedral to anhedral, angular to subangular grains, no pitting, fracturing, or etching. These opaques are abundant in all fractions from -1Ø to 4Ø, and occur in all types of deposits as concentrates and disseminated grains. When speaking of this group, the term magnetite is used because it is the dominant mineral.

Other heavy minerals identified include: andalusite, analcite(?), augite, fluorite, sphene, topaz(?), tourmaline, and zircon. The mineral staurolite was not found in any of the deposits studied, although it is reported to occur in the Catalina gneiss (DuBois, 1959).

## PLATE X

## GARNET CONCENTRATES

Concentrations of garnet with coarser light minerals in a stream channel deposit. The dominant coarse material is feldspar and one large grain of muscovite (upper left corner).

# SEDIMENT TRANSPORTATION

## Time and Nature of Transport

A definite and limited amount of time exists during water movement for sediment transport in Sabino Creek. Since most of the sediment in the canyon area is composed of very fine gravels and very coarse sands, transport will occur only during periods of increased water velocity. From observations and studies of various locations, the most effective period of stream transport occurs within a period of 1 to 3 days after a major rain storm or snow melt. After a period of 3 days, even though water continues to flow in the creek channel, the discharge of water diminishes enough to cause a sharp drop in sediment transport, with the exception of fine sands and coarse silts.

The materials are moved by rolling, saltation, and in suspension. Each process, during an average stream runoff, will move only materials of certain size parameters. Materials having sizes greater than coarse sand are moved chiefly by rolling, with lesser amounts moving by saltation. Sediments in the size range from coarse sand to fine sand are moved chiefly by saltation, but also by rolling. Very fine sand and silt is transported almost entirely in suspension.

## Change in Sediments

Comparisons of samples along the 11-mile length of Sabino Creek show changes in certain parameters but none in others. The results of the study compare favorably with those obtained by Rittenhouse (1943) in New Mexico stream deposits.

Although it would be expected in most streams, selective wear and breakage of the sediments is not apparent in Sabino Creek. The sediments at the upper end of the area studied have mean sizes of 0ø to -1.40ø, while at the mouth of the creek, the range is from -0.80ø to -1.62ø.

Nearly all the detritus is angular to subangular. Some exceptions are found in a few feldspar and quartz grains which are subrounded. No definite patterns of change from angular to subangular forms was observed in any of the minerals present along the stream course.

Sorting of sediments is poor to moderate along the creek channel, with no pattern of sorting indicated. This feature appears to be a result of detrital contamination from canyon slopes and tributary streams. Eleven major canyon streams and over 100 slope and desert floodplain channels deliver sediments to Sabino Creek at various locations. If better sorting had developed for any stretch of the creek, it would soon be contaminated by debris from one of these heterogeneous sources. The role of contamination is well illustrated in the channel sediments immediately upstream from the mouths of Rattlesnake and Bear Canyons; here they are moderately sorted, while downstream from the canyon mouths, they are poorly sorted.

From observations and from the study of 10 short (7 inches) cores from the stream channel, it can be shown that the irregularity of stream velocity is reflected in the sediments (Table 1). Core 1 is from the channel 10 feet upstream from stream ford 5, while Core 2 is from a rapids located 20 feet upstream from stream ford 8.

Chemical analyses of water from Sabino Creek by the College of Agriculture of the University of Arizona suggest that little material is transported in solution. Only 690 parts per million of soluble salts are found in waters near the mouth of Sabino Canyon.

## Mineral composition

Quartz-feldspar ratios vary widely along the channel of Sabino Creek. The average sediment has a quartz-feldspar ratio of 0.59 with a maximum of 1.12 and a minimum of 0.25.

The heavy minerals show no change in size, angularity, or sorting along the stream course. Each major mineral has a characteristic average size, and generally occurs in sedimentary deposits with a phi size 2 to 3 sizes larger (Table 2). This is a good example of hydraulic equivalency (Rittenhouse, 1943; Pettijohn, 1957).

