University of Nevada
Reno

QUATERNARY GEOLOGY OF THE CENTRAL TRUCKEE MEADOWS, NEVADA

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of Master of Science
in Geology

by

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ABSTRACT

On the basis of their physical and statistical characteristics four units of unconsolidated sediments have been established as Quaternary and Holocene deposits within the Central Truckee Meadows area. A zone of weathering and decomposing clasts is indicative of the outwash gravel, while the more clayey reworked gravel lacks these weathering features. The alluvium, a poorly sorted deposit overlies the outwash gravel and laterally grades into the very fine silty sands of the lacustrine deposits.

Two problems arose in mapping the Central Truckee Meadows urban area. These are: 1) the low relief of the basin which allows movement of the unconsolidated sediments, and difficulty in differentiation of fill material and origional deposits, and 2) the poor sampling localities which introduces errors in sampling. Inconsistant grain-size statistics and eroneous conclusions in sedimentary environments may result from these urban problems.

Mean size, inclusive standard deviation, inclusive graphic skewness, kurtosis, and CM diagrams were used to determine depositional environments. The outwash gravel sediments were deposited within graded suspension and protedted channel environments, while the alluvium is suggestive of a turbidity or mudflow environment. Lacustrine sediments were found to be deposited in quiet water environments such as valley-flats.

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INTRODUCTION

Purpose

The purpose of this study is the description of the surface geology of the Central Truckee Meadows area; the interpretation of mechanical analysis by grain-size parameters; and the determination of CM patterns as a significant geologic tool (C, and approximation of the maximum grain-size, and the median grain-size, M). These purposes were achieved by extensive field study of Quaternary basin deposits and the mechanical analysis of selected samples. Statistical parameters were developed from these analyses and used to establish factors for CM patterns, grain-size parameter scatter plots, and sand-silt-clay scatter plots. These patterns were then used to determine the depositional environments of each unit within the study area.

Location

The city of Reno is located on the Truckee River near the western boundary of the State of Nevada, in Washoe County (Fig. 1). The study area is a 4.5 square mile area within the Central Truckee Meadows Valley. The Central Truckee Meadows structural depression is bounded on the east by the Virginia Range and Huffakrer Hills, and on the west by the Carson Range.

The study area is located in the northeast corner of the Mount Rose NE Quadrangle, Township 19 North, Range 20 East

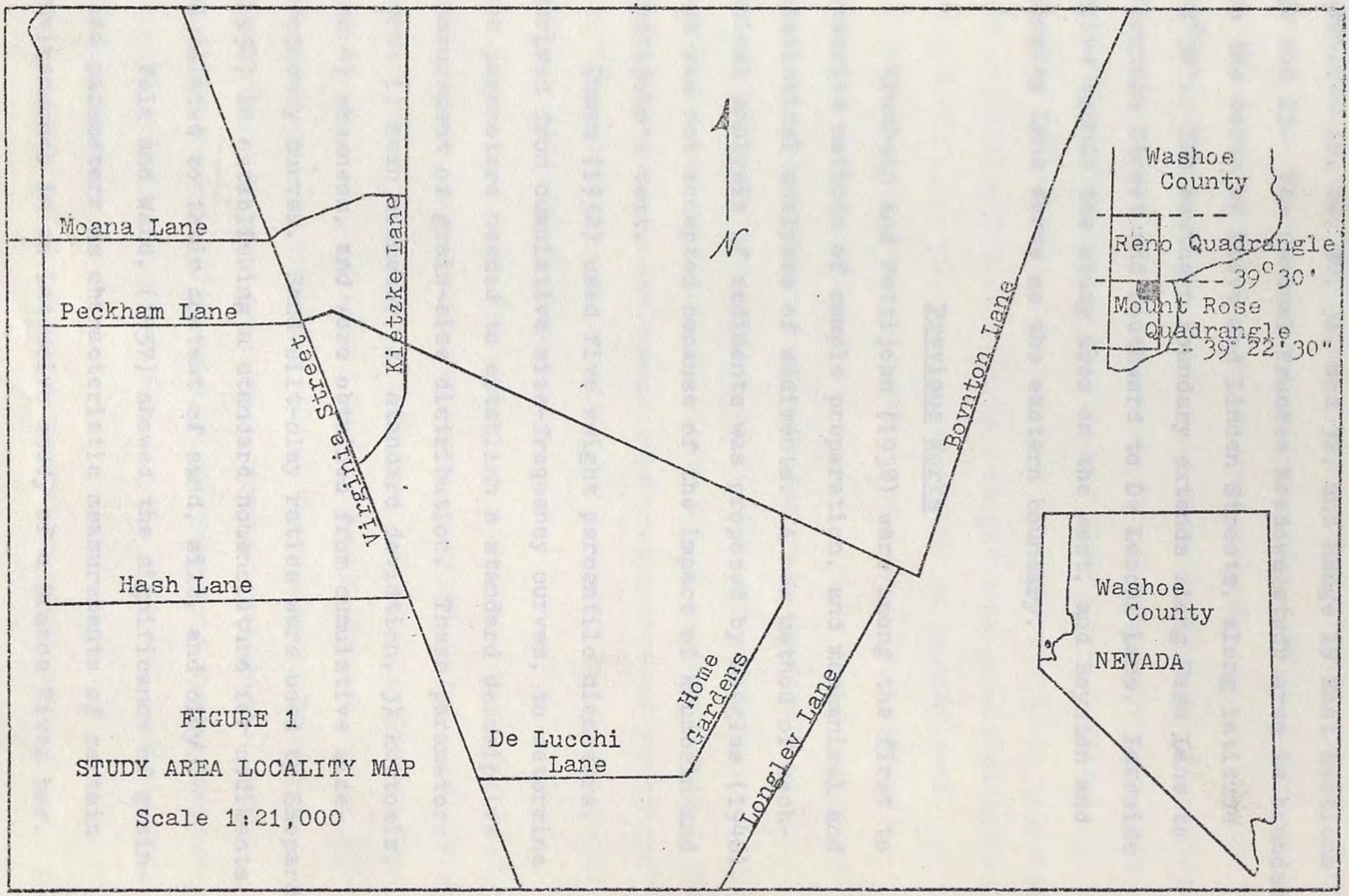

FIGURE 1

STUDY AREA LOCALITY MAP

Scale 1:21,000

sections 19, 20, 30, 31, and 32, and Range 19 East sections 24 and 25. The Central Truckee Meadows study area is bounded on the north by Grove and Linden Streets, along latitude 39°30'. The southern boundary extends along Hash Lane to Virginia Street and southward to De Lucchi Lane. Lakeside Drive bounds the study area on the west, and Boynton and Longley Lane serve as the eastern boundary.

Previous Works

Krumbein and Pettijohn (1938) were among the first to describe methods of sample preparation, and mechanical and statistical analyses of sediments. A new method of mechanical analysis of sediments was proposed by Doeglas (1946), but was not accepted because of the impact of Krumbein and Pettijohn's text.

Inman (1952) used five weight percentile diameters, derived from cumulative size-frequency curves, to determine the parameters needed to establish a standard descriptive measurement of grain-size distribution. These parameters were: 1) mean diameter, 2) standard deviation, 3) kurtosis, and 4) skewness, and were obtained from cumulative size-frequency curves. Sand-silt-clay ratios were used by Shepard (1954) in establishing a standard nomenclature for sediments as related to their content of sand, silt, and clay.

Folk and Ward, (1957) showed the significance of grain-size parameters as characteristic measurements of certain environments in an intensive study of a Brazos River bar.

Two grain-size parameters, maximum grain-size, C, and median grain-size, M, were described by Passega (1957) as indicative of the depositional agents of clastic sediments.

Beach, dune, and river sand deposits were distinguished by sediment textural characteristics of skewness, mean value, and standard deviation by Friedman (1961). Bull (1962) related CM patterns, as used in logrithmic plots, to alluvial fan depositional environments. CM patterns were established as a useful geologic tool in the study of depositional environments by Passega (1964), and a need for further research was indicated.

Further studies of CM patterns by Royse (1968) established the recognition of fluvial environments by particle-size distribution within the CM pattern. Folk (1968) described methods for analysis of unconsolidated sediments, and the statistical parameters involved in the understanding of depositional environments.

Axelrod (1958) discussed the controversial naming of the Pliocene Truckee Meadow sediments, containing the Verdi Flora, as Coal Valley or Truckee Formation. Axelrod suggested the sediments should be called Coal Valley Formation, while Thompson and White (1964) called the sediments Truckee Formation. In this same study Thompson and White (ibid) mapped the regional geology of the Steamboat Springs area, Nevada. Their study included the Mt. Rose and Virginia City Quadrangles.

A study of the Quaternary geology of Winnemucca, Nevada by Hawley and Wilson (1965) used CM patterns as indicators of depositional environments. The CM patterns developed from the Winnemucca study showed good correlation with previous studies. In a study of the hydrogeology and hydrogeochemistry of the Truckee Meadows, Coen and Loeltz (1964) discussed the unconsolidated deposits of the area and their depositional environments.

Type sections for Quaternary soils were described in two papers by Birkeland (1965a, 1965b) in an INQUA field trip publication on the area of the Truckee Meadows and across the Sierra Nevada. Birkeland (1967a) discussed the correlation of Quaternary soils in Western Nevada and California. He described the soil development on the Donner Lake deposits along the Truckee River between Truckee, California and Mustang, Nevada. Quaternary geosoils were described by Morrison (1967) as distinct entities within the stratigraphic column. Birkeland (1967b) also correlated the Quaternary stratigraphy of the Sierra Nevada and Lake Lahontan areas.

Olsen (1970) discussed the significance of grain-size parameters in a study of Lake Lahontan sediments. Quaternary units of the Reno Quadrangle were described by Bonham and Bingler (1973). This was done as a portion of a reconnaissance study of the Reno area. The unconsolidated deposits of the Truckee Meadows area were discussed by Bingler (1975) in a GSA field trip publication.

Procedures

A study of the sedimentation and stratigraphic relationships of the unconsolidated sediments in the Central Truckee Meadows, Nevada was conducted using both field and laboratory investigations.

Field investigations included locating and measuring of sections (Appendix I), sampling, and mapping significant horizons. The low relief of the study area and lack of natural exposures precluded the use of drainage and construction ditches as sample localities. The mapping was done on a 1:12,000 scale aerial photograph and transferred to a base map of the same scale (Plate I).

The laboratory investigation consisted of three parts. The first was examination of sediment samples for cementing agents and pebble rock types with a X10 hand lens (Appendix II). The second part of the laboratory work involved separation of the greater than two millimeter particles by wet sieveing and pipette analysis of the finer silt and clay fraction (Appendix II, III). The third part was dry sieveing of the coarser sample fraction (Appendix II, III).

Statistical parameters were established for each sample to better evaluate the separate depositional units. Mean grain-size, inclusive standard deviation, inclusive graphic skewness, kurtosis, sand-silt-clay ratios, and CM patterns were used to study sorting, grain-size of the the sample maxima and minima, and agents and environments of deposition. These grain-size parameters were evaluated by the use of a computer program (Appendix IV).

The units of the Central Truckee Meadows area consist of distinctive fluvial, alluvial, and lacustrine deposits which can be recognized within the Truckee Meadows area on the basis of their physical characteristics. No formation status has been assigned to the unconsolidated valley fill material.

The unconsolidated sediments of the study area reflect the character of the rocks comprising the Carson and Virginia Ranges. The Truckee River and downslope movement are the agents responsible for the depositional environments in which the Central Truckee Meadows sediments were deposited.

