DETRITAL MINERAL STUDIES OF SOME CENOZOIC SEDIMENTS, SAFFORD VALLEY, ARIZONA

by

William F. Mathias, Jr.

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

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ABSTRACT

More than 27 mineral species have been identified in Cenozoic sediments of varying lithology within the Safford Valley of Arizona. The mineral assemblages suggest the following possible sources for the basin-filling detritus: (1) acid igneous rocks, (2) basic igneous rocks, (3) high-rank metamorphic rocks, (4) reworked sediments, and (5) explosive volcanic activity.

The high angularity and low stability of most of the heavy minerals suggests that the crystalline rocks of the mountains that flank the valley were the source of most of the detritus. The presence of glass and fresh euhedral volcanic minerals suggests that explosive volcanic activity has also contributed greatly to the detritus that fills the valley.

The use of heavy minerals as a means of differentiation and correlation of strata must be based upon frequency of occurrence of mineral species, rather than on any major mineralogical changes.

The uniformity of the general heavy mineral suite over a considerable vertical and lateral range, and the characteristic lenticular and discontinuous nature of the Cenozoic sediments, may make the determination of mineral zones difficult.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

General Statement of Problem

The Safford Valley of Arizona is an intermontane trough which has been filled by a sequence of poorly to medium-well consolidated sediments of Cenozoic age. This study is an investigation of detrital minerals within some of these Cenozoic sediments. It provides further insight into the sources of the detritus that fills the Safford Valley.

Previous Work

The only other study of detrital minerals in the Safford Valley area was done by Van Horn (1957). He made a qualitative study of the heavy minerals in order to gain an idea of the source of some of the sediments.

Studies of the ground-water conditions of the Safford Valley were made between 1919 and 1956. Van Horn (1957) gives an extensive bibliography which lists most of these works. Knechtel (1938) discusses in some detail the geology of the area.

Location and Geologic Setting of the Area

The area covered by this study lies within the greater Safford Valley along the Gila River from Coolidge Dam on the northwest, to the junction of the Whitlock Valley and the San Simon Valley on the southeast.

This study was confined to two specific localities within the Safford Valley: (1) the base of the Whitlock Hills at the lower end of the Whitlock Valley, and (2) the lower end of the Safford Valley proper in the vicinity of Calva (Fig. 1). Detailed locations of the sampling sites are given within the text.

The Safford Valley area is considered to be a basin of deposition within the Basin and Range Province. The valley, which ranges from 10 to 20 miles in width, is drained by the Gila River (Fig. 1). The altitude of the Safford Valley ranges from 3,000 feet above sea level at the upper end near Sanchez to about 2,400 feet above sea level at the lower end near the San Carlos Reservoir.

The valley is bounded on the northeast side by the Gila Mountains and the Peloncillo Mountains. To the southwest, the valley is flanked by the Turnbull Mountains, the Santa Teresa Mountains, and the Graham Mountains. These mountains which flank the valley all reach elevations in excess of 6,000 feet—the highest point being Mount Graham which rises to more than 10,700 feet.

