LATE CENOZOIC STRATIGRAPHY IN THE DRY MOUNTAIN AREA, GRAHAM COUNTY, ARIZONA

by

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APPROVAL BY THESIS DIRECTOR

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May 11, 1960
Date

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INTRODUCTION

Location

Dry Mountain is located at the northwestern corner of the Whitlock Hills, near the intersection of the Gila and San Simon Valleys, Graham County, Arizona. Field investigation includes parts of secs. 21, 22, 27, 28, 29, 31, 32, 33, and 34, T. 8 S., R. 28 E., and parts of secs. 3, 4, and 5, T. 9 S., R. 28 E.

The area is accessible by driving 13.6 miles east of Safford, Arizona on U. S. Highway 70, and then continuing south on a good dirt road 4.5 miles to the abandoned 111 Ranch. This is the northeastern boundary of the study (Fig. 1).

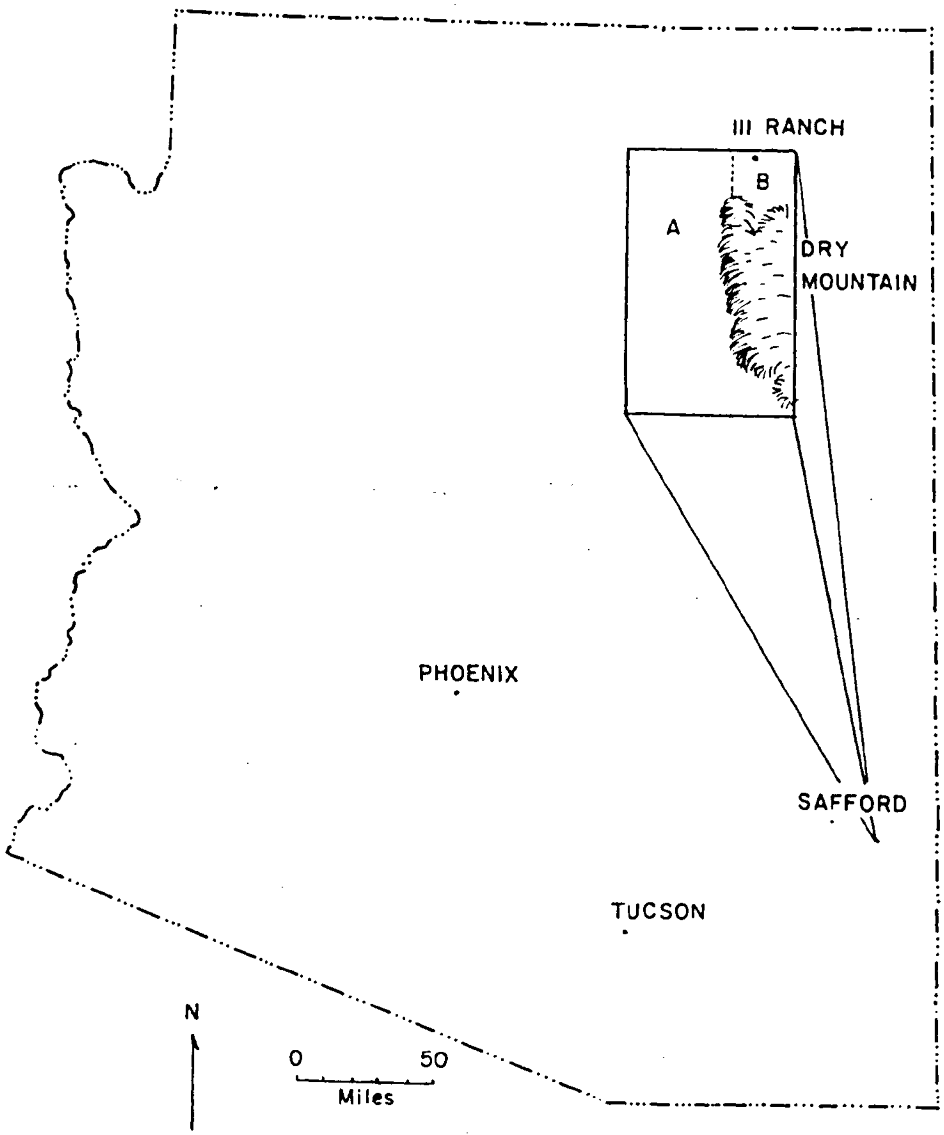
Topography and Drainage

The elevation of the 111 Ranch is approximately 3,700 feet. It increases only slightly as the Whitlock Hills are approached. Along the foot of the mountains the basin-fill material has been eroded into a semi-badland topography having a relief of approximately 200 feet.

Drainage consists of an intricate pattern of gullies resulting from summer cloudbursts. During periods of heavy rains and flash floods water flows in the gullies into San Simon Creek, an intermittent

FIGURE 1

Index map of the Dry Mountain and 111 Ranch areas.



A. THIS THESIS

B. P. SEFF THESIS

stream which in turn drains into the Gila River. The Gila River is the major drainage stream of the Gila, Safford, and San Simon Valleys.

Climate and Vegetation

The climate in Graham County is hot and dry. Rainfall statistics from the Safford Experimental Farm show for the 1948-1954 period an average annual precipitation of 7.20 inches. Records of the Safford Weather Station from 1896-1953 show an average annual rainfall of 9.23 inches. During these same years temperature records show a mean maximum of 81.1° and a mean minimum of 45.7°. The maximum temperature recorded during this period was 114°, and the lowest temperature was 7° (Smith, 1956).

Vegetation of the Whitlock Hills includes mesquite, gama grass, creosote bush, ocotillo, yucca, and barrel and prickly pear cactus.

Purpose of Study

The purpose of this study was to map and correlate the Quaternary sediments in the Dry Mountain area. The sedimentational characteristics of the detrital and chemical sediments were studied for variations in lithology to determine possible drainage directions and sources of the sediments, and information as to their petrogenesis.

Field and Laboratory Techniques

Field mapping was conducted during the summer months of 1959. Laboratory examination was completed during the fall and winter of 1959-1960.

Mechanical analyses were made on the channel sands and flood plain silts. The channel sands were sieved with U. S. Standard Sieves. The pipette method of analysis (Krumbein and Pettijohn, 1938) was used for the silts and clays.

Results of mechanical and pipette analyses were plotted as histograms and cumulative curves. Statistical data were derived from the cumulative curves.

Each channel sand sample was examined with a binocular microscope to determine gross differences between samples as well as differences between each grade size. Selected samples of channel sands were mounted in Canada balsam and ground to 0.03 mm for thin section identification of the grains.

Heavy minerals were separated from 38 samples of channel sands and silts and examined with a petrographic microscope to determine variations in quantity and distribution.

Thin sections of all limestone units were examined in order to properly classify them and determine the nature of the insoluble detritus. An insoluble residue analysis was made on each unit containing appreciable carbonate.

Selected chert samples were obtained from Philip Seff, who is making a detailed study of the 111 Ranch area adjacent to this study (Fig. 1). Slides of the chert were examined to determine its mode of formation.

Previous Studies

Several studies on the water supply of the Safford-San Simon Valleys have been published. These include Schwenneson (1917), Knechtel (1938), Halpenny and Feth (1952), Halpenny and DeCook (1952), and Cushman and Halpenny (1955).

The most complete work to date on the geology of the area is by Knechtel (1936, 1938), and by Van Horn (1957). Mathias (1959) made a detailed study of detrital minerals in the region.

Acknowledgments

The author wishes to express his appreciation to the following people for their assistance in the completion of this thesis. Willard D. Pye, thesis director, critically reviewed the ideas of the writer and offered many valuable suggestions; John F. Lance suggested the problem and consulted with the writer on several occasions; Joseph F. Schreiber, Jr. devoted his time to direction of the laboratory analysis, and offered many suggestions as to procedure, form, and presentation of laboratory data. My thanks go to Philip Seff, who accompanied the writer in the field during much of the study; and to the graduate students of the University of Arizona with whom I have discussed the problem.

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STRATIGRAPHY

Introduction

Safford Valley is a basin of deposition for the surrounding mountain ranges. The Gila River flows through the center of the valley and is the effective base level of erosion for the region. North of the Gila River are the Gila Mountains, and at the southeastern end of the valley the Peloncillo Mountains. These mountains consist mainly of intrusive and extrusive igneous rocks which are probably of Tertiary age. They also contain lavas, some of which may be of Quaternary age (Knechtel, 1938).

South of the river are the Turnbull, Santa Teresa, and Graham Mountains. According to Ross (in Knechtel, 1938), Precambrian Pinal schist and associated igneous rocks comprise the Graham Mountains, and form the cores of the Turnbull and Santa Teresa Mountains.

The Whitlock Hills are south of the Gila River and at the southeastern end of the valley. The geologic map of Graham County indicates that they are composed of Tertiary andesite, rhyolite, and basalt, with included tuff and agglomerate. The basalt may be of Quaternary age. The writer did not study in detail the igneous rocks of the Whitlock Hills. However, several thin sections of present-day channel sands being derived from the Whitlock Hills were examined and the mineralogy of these sands confirms the andesite, rhyolite, and basalt composition of these crystalline rocks. On the west side of Dry Mountain there is a large north-south-trending perlite dike. The channel sands near the outcrop of the dike contain detrital perlite fragments.

Tertiary Sediments

Gila Conglomerate

The Gila conglomerate of Tertiary and Quaternary age is the most extensive and oldest sedimentary formation outcropping in the Safford Valley. It was first described and named by G. K. Gilbert (1875). Gilbert included in his description the "lake beds" as well as a characteristic fanglomerate member.

Schwenneson (1919), considered the fanglomerate as a distinct unit formed previous to the "lake beds." Knechtel (1936), considered the fanglomerate and "lake beds" as equivalent units, with their contact representing a change in facies. Well log data indicate that the contact is not abrupt as it would be if they were deposited at separate times, but instead the contact is gradational. Knechtel (1938), noted that the fanglomerate facies is absent around the Whitlock Hills but is lithologically represented by the "lake beds."

Heindl (1958) describes three phases of deposition between the mouth of Bonita Creek and Frye Mesa. The first two phases are divisions which he recognized in the Gila conglomerate of Gilbert. The first phase is an upper conglomerate which Heindl named the Solomonsville beds (these include the "lake beds"). The second phase is a lower conglomerate which he named the Bonita beds. Heindl's third phase of deposition is large alluvial fans on the west side of the valley.

Quaternary Sediments

Quaternary sediments of the Dry Mountain area are represented by the Solomonsville beds. Graphic representation of the section in this area is given in Figure 2. Detailed measured sections are described in Appendix I.

Exposures of the Solomonsville beds around the base of the Whitlock Hills are limited to about 7 square miles.

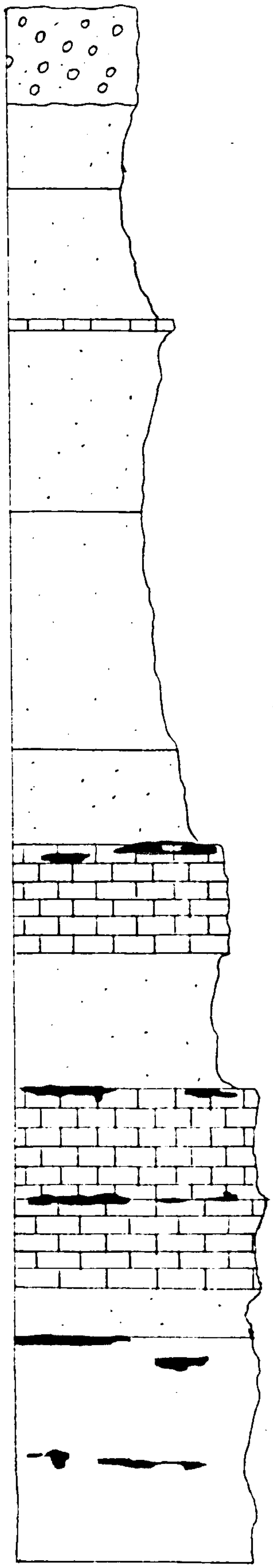
Thickness

The maximum composite thickness of exposed Solomonsville beds at the base of Dry Mountain is 180 feet. Seff (personal communication, March 12, 1960) measured a 212-foot composite section 1 mile northeast of this study.