Age and Correlation

Source Area and Transportation Elements of the Central Truckee Meadows Sediments

Units of the Central Truckee Meadows study area are studied as valley-fill sediments of the Basin and Range province. The basin sediments, of each individual basin, are directly related to the rock units composing the surrounding mountain ranges. Sediments of the outwash gravel contain granitic and andesitic clasts derived from the Carson Range and the eastern flank of the Sierra Nevada Mountains. These possibly represent the farthest recognizable transport by the Truckee River for sediments of the study area. The

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Andesite clasts were possibly derived from the topographically higher Kate Peak Formation, and the well rounded sand grains may have been eroded from the "Sandstone of Hunter Creek" and both rock types were deposited together. The large sandstone clast studied at Locality 2 (Appendix I) is derived directly from the "Sandstone of Hunter Creek" which crops out several miles to the southwest of Locality 2.

The "Sandstone of Hunter Creek" has not yet been formalized the term being used informally by Bingler (1975, p.1). Axelrod (1958) assigned the name Coal Valley Formation to the sedimentary rocks cropping out at the northern end of the Carson Range on the basis of similar lithologies and assumed similarity in the age of the type section. Axelrod states the rocks containing the Verdi Flora are primarily andesite clasts eroded from the older Alta and Kate Peak Formations, and these unconformably overlie the Kate Peak. Thompson and White (1964) assigned these sediments to the Truckee Formation, and describe them as interfingering with the Kate Peak Formation. Recent studies have informally named these andesitic water-laid sediments the "Sandstone of Hunter Creek" (Bingler, ibid), and they are considered to unconformably overlie the Mio-Pliocene Kate Peak Formation (Firby, 1975, Personal Communication).

The source material for the reworked gravel was derived from the surrounding outwash gravel and alluvial-fan material of the Carson Range. Downslope movement of the outwash gravel, for redeposition, can be measured in tens of feet, while the allvuial fan material may have been transported over longer distances.

Sediments available for deposition of the alluvium were transported from source areas over varying distances. Erosion of the outwash gravel and subsequent redeposition as alluvium, may have occurred within several feet of the erosional area. The source material of the more subangular andesite clasts was the Kate Peak Formation, which surrounds the valley area. Reworking of the alluvial-fans, and outwash gravel sediments would provide the finer clay size particles found in deposits of alluvium.

Source areas for the fine clays and sands of the lacustrine deposits are more varied than other Central Truckee Meadow deposits. The finer sediments could have been carried in suspension over great distances before being deposited. Some of the larger clasts were eroded from the Surrounding Kate Peak Formation and the "Sandstone of Hunter Creek", the outwash gravel and the older alluvium. The "Sandstone of Hunter Creek" may represent a major source area for the very fine clays, sands, and coarser breccia fragments.

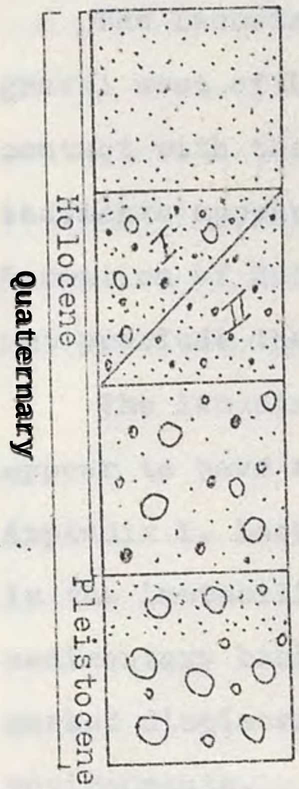
Relative Age of the Central Truckee Meadow Sediments

The oldest deposit of the Central Truckee Meadows lithologic units is the Kate Peak Formation, which was deposited in middle Tertiary time. The "Sandstone of Hunter Creek" was unconformably deposited on the Kate Peak, and after deposition the region was uplifted, and these deposits were eroded.

The oldest unconsolidated unit of the Central Truckee Meadows is the outwash gravel (Fig. 2). The outwash gravel is not found to be in contact with the older Kate Peak and units of the "Sandstone of Hunter Creek" within the study area, but in the Reno Quadrangle, north of the Central Truckee Meadows area, these units are in unconformable contact.

Continued uplift of the region and subsequent normal faulting of the outwash gravel resulted in the erosion of the topographically higher deposits. The reworked gravel, alluvium, and lacustrine deposits are undisturbed and appear to have been deposited after the period of normal faulting was ended. The contact between the older outwash gravel and the younger reworked gravel was not studied because of the lack of exposures. The contact may be an angular unconformity because of the faulting of the outwash gravel, and subsequent erosion and deposition of the reworked gravel (Plate II).

The alluvium is not found to be in contact with the reworked gravel within the study area (Plate I, II). However,



LACUSTRINE DEPOSITS. Clay to coarse sandy silt, light tan to grey, interfingers with alluvium in a lateral gradational contact.

ALLUVIUM DEPOSITS. (I) muddy sandy gravel, brown or grey; (II) silty gravelly sand, tan to light brown, unconformably overlies the Outwash Gravel.

REWORKED GRAVEL. Clayey small pebble gravel, unconformably overlies the Outwash Gravel, found only in grabens within the Outwash gravel.

OUTWASH GRAVEL. Sandy pebble gravel to gravelly sand, granitic and andesitic clasts weathering in place, upper 6-15 in. are leached, extremely faulted.

FIGURE 2

STRATIGRAPHIC COLUMN OF THE CENTRAL TRUCKEE MEADOWS within, the Washoe County Golf Coarse and east of Plumas Street, the alluvium conformably overlies the reworked gravel. The alluvium overlies the outwash gravel (Appendix I, Locality 9 and 15) in an unconformable contact (Plate II). This contact may be a disconformity, as the outwash gravel and the alluvium are very nearly flat lying (Fig. 2).

The Lacustrine deposits conformabley overlie the outwash gravel west of Locality 33 (Appendix I), and do not come in contact with the reworked gravel unit. The lacustrine sediments appear to unconformably overlie the Kate Peak Formation of Huffakre Hills, but poor study localities do not preclude the possibility of a conformable contact.

The lacustrine and alluvial sediments of Holocene age appear to have a lateral gradational contact (Plate II; Appendix I, Locality 27). The reason for this type of contact is the instability of the sedimentary environments in or near sedimentary basins. Minor changes of base level cause marked displacement of the deposits formed within these environments.

Quaternary Deposits

Outwash Gravel

Texture of the river laid outwash gravel consists of sediments ranging from clays to cobble gravel. The maximum measured thickness of the outwash gravel is eight feet at Locality 1 (Appendix I). An isopachous map of the outwash gravel (Fig. 3) shows thinning toward Virginia Street and Peckham Lane. At the intersection of Virginia Street and Kietzke Lane an area of outwash gravel has been isolated by faulting and erosion. The maximum thickness within this area is five feet at locality 24A (Appendix I).

Thompson and White (1964) mapped within the Mt. Rose area. They describe an isolated area of outwash near the intersection of Grove and Virginia Streets. This study has not determined any change of lithology west of the out-crop of outwash gravel at Grove Street. The outwash gravel appears continous from Grove Street westward until it is faulted along Lakeside Drive (Plate II).

The character of the outwash gravel changes from a sandy gravel to a gravelly sand. Decomposing granitic clasts and a weathering zone are characteristics which are used to distinguish the outwash gravel throughout the area.

A zone of weathering, between five and twenty-five inches thick, brown to dark brown in color, and very clayey, may be a poorly developed soil horizon (Appendix I, Locality 5, 9, and 12). In both the weathered and non-weathered zones granitic and andesitic clasts, two to fifteen centimeters in diameter, are decomposing in place. The weathered clasts are found less frequently in the sandy lenses of the outwash gravel (Appendix I, Locality 2, 5, and 10).

Five major lithologies comprise the outwash gravel. These are quartz monzonite and diorite, hornblend and plagio-

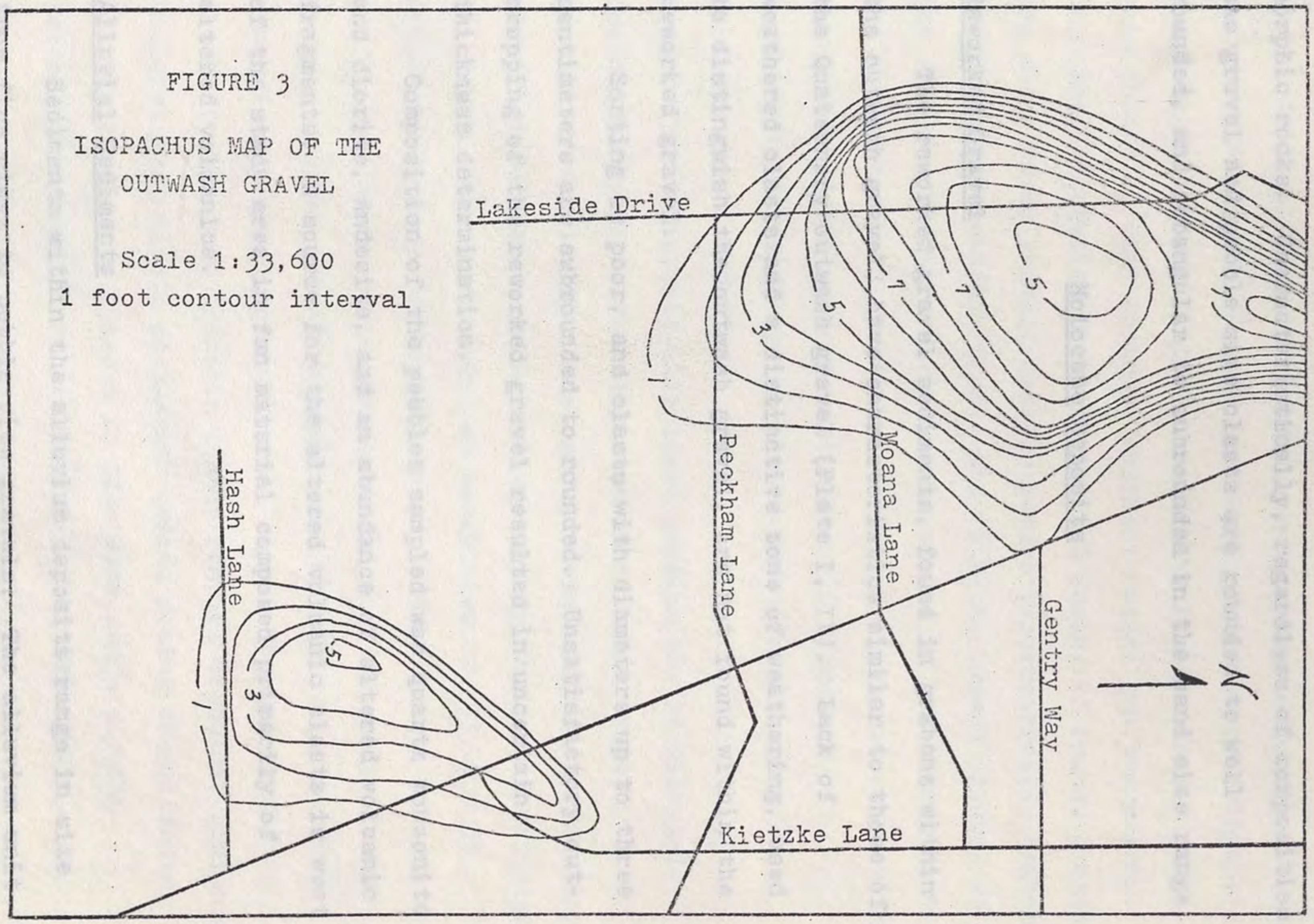


FIGURE 3

ISOPACHUS MAP OF THE
OUTWASH GRAVEL

Scale 1:33,600
1 foot contour interval

clase andesite, and some minor amounts of basalt and metamorphic rocks. Characteristically, regardless of composition, the gravel and pebble size clasts are rounded to well rounded, and subangular to subrounded in the sand size range.