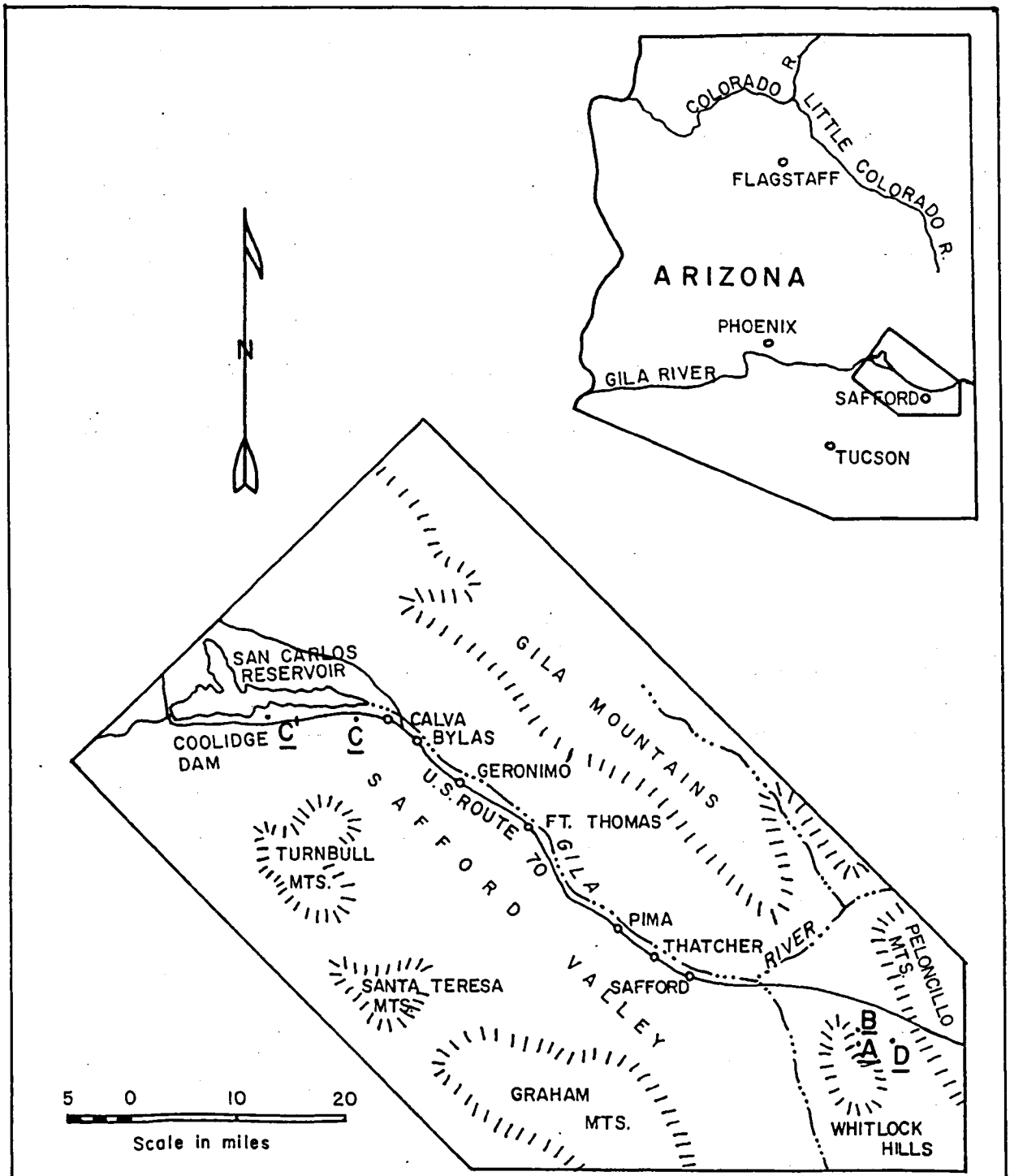

FIGURE 1. INDEX MAP OF THE SAFFORD VALLEY, ARIZONA AND THE SITES OF SAMPLES A, B, C, C', AND D

The Gila and Peloncillo Mountains consist predominantly of volcanic rocks. According to Bromfield and Shride (1956), these rocks are of two distinct ages: (1) older Tertiary volcanic rocks which include basalt, rhyolite, andesite, breccias, and tuffs, and (2) younger Tertiary and Pleistocene volcanic rocks which are represented by basalt flows interbedded with sedimentary rocks.

The mountain ranges constituting the southwestern flank of the Safford Valley area consist of predominantly metamorphic and igneous rocks. The rock types include granite, gneiss, schist, andesite, and diabase. The rocks are of older Precambrian and Cretaceous-Tertiary age (Geologic Map of Graham and Greenlee Counties, Arizona, 1958).

The valley between these mountain ranges is considered to be a structural basin formed by a down-dropped block between adjacent and relatively upraised mountain blocks. Within this structural basin occur poorly to medium-well consolidated sedimentary deposits, including coarse conglomerates derived from the surrounding mountains. Lake and flood-plain deposits are composed of limestones, mudstones, gypsum, diatomaceous sediments, cherts, and tuffs. Generally, the lithologic units are quite thin, and facies changes are common and occur in short distances. As a result, few beds within the Safford Valley may be traced laterally for any appreciable distance and differentiation of strata and correlation are most difficult. These sediments are believed to be of Pliocene and Pleistocene age and may have had an original

thickness of some 2,400 feet (Van Horn, 1957).

Coarse gravels of Pleistocene(?) age unconformably overlie the late Tertiary and early Pleistocene sediments. Present-day drainage courses are occupied by Recent silts, sands, and gravels.

The basin sediments have been discussed in other reports, the most noteworthy being the studies by Knechtel (1938) and Van Horn (1957). Detailed studies on these sediments are now being carried on by members of the University of Arizona under the auspices of the Utilization of Arid Lands program.

Collection of Samples

Samples for this investigation of detrital minerals were taken from four prominent beds at different positions within the sequence of Cenozoic sediments.

At each locality, four channel samples were taken at approximately 25-foot intervals. These samples were then crushed and equal weights of each were combined to make one composite sample. According to Krumbein and Pettijohn (1938) this method of sampling reduces by one-half the extremes of sediment variation within a bed at any given locality by combining the properties of all the material at that point.

The composite channel sample was then reduced to about a one-half pound size by means of a Jones type sample splitter.

Acknowledgments

The writer wishes to acknowledge the aid of the following staff members and fellow graduate students at the University of Arizona who have aided greatly in this thesis: Willard D. Pye, director of the thesis, advised on methods of study and suggested laboratory procedures; John F. Lance suggested the problem, accompanied the author in the field, and furnished much valuable information on the geology of the area; Joseph F. Schreiber, Jr. offered suggestions concerning procedures and the interpretation and presentation of the data; Sidney A. Williams aided in the mineral identification and thin section analyses; and James Marlowe and Philip Seff freely offered their knowledge of the stratigraphic details within the area of study.

This investigation is part of the Utilization of Arid Lands program which has been established through a grant from the Rockefeller Foundation. Financial aid for this work was provided from this project.

TECHNIQUE OF DETRITAL MINERAL EXAMINATION

Introduction

Conventional methods (Krumbein and Pettijohn, 1938, Milner, 1929, and Leroy, 1951) for disaggregating sediments were tried on the fine-grained sediments with little success. Therefore, part of the problem became the development of a method which would permit satisfactory separations of the minerals with no recognizable grain breakage that would effect mineral frequency computations.

Preparation of Sample

The sample was soaked in acetone for 24 hours. The acetone was then filtered off for reuse and the sample soaked in water for at least 10 hours. The sample was then poured into a U. S. Standard Sieve Number 45 (0.351 mm.), and gently brushed to break up any aggregates which might remain after the soakings. The finer fractions were decanted and recovered on filter paper. Brushing and washing of the fraction that passed through the sieve was continued until all of the finer fraction had been removed. The retained sediment was then boiled in dilute hydrochloric acid for 15 minutes to clean the grains.

Heavy and light mineral separations were made following standard

procedures (Krumbein and Pettijohn, 1938). Acetylene tetrabromide with a specific gravity of 2.875 was the separation medium. In order to insure a clean separation of the heavy minerals, this fraction was reseparated.

If the mineral fractions were unduly large, they were reduced by means of a microsplit. Magnetite was removed from the heavy mineral fractions by a magnet to facilitate counting. The magnetic and nonmagnetic fractions were then mounted in Canada balsam for study. The light fractions were mounted in Canada balsam and in refractive index liquids to facilitate mineral identification, and especially the separation of quartz and potassium feldspars.