According to Halpenny and Feth (1952), "the deepest well recorded in the Safford basin penetrated 3,767 feet without encountering bedrock." Based on well logs, Van Horn (1957) estimated that the

FIGURE 2

Columnar section of the Dry Mountain area.



Terrace gravel cap, 11.5 feet, cemented by caliche ($CaCO_3$).

Sand, 9.2 feet, light gray to brown, some cross-lamination.

Silt, 15.2 feet, light brown, slightly sandy in places.

Limestone, 1.2 feet, white.

Silty sand, 21.2 feet, brown to gray, contains sandy lenses, occasional cross-lamination.

Sandy mud, 27.5 feet, brown, contains some $CaCO_3$.

Sandy mud, 11.1 feet, buff to reddish-brown, sandy near top.

Limestone, 12.6 feet, white when pure, locally associated with chert.

Sandy mud, 15.6 feet, brown, sandy in places, massive, some cross-lamination.

Limestone, 12.9 feet, white when pure, locally associated with chert.

Limestone, 10 feet, white when pure, locally associated with chert.

Sandy mud, 6+ feet, brown.

Diatomite, 26+ feet, white, massive, contains chert lenses.

Solomonsville beds may exceed 2,400 feet.

Age of the Sediments

Lance (1958) reports the presence of Equus (Equus) teeth that "... indicates that deposition continued into Irvingtonian, or post-early Kansan time." One crushed capybara skull has been found which Lance tentatively assigned to an extinct genus, Neochoerus. This fossil may indicate a warm and wet climate during part of Irvingtonian time.

Additional work on the paleontology of the Dry Mountain and 111 Ranch areas is in progress at the University of Arizona.

Relation of Solomonsville beds to the Whitlock Hills

The last major deformation of the area occurred prior to deposition of the Solomonsville beds. Drainage patterns in the Whitlock Hills had been well established and streams had cut narrow "V-shaped" valleys in the volcanics. The Solomonsville beds that were deposited around the base of Dry Mountain were laid down over this irregular surface. The sediments filled the previous formed valleys of the Whitlock Hills with a resulting pattern of re-entrances of sediments and projections of basement rock.

The contacts between the Solomonsville sediments and the igneous rocks of the Whitlock Hills are covered with recent detrital material and can be observed in only one or two places.

Correlation

Individually the units are moderately thin, generally less than 10 feet in thickness. However, laterally they may vary as much as 8 feet in thickness over a distance of 1 mile. Three units are very persistent. The middle unit is a massive, brown silt, and the other two are white- to light-gray limestones with associated chert lenses. Because of their resistance to erosion and white color, these limestones were used along with the silt unit as key horizons in mapping the area and correlating the intervening units (Figs. 3 and 4).

The units of sections 1 and 2 are near the portion of the 111 Ranch area mapped by Seff. These units are also correlative across that area.

Facies changes occur both laterally and vertically. Laterally all units fluctuate, not only in thickness but also in lithology. Limestone becomes clayey or sandy and then limy again. Silt units become sandy in places and then grade back into silt. Vertically the contacts are gradational and sedimentation was as continuous as can be expected under fluvial and lacustrine conditions (Fig. 5).

Approximately 2-1/2 miles south of the 111 Ranch all the limestone units are beneath the surface. The section from this point south consists of more recent Solomonsville silts and sands. These silts and sands are not very extensive in the northern part of the area for they

FIGURE 3

Index map showing location of measured sections.

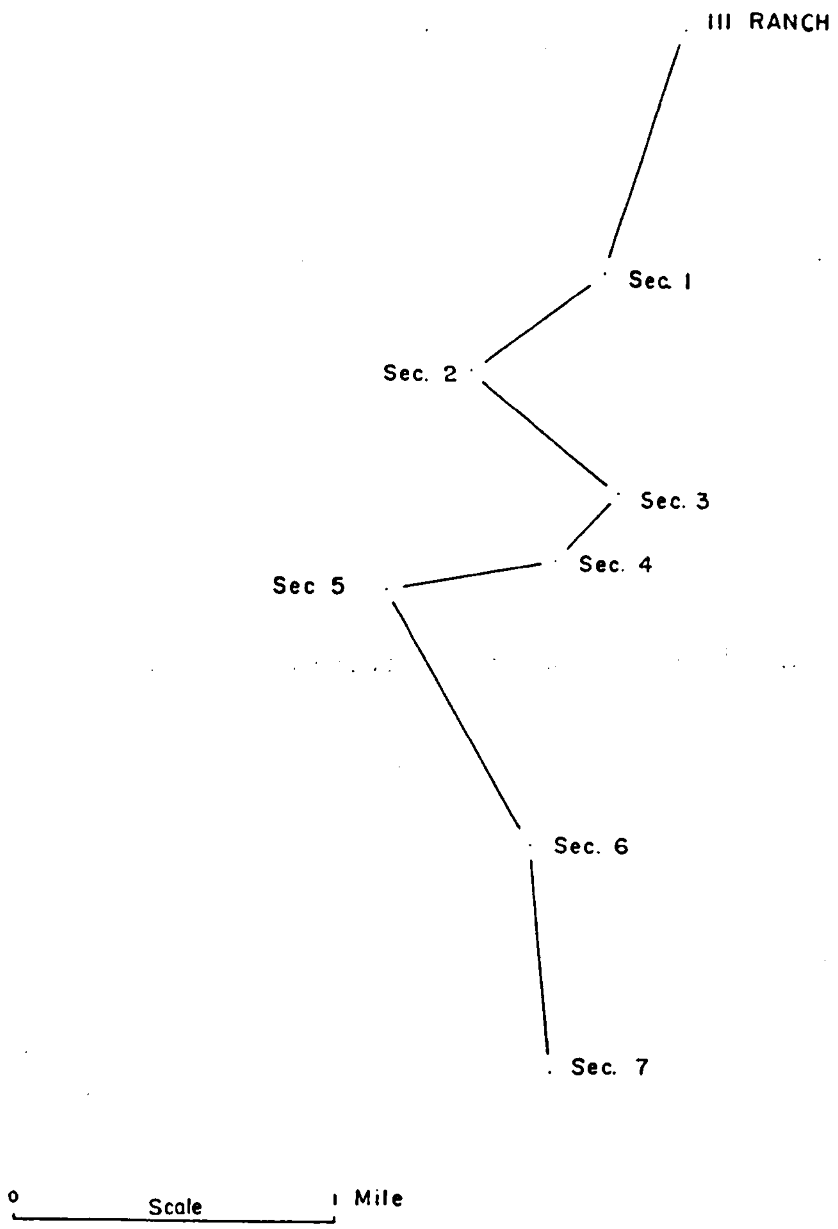

III RANCH
Sec. 1
Sec. 2
Sec. 3
Sec. 4
Sec 5
Sec. 6
Sec. 7
N
0
Scale
1 Mile

FIGURE 4

Stratigraphic section of the Dry Mountain area.

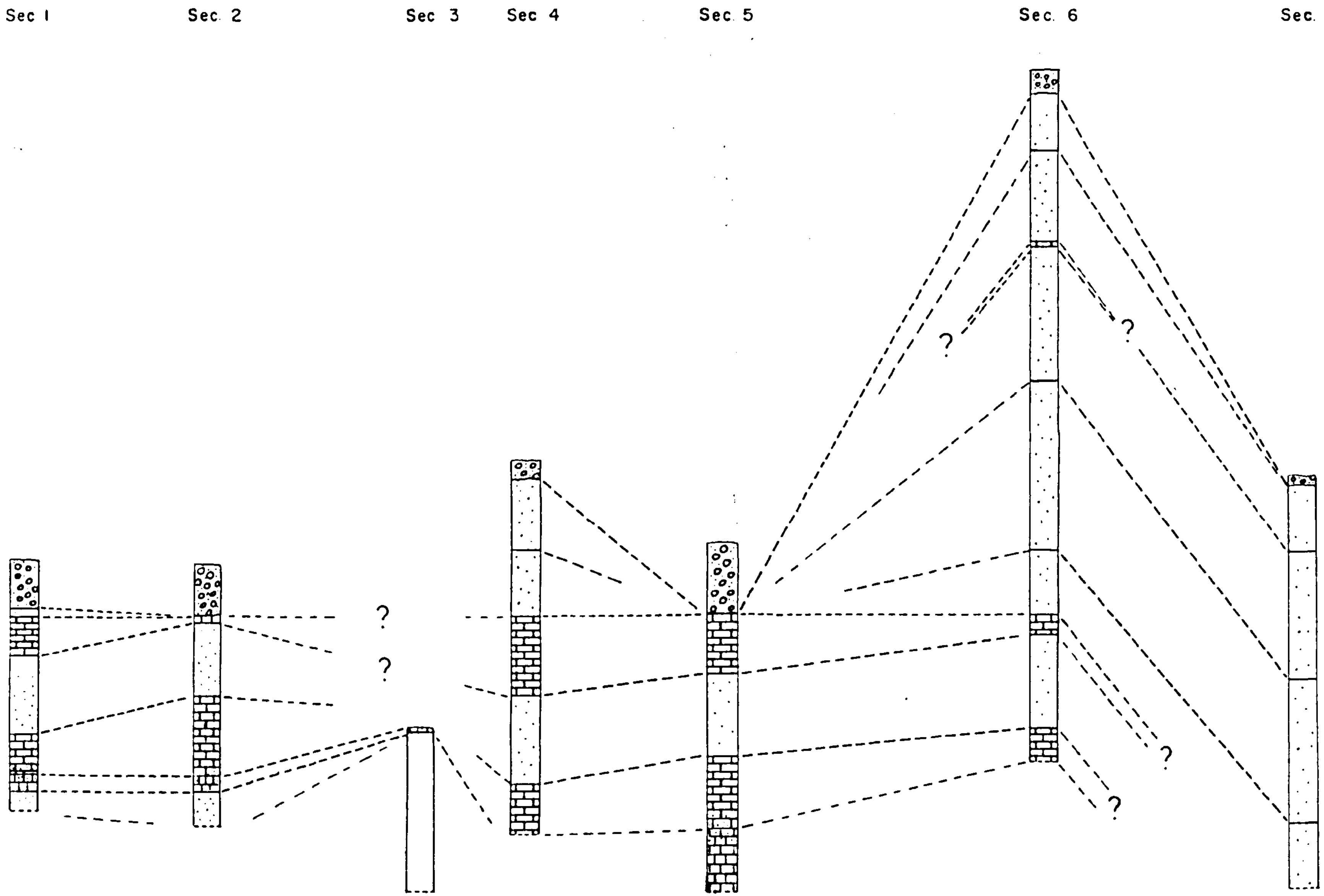

Sec 1
Sec. 2
Sec 3
Sec 4
Sec. 5
Sec. 6
Sec. 7
?
?
?
?
?
?

FIGURE 5

Badland Topography

A

Typical "badland topography" in the Dry Mountain area.

B

Typical "badland topography" in the Dry Mountain area.

FEB 60

APR 60

have been removed by erosion. Near the southern limit of the mapped area recent gravels disconformably cover the exposures and further correlation becomes impossible (Fig. 6).

Terrace Gravel

The terrace gravels are deposits of coarse detrital material consisting of sand, pebbles, and small cobbles. Occasionally cobbles and boulders 1 foot and more in diameter are encountered.

Near the Whitlock Hills this material has accumulated as alluvial deposits covering the Solomonsville beds. According to Van Horn (1957), the gravels were formed during a period of aridity following deposition of the Solomonsville beds. They lie unconformably upon the lake beds but are previous to deposition of the Recent alluvium. On this basis Knechtel (1938) assigned them to Pleistocene(?) age.