Holocene Deposits

Reworked Gravel

The reworked gravel sediments, found in grabens within the outwash gravel, have characteristics similar to those of the Quaternary outwash gravel (Plate I, II). Lack of weathered clasts and a distinctive zone of weathering, used to distinguish the outwash gravel, are not found within the reworked gravel.

Sorting is poor, and clasts with diameters up to three centimeters are subrounded to rounded. Unsatisfactory outcropping of the reworked gravel resulted in uncertain thickness determination.

Composition of the pebbles sampled was quartz monzonite and diorite, andesite, and an abundance of altered volcanic fragments. A source for the altered volcanic clasts is west of the study area in fan material composed primarily of altered volcanics.

Alluvial Sediments

Sediments within the alluvium deposits range in size from fine clays to pebble size gravels. The alluvium unit incorporates a possible facies change from a muddy sandy gravel to a silty gravelly sand. This change occurs northwest ward along the faulted area west of the intersection of Virginia Street and Kietzke Lane (Plate I, II). Basis for this change is clay content, sediment color, and topography.

The lithofacies with the largest amount of coarse clasts, the muddy sandy gravel, usually occurs topographically higher, closer to the mountain front, and with the outwash gravel on the west and Huffakre Hills on the east. At Localities 3, 9, and 41 (Appendix I) the alluvium is light brown or gray, with subrounded clasts up to 7 centimeters in diameter. At Locality 15 (Appendix I) no clasts over 3 centimeters in diameter were found.

In the topographically lower portion of the alluvial deposits, the silty gravelly sand is a lighter color, contains fewer large clasts, and possesses indistinct bedding. Clasts of between 1 and 4 centimeters are found at Localities 18 and 22 (Appendix I); but at Localities 12, 32, and 36 (Appendix I) very few granule size clasts exist.

Composition of the gravel fraction of the alluvium is fresh andesite, quartz monzonite and diorite, and minor amounts of altered volcanics; all clasts are subrounded to rounded. The sand fraction clasts consist of quartz grains, andesite, and clasts of smaller quartz grains consolidated by clay particles. Clasts in this size range display primarily subangular to subrounded characteristics.

At Localities 9 and 15 (Appendix I) the alluvium deposits unconformably overlie the outwash gravel (Plate II). The weathered zone is not present in the gravel, but clast composition and degree of roundness are indicative of the outwash gravel.

Lacustrine Deposits

The finest grained sediments of the study area are the clay to coarse sand lake deposits (Plate I, II). These sediments are topographically low, encompassed in a small basin area, and represent a low energy environment.

The character of the lacustrine deposits changes within a few feet from a sandy silt at Loclaity 40, sample 5, to a silty sand at Locality 35, and a clayey silt at Locality 31 (Appendix I). Sand size clasts are primarily consolidated clay and silt particles, well rounded quartz grains, and rounded volcanic fragments. A very small number of the sand size clasts are distinguishable as fresh andesite.

The lake sediments do not overlie the alluvium, they have a lateral gradational contact. The inter-fingering and lateral gradation of the deposits may be caused by the ephemeral nature of the lake and continuous uplift of the surrounding mountains (Appendix I, Locality 29).

Structure

The Truckee meadows is a structural depression, which has been dperessed as the surrounding mountain ranges have been uplifted. The oldest unconsolidated unit in the study area, the Quaternary outwash gravels, are the only sediments of the area to be structurally disturbed. Normal faults along Lakeside Drive and Virginia Street, trending northward, have caused off-sets of up to fifteen feet (Appendix I, Localtiy 1 and 2). Deposits under the alluvium and lacustrine sediments may be structurally deformed, but these features are obscured by the Holocene sediements.

Thompson (1956) suggested the Virginia Range as the eastern limb of a broad syncline, and eastward-dipping rocks of the Carson Range as the western limb. The axis of the syncline is postulated to be the Truckee Meadows valley. A period of gentle uplift caused folding of the syncline and normal faulting to occur simultaneously.

GEOLOGIC HISTORY

Pre-Middle Tertiary History

Deposition of geosynclinal sediments was the earliest geologic event of the area, occuring during the early part of the Mesozoic Era. This was followed by a period of volcanism and intense folding, faulting, and metamorphism of the sediments in Late Jurrassic and Early Cretaceous. A period of plutonic intrusions in Middle Mesozoic time, followed by emplacement of granodiorite and other granitic rocks in the Sierra Nevada complex. Early Tertiary uplift involved gentle warping and normal faulting (Cohen and Loeltz, 1964).

Middle Tertiary History

During Miocene and Pliocene time, the Kate Peak Formation was deposited as thick sequence of andesitic lavas. The Kate Peak Formation interfingers with water-laid sediments of the "Sandstone of Hunter Creek" north of the study area (Thompson and White, 1964). Normal faulting formed elongate mountain range and valley structure. Displacement of the previous regional drainage, by normal faulting, formed lakes within the structural basins. The greatest thickness of the "Sandstone of Hunter Creek" was deposited during this time of uplift.

Upward movement along normal faults intensified during the middle Pliocene, causing disruption of topography and drainage systems. The present day Truckee River drainage system, and topography, was initiated during the intensive uplift of middle Pliocene time (Hawley and Wilson, 1965).

Intermittent uplift of the Virginia Range caused blockage of the Truckee River, resulting in the repeated formation of lakes in the Truckee Meadows area. Erosion of the rocks and devedopment of a water gap allowed normal downstream movement of the Truckee River, until uplift once more blocked the river. The outwash gravels of the Central Truckee Meadows area were deposited during this episodic blockage of the Truckee River.

Pleistocene and Holocene History

Uplift and faulting along the eastern flank of the Carson Range in late Pliocene and early Pleistocene time truncated outwash gravels and alluvial fans, causing rejuveniation of streams and the reworking of fan and stream material. The reworked sediments were deposited in localized depressions, such as the graben along Lakeside Drive near the south end of Virginia Lake (Plate I, II).

In Pleistocene time, continued uplift and blockage of the Truckee River resulted in deposition of the alluvium and lacustrine deposits now found in the Central Truckee Meadows area. In May 1952 and January 1956, flooding of the Central Truckee Meadows occurred. Fine lacustrine sediments were deposited in the northern part of the study area and along the Truckee River.

INTERPRETATION OF STATISTICAL ANALYSIS

Grain-size Parameters

Sedimentary grain-size parameters are means of comparing and correlating clastic sedimentary types and their environments of deposition; different parameter systems have been used. Inman (1952) used the Ø (phi) nomeclature, where phi is the negative log to the base two in millimeters. Folk ans Ward (1957) expanded the equation established by Inman to include the ends of sediment cumulative curves. These parameters are more significant because they consider all variables involved in sediment deposition, and they have been assigned the name Inclusive Graphic Parameters, to differentiate the revised equations from the older equations derived from the Method of Moments (Folk and Ward, 1957).

Folk and Ward's (1957) equations for graphic mean size, inclusive standard deviation, inclusive graphic skewness, and kurtosis have been used in this study. Weight percentiles, in phi unit sized, have been graphically determined from cumulative curves (Appendix V), and used in the following equations:

Graphic Mean Size, $M1=\phi16+\phi50+\phi84/3$

Inclusive Standard Deviation, $S1=\phi84-\phi16/4 + \phi95-\phi5/6.6$

Inclusive Graphic Skewness, $I1=\phi16+\phi84-2\phi50/2(\phi84-\phi16) +$
$\phi5+\phi95-2\phi50/2(\phi95-\phi5)$

Kurtosis, $K1=\phi95-\phi5/2.44(\phi75-\phi25)$.

The computed percentile values for graphic mean size, inclusive standard deviation, inclusive graphic skewness, and kurtosis are presented in Appendix IV.

Inman (1952) used Ø16+Ø84/2 to measure mean size, but this proved unsatisfactory in strongly skewed and bimodal samples; therefore graphic mean, M1, is the best measure for graphically determining the mean size of a sample (Appendix VI). Phi 16 can be used as the average size of the coarsest third of the sample, Ø50 represents the average size of the middle, and Ø84 can be considered the average size of the finest fraction. Determination of mean size by Ø50 or the fiftith percentile, can be eroneous since the coarse and fine tails of the sediment are ignored.

Degree of sorting within the sediment deposit is determined by inclusive standard deviation, S1 (Appendix VI). This parameter includes 90% of the distribution, while Inman's graphic standard deviation S2, and phi quartile deviation, Q1, indicate sorting in the central 70% of the sample (Appendix IV, VI). A classification scale for sorting values is:

under .35Ø	very well sorted
.35Ø to .50Ø	well sorted
.50Ø to .71Ø	moderately well sorted
.71Ø to 1.0Ø	moderately sorted
1.0Ø to 2.0Ø	poorly sorted
2.0Ø to 4.0Ø	very poorly sorted
over 4.0Ø	extremely poorly sorted (Folk, 1968, p.46).

Because inclusive standard deviation measures the spread of the sample sorting values in phi units, the ø is attached to the numerical values.

Studies by Folk (1968) show better sorting as a factor of decreasing mean size and not transportation distance. Best sorting has been found in dune and beach sands with values of .25 to .35ø. Standard deviation for river sediments is between .4 and 2.5ø, and flood plain silts and clays which must be pipetted have values between 2.0 and 3.5ø. The poorset sortin, 5 to 10ø, has been found in glacial tills and mudflows.

The Central Truckee Meadow sediments fall into the categories established by Folk (9168). Standard deviation for outwash gravel sediments are between 2.55 and 4.0ø. These are higher values than Folk's river sediments, but the Truckee River was influenced by glacial melt. Alluvial deposits have a standard deviation between 1.6 to 2.95ø for the finer facies, and 3.5 to 5.5ø for the coarser facies. Lacustrine deposits range from 1.2 to 2.5ø (Appendix VI).

Skewness, a measure of the asymmetry of the sorting curve, determines if the curve has a tail to the left (-) or right (+). Phi quartile skewness, I2, measures the central portion of the curve, while graphic skewness, I3, measures the median displacement from the average of ø16 and ø84 (Appendix IV, VI). Phi quartile skewness is greatly affected by sorting and graphic skewness is geometrically independent of sorting.

The most reliable measure for skewness in the tails of the curve is inclusive graphic skewness, I1 (Appendix VI). This measure includes 90% of the curve and is geometrically independent of sorting. A sample with an excess of fine material will be positively skewed with a tail to the right, and a negatively skewed sample will have a tail to the left and contain an excess amount of coarse material. The degree of asymmetry in a sample is dependent on the degree of departure from 0.00 by skewness values. Established limits for skewness values are:

from +1.0 to +0.3 strongly fine-skewed
+0.3 to +0.1 fine-skewed
+0.1 to -0.1 near symmetrical
-0.1 to -0.3 coarse skewed
-0.3 to -1.0 strongly coarse skewed (Folk, 1968, p. 47).