Counting of Grains

Determination of mineral frequencies was based upon mineral counts. The statistics of grain counting has been described by Dryden (1931) who recommends that a count of about 300 grains will achieve satisfactory percentages for most studies.

The number of grains counted for each sample ranged from 275 grains to almost 2,000 grains. Comparison of calculated percentages showed that smaller counts gave percentages very close to those of the more exhaustive counts. However, the fundamental mineral assemblages from the different sediments are not too varied. In fact, the same minerals tend to occur in all samples. Differentiation of the

mineral suites rests upon variations within the mineral species and upon the relative frequency of occurrence. For this reason, a large number of grains were counted (about 1,000) in order to fix frequency variations as closely as possible.

LOCATION AND PETROLOGY OF SAMPLES

Introduction

Samples A, B, and D were collected from prominent beds at different positions within the stratigraphic sequence in the vicinity of the 111 Ranch at the southeastern end of the Safford Valley.

Samples C and C' were collected from a prominent bed of known wide lateral extent in the vicinity of Calva at the northwestern end of the Safford Valley. These samples were investigated in order to gain some idea of the manner in which lateral variations of the detrital minerals might occur within the Cenozoic sediments.

Figure 2 shows the general stratigraphic relationships of the samples.

Sample A

Sample A was taken from an exposure located in an unnamed canyon in the SW 1/4, sec. 23, T. 8 S., R. 28 E., and about 1/4 mile southwest of the location of the outcrop from which sample B was taken.

The bed sampled is a member of a canyon wall-forming series. Its position is about 20 feet down from the top of the canyon. The exposure is stained a reddish color by iron oxides derived from beds higher

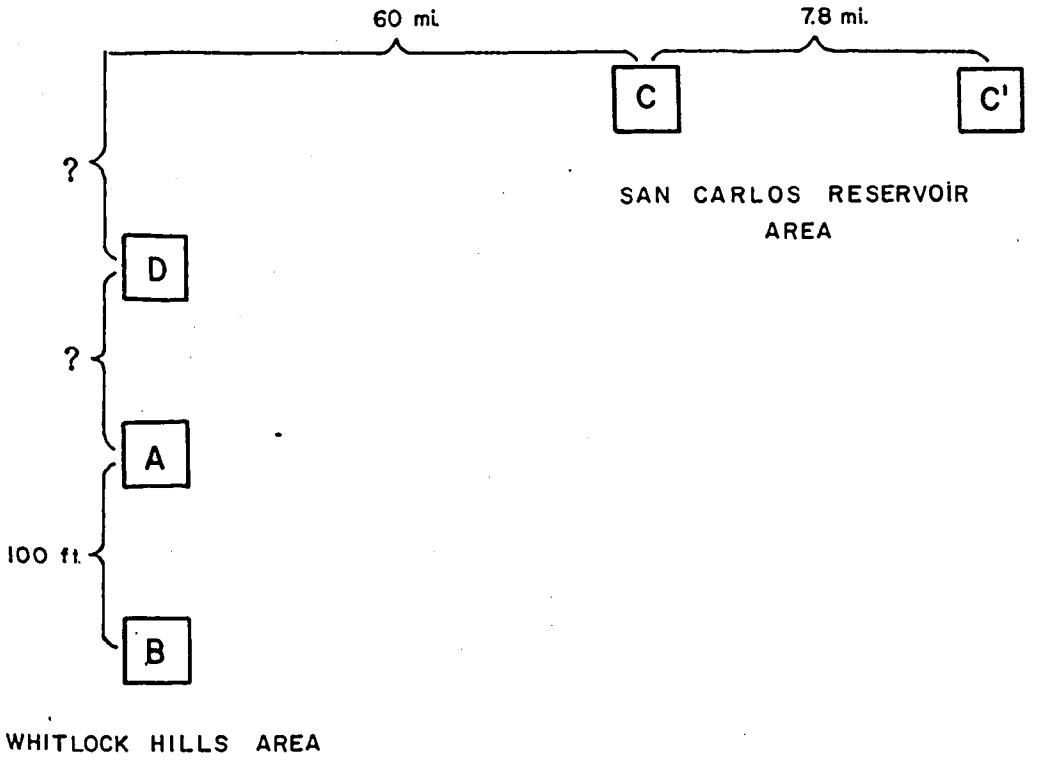

FIGURE 2. GENERAL STRATIGRAPHIC RELATIONSHIP OF SAMPLES

in the stratigraphic section. The fresh surface is a uniform gray-white. The bed is about 2 feet thick and is a fairly well-consolidated, even-textured diatomite which contains a small amount of silt-size grains. It is overlain by a thin zone of dense green chert and underlain by a buff-colored siltstone.

Thin section analysis shows that the sample consists predominantly of diatoms and diatom fragments (75-85 percent). The rest of the sediment consists of angular silt-size quartz and feldspar (10-20 percent), mafic minerals (less than 1 percent), siliceous sponge spicules (less than 1 percent) and rounded "opaline" ($n = 1.448 \pm .002$) material (less than 2 percent).

X-ray powder photographs were taken in an attempt to determine the composition of the matrix, but the results were inconclusive as only the presence of quartz was indicated. It is believed, however, that the matrix consists of diatom fragments and that the cement is predominantly silica.

Sample B

The outcrop from which Sample B was taken occurs in the NW 1/4, sec. 22, T. 8 S., R. 28 E., at the base of the Whitlock Hills. The locality is about 3/4 mile due south of the 111 Ranch on the 111 Ranch road. The bed, at the sampling site, has been excavated for local use as a plaster and contains the remains of a kiln which was used for

calcining the plaster.

The outcrop forms a distinct ledge and is characterized by a prevailing white color on both fresh and weathered surfaces. Often mistaken for a tuff in handspecimen, this fairly well-consolidated sediment is actually a diatomite with a chalk-like texture. The thickness of the bed at the sampling site was not determined as the bottom contact is buried; however, 8 feet of the unit is exposed. The overlying bed is a brownish-colored siltstone.