The gravels form a resistant layer capping outliers of Solomonsville sediments and dissected alluvial terraces at the base of the Whitlock Hills. Where this layer has been completely removed by erosion, outcrops of the unconsolidated lake beds are exposed. The gravel cover becomes increasingly persistent along the southwest side of Dry Mountain. Where the gravel is cemented it occurs as a resistant cap generally several feet thick, although it may vary from an inch to approximately 12 feet in thickness. Where consolidated it is cemented with $CaCO_3$ in the form of caliche. In a few localities the caliche has built a deposit

FIGURE 6

Recent Alluvial Cover

Recent alluvial cover over the Solomonsville beds at the south end of the thesis area.

of white carbonate an inch or more thick on top of the gravel. The caliche is confined to the flatter surfaces near the summit of the hills, leaving the gravel-covered flanks unconsolidated.

Recent Alluvium

Recent alluvium, consisting of sand and silt, is carried and deposited by sheetfloods which occur several times each year. The alluvium is widely deposited around the hills and flatter parts of the area. It is derived from both the Whitlock Hills and from reworking of the lake beds.

SEDIMENTATION

Diatomite

Diatomite crops out in numerous places in the northeastern portion of the area adjacent to the Whitlock Hills. The diatomite is a pure white, unconsolidated silty material. Stratigraphically it is the oldest sedimentary unit encountered during the study. Its lower contact is covered and therefore the total thickness cannot be determined; however, 25 feet of the unit is exposed in a prospect pit half a mile east of the Dry Mountain area. It can be traced only a short distance to the north and only 1 mile to the southwest before dipping under younger sediments.

Mathias (1959) made a detailed study of the diatomite samples collected approximately half a mile to the east of the present study. His thin-section analysis of the diatomite found it to contain 75 to 85 percent diatoms and diatom fragments. The remainder consisted of "... silt-size quarts and feldspar (10-20%), mafic minerals (less than 1%), siliceous sponge spicules (less than 1%), and rounded 'opaline' material (less than 2%)."

Samples collected by Knechtel (1938), and examined by K. E. Loham, are reported to contain only 30% diatoms. His samples were collected near the 111 Ranch in the SE 1/4 sec. 21, T. 8 S., R. 28 E. This is approximately 1 mile southwest of the Mathias diatomite locality.

Several claims have been staked for the diatomite, but there has been no production to date.

Limestone

In the Dry Mountain area, lacustrine limestone is represented by irregular but persistent beds 1 foot or more in thickness extending over most of the area mapped.

The limestone is a calcilutite (Pettijohn, 1957) and is composed of finely crystalline, chemically deposited calcite. Cutting the limestone beds are small veins or stringers of coarser secondary calcite.

The limestone beds represent deposition in small, possibly saline lakes and ponds that persisted sporadically during Pleistocene time. This deposition is represented most prolifically by three beds of dense, white to light-gray limestone. Each unit is associated with varying amounts of calcareous clay and silt. Laterally they thicken or thin, increase or decrease in carbonate content, or they may split into several thin units of limestone separated by white to green calcareous clay. The units range from pure limestone to calcareous and non-calcareous silts and clays. The inconsistent lithologic characteristics of the limestone indicate a probable transition from lacustrine to marsh, swamp, or flood-plain environments.

At some localities thin layers of bedded gypsum are associated with the limestone units. Both satin spar and selenite are represented. The evaporites probably represent the drying-up of some of the ponds.

Thin sections of samples collected at each measured section showed that it is impossible to distinguish the individual beds on the basis of their petrographic characteristics. One sample appears very much like another, except for more or less detrital material. The character and percent of detrital material present in a sample is not significant for correlation purposes (Table 1).

The following detrital minerals were identified in the limestone: oligoclase, andesine, quartz, augite, brookite, biotite, hornblende, magnetite, and other opaques.

The mineralogy compares favorably with that of the channel sands and silts (see Tables 3 and 5). The mineralogy suggests that the most important source area for these detrital grains is the Whitlock Hills.

Fossil fragments were not present in the thin sections although in the field fresh-water molluscs, turtle fragments, and vertebrate fossils were located in the calcareous clays.

Only those units with a carbonate content of greater than 10 percent are listed in Table 1. Some of the limestone units at a particular section have less than 10 percent $CaCO_3$, and are considered clay or silt.

TABLE 1

INSOLUBLE RESIDUE ANALYSIS

Sample	Correlative Horizon	Percent Insoluble Residue
Section 1		
Unit 3	B	10.0
Unit 6	D	37.0
Section 2		
Unit 2	B	11.0
Unit 4	C	29.0
Unit 5	D	31.0
Section 4		
Unit 6	C	37.5
Section 5		
Unit 2	B	51.0
Unit 4a	C	23.5
Unit 4b	C	90.0
Unit 5	D	25.5
Section 6		
Unit 4	A	21.0
Unit 8	B	32.5

Note: Correlative horizons in the different sections are indicated by the same letters in column 2 of the above table.

Chert

Genetically associated with the limestone and diatomaceous deposits are lenses and nodules of chert. At places the nodules are isolated, but more typically they are connected forming lenses or continuous layers along the bedding planes of the limestone and diatomite. According to Pettijohn (1957), nodules are located along and parallel to bedding planes because of the ease of replacement in these zones.

The chert is typically dense, hard, and gray to white in color. However, transitions from porcellanite on the one hand to unaltered limestone on the other hand can be observed at many places.

As the chert is traced southward toward the Whitlock Hills it becomes massive, with many lenses giving a rhythmically bedded appearance.

The chert is badly fractured and in places slump structures are noted. According to Pettijohn (1957), chert layers which are involved in slump structures must be penecontemporaneous with sedimentation and be prelithification. The slumping is probably a result of sediment compaction.

Carnotite has been deposited along the fractures and bedding planes of the chert. The nearness of the Whitlock Hills seems to have influenced both the deposition of the carnotite and the formation of the chert, since each becomes more abundant as the mountains are approached. In the past few years prospectors have staked claims for carnotite over the area, but it is not abundant enough to be of economic value.

Vertebrate fossils are occasionally found in the chert and several large pieces of opalized wood were found. In some cases the fossils have been completely replaced by silica. These are being studied by another author and will appear in a separate paper.

Thin-section analysis shows the chert to be a replacement by cryptocrystalline chalcedonic quartz and opal along fractures and vugs in the limestone. The vugs are filled with long radiating fibers growing in optical continuity with each other. In samples with greater amounts of replacement the calcite becomes a minor constituent.

Pettijohn (1957) lists the following criteria for the epigenetic origin of chert.

(1) The occurrence of chert along fissures in limestone.

(2) The very irregular shape of the chert nodules.

(3) The presence of irregular patches of limestone within some nodules.

(4) The association of silicified fossils and cherts in some limestones.

(5) The presence of replaced fossils in some chert.

(6) The presence of textures and structures (especially bedding) in some cherts (Bastin, 1933; White, 1937).

(7) The failure of some cherts to follow definite zones in limestone formations.

(8) The occurrence of silicified oolites formed by replacement of calcareous ones.

The first five criteria listed are noted in the cherts of the Solomonsville beds of the Dry Mountain area. Therefore, based on these criteria, it is believed that the chert is of epigenetic origin.

Channel Sands

One of the more distinctive features of this area in contrast to the 111 Ranch area is the presence of numerous channel sands. In the 111 Ranch area, channel sands are rare, and clastic sedimentation is restricted to silts of a flood-plain environment. In the Dry Mountain area, channel sands appear in the same limestone and silt horizons that are present in the 111 Ranch area. Southward the channel sands become more abundant, and the silt units tend to be slightly thicker. However, there does not seem to be any appreciable difference in mean grain size or sorting in either the sands or silts. The channel sands reflect the influence of the Whitlock Hills. There can be little doubt that the sands are detrital material derived from the Whitlock Hills, and from Dry Mountain in particular. Many of the sands exhibit excellent cross-lamination of a typical lenticular pattern, with orientations indicating that the drainage direction is from the Whitlock Hills. In some cases outcrops are sufficient to permit tracing of the channels for short distances. The results substantiate the cross-stratification directions. The mineralogy of the sands corresponds very closely to the mineralogy of the Whitlock Hills.

Sorting, mean size, and mineralogy of present-day channel sands being derived from the Whitlock Hills compare favorably with the channel sands of this study.

To the south the limestone and silt units disappear under younger Solomonsville sediments. A stratigraphic section of these younger sediments is represented by thicker units of silt and an increasing number of channel sands. These younger Solomonsville units were probably also present in other parts of the Dry Mountain and 111 Ranch areas, but have been removed by erosion. They represent a changing environment of deposition with time, from the warm, moist, lacustrine environment to the present-day, dry, semi-arid environment of detrital clastic sedimentation.

Size analyses were made on each of the channel sands sampled. Due to the unconsolidated condition of the sand, very little preparation of the sample was necessary. The few grains adhering to one another were easily separated by gently rubbing with the fingers. A Jones sample splitter was used to reduce the total sample to a 50 gram representative sample.

The results of the sieve analyses are plotted as histograms and cumulative curves in Figures 7, 8, 9, and 10. They are recorded in the Phi (Ø) units of Krumbein (1938), since these values are more

FIGURE 7

Classification of Channel Sands (Folk, 1954)

G	=	Gravel
mG	=	muddy Gravel
msG	=	muddy sandy Gravel
sG	=	sandy Gravel
gM	=	gravely Mud
gmS	=	gravely muddy Sand
gS	=	gravely Sand
(g)M	=	slightly gravely Mud
(g)sM	=	slightly gravely sandy Mud
(g)mS	=	slightly gravely muddy Sand
(g)S	=	slightly gravely Sand
M*	=	Mud
sM	=	sandy Mud
mS	=	muddy Sand
S	=	Sand

* Mud is composed of silt plus clay.