The heavy mineral occurrences are divisible into 2 major size

Table 1—Vertical Distribution of Sediments in Stream Channel

| Depth (Inches) | Description (Core 1) |
| --- | --- |
| 0-1/8 | 1ø to 2ø material deposited within 2 days after a heavy rain by fast but not violent flow of channel water during January 1961. |
| 1/8-1 | 3ø detritus with intermixed wood and leaf fragments; material deposited during a period of almost negligible stream discharge from August 1960 to January 1961. |
| 1-7 | -1ø to 0ø material deposited during a violent stream discharge, possibly following a large rain in mid-July 1960. |

| Depth (Inches) | Description (Core 2) |
| --- | --- |
| 0-3/8 | 0ø to 1ø sediment probably deposited by rapidly moving water in January 1961. |
| 3/8-1 7/8 | -3ø to -2ø material deposited in swift, violent water during a rapid and large stream discharge, possibly in July 1960. |
| 1 7/8-3 3/4 | 2ø material cemented by organic-rich silts; material represents deposition during erratic (fast and slow) flow, but non-violent discharge periods. |
| 3 3/4-5 | -3ø to 0ø materials deposited by fast, violent stream discharges. |

Table 2—Heavy and Light Mineral Relationships

| Heavy Mineral | Sp. Gr. | Ø Size | Light Mineral Ø Size |
|---|---|---|---|
| Garnet | 3.80 | 1 | -1 |
| Magnetite | 5.17 | 1 | -1 |
| Epidote | 3.37 | 3 | 0 |
| Hornblende | 3.15 | 2 | 0 |
| Apatite | 3.20 | 3 | 0 |

* Average light mineral specific gravity is about 2.65

groups—the garnet-magnetite and the epidote-hornblende-apatite.

## SEDIMENTATION IN SABINO LAKE

Sabino Lake is a small, artificial lake located 1/4 of a mile downstream from the mouth of Sabino Canyon. The dam of rock and concrete was built in 1936-37, and is 100 feet long and stands 12 feet above the channel floor of Sabino Creek. The lake occupies an area of 30,000 square feet, and has a maximum depth of about 7 feet at crest level immediately behind the dam.

Sabino Lake serves as a trap for the sediments moving downstream to Tanque Verde Creek. The lake sediments were studied using the same techniques as those for the Sabino Creek sediments, and the results were almost identical. At the present time the lake basin is almost filled with the detritus from the drainage area feeding it.

## SEDIMENTATION IN ADJACENT CANYONS

Field observation and some laboratory studies of the sediments in Bear, East Fork of Sabino, Rattlesnake, and Sycamore Canyons yielded results similar to those for the Lower Sabino Canyon sediments.

Of the 15 samples studied from the adjacent canyons, 9 were gravelly sand, with the other 6 being sandy gravel. All of the slope and channel materials were composed of feldspar, quartz, mica, and minor amounts of heavy minerals, and thus reflect the mineral composition of the Catalina gneiss, which is the host rock.

The mean size values for sediments in canyons other than Lower Sabino were obtained from Bear and East Fork of Sabino Canyons. The average values are -0.57ϕ and -0.70ϕ respectively. All of the materials are angular to subangular.

Poorly sorted sediments are most common. The average inclusive graphic standard deviation values are: Bear -1.13, East Fork of Sabino -1.32, and Sycamore -1.03.

Quartz-feldspar ratios are variable along Bear Canyon, with an average ratio of 0.42, with a maximum of 0.62, and a minimum of 0.26. No light mineral changes of any consequence were noted with respect to size, angularity, or sorting in any of the adjacent canyons.

Heavy minerals were observed in all types of deposits in the canyons studied, and were found as disseminated grains and concentrates. Garnet is the most abundant heavy mineral with the largest deposits occurring in Bear Canyon. The individual characteristics of the minerals such as, size, angularity, and sorting are all similar to those obtained in Lower Sabino Canyon studies.