Kurtosis, K1, measured the ratio of sorting in the tails of the distribution with sorting in the central portion of the curve, or the normality of the distribution (Appendix VI). Normal curves, a straight line on probablity paper, have a kurtosis of 1.0 based on the spread of phi units between Ø5 and Ø95 conpared to 2.44 times the spread between Ø25 and Ø75. A departure from the straight line alters the sorting ratio, and the departure from the normality is described by kurtosis. When sorting is better in the tails than in the central portion, the curve is flat peaked or platykurtic, and when the central portion is better sorted than the tails, the curve is excessively peaked or leptokurtic. Established limits for kurtosis are:

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 (Folk, 1968, p. 48).

Skewness and kurtosis can be used to determine the modes of a sample, where there might not be readily visible on a frequency or cumulative curve. Extreme values of kurtosis indicate sorting within a portion of the sample occurred in a different environment, of possibly higher energy. This portion was transported, with the sorting unchanged, and deposited within a different environment.

Interpretation of Grain-size Parameter Scatter Plots

Graphic Mean Versus Inclusive Standard Deviation

Scatter plots of mean size versus inclusive standard deviation give significant information about an environment. Clay to gravel grain-size ranges in samples will form a M-shaped point tren, while a small grain-size range will result in segments of the M-shaped trend. Prominant modes within the sample are found to be the best sorted and at the open ends of the M-shape. Poorest sorting is found to be located between modal diameters and usually is plotted within the closed portion of the M-shaped trend.

In the Central Truckee Meadow sediments, a broad M-shaped pattern is developed (Fig. 4). Sorting is best where the gravel mode is dominant, samples 17 and 49, and as the sand fraction increases sorting becomes poorer, samples 8 and 9. A decrease in the gravel fraction to a lurer sand mode, results in a smaller mean size and better sorting as shown in samples 2, 7, 10, 13, and 18. Sorting becomes poor as the silt mode increases. A decrease in mean size and better sorting is shown in the right limb of the M-shape pattern, where lacustrine sediments with a mean size between 3.20 and 5.80 are plotted.

Graphic Mean Versus Inclusive Graphic Skewness

The symmetrical curve produced by plotting inclusive graphic skewness against graphic mean size shows skewness to be a function of grain-size. Fractions of the sample which have been pure modes or equal parts of two modes are near symmetrical, but unequal mixing of two different size modes will produce either positive ore negative skewness. If the finer silt and clay mode is more abundant the sample will be negatively skewed, while an excess of the coarser sand and gravel mode will be positively skewed. Skewness is affected by gravel content over 5% and becomes negatively skewed (Folk and Ward, 1957).

Graphs are near symmetrical because of an almost pure sand mode, samples 9 and 18, or because of equal sand and gravel modes, samples 1 and 15, and equal amounts of sand and

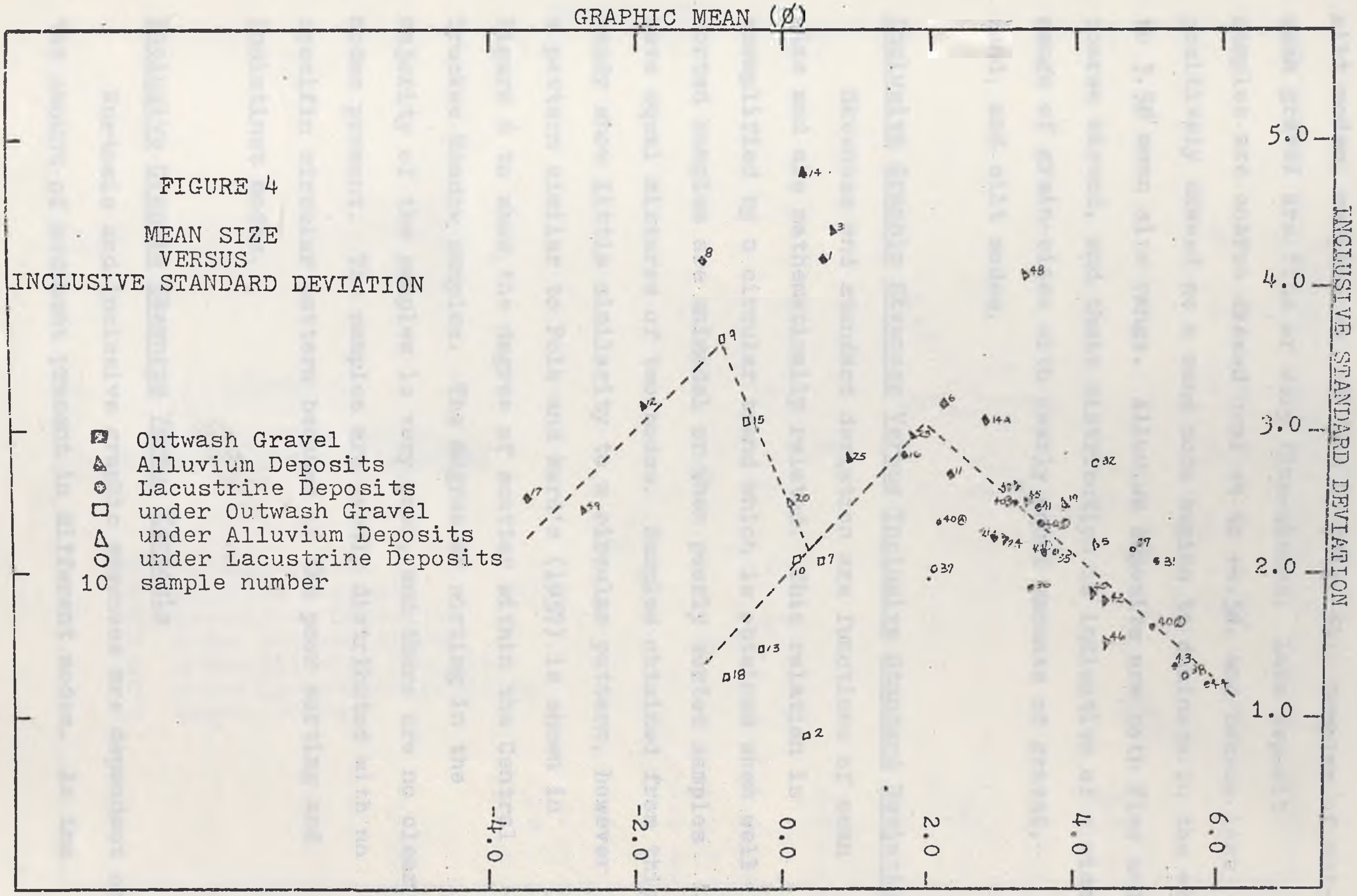


FIGURE 4

MEAN SIZE
VERSUS
INCLUSIVE STANDARD DEVIATION

silt modes, samples 24, 46, and 47 (Fig. 5). Samples of outwash gravel are fine or very fine-skewed. Lake deposit samples are coarse skewed nrar +4 to +4.50, and become less positively skewed as a sand mode begins to dominate in the +2 to 3.50 mean size range. Alluvium deposits are both fine and coarse skewed, and their distribution is indicative of a wide range of grain-sizes with nearly equal amounts of gravel, sand, and silt modes.

Inclusive Graphic Skewness Versus Inclusive Standard Deviation

Skewness and standard deviation are functions of mean size and are mathematically related. This relation is exemplified by a circular trend which is obtained when well sorted samples are unimodal or when poorly sorted samples have equal mixtures of two modes. Samples obtained from this study show little similarity to a circular pattern, however a pattern similar to Folk and Ward's (1957) is shown in Figure 6 to show the degree of scatter within the Central Truckee Meadow samples. The degree of sorting in the majority of the samples is very poor, and there are no clear modes present. The samples are evenly distributed with no specific circular pattern because of the poor sorting and indistinct modes.

Inclusive Graphic Skewness Versus Kurtosis

Kurtosis and inclusive graphic skewness are dependant on the amount of sediment present in different modes. As the