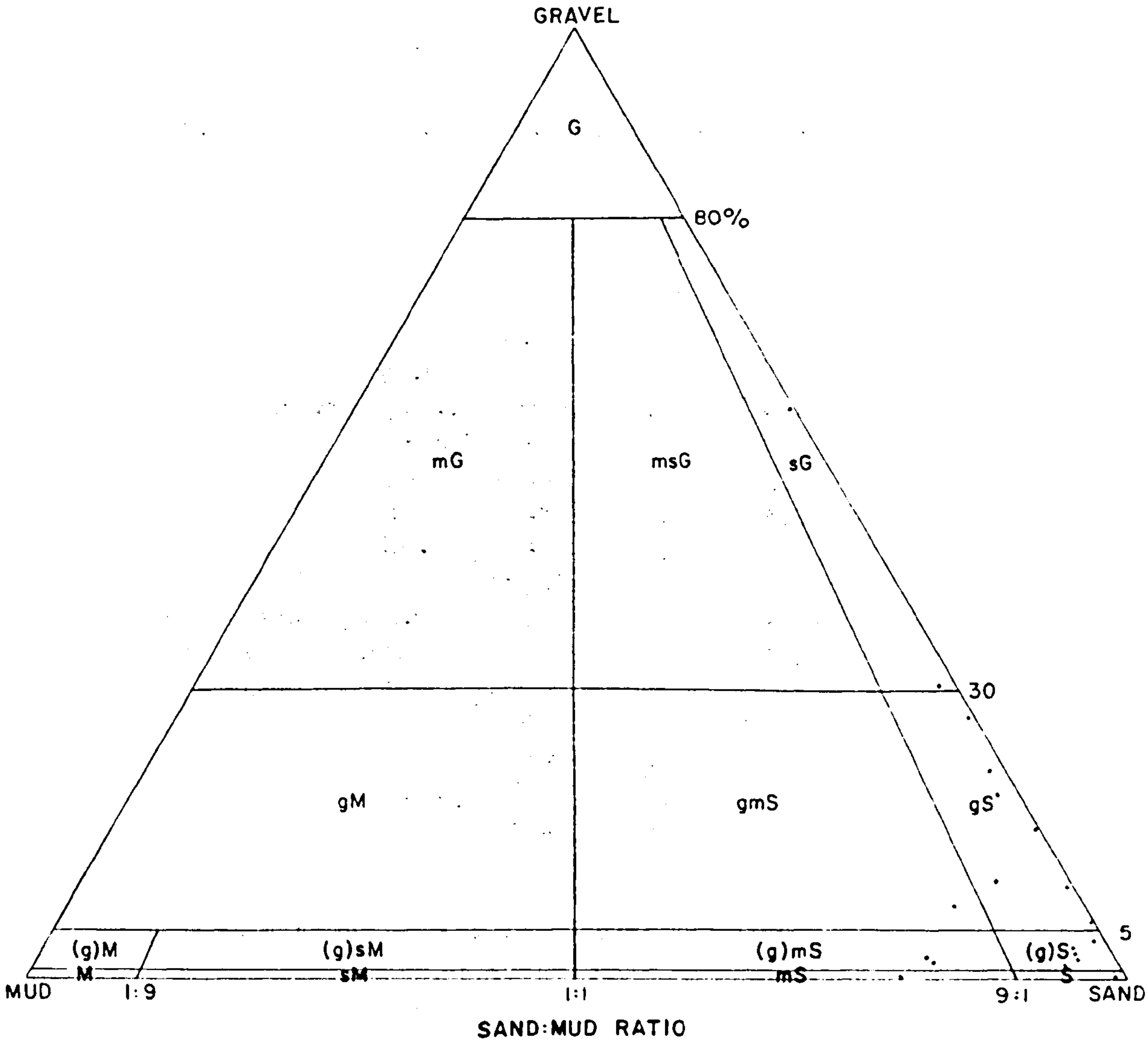

GRAVEL
G
80%
mG
msG
sG
30
gM
gmS
gS
5
(g)M
(g)sM
(g)mS
(g)S
M
sM
mS
S
MUD
1:9
1:1
9:1
SAND
SAND:MUD RATIO

FIGURE 8

Histograms of channel sands.

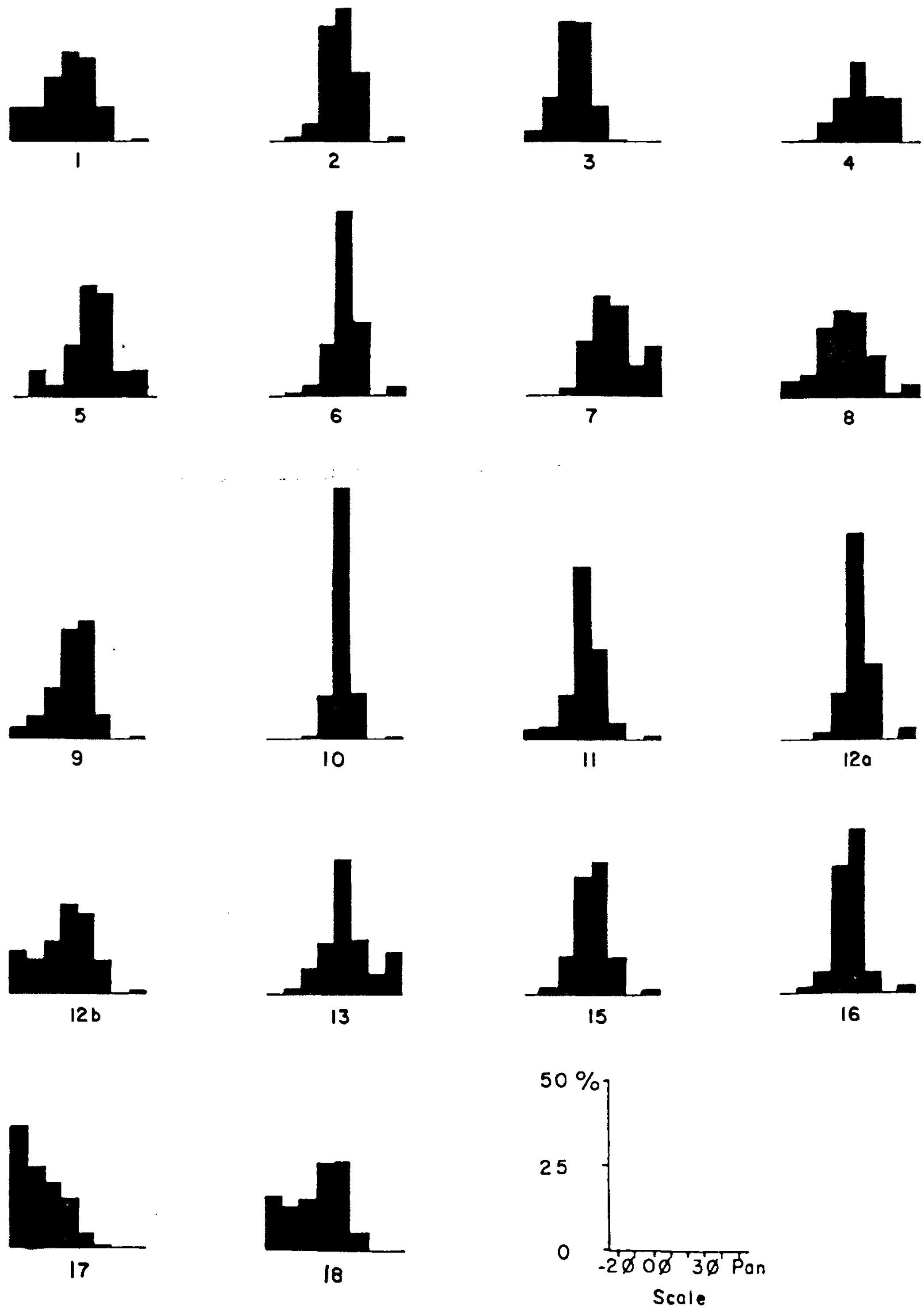

1
2
3
4
5
6
7
8
9
10
11
12a
12b
13
15
16
17
18
50 %
25
0
-2Ø 0Ø 3Ø Pan
Scale

FIGURE 9

Cumulative curves of channel sands.

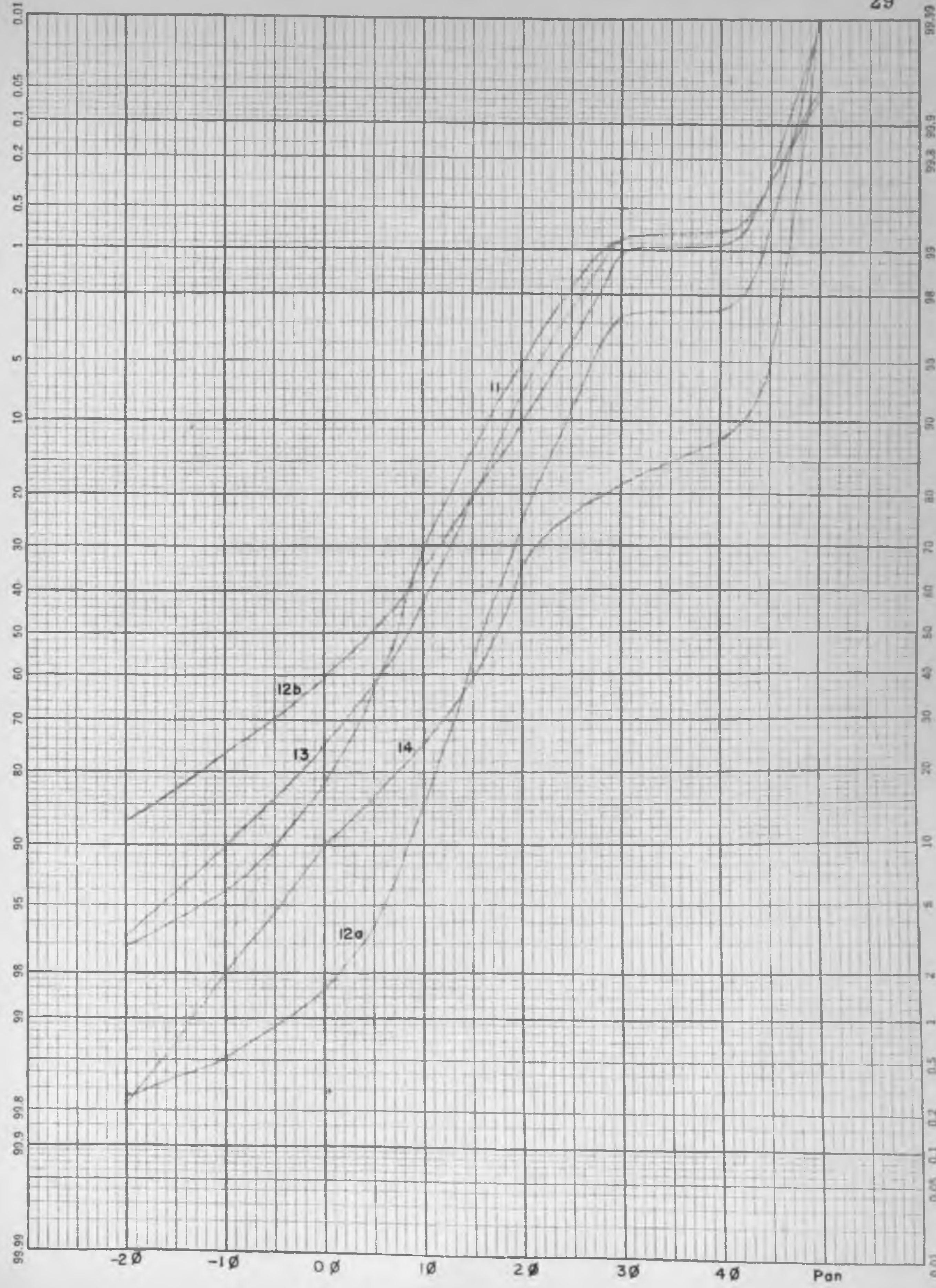
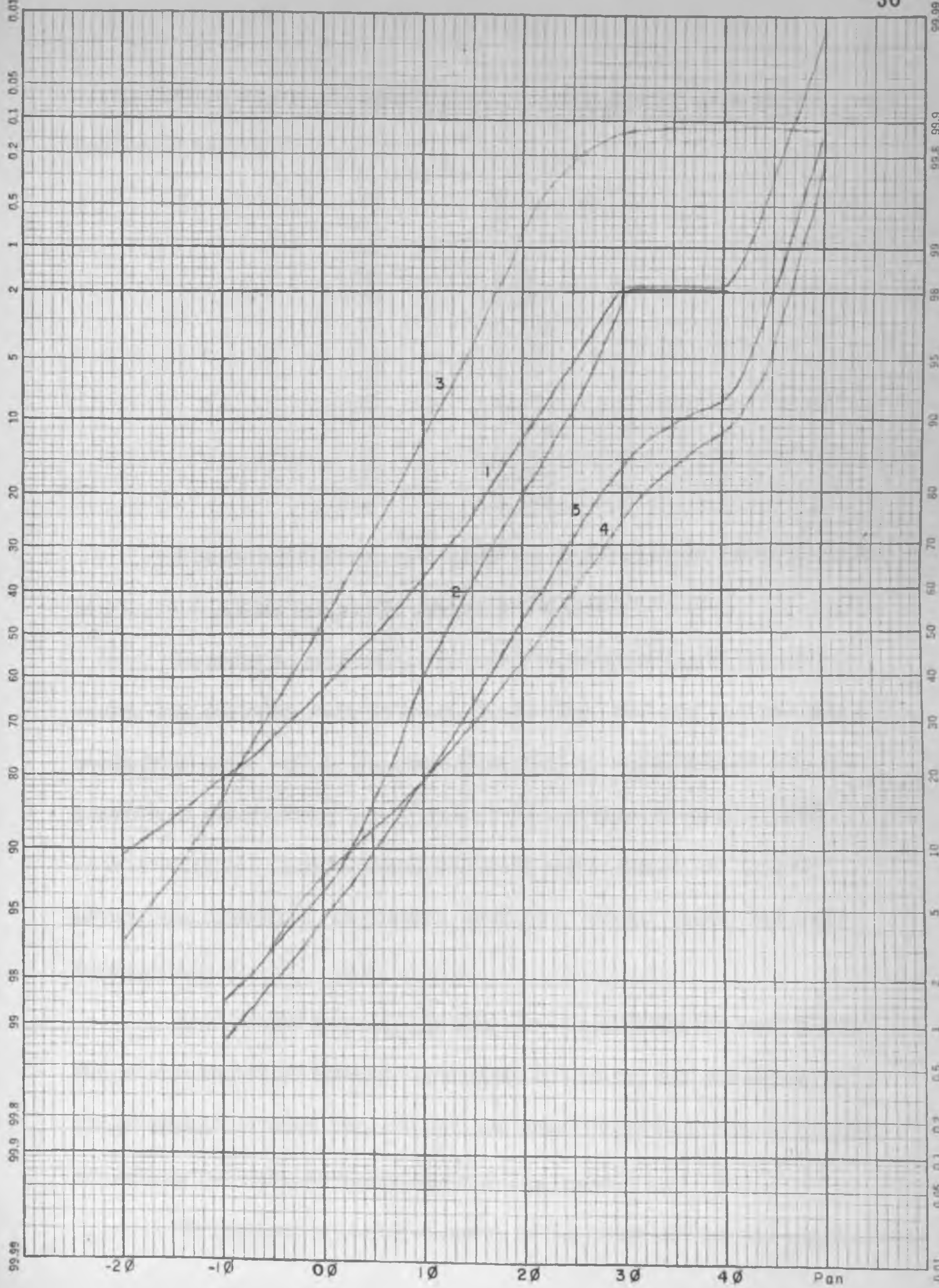