## SUMMARY AND CONCLUSIONS

The main features associated with the origin, transportation, and deposition of the sediments of the Lower Sabino Canyon area are given in the following list.

1. The rock fragments, light minerals, and heavy minerals contained within the slope and stream deposits reflect the mineralogical composition of the host rock, the Catalina gneiss.

2. Physical weathering is the dominant rock-crumbling force operating upon the sedimentary materials on the slopes and in the stream channel.

3. Most of the transport of materials to and in the stream takes place during large water runoffs, which are the result of a rapid snow melt or heavy rainfall.

4. The typical sediment in any deposit is either a sandy gravel or a gravelly sand, poorly to moderately sorted, and angular to subangular.

5. During stream transport, little change in physical characteristics such as, size, angularity, and sorting occurs.

6. Quartz-feldspar ratios illustrate the fact that feldspar is the dominant light mineral in the slope and stream deposits.

7. The heavy minerals are represented by two groups, the garnet-magnetite, and the epidote-hornblende-apatite, with the former being the more common.

8. Sediments in Sabino Lake and adjacent canyons such as, Bear, East Fork of Sabino, Rattlesnake, and Sycamore have physical characteristics which closely resemble those of the Lower Sabino Canyon materials.

The foregoing material characterizes the current arid environment, and could be used to help visualize transport in paleoenvironments. The physical characteristics of the sediments could also be compared with those of ancient sediments to help interpret their conditions of deposition.

APPENDICES

Appendix I
Mechanical Composition of Sediments
(All figures in percent by weight)

| Sample No. | Ø Size -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 2.7 | 20.4 | 50.3 | 23.8 | 2.4 | 0.2 | 0.2 |
| 2 | 12.7 | 38.3 | 21.8 | 9.9 | 12.0 | 4.3 | 0.8 | 0.2 |
| 3 | 0.7 | 10.5 | 28.7 | 34.8 | 19.7 | 4.5 | 0.7 | 0.4 |
| 4 | 0.0 | 5.7 | 38.1 | 42.8 | 11.6 | 1.3 | 0.3 | 0.1 |
| 5 | 0.0 | 4.3 | 17.1 | 27.9 | 22.8 | 16.8 | 7.5 | 3.1 |
| 6 | 0.0 | 16.7 | 43.5 | 28.5 | 9.0 | 1.5 | 0.4 | 0.4 |
| 7 | 11.1 | 13.5 | 22.4 | 23.9 | 19.0 | 7.7 | 1.7 | 0.7 |
| 8 | 0.0 | 3.6 | 10.9 | 42.7 | 37.6 | 4.5 | 0.5 | 0.2 |
| 9 | 11.8 | 24.0 | 35.0 | 22.4 | 6.8 | 1.0 | 0.1 | 0.1 |
| 10 | 5.5 | 30.3 | 41.5 | 14.2 | 5.9 | 1.8 | 0.5 | 0.3 |
| 11 | 10.3 | 16.8 | 24.0 | 29.0 | 15.7 | 3.4 | 0.5 | 0.3 |
| 12 | 1.3 | 5.8 | 16.4 | 25.9 | 29.8 | 16.8 | 3.3 | 0.7 |
| 13 | 2.9 | 10.5 | 13.8 | 23.8 | 31.9 | 14.8 | 1.8 | 0.5 |
| 14 | 33.1 | 21.7 | 13.2 | 13.4 | 14.7 | 3.2 | 0.5 | 0.2 |
| 15 | 12.3 | 20.0 | 22.6 | 24.9 | 16.3 | 3.3 | 0.5 | 0.1 |
| 16 | 1.7 | 11.0 | 34.9 | 32.6 | 16.9 | 2.3 | 0.4 | 0.2 |
| 17 | 0.0 | 3.8 | 13.3 | 23.7 | 27.4 | 22.5 | 7.2 | 2.1 |
| 18 | 4.7 | 38.3 | 40.6 | 13.5 | 2.5 | 0.3 | 0.1 | 0.0 |
| 19 | 0.0 | 1.0 | 20.7 | 54.3 | 21.3 | 2.2 | 0.4 | 0.1 |
| 20 | 0.0 | 9.9 | 46.9 | 31.9 | 7.7 | 2.4 | 0.9 | 0.3 |