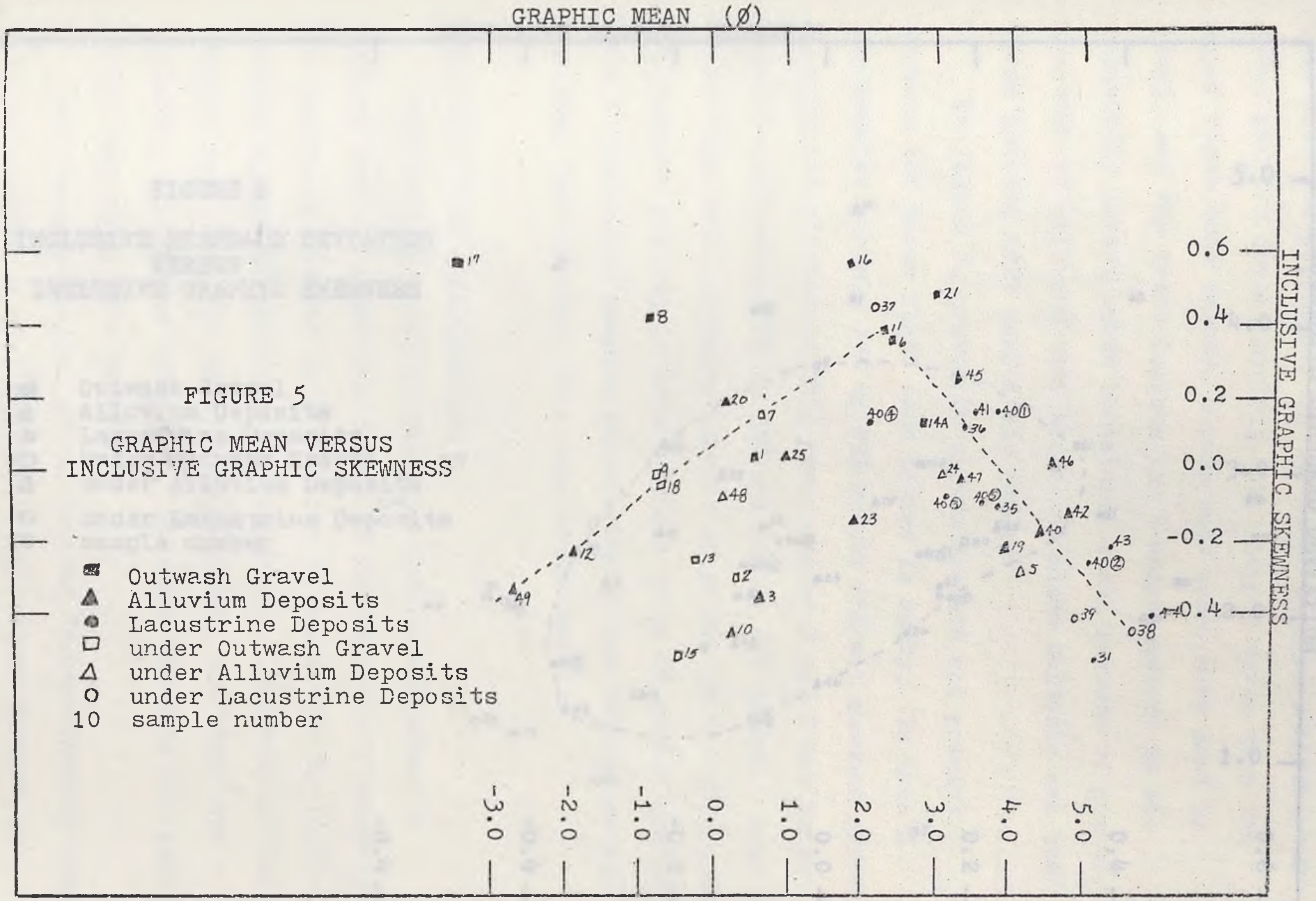


FIGURE 5

GRAPHIC MEAN VERSUS
INCLUSIVE GRAPHIC SKEWNESS

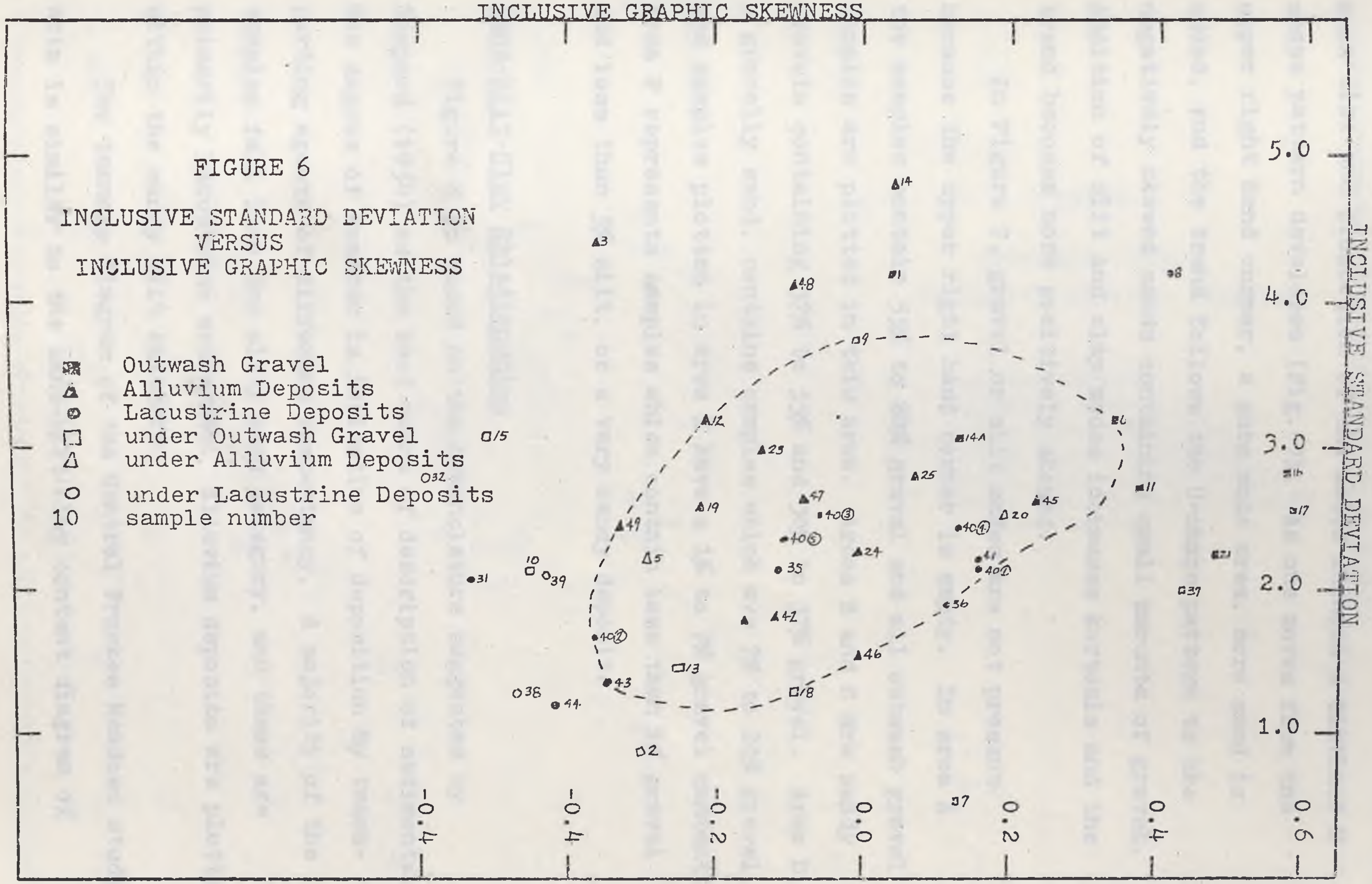


FIGURE 6

INCLUSIVE STANDARD DEVIATION
VERSUS
INCLUSIVE GRAPHIC SKEWNESS

mean size and proportion of the modes changes a distinct U-shape pattern developes (Fig. 7). As one moves from the upper right hand corner, a pure mode area, more sand is added, and the trend follows the U-shape pattern to the negatively skewed sands containing small amounts of gravel. Addition of silt and clay modes increases kurtosis and the trend becomes more positively skewed.

In Figure 7, gravel or silt modes are not present because the upper right hand corner is empty. In area A the samples contain 55% to 80% gravel and all outwash gravel samples are plotted in this area. Areas B and C are sandy gravels containing 37% to 55% and 30% to 37% gravel. Area D, a gravelly sand, contains samples which ave 7% to 20% gravel, and samples plotted in area E have a 1% to 7% gravel content. Area F represents samples which contain less than 1% gravel and less than 5% silt, or a very sandy deposit.

Sand-Silt-Clay Relationships

Figure 8 is based on the nomenclature suggested by Shepard (1954) as the best means of description of sediments. The degree of scatter is indicative of deposition by transporting agents of different compentancy. A majority of the samples fall into the silty sand category, and these are primarily lacustrine sediments. Alluvium deposits are plotted within the sandy silt category.

The ternary diagram of the Central Truckee Meadows study area is similar to the sand-silt-clay content diagram of