11
12b
13
14
12a
-2Ø
-1Ø
0Ø
1Ø
2Ø
3Ø
4Ø
Pan

FIGURE 10

Cumulative curves of channel sands.


0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
-2Ø
-1Ø
0Ø
1Ø
2Ø
3Ø
4Ø
Pan
1
2
3
4
5
K&E PROBABILITY SCALE 359-23
X 90 DIVISIONS
KEUFFEL & ESSER CO.

easily used in statistical computation. Millimeter-phi conversion units are listed below.

-2ø	=	4	mm
-1ø	=	2	
0ø	=	1	
+1ø	=	0.5	
+2ø	=	0.25	
+3ø	=	0.125	
+4ø	=	0.062	
+5ø	=	0.031	
+6ø	=	0.016	
+7ø	=	0.008	
+8ø	=	0.004	
+9ø	=	0.002	
+10ø	=	0.001	

The nomenclatural classification of the channel sands is given in Figure 7.

In order to determine the mineral composition of the channel sands, two samples were selected (5 and 12b), and thin sections were made from each. Since the channel sand is unconsolidated it was impossible to determine grain to grain relationships or other overall characteristics. The following minerals were identified: quartz, orthoclase, andesine, oligoclase, enstatite, augite, mica, and rock fragments.

A binocular microscope was used to examine the sand grains for such features as texture, roundness of grains, and variations of gross characteristics between various grade sizes of the same sample as well as variations between different samples.

The following is a discussion of the observations and conclusions reached from the binocular examination of the channel sand samples and from each individual size grade.

Roundness was determined by comparing the grains with the Powers (1952) roundness chart.

The -2ϕ fraction consists entirely or rock fragments, which on the basis of mineralogy appear to be quartz latite or dacite in composition. Perlite fragments are occasionally encountered. They are derived from a large perlite dike outcropping at the northwestern end of Dry Mountain. Channel sands containing these fragments are generally near exposures of the dike.

The rock fragments range from angular to subrounded, but the majority are subangular. Shape varies from spheroid to roller, and from disks to blades. The present shape reflects to a considerable extent the original shape of the fragment as it was broken or weathered from a larger rock.

Surface texture varies from smooth in some cases to rough and irregular in other cases. Some grains are pitted or frosted, a result of mechanical weathering during transportation.

Most of the grains in the -1ϕ grade fraction consist of rock fragments, although a few grains of quartz and feldspar are present. This seems to be the size at which the rock fragments begin to break down into their individual minerals. The rock fragments are still angular to subrounded, and in general exhibit the same properties as do those of the -2ø size. The quartz and feldspar grains are slightly smaller than the rock fragments and show slightly less mature properties. Some grains exhibit euhedral faces, with the edges fresh or only slightly rounded. Other grains are broken fragments, but for the most part they represent minerals that have weathered from the parent rock. Some of the better rounded varieties show a slight frosting.

In the 0ø size, rock fragments still are more abundant than the quartz and feldspar grains, however, the ratio between the two becomes much smaller. The only noticeable difference in this size material is the increased maturity of all grains. Although the shape is still classified as subangular to subrounded, the edges on grains are not as sharp. The quartz grains exhibit textures which include irregular fractures as well as smooth and frosted surfaces. Most of the grains are somewhat frosted, the intensity depending upon the degree of maturity. The better rounded grains are the ones with the greatest amount of frosting. It is evident that the frosting and probably most of the weathering of the stream channel sands is of a mechanical nature.

Most of the grains represent spheroid and roller forms; a few, however, are blade- and disk-shaped.

Quartz and feldspar in the 1ø grade exceed rock fragments in abundance. The grains are subangular to subrounded and frosted. The shape ranges through spheroid, roller, disk, and blade forms. A small amount of mica is present in some of the sands (less than 1%). Sample

17, which is a modern stream sand, exhibits a larger percentage of perlite rock fragments than the other sands. This is a result of the proximity of the perlite dike.

In the 2Ø grade size, quartz, feldspar, and rock fragments exhibit about the same features as in the 1Ø size, except that as the sand becomes smaller the percentage of rock fragments becomes less and the percent of quartz and feldspar becomes greater. By far the most striking feature of this fraction is the appearance of a considerable amount of heavy minerals. Many of the heavy minerals are magnetic, and because of their abundance in the rock fragments, many of them can be removed from the sand of any fraction with a small magnet. A more complete discussion of the heavy minerals will be considered later in the paper.

The rock fragments are almost completely destroyed by the time the channel sands have been reduced to 3Ø size. Quartz is the most abundant mineral followed by feldspars and the heavy minerals. All grains are slightly more rounded than the larger grains, but the same shapes and textures are common.

Only occasional rock fragments are noted in the 4Ø grades. Quartz, feldspar, and heavy minerals are abundant. The majority of the quartz and feldspar grains exhibit subrounded and frosted surfaces. The heavy minerals are subangular to subrounded, but a few still have euhedral faces. Samples 7, 17, and 13 have markedly fewer heavy minerals than the other channel sand samples.

The pan fraction contains all particles smaller than 4ø size. In most samples the grains are large enough to be identified; however, in sample 15 the grains were too small for binocular identification. Quartz, feldspar, and heavy minerals have the same properties as defined in the 4ø fraction. Rock fragments are only occasionally encountered. The only mineralogical addition to thise size grade is the presence of gold in all the samples. It consists of individual scattered flakes. There is not enough gold present in these sands to create an economic interest.

In summary, the rock fragments are magnetic, indicating the abundance of magnetic minerals. The rock fragments begin to break down into their individual minerals at 0ø size. Rock fragments finer than this size decrease in abundance rapidly, with only occasional grains remaining by the time they are reduced to the pan fraction. In the larger sizes, quartz and feldspar are angular, some of the fragments are broken, while others show some euhedral faces. As they become smaller they become progressively better rounded and more frosted. Heavy minerals begin to appear at the 2ø size, and are very abundant in the finer size grades. Some of the heavy minerals are euhedral, but most exhibit subangular to subrounded relationships.

Statistical Studies of the Channel Sands

Methods for computation of the statistical measures of both the channel sands and the silts were adapted from Inman (1952), and Folk and Ward (1957).

These authors, in calculating statistical measures of the kind used in this paper, make use of a greater portion of the cumulative curve than was done previously by Krumbein's quartile measures. The cumulative percentages are plotted on probability scale paper (Figs. 9 and 10). The Phi (ø) values at 15, 16, 25, 50, 75, 84, and 95 percentiles are determined from the cumulative curve. These values are substituted in the following formulae (Folk and Ward, 1957; Table 2 of this report).

Mean Size:

$$M_z = \frac{\phi16+\phi50+\phi84}{3}$$

Inclusive Graphic Standard Deviation:

$$\sigma_I = \frac{\phi84-\phi16}{4} + \frac{\phi95-\phi5}{6.6}$$

Inclusive Graphic Skewness:

$$Sk_I = \frac{\phi16+\phi84-2\phi50}{2(\phi84-\phi16)} + \frac{\phi5+\phi95-2\phi50}{2(\phi95-\phi5)}$$

Graphic Kurtosis:

$$K_g = \frac{\phi95-\phi5}{2.44(\phi75-\phi25)}$$

The mean size of the channel sands ranges between -0.10ø and

TABLE 2

STATISTICAL MEASURES OF CHANNEL SANDS

Sample No.	M_z	σ_I	Sk_I	K_g
1	0.33	1.55	0.48	1.0
2	1.29	0.86	0.09	0.15
3	-0.10	0.44	-0.03	1.00
4	2.18	1.38	-0.04	1.18
5	1.90	1.02	0.22	0.94
6	1.06	0.83	-0.25	1.22
7	2.26	1.39	0.22	1.01
8	0.73	1.34	-0.04	1.03
9	0.66	1.03	-0.19	1.07
10	1.25	0.44	-0.45	1.97
11	0.68	0.99	-0.16	1.33
12a	1.28	0.72	0.05	1.10
12b	0.19	2.02	-0.27	1.46
13	0.67	1.02	-0.28	1.13
14	2.54	1.46	0.11	0.59
15	1.03	0.91	-0.08	1.00
16	0.75	0.77	-0.83	1.28
17	-1.37	1.29	-0.32	0.51
18	-0.26	1.57	-0.28	1.15

2.54∅. On the Wentworth scale they range from fine to coarse sands. The largest percentage of the sand falls between the 1∅ to the 2∅ range, which places them in the medium (Wentworth) sand classification.

The sorting of the channel sands, or "inclusive graphic standard deviation" of Folk and Ward, varies from well sorted to poorly sorted. The majority of the sands, however, are moderately sorted.

Although the full significance of skewness and kurtosis studies in sedimentation has not been determined they are being included in this study for future reference.

Skewness and kurtosis cover a wide range of values. Many of the sands are negative-skewed, and many are nearly symmetrical. A positive value of skewness represents samples having "tails" in the fines, while negative values indicate a coarse-grained "tail."

Kurtosis according to Folk and Ward "measures the ratio of the sorting in the extremes of the distribution compared with the sorting of the central part." Kurtosis values of the channel sands range from very platykurtic, or flat curves, to very leptokurtic, or excessively peaked curves. Many of the channel sands exhibit mesokurtic relationships.

The verbal limits for statistical measures set by Folk and Ward are listed below:

Sorting:
under 0.35, very well sorted

0.35 to 0.50, well sorted
0.50 to 1.00, moderately sorted
1.00 to 2.00, poorly sorted
2.00 to 4.00, very poorly sorted

Inclusive Graphic Skewness, Sk_I:
-1.00 to -0.30, very negative-skewed
-0.30 to -0.10, negative-skewed
-0.10 to 0.10, nearly symmetrical
0.10 to 0.30, positive-skewed
0.30 to 1.00, very positive-skewed

Graphic Kurtosis, K_g:
under 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

Heavy minerals were separated from the 3ϕ grade of each sand. They were mounted on slides and identified by petrographic methods. Table 3 lists the minerals identified from each sample together with their relative frequency.

It is interesting to note the similarity and persistence of the mineral suite in each sample, and also the near constant frequency. This is indicative of a common source for the sands, which, as pointed out earlier, is the Whitlock Hills.