| Sample No. | -2 | -1 | 0 | Ø Size 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 21 | 0.0 | 8.8 | 48.1 | 35.3 | 4.9 | 2.3 | 0.5 | 0.1 |
| 22 | 0.0 | 12.6 | 44.6 | 36.2 | 6.0 | 0.4 | 0.1 | 0.1 |
| 23 | 0.0 | 15.4 | 35.1 | 36.6 | 11.7 | 1.0 | 0.1 | 0.1 |
| 24 | 3.4 | 15.0 | 31.6 | 21.4 | 17.0 | 9.3 | 1.9 | 0.4 |
| 25 | 11.4 | 15.8 | 40.2 | 25.6 | 6.1 | 0.9 | 0.0 | 0.0 |
| 26 | 0.0 | 3.9 | 56.0 | 34.8 | 4.9 | 0.2 | 0.1 | 0.1 |
| 27 | 22.5 | 27.4 | 25.1 | 16.4 | 7.2 | 1.1 | 0.2 | 0.1 |
| 28 | 0.0 | 8.6 | 46.4 | 32.6 | 10.9 | 1.3 | 0.1 | 0.1 |
| 29 | 1.3 | 35.5 | 44.2 | 12.7 | 5.2 | 0.9 | 0.1 | 0.1 |
| 30 | 3.8 | 16.0 | 36.6 | 37.3 | 5.7 | 0.3 | 0.2 | 0.1 |
| 31 | 13.0 | 29.1 | 37.6 | 15.3 | 4.4 | 0.4 | 0.1 | 0.1 |
| 32 | 9.2 | 13.9 | 27.4 | 31.8 | 14.5 | 2.6 | 0.4 | 0.2 |
| 33 | 10.5 | 26.1 | 36.4 | 21.4 | 5.2 | 0.4 | 0.0 | 0.0 |
| 34 | 30.3 | 32.3 | 25.6 | 9.5 | 2.1 | 0.1 | 0.0 | 0.1 |
| 35 | 31.0 | 32.8 | 24.3 | 9.4 | 2.3 | 0.1 | 0.1 | 0.0 |
| 36 | 0.0 | 5.2 | 32.2 | 42.6 | 17.5 | 2.3 | 0.1 | 0.1 |
| 37 | 20.1 | 13.5 | 22.7 | 33.3 | 10.0 | 0.3 | 0.1 | 0.0 |
| 38 | 0.0 | 8.9 | 46.1 | 37.9 | 6.8 | 0.2 | 0.1 | 0.0 |
| 39 | 14.1 | 30.5 | 26.2 | 19.6 | 8.1 | 1.3 | 0.1 | 0.1 |
| 40 | 14.4 | 17.8 | 35.6 | 22.3 | 8.4 | 1.3 | 0.1 | 0.1 |
| 41 | 0.0 | 1.7 | 10.1 | 23.8 | 32.9 | 20.6 | 7.9 | 3.0 |