Thin section study shows this sample to be quite similar to Sample A, consisting of diatoms and diatom fragments (80-90 percent), fine angular silt-size quartz and feldspar (10-15 percent), mafic minerals (less than 1 percent), sponge spicules (less than 1 percent), and "opaline" ($n = 1.438 \pm .002$) material (less than 1 percent).

X-ray powder photographs were inconclusive as to the composition of the matrix material. As in the case of Sample A, it is assumed that the matrix consists mainly of diatom fragments.

No attempt was made to identify the diatoms or sponge spicules in either sample; however, Knechtel (1938) gives a listing of the diatom species that have been identified within the area. It is to be noted that the specimens studied by the writer contain a much higher percentage of diatoms than those studied by Knechtel.

Sample C

The outcrop from which this sample was obtained occurs in the SE 1/4, sec. 7, T. 3 S., R. 21 E. The locality is 150 yards from old Route U. S. 70, 0.9 mile west of the Southern Pacific viaduct over this highway, at the northwestern end of the Safford Valley just west of Calva.

The outcrop sampled is a buff-colored, well-bedded and cross-bedded, blocky, and poorly consolidated sediment, which in the field resembles a siltstone. It is about 2 feet thick, forms a prominent ledge, and is overlain by brownish siltstone and claystone and underlain by green and brown claystone.

Thin section analysis shows that quartz and feldspar (40-50 percent) is quite angular, with some of the feldspar in various stages of alteration. The mafic minerals (less than 5 percent) include mostly such volcanic species as fresh augite and fresh euhedral hornblende. The rest of the coarse fraction in the thin section is composed of glass (less than 2 percent) which is rhyolitic in composition ($n = 1.495 \pm .002$). The light mineral separation of this sample, however, shows that the glass content is more than 60 percent. The discrepancy in the thin section may be partly due to the masking of the glass by alteration products. The matrix and cementing agent (40 percent) is not discernible under a microscope. X-ray powder photographs of the matrix material indicate

the possible presence of quartz and plagioclase feldspar. The fine feldspars, and their alteration product, may be acting as the bonding agent for this poorly consolidated sediment.

A search of the literature shows no classification into which this sediment may be placed as described through thin section analysis. On the basis of the manner in which the mafic minerals occur, the sediment appears to most closely resemble a volcanic arenite as defined by Williams, Turner, and Gilbert (1954, p. 308).

Sample C'

This sample, which was taken from the same bed as Sample C, was collected in the SE 1/4, sec. 12, T. 3 S., R. 19 E. It was obtained from an exposure in a roadcut 14.3 miles east of Coolidge Dam on old Route U. S. 70.

The appearance of the bed at this location is similar to its appearance at the location of Sample C. However, the thickness has increased to about 6 feet and the bed contains a few rounded basalt fragments along some of the bedding planes. Crossbedding indicates that the location of this sample is in the down-current direction from Sample C.

Thin section analysis shows no notable variation from that of Sample C.

Sample D[1/]

The outcrop from which Sample D was taken is found in the NE 1/4, sec. 17, T. 8 S., R. 29 E., about 5 miles east-northeast of the 111 Ranch.

The outcrop is characterized by a prevailing brown color on both fresh and weathered surfaces. The bed is about 7 feet thick, flat bedded, even textured, and fairly well consolidated.

Thin section analysis shows that the sediment is a silty tuff. Quartz and feldspar (30-40 percent) are quite angular. Most of the feldspar is in various stages of alteration. The glass (40-50 percent) is notably fresh and corresponds to a basic andesite in composition ($n = 1.516 \pm .002$). Mafic minerals constitute less than 1 percent of the thin section.

The matrix of the sediment was not discernible under a microscope. X-ray powder photographs of the matrix material indicate the possible presence of quartz and plagioclase feldspar. The bonding of this sediment is probably caused by the alteration products of the fine feldspar.

[1/] Sample and field data supplied by Edward S. Davidson of the U. S. Geological Survey, Ground Water Branch, Tucson, Arizona.

DESCRIPTIVE MINERALOGY OF SEDIMENTS

Introduction

Although many mineral species occur within the samples investigated, most of the species are quite scarce. With the exception of glass within the tuffaceous sediments, the light fractions of the samples are dominantly composed of quartz and a lesser amount of feldspar. The ratios between these two species vary to a considerable degree among the samples.

The percentage of heavy minerals within the different samples varies appreciably, but notably higher percentages of heavy minerals are present within the tuffaceous sediments. The same general heavy mineral assemblage characterizes all samples. Variations in the assemblages are marked by frequency of occurrence changes, rather than by mineralogical changes.

The distributions and frequencies of the minerals are shown in Tables 1 and 2 and Figures 3 and 4 (see section on Mineral Frequencies).

Light Minerals

Glass.--In Samples C and C', rhyolitic glass of a very light-brown color is very common. Most of the shards are irregular flat

plates, generally with some minute inclusions of magnetite. Small vesicles are common in all shards, shaped as spheres, discs, and curved tubes. Though some of the glass is unaltered, most shards show traces of devitrification to faintly polarizing cryptocrystalline aggregates of unidentifiable materials.

The glass in Sample D is colorless and corresponds to a basic andesite in composition. Most of the shards are slightly curved, lunar, or Y-shaped. The shards commonly have four or more concave sides. Small vesicles are common in some of the glass fragments, generally as spheres or tubes. In most cases the glass is very fresh, with devitrification being noted within a very few shards.

Gypsum. --Gypsum occurs as colorless or white, well-formed crystals (selenite) and cleavage fragments. This species is found only in Sample B. Due to the generally large size of the crystals (up to 1.5 mm.) and the excellent state of preservation, it is most probable that this mineral is authigenic.