Silts

In the following figures, reference symbols are used for identification of individual silt units. These symbols are listed below:

TABLE 3

HEAVY MINERALS FROM CHANNEL SANDS

Sample	Augite and Enstatite	Brookite	Apatite	Zircon	Horn-blende	Biotite	Magnetite and Other Opaques
1	A	VF	S		VR		A
2	A	VF					A
3	A	VF	VR				A
4	A	VF	R		VR		A
5	A	VF					A
6	A	VF	R				A
8	A	VF	R				A
9	A	VF	S				A
10	A	VF	VR			VR	A
11	A	VF			VR		A
12a	A	VF	R	R			A
12b	A	VF	R	R	VR		A
13	A	F	R				A
14	A	VF	R				A
15	A	VF	R				A
16	A	F	VR				A
18	A	VF	VR		VR		A

Frequency Scale

A = Abundant
VF = Very Frequent
F = Frequent
S = Scarce
R = Rare
VR = Very Rare

Section	Reference Symbol
Section 7, Unit 2	a
Section 6, Unit 3	b
Section 7, Unit 3	c
Section 6, Unit 5	d
Section 4, Unit 2	e
Section 6, Unit 6	f
Section 7, Unit 4	g
Section 1, Unit 2	h
Section 4, Unit 3	i
Section 6, Unit 7	j
Section 1, Unit 4a	k
Section 1, Unit 4b	l
Section 2, Unit 3	m
Section 4, Unit 5	n
Section 5, Unit 3	o
Section 6, Unit 9	p
Section 2, Unit 6	q

Correlative units are bracketed. To determine the stratigraphic position of these units see Figure 4.

Two silt units (f and p) are very persistent and can be correlated over most of the 111 Ranch and Dry Mountain area. All other silt units are of more local extent and cannot be correlated over broad areas. The silts are not cemented but are consolidated enough to form vertical slopes. In other places they are represented by steep and gentle slopes. The thickness tends to increase slightly toward the south, but this is probably not of significance since both the magnitude of the thickness and the area over which the sediments are distributed are small.

The silts were deposited for the most part in a flood-plain environment. Some parts are undoubtedly of lacustrine origin, as for example near the contacts of limestone units where the limestone becomes silty and then grades into a true silt unit. The gradational zone probably represents a lateral transition from a lacustrine to a flood-plain environment.

Vertebrate fossils are found in the flood-plain deposited silt. In some cases a good portion of the skeleton was still in place.

The pipette method was used to secure the size distribution of the silt and clay samples. A 15 gram sample plus 2.48 grams of sodium hexametaphosphate were added to distilled water. These were then mixed in a malt mixer for 10 minutes. The sand content of the sample was separated by wet sieving, then dry sieved to determine its size distribution. The remaining suspension of silt and clay was separated into individual phi sizes by the pipette method. Nomenclature classification of the silts is given in Figure 11. Histograms and cumulative curves of the silts are plotted in Figures 12, 13, and 14.

FIGURE 11

Classification of Silts (Folk, 1954)

S	=	Sand
cS	=	clayey Sand
mS	=	muddy Sand
zS	=	silty Sand
sC	=	sandy Clay
sM	=	sandy Mud
sZ	=	sandy Silt
C	=	*Clay
M	=	*Mud
Z	=	*Silt

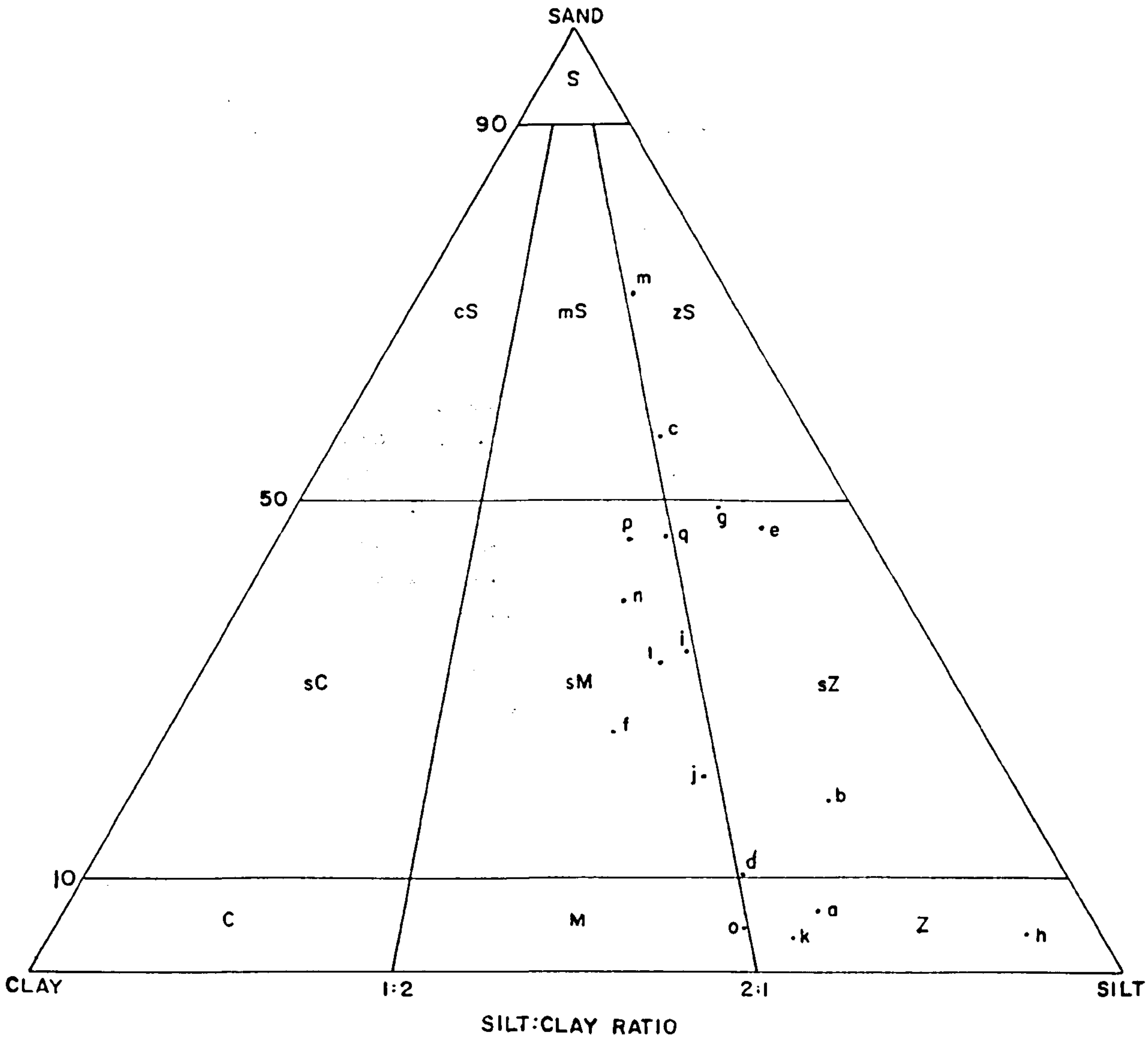
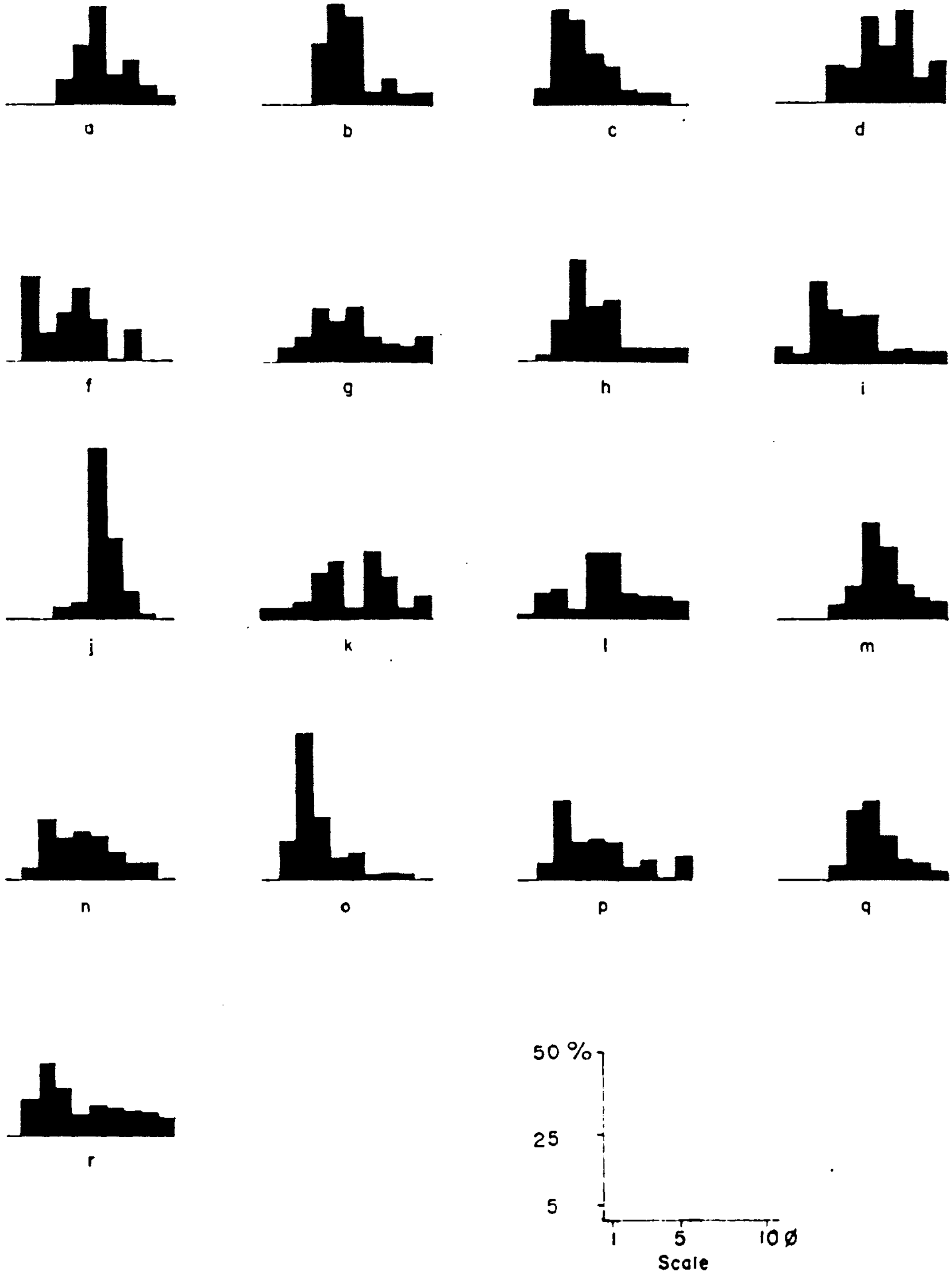

SAND
S
90
cS
mS
zS
m
c
50
p
q
g
e
n
i
l
sC
sM
sZ
f
j
b
d
10
C
M
o
k
a
Z
h
CLAY
1:2
2:1
SILT
SILT:CLAY RATIO

FIGURE 12

Histograms of silts.