| Sample No. | -2 | -1 | 0 | Ø Size 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 42 | 32.8 | 29.1 | 26.9 | 7.4 | 3.2 | 0.5 | 0.1 | 0.0 |
| 43 | 8.7 | 34.3 | 28.0 | 24.1 | 4.2 | 0.4 | 0.1 | 0.2 |
| 44 | 17.9 | 25.2 | 32.0 | 17.9 | 5.5 | 1.2 | 0.2 | 0.1 |
| 45 | 21.0 | 21.3 | 30.5 | 17.8 | 7.4 | 1.8 | 0.2 | 0.0 |
| 46 | 4.6 | 13.8 | 31.4 | 38.8 | 10.9 | 0.4 | 0.0 | 0.1 |
| 47 | 7.1 | 34.6 | 34.1 | 19.2 | 4.9 | 0.1 | 0.0 | 0.0 |
| 48 | 8.4 | 19.0 | 37.3 | 25.4 | 8.2 | 1.5 | 0.2 | 0.0 |
| 49 | 7.9 | 31.7 | 34.5 | 19.1 | 6.1 | 0.7 | 0.0 | 0.0 |
| 50 | 21.4 | 21.9 | 27.8 | 17.3 | 9.1 | 2.1 | 0.3 | 0.1 |
| 51 | 0.0 | 14.6 | 37.9 | 34.0 | 11.8 | 1.4 | 0.2 | 0.1 |
| 52 | 5.3 | 35.5 | 37.1 | 16.5 | 5.2 | 0.3 | 0.1 | 0.0 |
| 53 | 20.5 | 22.5 | 32.3 | 16.7 | 6.3 | 1.3 | 0.3 | 0.1 |
| 54 | 9.8 | 14.6 | 32.8 | 29.8 | 11.8 | 0.9 | 0.2 | 0.1 |
| 55 | 1.8 | 27.8 | 43.3 | 20.8 | 5.7 | 0.4 | 0.1 | 0.1 |
| 56 | 0.0 | 1.2 | 9.5 | 26.2 | 38.4 | 20.2 | 3.3 | 1.2 |
| 57 | 30.0 | 18.3 | 20.6 | 16.7 | 11.6 | 2.3 | 0.3 | 0.2 |
| 58 | 4.5 | 14.1 | 23.2 | 39.6 | 16.9 | 1.2 | 0.2 | 0.3 |
| 59 | 36.8 | 24.9 | 18.7 | 10.7 | 5.2 | 2.5 | 1.0 | 0.2 |
| 60 | 0.0 | 0.4 | 25.7 | 58.6 | 11.5 | 2.1 | 1.0 | 0.7 |
| 61 | 0.0 | 8.7 | 45.5 | 36.6 | 7.3 | 1.2 | 0.3 | 0.4 |
| 62 | 7.1 | 27.1 | 35.6 | 20.9 | 7.8 | 1.2 | 0.2 | 0.1 |

| Sample No. | -2 | -1 | 0 | Ø Size 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 63 | 8.8 | 20.5 | 38.8 | 23.5 | 6.9 | 1.1 | 0.1 | 0.3 |
| 64 | 5.1 | 16.5 | 39.6 | 32.9 | 5.2 | 0.5 | 0.2 | 0.0 |
| 65 | 8.9 | 32.7 | 26.7 | 20.6 | 8.4 | 1.8 | 0.4 | 0.5 |
| 66 | 14.2 | 39.2 | 31.2 | 10.8 | 3.2 | 1.1 | 0.2 | 0.1 |
| 67 | 15.4 | 18.3 | 27.6 | 20.4 | 11.2 | 4.7 | 1.6 | 0.8 |
| 68 | 0.0 | 1.6 | 27.7 | 51.6 | 17.5 | 1.1 | 0.1 | 0.4 |
| 69 | 41.3 | 16.0 | 24.8 | 15.9 | 1.6 | 0.2 | 0.1 | 0.1 |
| 70 | 2.7 | 19.5 | 43.1 | 27.8 | 6.1 | 0.5 | 0.1 | 0.2 |
| 71 | 11.3 | 21.7 | 34.8 | 21.4 | 8.3 | 2.1 | 0.3 | 0.1 |
| 72 | 15.0 | 19.0 | 24.7 | 29.6 | 9.8 | 1.3 | 0.3 | 0.3 |
| 73 | 0.0 | 23.1 | 43.0 | 25.6 | 7.1 | 1.0 | 0.1 | 0.1 |
| 74 | 6.7 | 19.1 | 31.6 | 25.7 | 11.0 | 4.0 | 1.0 | 0.9 |
| 75 | 6.5 | 20.2 | 47.2 | 22.6 | 3.2 | 0.1 | 0.1 | 0.1 |
| 76 | 30.8 | 23.6 | 20.9 | 14.3 | 8.2 | 1.7 | 0.3 | 0.2 |
| 77 | 4.4 | 26.0 | 26.1 | 27.7 | 13.9 | 1.0 | 0.4 | 0.5 |
| 78 | 3.7 | 29.7 | 37.0 | 22.8 | 6.0 | 0.6 | 0.1 | 0.1 |
| 79 | 0.0 | 7.3 | 36.1 | 40.1 | 14.6 | 1.2 | 0.2 | 0.5 |
| 80 | 29.9 | 19.8 | 15.3 | 15.4 | 16.0 | 3.1 | 0.4 | 0.1 |
| 81 | 6.1 | 43.7 | 21.5 | 13.5 | 12.1 | 2.5 | 0.3 | 0.3 |
| 82 | 10.3 | 29.9 | 41.3 | 16.4 | 1.7 | 0.2 | 0.1 | 0.1 |
| 83 | 15.8 | 19.5 | 27.6 | 28.6 | 7.1 | 0.7 | 0.3 | 0.4 |