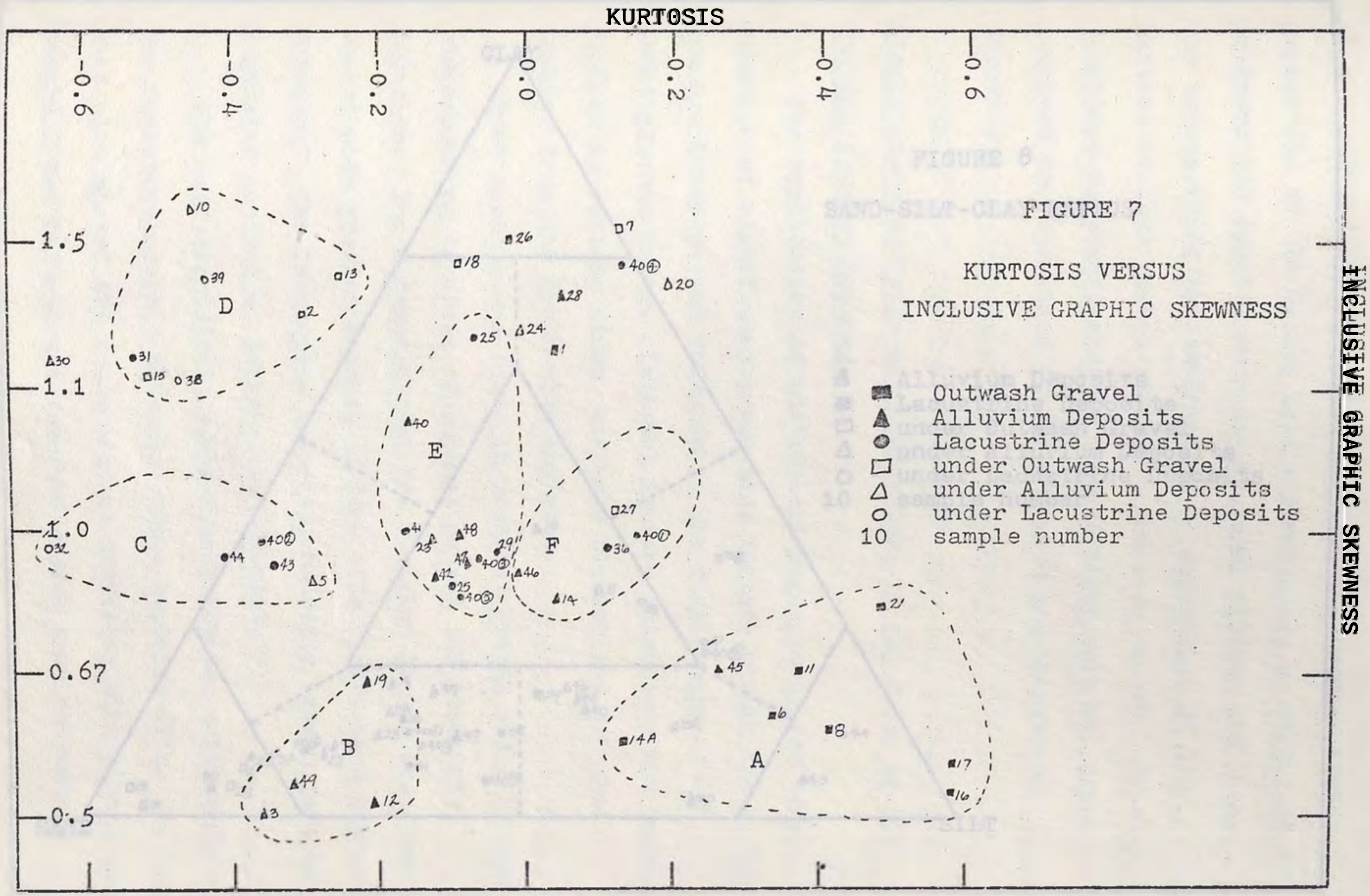


FIGURE 7

KURTOSIS VERSUS

INCLUSIVE GRAPHIC SKEWNESS

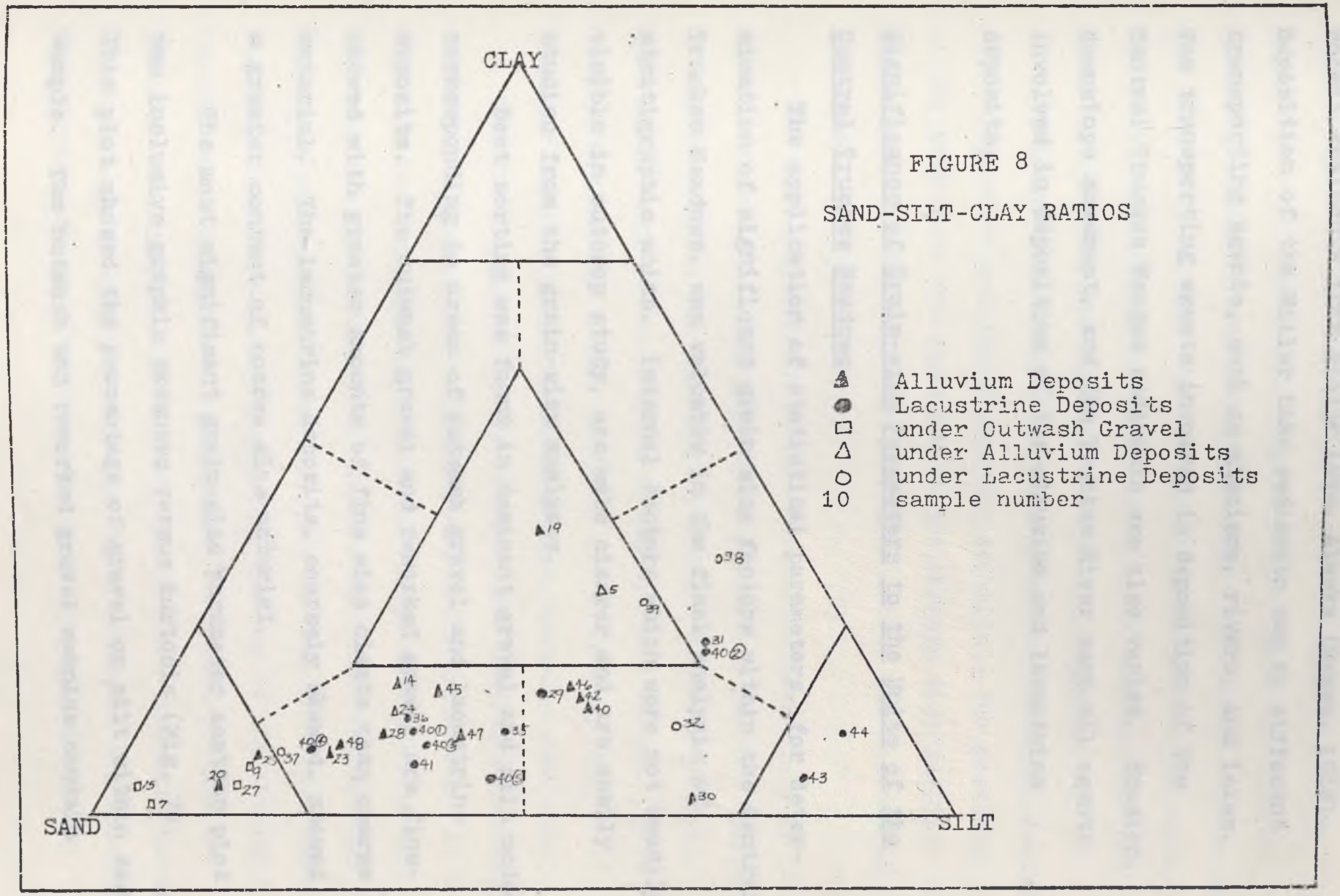


FIGURE 8

SAND-SILT-CLAY RATIOS

recent sediments from Miller Lake, Alaska (Royse, 1968). Deposition of the Miller Lake sediments was by different transporting agents, such as glaciers, rivers, and lakes. The transporting agents involved in deposition of the Central Truckee Meadow sediments are also varied. Erosion, downslope movement, and the Truckee River were all agents involved in deposition of the alluvium and lacustrine deposits.

Significance of Grain-size Parameters to the Units of the Central Truckee Meadows

The application of statistical parameters, for determination of significant grain-size factors within the Central Truckee Meadows, was valuable in the final analysis of stratigraphic units. Internal factors which were not readily visible in outcrop study, are make clearer and are easily studied from the grain-size analyses.

Best sorting was found in dominant gravel and silt modes, corresponding to areas of outwash gravel and lacustrine deposits. The outwash gravel and reworked gravel are fine-skewed with greater amounts of fine size clasts than coarse material. The lacustrine deposits, coarsely skewed, showed a greater content of coarse size material.

The most significant grain-size parameter scatter plot was inclusive graphic skewness versus kurtosis (Fig. 7). This plot showed the percentage of gravel or silt within each sample. The outwash and reworked gravel samples contain between 55% and 80% gravel, which was the basis for their designation in the field. Figure 7 also supported field investigations in that lacustrine deposits contain between 1% and 7% gravel or less than 1% gravel and less than 5% silt. The more scattered points for the alluvium samples were a result of the two facies found within the deposit.

Dominant sand modes were determined for the finer facies of the alluvium and the lacustrine deposits. The presence of the sand mode was apparent in the ternary diagram (Fig. 8). The sand-silt-clay relationships also showed the absence of a clay mode.

The most significant factor determined from study of the Central Truckee Meadows grain-size parameters was the degree of scatter within the statistical plots. Previous studies have shown very little scatter within certain limits. This scatter may be due to the problems encountered in the geologic mapping of the Central Truckee Meadows urban area.

The first problem is the surface area samples may have contained deposits not originally deposited by nature. In a basin or low relief area, fill material is easily moved by man, and can be contoured to the land surface. Valley-fill sediments are unconsolidated and have no well developed soil horizon, therefore material added to the top of any natural deposit would be difficult to detect. A second problem is the poor availability of sampling localities. Samples taken from drainage or construction will have weathered differently from areas near by which have not been exposed, and therefore will exhibit different grain-size properties than a sample not taken from an exposed ditch. The third problem is the standard sampling technique, which may have introduced substantial error into the statistical results.

These problems will lead to inconsistencies within the statistical data, and the resulting interpretations may be faulty. The development of new techniques may be needed in the study of urban areas, or further study could prove that excessive scatter of the sample points within the statistical plots is characteristic of valley-fill material within the Basin and Range Province.

GEOLOGIC SIGNIFICANCE OF CM PATTERNS

CM Patterns

Passega (1957, 1964) suggested the use of "sample point patterns representing the variations in a deposit of two parameters (C, an approximation fo the maximum grain-size, and M, the median grain-size)" as characteristics of the depositional agents. C, defined as the coarsest on percentile, measures stream competency more accurately than does the maximum grain-size in the coarsest half. The five percentile is sometimes used to reduce sampling errors, but it is less representative than C of the maximum grain-size in sediments transported in suspension.

The only limit on the CM pattern is the line C=M (Fig. 9). Points on the line represent samples in which the median and coarsest grain-size are equal, and the coarsest half is well sorted. Sample points displaced anywhere left of the limit C=M are an index to sorting in the coarsest half.

Four types of deposits, tractive current deposits, turbidity current deposits, beach deposits, and quiet water sediment deposits, have been studied on CM patterns (Fig. 9). Pattern I shows the area where deposits of uniform suspension are plotted. Pattern IV represents the area of graded suspension sediments, and Pattern V is the area of bed load deposits. Main channel and back water sediments are found to plot within Patterns I, IV, and V. Pattern II represents turbidity current deposits, while quiet water or

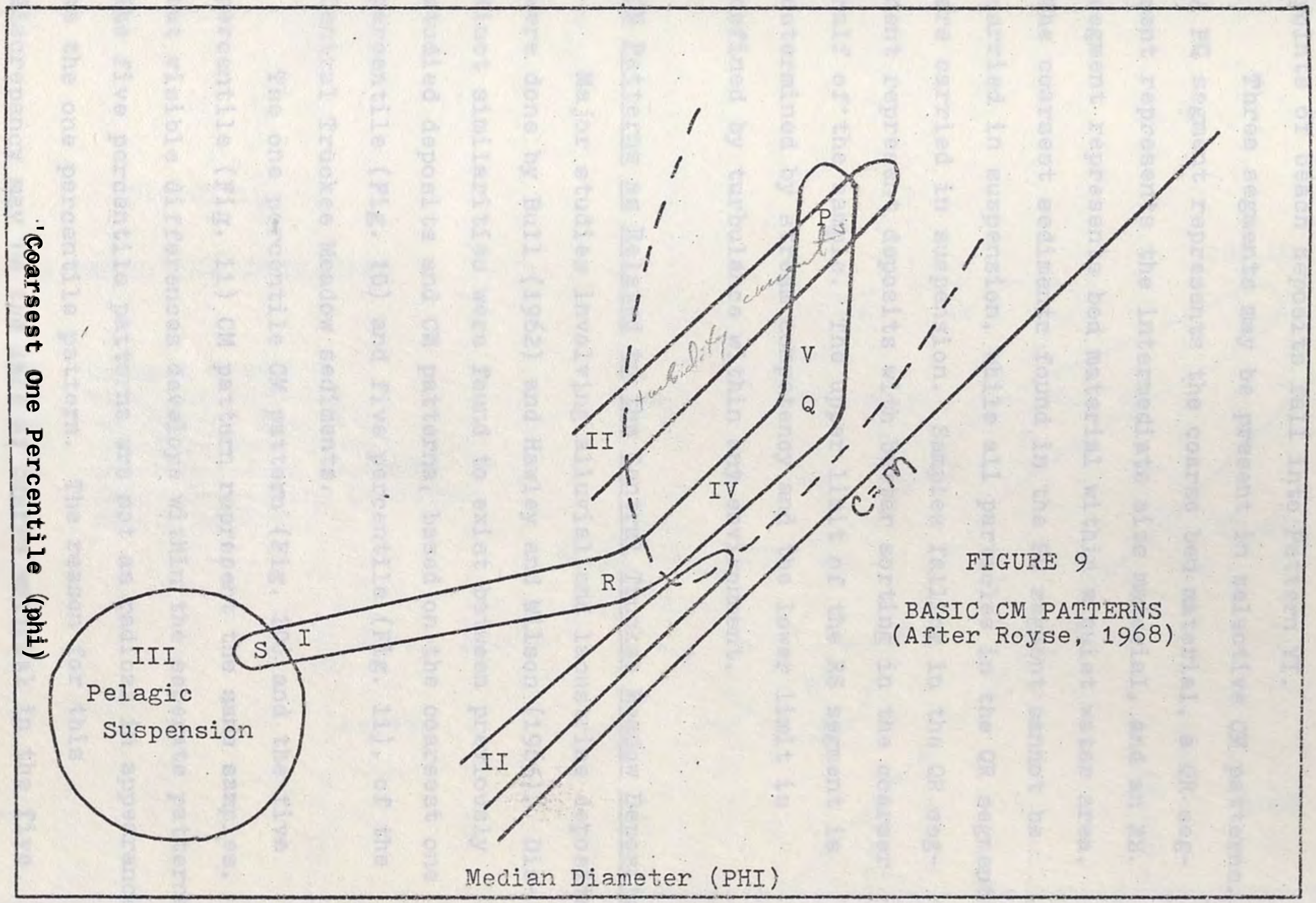


FIGURE 9

BASIC CM PATTERNS
(After Royse, 1968)

pelagic deposits are represented by Pattern III. Sample points of beach deposits fall into Pattern VI.

Three segments may be present in selective CM patterns. A PQ segment represents the coarse bed material, a QR segment represents the intermediate size material, and an RS segment represents bed material within a quiet water area. The coarsest sediments found in the PQ segment cannot be carried in suspension, while all particles in the QR segment are carried in suspension. Samples falling in the QR segment represent deposits with better sorting in the coarser half of the sample. The upper limit of the RS segment is determined by stream competency and the lower limit is defined by turbulance within any environment.

CM Patterns as Related to the Central Truckee Meadow Deposits

Major studies involving alluvial and lacustrine deposits were done by Bull (1962) and Hawley and Wilson (1965). Distinct similarities were found to exist between previously studied deposits and CM patterns, based on the coarsest one percentile (Fig. 10) and five percentile (Fig. 11), of the Central Truckee Meadow sediments.