a
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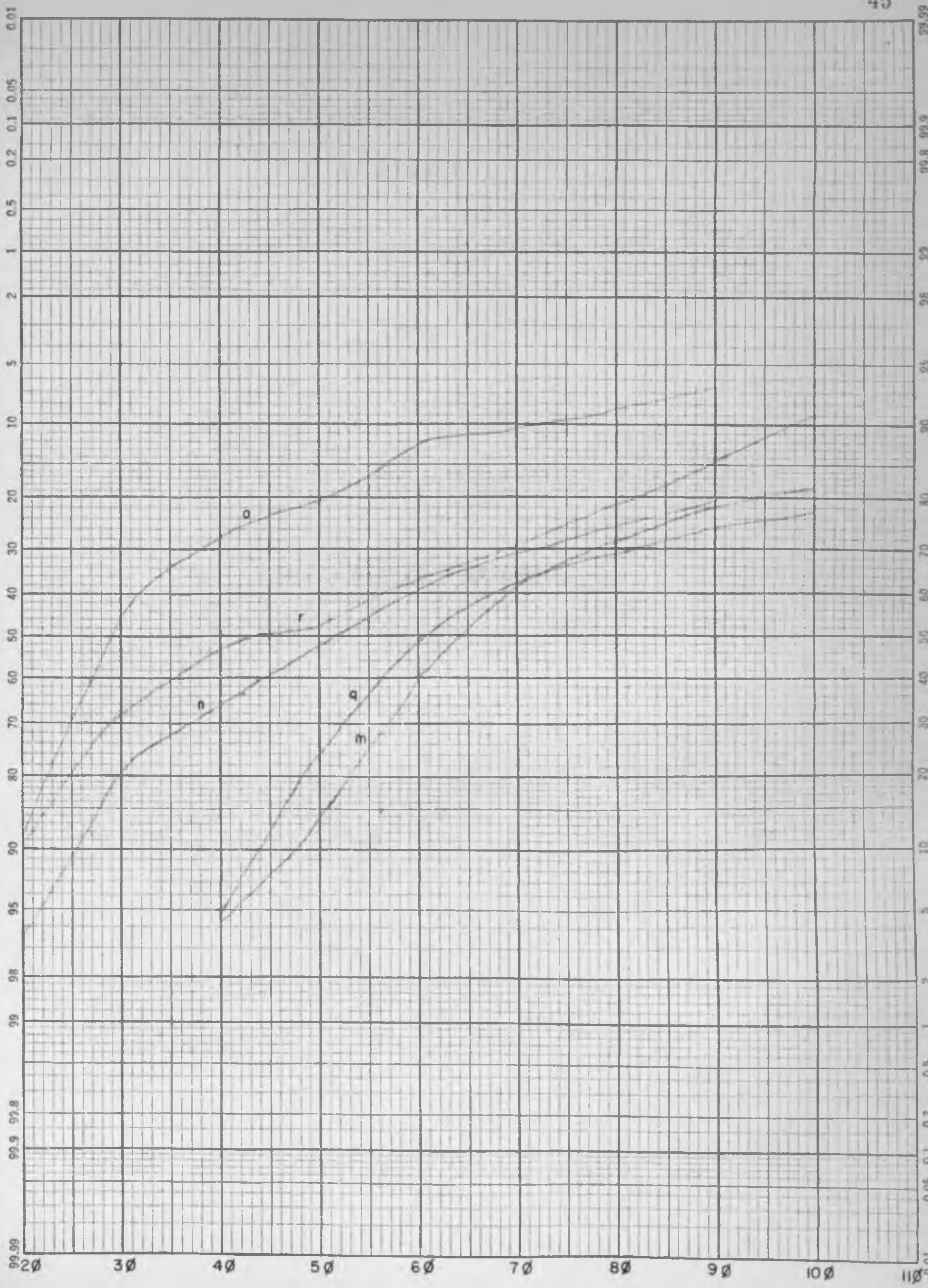
Scale

FIGURE 13

Cumulative curves of silts.


o
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m
20
30
40
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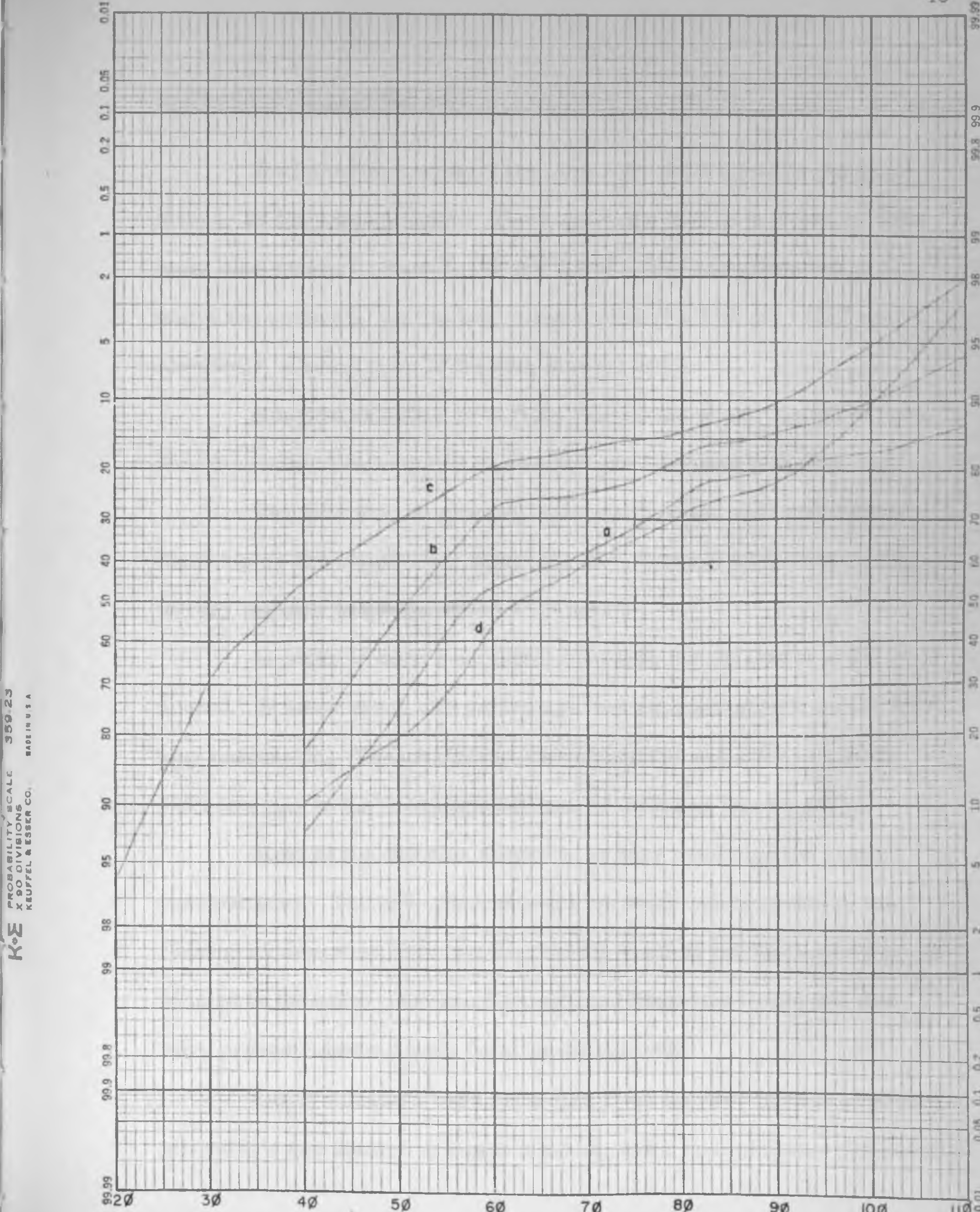
60
70
80
90
100
110
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99

FIGURE 14

Cumulative curves of silts.



c
b
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20
30
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110
0.01
0.05
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1
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10
20
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40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
K+E PROBABILITY X SCALE 359-23
X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

Statistical Studies of the Silts

Statistical measures of the silts were determined in the same manner as the channel sands. The results are plotted in Table 4. The mean size ranges between 4.14ø and 7.96ø. Two samples (section 1, unit 4 and section 5, unit 3) have a mean size of 9.49ø and 9.35ø respectively, placing them in the clay size material.

Standard deviation or sorting range from poorly sorted to very poorly sorted. The majority of samples are very poorly sorted.

The silts are, in general, very positive-skewed, and most of the samples are leptokurtic, however, they do range from platykurtic to very leptokurtic (see p. 38).

In order to determine these measures the percentile at ø95 is needed. In some cases this percentage was not recovered from the silt/ clay suspension. The cumulative curve obtained was extrapolated to ø95 according to the procedure outlined by Folk and Ward (1957).

Most of the samples appear to be very much like the channel sand samples. The only mineralogical variation noticed between the flood-plain deposited silts and the channel sands is the increased amount of mica in the silts. One sample contained limestone fragments that were probably derived from local limestone beds.

Heavy minerals were separated from the sand portion of each silt sample and studied by use of a petrographic microscope. The results

TABLE 4

STATISTICAL MEASURES OF SILTS

Sample No.	M_z	σ_I	Sk_I	K_g
a	6.92	2.84	.82	1.26
b	5.45	1.36	.49	1.41
c	4.14	2.62	.97	1.50
d	6.56	2.62	.44	1.16
e	4.22	3.27	.03	1.38
f	6.32	3.57	.35	.78
g	6.29	2.61	.51	1.66
h	7.96	1.01	.26	1.70
i	6.74	2.65	.27	1.42
j	7.92	3.45	.42	1.20
k	9.49	2.72	.38	1.19
l	7.74	3.41	.43	.87
m	4.49	2.13	.63	1.83
n	5.80	3.73	.34	.73
o	7.35	3.02	.55	.89
p	6.59	3.16	.41	.86
q	6.43	2.81	.37	1.31

are listed in Table 5.

The one outstanding feature noticed is the nearly identical heavy-mineral suite of the silts and the channel sands. The same mineral suite and frequency are common to both deposits. This probably reflects a common source for the sedimentation of the channel sands and the flood-plain deposits, that is, the Whitlock Hills.

TABLE 5

HEAVY MINERALS FROM SILTS

Sample	Augite and Enstatite	Brookite	Apatite	Zircon	Horn-blende	Biotite	Magnetite and Other Opaques
a	A	F	F	S	VR	VR	A
b	VF	F	F	S	VR	VR	VA
c	A	F	F	S	VR	VR	A
d	VF	F	F	S	VR	VR	VA
f	A	F	F	S	VR	VR	A
g	A	F	F	S	VR	VR	A
h	A	F	F	S	VR	VR	A
j	A	F	F	S	VR	VR	A
k	A	F	F	S	VR	VR	A
l	A	F	F	S	VR	VR	A
m	A	F	F	S	VR	VR	A
o	A	F	F	S	VR	VR	A
p	A	F	F	S	VR	VR	A
q	A	F	F	S	VR	VR	A

Frequency Scale

VA = Very Abundant
A = Abundant
VF = Very Frequent
F = Frequent
S = Scarce
R = Rare
VR = Very Rare

STRUCTURE

Introduction

It is generally considered that the valley of the Gila River is a structural trough formed by down-faulting between adjacent mountains.

Miocene(?) rocks of the region are intensely deformed while Pliocene deposits have remained undisturbed. This led Knechtel (1936) to attribute a late Miocene age to the last major deformation of the Gila and San Simon Valley region. He further indicates that this deformation "...may have been the cause of ponding of water in the valleys..."

Dating the last major deformation as late Miocene is confirmed by Van Horn (1957). He observed that the Solomonsville beds abutt against the volcanics of the Gila Mountains, and, therefore, he concluded that the faulting must have been prior to deposition of at least the upper part of the Solomonsville beds.

Structure of the Solomonsville Beds

Cross-stratification

Stream channels are abundant in the Dry Mountain area and many of them exhibit good cross-stratification (Fig. 15). They represent

FIGURE 15

Cross-lamination in Channel Sands

Cross-lamination in channel sands of the Dry Mountain area.

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for the most part the lenticular variety of planar cross-stratification outlined by McKee and Weir (1953), i.e., the lower bounding surface is an erosional plane, and one of the converging surfaces is curved.

Slumping

Slump structures are common in the 111 Ranch and Dry Mountain area (Fig. 16). They are usually small scale, involving less than 1 or 2 feet of displacement. In some cases the slumping is a result of solution of the limestone, followed by collapse of the overlying sediments. However, most of the slump structures are probably a result of differential compaction of the sediments.