| Sample No. | Ø Size -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 84 | 1.7 | 18.7 | 35.2 | 35.6 | 6.3 | 1.0 | 0.5 | 1.0 |
| 85 | 28.3 | 29.0 | 23.1 | 15.4 | 3.2 | 0.4 | 0.2 | 0.4 |
| 86 | 0.0 | 8.9 | 14.7 | 30.9 | 31.6 | 11.1 | 2.0 | 0.8 |
| 87 | 0.0 | 2.7 | 19.2 | 60.6 | 16.5 | 0.7 | 0.1 | 0.2 |
| 88 | 13.4 | 25.9 | 19.0 | 34.2 | 5.7 | 1.0 | 0.5 | 0.3 |
| 89 | 0.0 | 22.6 | 34.0 | 35.0 | 5.3 | 0.9 | 0.4 | 1.8 |
| 90 | 0.0 | 25.8 | 30.3 | 33.5 | 9.3 | 0.9 | 0.1 | 0.1 |
| 91 | 20.9 | 29.4 | 20.7 | 18.4 | 8.4 | 1.7 | 0.4 | 0.1 |
| 92 | 32.4 | 28.8 | 20.2 | 9.6 | 5.2 | 2.0 | 0.7 | 1.1 |
| 93 | 20.6 | 39.7 | 17.7 | 15.4 | 4.3 | 0.6 | 0.3 | 1.4 |
| 94 | 45.9 | 21.7 | 13.5 | 13.7 | 4.3 | 0.6 | 0.1 | 0.2 |
| 95 | 3.8 | 28.7 | 24.2 | 25.3 | 11.2 | 3.7 | 1.5 | 1.6 |
| 96 | 0.0 | 21.9 | 25.6 | 38.6 | 10.9 | 2.2 | 0.5 | 0.3 |
| 97 | 10.6 | 30.4 | 7.2 | 11.8 | 10.4 | 8.2 | 6.0 | 15.4 |
| 98 | 37.7 | 31.3 | 18.3 | 9.0 | 2.2 | 0.9 | 0.3 | 0.3 |
| 99 | 7.8 | 42.0 | 33.4 | 14.0 | 1.8 | 0.4 | 0.1 | 0.5 |
| 100 | 6.4 | 38.4 | 25.8 | 14.2 | 6.4 | 3.8 | 2.1 | 2.9 |
| 101 | Sample Not Tested | | | | | | | |
| 102 | 3.2 | 28.4 | 24.8 | 19.1 | 15.3 | 6.3 | 2.2 | 1.7 |
| 103 | 0.0 | 32.4 | 32.2 | 27.8 | 5.8 | 0.9 | 0.2 | 0.7 |
| 104 | 11.9 | 18.9 | 25.2 | 19.6 | 11.9 | 5.7 | 3.3 | 2.5 |