Microcline. --One grain of microcline was noted within Sample C where it appears as a "blotchy" gray, well-rounded cleavage flake. The grain is highly altered, but still exhibits the typical microcline "cross hatching" in polarized light.

Muscovite. --Although considered a heavy mineral, this species is included within the light fraction since because of its platy nature it

often fails to settle out with the heavier fractions. This mineral appears as fresh, nearly colorless, platy grains with only slightly frayed edges. All grains are poorly rounded, with a few containing minute anisotropic inclusions. Although this species is very rare, it was noted in all samples.

Opaline material. --Opaline material occurs as colorless, irregularly rounded, thin flakes. This material is very rare and is found only in Samples A and B.

Orthoclase. --Orthoclase occurs as colorless or gray, irregularly shaped grains in various stages of rounding. A very few grains exhibit Carlsbad twinning. In general the grains show some alteration, although they may be remarkedly fresh. Minute anisotropic inclusions are present in some of the grains. This species is rather common in all samples.

Plagioclase. --Plagioclase occurs as gray, slightly to fairly well-rounded grains. The fragments all exhibit some degree of alteration, generally along cleavage planes. The composition of the plagioclase is andesine. This species is relatively rare, but is found in all samples.

Quartz. --Quartz occurs as colorless or stained, generally either as highly angular or subangular irregular grains. The following types of quartz are noted in various proportions within all samples:

1. Clear, inclusion free quartz
2. Clear quartz with rounded opaque inclusions
3. Relatively clear quartz with irregular opaque inclusions
4. Relatively clear quartz with acicular inclusions
5. Dusty quartz with very minute opaque inclusions

In all cases, the inclusions were too small to be identified with a microscope.

Though no attempt was made to genetically classify the quartz, it appears to be both plutonic and volcanic in origin.

Mineral aggregates. --Mineral aggregates occur as subrounded to well-rounded rock fragments up to 2.5 mm. in diameter. These aggregates were noted only from Sample B in which they are very rare. The rock fragments are basaltic, rhyolitic, and andesitic(?) in composition.

Heavy Minerals

Apatite. --Apatite occurs as colorless or very pale-green prismatic grains in various stages of rounding. The grains are slightly pleochroic. This species is very rare and was found only in Sample D.

Augite. --Most of the augite is noted chiefly as pale yellow-green prismatic grains that are angular to slightly rounded. A high percentage, especially in Sample A, show serrated terminations due to cleavage.

Most grains exhibit a faint pleochroism of various shades of light green. This mineral is very persistent, constituting more than 20 percent of the heavy minerals of each sample.

Axinite.--Axinite is found chiefly as pale-yellow, irregular, angular to poorly rounded grains with a few long, rounded prismatic forms. Its pleochroic formula is: $n_y = 1.688$, x = yellow, y = pale blue, z = viridine green. Unidentified inclusions were noted within a few grains. It is relatively rare and is found only in Sample D.

Epidote.--Epidote occurs as "blotchy" pale greenish-yellow, angular to poorly rounded grains. Some grains appear to be in various stages of alteration. Pleochroism is very faint or absent. It is fairly common in all samples except D, where it is absent.

Garnet.--This species occurs chiefly as colorless or faintly pink, isotropic fracture fragments in all stages of rounding. Euhedral dodecahedrons and garnets containing anisotropic inclusions were noted only in Sample B. Garnet is a minor constituent and is found in all but Sample C'.

Hornblende (brown).--Most of the hornblende was noted as dark-green or greenish-brown, irregular, elongated, platy cleavage flakes. Its color becomes paler toward the grain boundaries. Frayed ends are most common, though some show minor rounding. Some well-

preserved doubly terminated euhedras were present in Samples C and C'. Pleochroism of the hornblende is various shades of dark green and greenish brown. It is present in varying amounts, and is particularly diagnostic of Samples C and C'.

Hornblende (Basaltic). --The basaltic hornblende occurs as deep reddish-brown elongated platy cleavage flakes. Usually the flakes have frayed ends though some show minor rounding. Pleochroism of this species is from reddish brown to dark yellow-brown. This mineral is generally scarce except in Samples C and C' where it is common.

Hornblende (green). --Green hornblende occurs mainly as light-green elongated platy cleavage flakes with frayed ends. Pleochroism is green to yellow-green. This species is generally scarce, although it is common in Sample A.

Hypersthene. --One grain of hypersthene was noted within Sample B where it appears with conspicuous cleavage traces. Pleochroism is brownish green to reddish brown.

Monazite. --Monazite occurs chiefly as pale yellow-brown, fairly well-rounded grains with very high birefringence. Pleochroism is very faint. It is a rare mineral and was not noted in Samples C and C'.

Olivine. --This species occurs as very pale-green, irregular, slightly rounded non-pleochroic grains. It is a very rare mineral and is found only in Sample C'.

Rutile. --Rutile is noted as slightly rounded, prismatic grains that are dark reddish brown in color. It is very rare and is found only in Sample B.

Sphene. --Sphene occurs mostly as greenish- to brownish-yellow, irregular grains in various stages of rounding. Some grains show a fine network of fracture cracks. Essentially it is non-pleochroic. It is fairly common in Samples A and B, but is rare in Samples C and C', and was not noted in Sample D.

Spinel. --Spinel is present as very pale-blue, poorly rounded, subhedral octahedrons. It is a very rare mineral, being found only in Sample B.

Titanaugite. --This distinctive purplish-brown mineral has an occurrence similar to that of augite except that the grains are more equi-dimensional and are not serrated. It is non-pleochroic. This species is found in Samples C and C', being fairly common in the latter.

Tourmaline. --Tourmaline is found generally as unrounded fragments produced by basal parting of crystals. Some incomplete

crystals exhibit trigonal pyramid terminations. Its color is light green or light brownish green. Its pleochroism is various intensities of the above colors. A rare mineral, this species is not found in Samples A and C?.