Folding

Dip measurements around the base of the Whitlock Hills are inconsistent in direction, but are nearly always of a magnitude of about 2°. Some dips are toward the mountains, and have been interpreted by the writer as a result of two factors: (1) local slump structures, and (2) primary dip of the sediments over irregularities in the basement rock. This suggestion is based upon observed slump structures and the apparent shallow depth to a buried portion of the mountain block.

An alternate hypothesis is that the dips toward the mountains are drag folds or slumpage formed by renewed movement on an old fault. However, such movement does not seem probable because one

FIGURE 16

Folding and Slumping in the Solomonsville Beds

A

Slump structure in the "lake beds" of the Dry Mountain area.

B

Small fold effecting chert and diatomite of the Solomonsville beds.

would not expect unconsolidated material to behave like its lithified equivalent, i. e., to exhibit drag folding. Secondly, field investigation and aerial photos fail to reveal faulting in the area.

At a location 1-1/2 miles south of the 111 Ranch a series of small, nearly symmetrical domes are exposed in a gully. The closure is usually less than 4 feet; however, several of the small folds are represented nearer the top of the outcrop by one or more larger folds (Fig. 17). The unit involved in this doming is diatomite separated by layers of chert. Dips in the chert vary from several degrees to a maximum of approximately 16°; while the maximum dip of the diatomite is 10° or 12°. The chert therefore cuts across the bedding planes of the diatomite. This may indicate that the folds formed prior to the chert replacement of the diatomite, and the chert layers did not confine themselves to replacement along the bedding planes of the diatomite. The folds become broader, with shallower dips near the top of the outcrops, and in all probability are dying out.

The folds are unique in their extreme localization. Not only are they the only such structures noted in the 111 Ranch and Dry Mountain area, but they do not persist laterally in any direction. The contact with the Whitlock Hills is less than 50 yards east, and to the north, south, and west good exposures of the diatomite are present within 100 yards, all revealing flat-lying beds.

Because of the nearness to the mountains and the decrease in

FIGURE 17

Folding in the Chert and Diatomite

Primary folding of chert and diatomite over irregularities in the basement rocks.


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intensity of folding near the top of the section the writer considers these folds to be primary features reflecting deposition over irregularities in the basement rocks.

SUMMARY

The Solomonsville beds of the Dry Mountain area consist of thin units of limestone and diatomite with associated chert lenses, and unconsolidated silts. The limestone represents deposition in a lacustrine environment while the silts were deposited in a flood-plain environment. The two are not entirely separate, but grade from one to the other and back again. In addition there are numerous channel sands representing drainage from the nearby Whitlock Hills. These old channels are pene-contemporaneous with the limestone and silt deposits.

Sedimentation studies reveal the silts to be identical to the channel sands in composition and represent only a different environment of deposition. The Whitlock Hills were determined to be the source area for the clastic sediments of the Dry Mountain area.

APPENDIX I

Description of Measured Sections

Section 1

Section 1 is located approximately 4/5 mile S. 17 W. of the 111 Ranch.

Unit No.	Description	Thickness in feet
1	Conglomerate, brown, subangular, rock fragment granules of andesite and dacite composition, cemented with $CaCO_3$ (caliche), eroded at top, unconformable on unit 2	8
2	Silt, brown, subangular to subrounded, unconsolidated, irregular bedding, forms steep slopes, upper contact unconformable, lower contact conformable and gradational (environment: fluvial-lacustrine)	1.7
3	Limestone, white, fine-grained, massive, bedding is poor or absent, top is gradational, conformable above and below, cliff former (environment: lacustrine)	6.2
4	Silt, brown, greenish near base, subangular to subrounded grains, unconsolidated, bedding is massive with regular laminations, contains some stream channels, marly in places, forms steep cliffs and slopes, conformable and gradational contacts (environment: fluvial and lacustrine)	13.3

Unit No.	Description	Thickness in feet
5	Marl and limy silt, dirty white to brown, irregular bedding, forms gentle slopes and ledges, conformable and gradational contacts (environment: fluvial and lacustrine)	6.3
6	Limestone, dirty white to light gray, fine-grained, impure, containing some silty lenses, bedding is poor or absent, forms both gentle slopes and ledges, conformable and gradational contacts (environment: lacustrine-fluvial)	3.2
7	Marl, brown to greenish brown, similar to unit 5 ..	3+
	Total thickness	41.7+

Section 2

Section 2 is located approximately 1-1/4 miles S. 31 W. of the 111 Ranch.

Unit No.	Description	Thickness in feet
1	Conglomerate, reddish brown, subangular rock fragment granules of volcanic composition, weakly to strongly cemented, forms erosion surface at the top, unconformable on unit 2	8
2	Limestone, white, fine-grained, marly near base, bedding is poor or absent, weathers in nodular fragments, top is unconformable, base is conformable and gradational, ridge former (environment: lacustrine)	1
3	Silty sand, light brown to buff, subangular to subrounded grains, unconsolidated, some calcareous cement, bedding is poor or absent, contains laminated channel sands, marly near the base, forms steep and gentle slopes (environment: mainly fluvial)	11.7

Unit No.	Description	Thickness in feet
4	Limestone, white grading to dark greenish brown, fine-grained, silty in center and marly at base, poorly consolidated, bedding is poorly defined, forms steep slopes, conformable and gradational contacts (environment: lacustrine)	12.8
5	Limestone, light gray to dirty white, fine-grained, poorly consolidated, silty in places, similar to unit 4	2
6	Sandy mud, brown, subangular to subrounded, unconsolidated, some calcareous cement, sandy near the base, bedding is poor, forms gentle slopes, upper contact is conformable and gradational, lower contact is concealed (environment: mostly fluvial)	6+
	Total thickness	41.5+

Section 3

Section 3 is located approximately 1-3/8 miles S. 7 W. of the 111 Ranch.

Unit No.	Description	Thickness in feet
1	Limestone, white, fine-grained, erosional remanent at the surface, conformable at the base	0.3

Unit No.	Description	Thickness in feet
2	Diatomite, white, fine-grained, unconsolidated, bedding is poorly laminated, top 9.3 feet is diatomite followed by 10.5 feet of green to brown clay marl, sand, silt, and bedded gypsum, and a thin layer of red sand, the underlying 6.2 feet of exposed section is white diatomite, the unit is gradational, forms steep slopes, upper contact is conformable, lower contact is concealed	26+
	Total thickness	26.3+

Section 4

Section 4 is located approximately 1-5/8 miles S. 13 W. of the 111 Ranch.

Unit No.	Description	Thickness in feet
1	Conglomerate, reddish brown, angular to subrounded granules and cobbles of andesitic, rhyolitic, dacitic composition, calcareous cement (caliche), top is an erosional surface, base is unconformable on unit 2, forms a resistant cap (environment: mostly fluvial)	3
2	Sandy silt, light brown, subangular to subrounded, unconsolidated, upper part contains shards, lower half contains sandy lenses, poorly bedded, forms steep slopes, contacts are conformable and gradational (environment: mostly fluvial)	11.4
3	Silty mud, light reddish brown, unconsolidated, grades into a thin lense of limestone in the middle of the unit, then back to marl, bottom part of unit is silty with some sand lenses, bedding is poorly laminated or absent, forms steep slopes, conformable contacts, grades into chert of unit 4 (environment: lacustrine and fluvial)	11.1

Unit No.	Description	Thickness in feet
4	Marl and limestone, white, partly consolidated, cherty at top, alternating limestone and marl lenses through the unit, appears to contain shards, bedding is absent, forms steep slopes and ridges, conformable and gradational contacts (environment: lacustrine)	12.6
5	Silty mud, brown, unconsolidated, poorly bedded, marly near the top, sandy and marly near the base, forms steep slopes and ridges, conformable and gradational contacts (environment: mostly fluvial)	14.5
6	Clay marl, dirty white to reddish brown, unconsolidated, bedding absent, grades into thin unit of limestone 1 foot thick, and back to marl, silty near base, forms steep slopes and persistent ridges, top is conformable and gradational, base is concealed (environment: lacustrine)	8+
	Total thickness	60.6+

Section 5

Section 5 is located approximately 1-3/4 miles S. 30 W. of the 111 Ranch.

Unit No.	Description	Thickness in feet
1	Conglomerate, reddish brown, subangular rock granules of rhyolitic, andesitic, and dacitic composition, top 3 feet is cemented by $CaCO_3$ (caliche), lower part of the unit is unconsolidated, sandy near the base, bedding is absent, forms a resistant cap over the section, top is an erosional surface, base is unconformable	11.5

Unit No.	Description	Thickness in feet
2	Marl and silt, white to brown, unconsolidated, bedding is poor and irregular, top of unit is a thin lense of impure chert, followed by silt, cemented in patches by $CaCO_3$, and a clay marl sequence with a thin lense of limestone. The unit forms moderate slopes with resistant ridges of limestone protruding, conformable below, unconformable above (environment: lacustrine)	9.4
3	Mud, brown, top is poorly cemented and calcareous, unconsolidated below, contains stream channel sands, bedding is good to poorly laminated, forms moderate to steep slopes, conformable and gradational (environment: mostly fluvial)	13.6
4	Limestone and marl, white to brown, fine-grained limestone near top grading into marl below, unconsolidated, bedding is poor or absent, weathers to crumbly or chunky fragments, becomes silty at the base, forms steep slopes and ridges, conformable and gradational contacts (environment: lacustrine)	11.7
5	Silt, light gray, unconsolidated, poorly laminated, strongly calcareous, contains sand lense, forms slopes, top is conformable and gradational, base is concealed (environment: lacustrine-fluvial)	0.8
	Total thickness	47.0

Section 6

Section 6 is located approximately 2-3/8 miles S. 11 W. of the 111 Ranch.

Unit No.	Description	Thickness in feet
1	Conglomerate, dirty white, subangular to subrounded pebbles and cobbles of andesitic, rhyolitic, and dacitic composition, strongly cemented by $CaCO_3$ (caliche), bedding is absent, forms a resistant cap over the section, top is an erosional surface, base unconformable	4.5
2	Sand, gray to brown, fine-grained, subangular to subrounded, unconsolidated, finely cross-laminated, and well-defined bedding, forms moderate to steep slopes, top unconformable, base is a sharp contact which may be unconformable(?) (environment: fluvial)	9.3
3	Sandy silt, light brown, fine-grained, subangular to subrounded, unconsolidated, good bedding, becomes sandy as the unit is descended, forms moderate slopes, top may be unconformable(?), base is conformable and gradational (environment: fluvial)	15.2
4	Limestone, white, fine-grained, massive bedding, very local extent, forms a ridge, gradational and conformable (environment: lacustrine)	1.2
5	Sandy silt, similar to unit 2, gradational and conformable	21.2
6	Sandy mud, similar to unit 3, gradational and conformable	27.5
7	Sandy mud, similar to unit 6, marly near the top and base	10.5

Unit No.	Description	Thickness in feet
8	Limestone, white, fine-grained, massive, bedding is poor or absent, ridge former, gradational and conformable contacts (environment: lacustrine)	3
9	Sandy mud, similar to unit 6	15.6
10	Sandy mud, brown, unconsolidated, marl at top contains a thin lense of limestone, silt below is similar to unit 6, base is not exposed	5+
	Total thickness	113.0+

Section 7

Section 7 is located approximately 3 miles S. 18 W. of the 111 Ranch.

Unit No.	Description	Thickness in feet
1	Conglomerate, light gray to brown, subangular granules of rhyolitic, andesitic, and dacitic composition, cemented with $CaCO_3$ (caliche), forms resistant cap over the section, eroded at the top, unconformable at the base	1.5
2	Silt, brown, subangular to subrounded, unconsolidated, laminated bedding, sandy in places, forms moderate slopes, unconformable at the top, conformable and gradational at the base (environment: fluvial)	10.6
3	Silty sand, similar to unit 2, but slightly coarser, conformable and gradational contacts	21.2
4	Sandy silt, light gray, similar to unit 3	23.6
5	Silty sand, similar to unit 3, base is not exposed ...	10.3+
	Total thickness	67.2+

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