| Sample No. | ∅ Size -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 105 | 18.9 | 14.7 | 19.8 | 15.8 | 9.9 | 4.7 | 2.9 | 3.3 |
| 106 | 8.9 | 16.7 | 19.4 | 18.8 | 15.4 | 10.1 | 6.2 | 4.5 |
| 107 | 1.1 | 17.5 | 9.2 | 19.1 | 32.0 | 13.9 | 4.7 | 2.5 |
| 108 | 13.3 | 39.2 | 19.8 | 12.3 | 7.4 | 3.6 | 2.2 | 2.2 |
| 109 | 4.6 | 39.1 | 20.5 | 15.1 | 10.7 | 6.2 | 2.6 | 1.2 |
| 110 | 18.8 | 34.3 | 23.6 | 13.1 | 5.6 | 1.8 | 1.0 | 1.8 |
| 111 | 2.4 | 37.4 | 12.9 | 11.3 | 9.8 | 8.8 | 7.1 | 10.3 |
| 112 | 6.1 | 35.4 | 13.7 | 11.2 | 11.0 | 9.1 | 5.8 | 7.6 |
| 113 | 5.8 | 32.4 | 23.9 | 16.3 | 11.9 | 5.3 | 2.4 | 2.0 |
| 114 | 5.2 | 31.7 | 14.7 | 12.9 | 11.5 | 9.5 | 6.6 | 7.9 |
| 115 | 17.4 | 27.5 | 19.6 | 15.1 | 11.0 | 5.2 | 2.1 | 2.1 |
| 116 | 14.6 | 34.5 | 16.7 | 12.7 | 8.2 | 5.0 | 3.4 | 5.0 |
| 117 | 3.2 | 26.0 | 22.2 | 19.9 | 14.4 | 7.8 | 3.6 | 2.9 |
| 118 | 10.7 | 35.7 | 20.9 | 16.2 | 9.3 | 3.8 | 1.7 | 1.7 |
| 119 | 23.9 | 27.0 | 11.9 | 8.1 | 9.7 | 7.9 | 5.6 | 5.9 |
| 120 | 19.8 | 22.4 | 13.8 | 8.9 | 10.6 | 8.5 | 6.9 | 9.1 |
| 121 | 26.4 | 24.6 | 24.4 | 17.5 | 5.1 | 0.8 | 0.5 | 0.7 |
| 122 | 0.6 | 42.9 | 9.3 | 8.6 | 7.9 | 7.2 | 6.8 | 16.7 |
| 123 | 0.0 | 25.6 | 11.1 | 16.0 | 15.6 | 10.7 | 7.8 | 13.2 |
| 124 | 4.9 | 24.5 | 11.7 | 15.6 | 14.8 | 11.7 | 8.8 | 8.0 |

Appendix II
Statistical Data for Typical Sediments

| Sample | Mean Size ($M_z$) | Sorting ($\sigma_I$) | Skewness ($SK_I$) | Kurtosis ($K_G$) |
|---|---|---|---|---|
| 4 | 0.16 | 0.76 | 0.07 | 1.06 |
| 9 | -0.23 | 1.14 | 0.21 | 1.24 |
| 13 | 1.26 | 1.38 | 0.22 | 0.94 |
| 16 | 0.11 | 0.67 | 0.07 | 0.90 |
| 21 | -0.07 | 0.65 | 0.15 | 1.15 |
| 26 | -0.01 | 0.56 | -0.13 | 1.09 |
| 29 | -0.68 | 0.79 | 0.16 | 1.20 |
| 35 | -1.43 | 1.25 | 0.04 | 1.28 |
| 38 | -0.07 | 0.70 | 0.05 | 1.22 |
| 39 | -0.72 | 1.24 | 0.14 | 0.90 |
| 42 | -1.37 | 1.25 | 0.02 | 0.85 |
| 45 | -0.82 | 1.36 | -0.03 | 0.93 |
| 46 | -0.08 | 0.97 | -0.15 | 1.01 |
| 47 | -0.72 | 0.99 | 0.14 | 0.93 |
| 49 | -0.66 | 1.05 | 0.08 | 0.88 |
| 59 | -1.34 | 1.52 | 0.22 | 0.71 |
| 64 | -0.29 | 0.88 | -0.06 | 1.05 |
| 68 | 0.41 | 0.70 | 0.05 | 1.02 |
| 80 | -0.83 | 1.98 | 0.13 | 0.75 |
| 82 | -0.72 | 0.82 | 0.12 | 0.81 |