The one percentile CM pattern (Fig. 10) and the five percentile (Fig. 11) CM pattern represent the same samples, but visible differences develope within the seperate patterns. The five percentile patterns are not as radical in appearance as the one percentile pattern. The reason for this discrepancy may be the lack of coarse material in the five

(m)

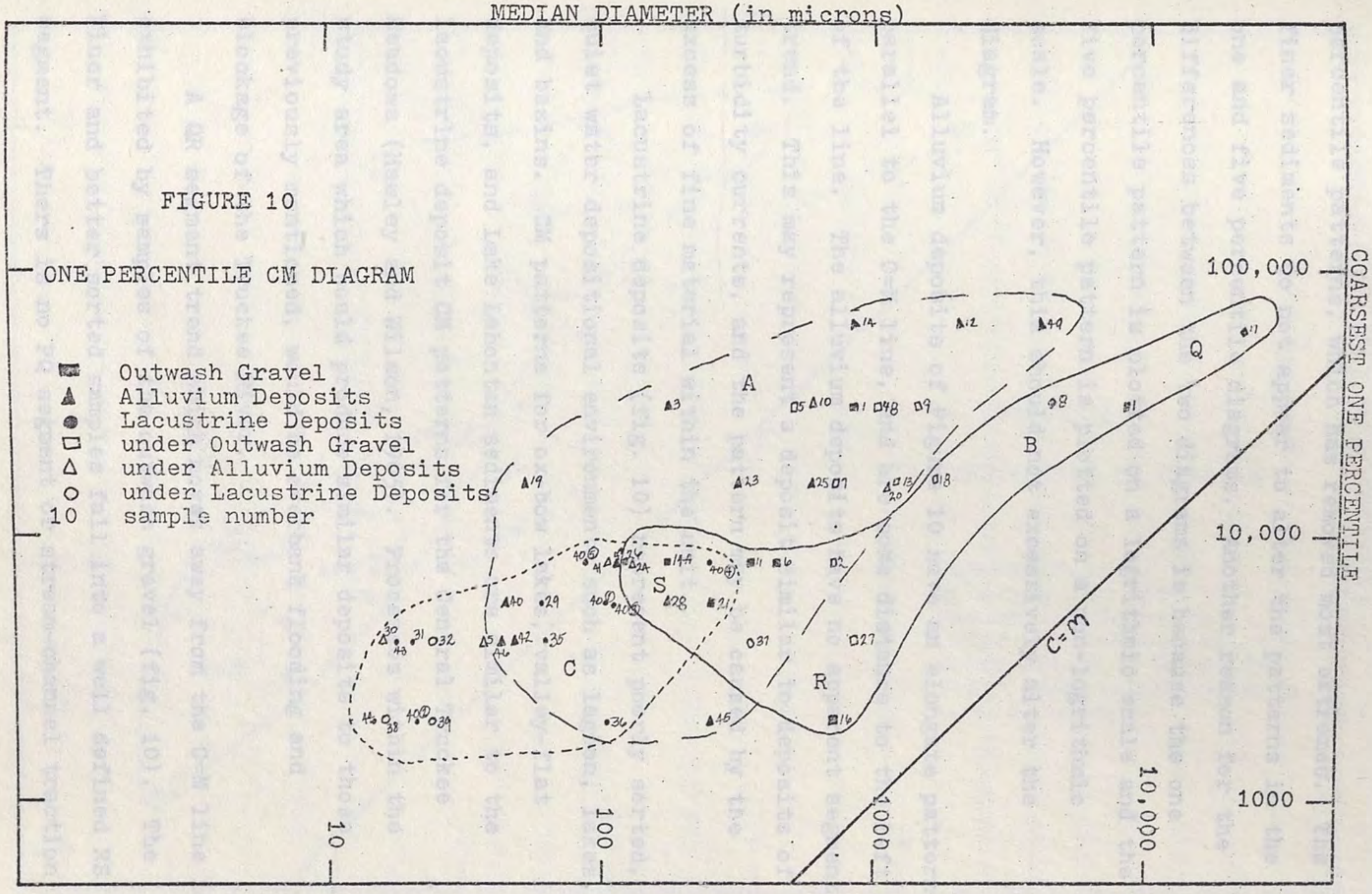


FIGURE 10

ONE PERCENTILE CM DIAGRAM

percentile patterns, which has removed most extremes. The finer sediments do not appear to alter the patterns in the one and five percentile diagrams. Another reason for the differences between the two diagrams is because the one percentile pattern is plotted on a logrithmic scale and the five percentile pattern is plotted on a non-logrithmic scale. However, this should not excessively alter the diagram.

Alluvium deposits of Figure 10 have an elongate pattern parallel to the C=M line, and are some distance to the left of the line. The alluvium deposits have no apparent segment trend. This may represent a deposit similar to deposits of turbidity currents, and the pattern may be caused by the excess of fine material within the unit.

Lacustrine deposits (fig. 10) represent poorly sorted, quiet water depositional environments such as lagoon, lakes, and basins. CM patterns for ox-bow lakes, valley-flat deposits, and Lake Lahontan sediments are similar to the lacustrine deposit CM patterns for the Central Truckee Meadows (Hawley and Wilson, 1965). Processes within the study area which would produce similar deposits to those previously mentioned, would be overbank flooding and blockage of the Truckee River.

A QR segment trend which moves away from the C=M line is exhibited by samples of the outwash gravel (fig. 10). The Finer and better sorted samples fall into a well defined RS segment. Thers is no PQ segment or stream-channel traction

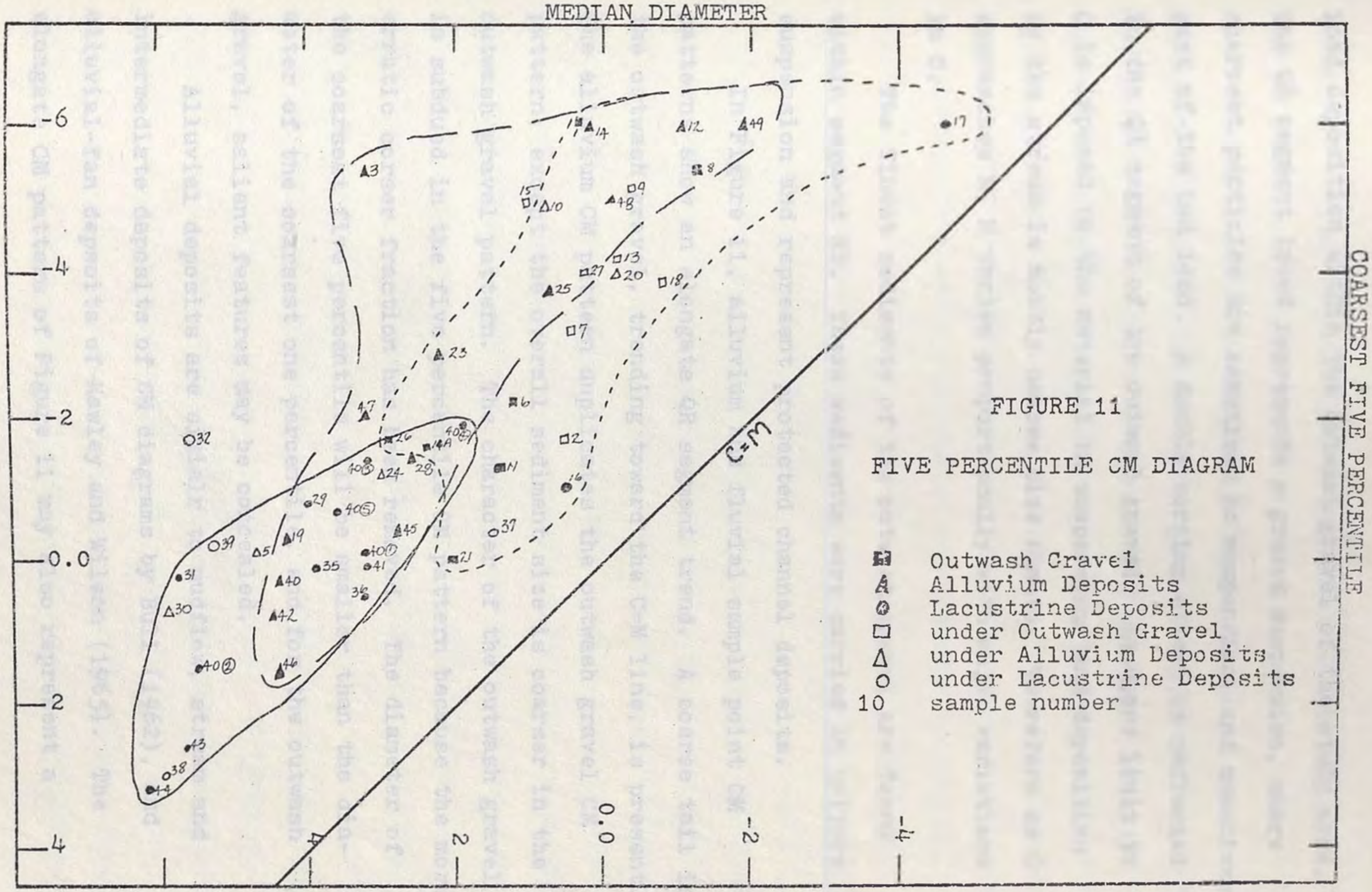


FIGURE 11

FIVE PERCENTILE CM DIAGRAM

load deposition within the outwash gravel of the study area, The QR segment trend represents a graded suspension, where coarsest particles are sometimes in suspension, and sometimes part of the bed load. A double sorting effect is reflected in the QR segment of the outwash gravel. An upper limit to C is imposed by the material in suspension, and deposition by the stream is mostly coarse size clasts. Therefore as C approaches M, M varies proportionally with major variations in C.

The finest sediments of the outwash gravel are found within segment RS. These sediments were carried in uniform suspension and represent protected channel deposits.

In Figure 11, alluvium and fluvial sample point CM patterns show an elongate QR segment trend. A coarse tail in the outwash gravel, trending toward the C=M line, is present. The alluvium CM pattern duplicates the outwash gravel CM pattern, except the overall sediment size is coarser in the outwash gravel pattern. The character of the outwash gravel is subdued in the five percentile CM pattern because the more erratic corser fraction has been removed. The diameter of the coarsest five percentile will be smaller than the diameter of the coarsest one percentile, and for the outwash gravel, salient features may be concealed.

Alluvial deposits are simialr to mudflow, stream and intermediate deposits of CM diagrams by Bull (1962), and alluvial-fan depsoits of Hawley and Wilson (1965). The elongate CM pattern of Figure 11 may also represent a turbidity current depositional environment as exhibited by the CM pattern of Figure 10.

Lacustrine deposit samples of Figure 11 show a more elongate CM pattern than do the samples in Figure 10. The elongate CM pattern may represent a fine-grained turbidity current environment of deposition, or a very quiet water environment.

CONCLUSIONS

Geology

The study of the Quaternary geology of the Central Truckee Meadows leads to the establishment of four units of unconsolidated deposits by field and laboratory study. These units, the outwash gravel, the reworked gravel, the alluvium, and the lacustrine deposits, were mapped on the basis of their observable characteristics. After extensive field mapping of the four units, statistical parameters were established. These parameters were used to substantiate the basis for delineation of the units.

The outwash gravel was mapped using two readily identifiable characteristics. A zone of weathering, approximately fifteen inches thick, is developed on the upper surface of the outwash gravel. This zone is leached to a light brown color, and is argilaceous. A second characteristic used in identifying the outwash gravel is the decomposition of large granitic and andesitic clasts, in place. The decomposing clasts were found distributed throughout the unit, but they seemed to predominate in the weathered zone.

Faulting of the outwash gravel, and subsequent erosion, resulted in deposition of the reworked gravel. The reworked gravel is compositionally similar to the outwash gravel; however, the reworked gravel does not contain the zone of weathering and the decomposing granitic and andesitic clasts present in the outwash gravel. The reworked gravel contains a greater amount of clay than does the outwash gravel.

Holocene alluvial deposits appear to undergo a facies change. The topographically higher muddy sandy gravel becomes a silty gravelly sand northwestward, near the intersection of Virginia Street and Kietzke Lane. The alluvium unconformaably overlies the outwash gravel, and laterally grades into the lacustrine deposits.

Lacustrine sediments, of Holocene age, are the finest deposits of the study area. Ranging in grain-size from a sandy silt and silty sand to a clayey sand, these deposits were deposited during blockage of the Truckee River (Hawley and Wilson, 1965).