Zircon. --Zircon appears in most samples as colorless or faintly pinkish, slightly rounded, prismatic crystals or crystal fragments. Pleochroism is absent. This mineral is scarce in all but Sample B where it is very common (14 percent). In Sample B, the zircons are mostly euhedral and unrounded. Approximately 20 percent of the grains show either zoning and/or elongate inclusions. This species is most diagnostic of Sample B.

Magnetite. --Magnetite is found as irregular to rounded grains, with a few partial octahedras being observed. This species is present in varying amounts in all samples, but is most common in D.

Other opaques. --Unrecognizable opaques appear mostly as dark grains with varying degrees of roundness and alteration. The opaques are fairly abundant in all samples.

Mineral Frequencies

The frequency scale. --The mineral frequencies in Tables 1 and 2 are based upon the following system. In the following chart,

minerals are assigned a frequency number which is equivalent to the percent indicated.

Frequency	Approximate Percentage
8+	90-100
8	75-89
8-	60-74
7+	45-59
7	35-44
7-	28-34
6+	23-27
6	18-22
6-	13-17
5	7-12
4	4-6
3	2-3
2	1-2
1	1/2-1
1*	1 grain only

This frequency scale was developed by the Burmah Oil Company (Krumbein and Pettijohn, 1938, p. 476) and was chosen by the writer to emphasize the lower frequency values which are deemed important in this investigation. The scale is not a true logarithmic plan.

The profile charts of mineral frequencies (Figs. 3 and 4) have been included so that the data may be readily visualized. In plotting the frequency numbers, 8+ is plotted as 8-1/3 units and 7- as 6-2/3, 1* is plotted as a half unit.

TABLE 1
LIGHT MINERAL FREQUENCIES

Sample	A	B	C	C'	D
Minerals	Number		Frequency		Percentage
Glass	-	-	8-	8-	8-
Gypsum	-	1	-	-	-
Microcline	-	-	1*	-	-
Muscovite	2	1	1	1	1
Opaline Mat.	1	2	-	-	-
Orthoclase	6+	6+	4	3	3
Plagioclase	3	2	2	3	1
Quartz	8-	8-	6+	7-	6+
Mineral Agg.	-	1	-	-	-

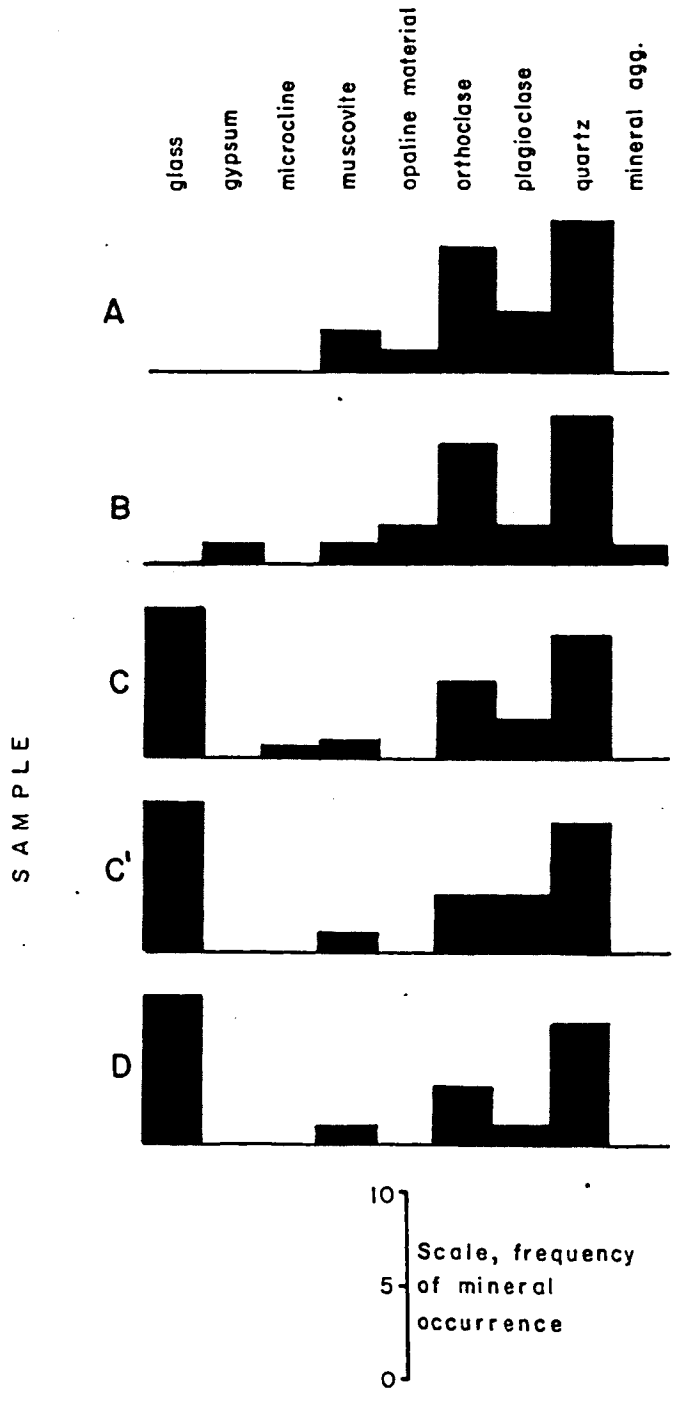

FIGURE 3. PROFILE CHART OF LIGHT MINERAL FREQUENCIES

TABLE 2
HEAVY MINERAL FREQUENCIES

Sample	A	B	C	C'	D
Weight Percent of Heavy Minerals	.023	.004	.37	1.20	.12
Minerals	Number		Frequency		Percentage
Apatite	-	-	-	-	1
Augite	7-	6	7-	6+	6+
Axinite	-	-	-	-	3
Epidote	4	4	4	2	-
Garnet	1	1	1	-	1
Hornblende (Reg.)	5	1	7+	7	4
Basaltic	5	1	2	1	2
Green	4	3	1	1	3
Hypersthene	-	1*	-	-	-
Monazite	1	1	-	-	1
Olivine	-	-	-	1	-
Rutile	-	1	-	-	-
Sphene	4	4	2	1	-
Spinel	-	1	-	-	-
Titanaugite	-	-	1	3	-
Tourmaline	-	1	1	-	1
Zircon	2	6-	2	1	1