| Sample | Mean Size ($M_z$) | Sorting ($\sigma_I$) | Skewness ($SK_I$) | Kurtosis ($K_G$) |
|---|---|---|---|---|
| 92 | -1.26 | 1.39 | 0.27 | 0.96 |
| 94 | -1.28 | 1.38 | 0.08 | 0.77 |
| 100 | -0.53 | 1.27 | 0.35 | 1.15 |
| 103 | -0.67 | 1.13 | -0.18 | 0.76 |
| Avg. | -0.49 | 1.08 | 0.08 | 1.02 |

Appendix III
Percentage Distribution of the Five Common Heavy Minerals

| Sample | Garnet | Magnetite | Epidote | Hornblende | Apatite |
|---|---|---|---|---|---|
| 4 | 12.8 | 37.2 | 28.2 | 11.5 | 10.3 |
| 9 | 40.2 | 49.2 | 8.4 | 0.7 | 1.5 |
| 13 | 35.1 | 19.0 | 28.3 | 9.3 | 6.3 |
| 16 | 77.3 | 22.3 | 0.7 | 0.0 | 0.0 |
| 21 | 30.0 | 25.0 | 36.6 | 2.2 | 6.2 |
| 26 | 19.0 | 32.9 | 32.9 | 7.6 | 7.6 |
| 29 | 76.3 | 19.7 | 2.3 | 0.7 | 1.0 |
| 35 | 63.3 | 21.4 | 8.4 | 3.2 | 3.8 |
| 38 | 19.5 | 16.1 | 47.6 | 11.4 | 5.4 |
| 39 | 76.0 | 15.3 | 5.3 | 2.2 | 2.2 |
| 42 | 48.0 | 19.1 | 22.6 | 6.1 | 4.2 |
| 45 | 39.6 | 24.4 | 31.6 | 3.8 | 0.6 |
| 46 | 85.0 | 7.5 | 2.9 | 1.7 | 2.9 |
| 47 | 19.0 | 17.0 | 50.0 | 11.0 | 3.0 |
| 49 | 81.6 | 10.1 | 1.8 | 1.3 | 5.1 |
| 59 | 32.7 | 29.1 | 33.0 | 1.8 | 3.4 |
| 64 | 50.2 | 21.9 | 26.9 | 1.0 | 0.0 |
| 68 | 9.7 | 18.7 | 61.2 | 7.2 | 3.2 |
| 80 | 10.0 | 16.0 | 60.3 | 11.7 | 2.0 |
| 82 | 7.7 | 55.1 | 25.5 | 0.4 | 11.3 |

| Sample | Garnet | Magnetite | Epidote | Hornblende | Apatite |
|---|---|---|---|---|---|
| 92 | 46.7 | 45.0 | 3.7 | 1.0 | 3.6 |
| 94 | 57.0 | 41.7 | 0.7 | 0.0 | 0.6 |
| 100 | 17.0 | 36.2 | 20.8 | 11.8 | 14.2 |
| 103 | 33.7 | 56.7 | 7.0 | 0.0 | 2.6 |
| Avg. | 41.1 | 27.3 | 22.9 | 4.5 | 4.2 |

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