TABLE 2—continued

Sample	A	B	C	C'	D
Weight Percent of Heavy Minerals	.023	.004	.37	1.20	.12
Minerals	**Number**		**Frequency**		**Percentage**
Magnetite	5	6	4	5	7
Opaques	6	6+	4	6	6+

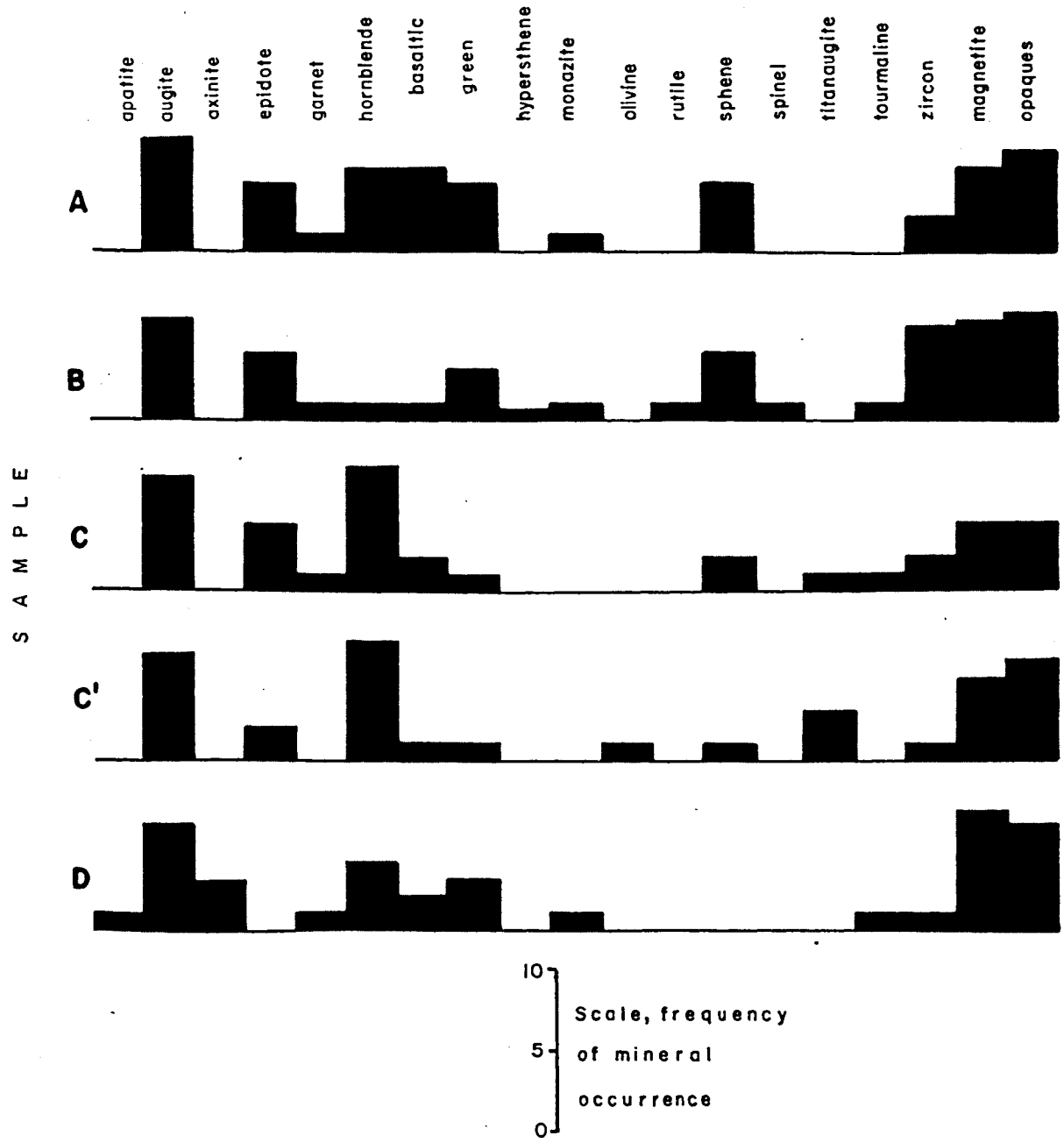

FIGURE 4. PROFILE CHART OF HEAVY MINERAL FREQUENCIES

SOURCE OF DETRITUS

Inferences from Detrital Minerals

It is not possible to arrive at any definite conclusions as to the origin and manner of dispersal of the detrital minerals. However, this study does allow some broad generalizations.

The detrital mineral assemblages imply that there has been a wide variety of sources for the detritus. The suggested sources are: (1) crystalline rocks, (2) explosive volcanic activity, and (3) older sediments.

A large portion of the detritus appears to have been derived directly from crystalline rocks. This is shown by (1) the high angularity of most of the quartz, feldspar, and heavy minerals, and (2) the high percentage of unstable heavy minerals.

Several types of crystalline source rocks are suggested by the mineral assemblages, particularly within the heavy mineral fractions. Of the constituents which compose more than 2 percent of the mineral suites, the following are said by Pettijohn (1957) to be characteristic of an acid igneous source: hornblende, monazite, sphene, euhedral zircon, and the igneous variety of quartz. A high-rank metamorphic source is suggested by the presence of greenish hornblende and epidote. Axinite,

which is uncommon in sedimentary rocks, also indicates a high-rank metamorphic source. A basic igneous source is suggested by the large amounts of augite, basaltic hornblende, and titanaugite. Direct proof that crystalline rocks were a source of some of the detritus is offered by the presence of rounded basalt, rhyolite, and andesite(?) fragments within one of the sediments.

The large amounts of glass within some of the samples attests to volcanic activity as another source of detritus. It may be reasonable to assume that some of the quartz and other minerals within the tuffaceous sediments were derived directly from the volcanic activity that supplied the glass shards.

Some of the detritus may have been derived from older sediments. In contrast to the predominant highly angular quartz fragments, a few grains are subrounded. Also, some of the minor constituents within the heavy mineral suites are notably stable and fairly well rounded, and, in some cases, corroded. These more rounded grains may have undergone only one period of transportation, but if so this period was quite long, as silt-sized quartz and the stable heavy minerals abrade very slowly.

Van Horn (1957) qualitatively studied the heavy minerals in some of the sediments within the Safford Valley in an effort to determine the source of the sediments. Among the minerals he observed were apatite, hypersthene, hornblende, tremolite-actinolite, epidote,

zircon, biotite, chlorite, garnet, and magnetite. On the basis of their high angularity and on the fact that such minerals as hypersthene, hornblende, epidote, and tremolite-actinolite are destroyed by long periods of weathering, he concluded that the sediments were derived from rocks close to their site of deposition.

The high angularity and generally low stability of the heavy minerals which comprise more than 2 percent of the heavy mineral fraction corroborates the findings of Van Horn. The high percentage of low-stability, angular, fresh augite, which was not noted in Van Horn's studies, further substantiates his conclusions.

Possible Source Areas

As noted in the discussion of the general geologic setting, a wide variety of igneous and metamorphic rocks are presently undergoing erosion within the Safford Valley and the surrounding mountain ranges. That these varied crystalline rocks have been a source of much of the detritus within the Safford Valley is suggested by the complex mineral assemblages within the sediments. Due to the small number of studied samples, however, these results are inconclusive.

Most of the published petrographic descriptions of these possible crystalline source rocks are concerned primarily with classification. As a result, only the essential mineral constituents of the rocks have been listed, with little information pertaining to the accessory

minerals being made available. One notable exception, however, is the study by Lindgren (1905) of the copper deposits of the Clifton-Morenci district. In the petrographic descriptions of the highly varied rock types within the area, Lindgren notes the occurrence of more than 50 minerals, including zircon, rutile, magnetite, garnet, hornblende, augite, epidote, tremolite, and apatite. Many of these minerals are noted within the heavy mineral fractions of the Safford Valley sediments.

The area studied by Lindgren is drained by tributaries of the Gila River, which in turn has transported much of the detritus to the Safford Valley. It may well be that this area has been a source for some of the detritus within the Safford Valley. Also, many of the rock types studied by Lindgren occur throughout the mountains that flank the Safford Valley, the detritus from which is readily available for deposition in the valley.

As previously suggested, volcanic activity may have supplied some minerals, as well as glass, to the sediments. At the lower end of the Safford Valley occur a number of diatremes of basaltic composition (James Marlowe, personal communication). The finer clastic debris that fills the diatremes has been interpreted by Marlowe as ejecta which has been washed back into the diatremes. Comparison of thin sections of these fine clastics within the diatremes and thin sections of samples C and C' shows a very strong similarity. In both cases highly angular quartz and feldspar and fresh angular augite, hornblende, and

titanaugite are noted.

Although the known diatremes within the Safford Valley intrude beds much higher in the section than the bed studied by the writer, it seems possible that many of the minerals within this sediment were once ejecta from a diatreme. Perhaps the associated diatreme is buried nearby, beyond the limits of the exposures that were sampled.

SUMMARY AND CONCLUSIONS

More than 27 mineral species have been identified in Cenozoic sediments of varying lithology within the Safford Valley. Analyses of the mineral assemblages suggest the following possible sources for the basin filling detritus:

(1) Acid igneous rocks

(2) Basic igneous rocks

(3) High-rank metamorphic rocks

(4) Reworked sediments

(5) Explosive volcanic activity

The high angularity and generally low stability of most of the heavy minerals suggests that the sediments were derived from rocks close to the site of deposition. The highly varied crystalline rocks that compose the mountains flanking the Safford Valley were the probable source of most of the detritus. This is suggested by the variety of accessory minerals within these rocks that are reflected in the basin filling sediments.

Explosive volcanic activity as a source for some of the detritus is indicated by the large amounts of glass, as well as volcanic minerals within some of the samples.

The possible use of heavy minerals as a means of differentiation and correlation of strata is suggested by minor variations among the heavy mineral suites and the frequencies of occurrence within the samples. Lateral variation of heavy minerals may be chiefly in the frequencies of their occurrence, rather than in mineralogical variations. Most of the sedimentary deposits within the Safford Valley are characteristically lenticular and discontinuous, making the determination of mineral zones difficult. The fact that the same general suite of minerals seems to occur throughout the range of stratigraphic units sampled indicates that attempts to use heavy minerals for correlation within the sequence of Cenozoic beds must be based on attention to frequency of occurrence of mineral species, rather than on any major changes in the assemblages.

The uniformity of the heavy mineral suites over a considerable lateral and vertical range implies an over-all uniformity of composition of the source rocks, even though there is considerable variation of rock types within the blocks. The extent to which frequency changes of mineral species within the sediments might be correlated with minerals from specific source areas has not been investigated.

The uniformity of the volcanic mineral assemblages over the area might be partly the result of extensive volcanic activity. This activity contributed similar detrital minerals throughout the area. The volcanic debris was then reworked into the non-tuffaceous sediments

and accounts for the varying degrees of angularity and preservation of grains in different beds. The freshness of many species of unstable minerals supports this origin for much of the detritus.

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