Grain-size Parameters

Statistical analysis of the graphic mean size versus inclusive standard deviation plot showed sorting to be best in samples with mean size between -3 to -3.50, and between +3.2 to 5.80. Dominant gravel or silt modes within a sample increased the degree of sorting. Graphic mean size versus inclusive graphic skewness scatter plots showed symmetrical points being plotted where samples contained a pure sand mode. This plot also showed outwash gravel deposits to be finely-skewed and lacustrine sediments to be coarsely skewed.

Inclusive graphic skewness versus inclusive standard deviation scatter plot was not useful in determining significant characteristics of the Central Truckee Meadow sediments; however inclusive graphic skewness versus kurtosis was the most significant of the statistical analysis scatter plots. The distribution of the sample points within certain areas of the skewness versus kurtosis plot showed distinctive similarities to areas which were designated by field mapping. Lacustrine and outwash gravel sample points are grouped within exact areas based on the percent of gravel or sand present within the unit. Alluvium sample points are more dispersed because of the facies involved within the unit.

The sand-silt-clay ratio diagram exhibited an extensive degree of scatter around the zero percent clay content line. This spread may be indicative of the different compentancy within the transporting agents, or a close source of sand size particles.

CM patterns of the outwash gravel indicate two possible environments of deposition within the Central Truckee Meadows. One environment, represented by the coarser fraction of sediment, attests to a graded suspension where, depending on the stream effency, the larger clasts could be carried in suspension or as bed load. The finer outwash gravel sediments represent protected channel environments.

Sample points developed from the alluvium form an elongate CM pattern. This pattern represents a turbidity current environment of deposition. The excess of fine material within the alluvium may be significant in the development of this trend.

A quiet water depositional environment is represented by the lacustrine deposit CM pattern sample points. The lacustrine CM pattern is similar to patterns established for ox-bow lakes, valley-flat, and Lake Lahontan sediments.

The primary agent of deposition within the study area is the Truckee River. The Truckee River is directly responsible for deposition of the outwash gravel and the lacustrine deposits. Structural movements such as faulting and uplift are responsible for the development of environments in which the reworked gravel, alluvium, and lacustrine sediments were depsoited.

Several problems arose in mapping the urban area of the Central Truckee Meadows. These are: 1) the low relief of the valley which allows easy movement of unconsolidated deposits by man, 2) the difficulty of detecting un-natural deposits above natural ones, 3) the poor availability of sample localities, and 4) poor sampling techniques. These problems could produce faulty statistical results.

In summary, the stratigraphic study of the unconsoli- sediments in the Central Truckee Meadows correlates well with the grain-size statistical analysis and previous studies. CM patterns and inclusive graphic skewness versus kurtosis plots can be used to correlate outcrops throughout a giver sedimentry basin. These parameters provide additional information on recent sediments and their environments of deposition.

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APPENDIX I

Localities and Measured Sections

Locality 1

NW¼, NW¼ Sec. 25, T19N, R19E. Section on the SE corner of Moana Lane and Lakeside Drive.

Approximately 8 feet of gravel; a large granitic boulder 1.5 feet in diameter is disintergrating in place; there is a well developed soil profile, dark brown in color.

Locality 2

NE¼, NE¼ Sec. 26, T19N, R19E. Measured Section behind the Presbyterian Church on Lakeside Drive.

		Thickness (meters)	Sample Number
A.	Dark brown, clayey, large granitic and andesite clasts, maximum clast size is 12 cm., equal amounts of fresh and altered andesite.	.19	1
B.	Sandy, unconformable contact with upper and lower beds, poorly sorted, large sandstone clast 24 in. long and 15 in. high rests on lower contact; may be Sandstone of Hunter Creek.	.34	
C.	Sand, very well sorted, no large clasts over 2 cm.	.60	2

Locality 3

NW¼, SW¼ Sec. 25, T19N, R19E. Measured Section in ditch south of Warren Way and parallel to Singingwood.

A.	Light brown, pebble size up to 7 cm. may be fill material.	.36	
B.	Tan, fine silt with no clasts, thickness increases to 40 in. to the east.	.34	3
C.	Gravel, sandy matrix around clasts, rounded clasts appear unweathered, no soil developed.	.60	4
D.	Fine clayey silt.	?	5

Locality 4

NE¼, SW¼ Sec. 25, T19N, R19E. Measured Section off of Lake Manzanita Drive in an open field south of Virginia Lake.

A.	Light grey to brown, leached, may be soil horizon.	.15	

B.	Dark brown, clayey, andesite gravel clasts are rounded, large amounts of fresh andesite, clasts weathering in place.	.34	

8

Locality 5

SE¼, NW¼ Sec. 25, T19N, R19E. Measured Section at corner of west Peckham and Garland Lane.

A.	Fill material.	.30	
B.	Sandy gravel, some rounded clasts, light brown.	.36	6
C.	Gravel, rounded granitic clasts 5 to 10 cm. weathering in place.	?	7

Locality 6

NW¼, NW¼ Sec. 25, T19N, R19E. Section on Peckham and Warren Way in an empty lot.
Rounded clasts on the surface; eastward the surface becomes covered with darker, finer material.

Locality 7

SE¼, NW¼ Sec. 25, T19N, R19E. Measured Section in ditch at the end of Angela Place.

A.	Dark brown, clayey, some rounded clas	.30
B.	Gravel, some sandy lenses, rounded clasts weathering in place.	.61

Locality 8

NE¼, SE¼ Sec. 23, T19N, R19E. Measured Section on Brinkby Avenue behind the elementary school in a ditch being excavated for sewer lines.

A.	Dark brown, clayey, contains large andesite clasts, may be fill material.	.15	8
B.	Brown, sandy, contains large andesite and granitic clasts.	.25	9
C.	Dark brown, sandy with large clasts.	.39	

Locality 9

SE¼, NW¼ Sec 25, T19N, R19E. Measured Section at the south end of Baker Lane on a new apartment construction site.

A.	Light brown, clayey, small rounded clasts up to 5 cm. in diameter, minor bedding features present.	.62	10
B.	Tan, clayey, rounded clasts, has a change in thickness to 1.5 ft. eastward.	.53	
C.	Gravel, well rounded andesite and and granitic clasts in a cemented sandy matrix, large granitic clasts weathering inplace.	.42	11

D.	Sand, grey, well rounded clasts up to 2 cm in diameter.	.57	12
E.	Grey, gravelly sand.	.15	13
F.	Grey, gravel.	.17	

Locality 9A

SE¼, NW¼ Sec. 25, T19N, R19E. Section at the south end of Baker Lane fifty feet east of Locality 9.

Top bed is clayey with some large clasts, becomes two feet thick, distinct bedding present, overlies a gravel similer to that at Locality 4; this locality shows probable contact between the gravel outwash and the alluvium. 14

Locality 10

NE¼, SW¼ Sec. 24, T19N, R19E. Measured Section left off of Brinkby Avenue near intersection with Virginia Street in an open field.

A.	Dark brown to grey, some well rounded granitic clasts, clasts weathering in place, possible soil horizon.	.15	14A
B.	Brown, clayey, granitic and andesite clasts weathering in place.	.32	
C.	Dark tan or light brown, sandy silt, few large clasts.	.16	15
D.	Gravel.	.62	

Locality 11

SW¼, NW¼ Sec. 25, T19N, R19E. Section at corner of Lake Manzanita and Lakeside Drive in an open field.
Auger Sample.

Locality 12

SE¼, NE¼ Sec. 30, T19N, R20E. Measured Section off of Peckham Lane at Village of the Pines before completion of complex.

A.	Dark grey, rounded clasts, possible fill material.	.30	
B.	Dark to light brown, very clayey, large quartz monzonite and andesite clasts.	.39	16
C.	Tan, well cemented gravel.	.27	17
D.	Tan, sandy, contains few granitic rounded clasts.	.24	18

Locality 13

SW¼, NW¼ Sec. 30, T19N, R20E. Section on Lakeside Drive at Lakeridge Villas before completion of complex.
Dark grey, to dark brown, contains numerous clasts of andesite, located above an old drainage area.

Locality 14

SW¼, SW¼ Sec. 25, T19N, R19E. Section on Lakeside Drive south of Lakeridge Villas and north of Hash Lane in an open field.

Brown clayey matrix, contains andesite clasts, some bedding features are present, grades down into a sandy well cemented clayey gravel.		49

Locality 15

SE¼, SW¼ Sec. 24, T19N, R19E. Measured Section at the southeast corner of Sierra and Grove Streets.

A.	Brown to grey, clayey, no clasts.	.31	
B.	Light tan, silty sand, average clasts size 2 cm.	.35	19
C.	Light tan, sandy silt, contains more clay and less clasts.	.75	20

Locality 16

SW¼, SW¼ Sec. 24, T19N, R19E. Section at the north end of Moana Shopping Center.

Five inches of dark brown clayey gravel, underlain by three feet of sand, southward this grades to a thick gravel.

Locality 16A

NE¼, SW¼ Sec. 24, T19N, R19E. Measured Section on Virginia Street south of Brinkby Avenue in an apartment complex area.

A.	Dark brown, few clasts, possible fill material.	.16	
B.	Brown, clayey, granitic clasts are weathering in place.	.45	21
C.	Tan, silty sandy clay, some bedding features, large granitic clasts up to 17 cm.	.46	22
D.	Gravel, sandy matrix, large clasts weathering in place.	.57	

Locality 17

SW¼, SW¼ Sec. 25, T19N, R19E. Measured Section south of Warren Way ditch and Locality 3.

A.	Dark grey, clayey, contains few clasts.	?	
B.	Light tan, sandy gravel, clasts have white calcite stain, granitic and andesite boulders up to 31 in. in diameter.	?	
C.	Light brown sand, very few clasts.	?	

Locality 18

SW¼, NE¼ Sec. 25, T19N, R19E. Section west off of Virginia Street behind Breuners Furniture Store.

A.	Gravelly, poorly bedded, clasts are between 1-4 cm., clayey, some altered volcanic clasts.	.27	23
B.	Clayey silt, very few small andesite clasts.	.23	24

Locality 19

SE¼, NE¼ Sec. 25, T19N, R19E. Measured Section east off of Virginia Street behind Answer Man on Peckham Lane.

A. Tan, small pebble gravel, clayey matrix. .39
B. Large pebble or small cobble gravel, no apparent bedding. .23
C. Silty clay, poor bedding, becomes a a well cemented fine gravel. .25

Locality 20

SW¼, SW¼ Sec. 19, T19N, R20E. Section east off of Kietzke Lane, south of the intersection with Moana Lane in an irrigation ditch.

Two feet of silty, slightly clayey sand, contains few andesite and altered andesite clasts.

Locality 21

SW¼, NE¼ Sec. 25, T19N, R19E. Section at the northwest corner of Virginia Street and Peckham Lane.

Gravel in a brown clayey matrix, becomes more sandy with depth.

Locality 22

SE¼, SE¼ Sec. 24, T19N, R19E. Measured Section in a ditch at Moana Lane and Yori Avenue.

A. Dark to light grey silty clayey sand, few fresh andesite and altered volcanic clasts between 2-4 cm. in diameter. .55 48
B. Silty sand, small pebble gravel. .16

Locality 23

NW¼, NE¼ Sec. 25, T19N, R19E. Section at the northeast corner of Peckham Lane and Baker Lane.

Auger Sample; clayey sand. 25

Locality 24

SE¼, SE¼ Sec. 25, T19N, R19E. Measured Section at the northwest corner of Hash Lane and Virginia Street.

A. Dark grey, contains few small clasts. .15
B. Brown, clayey, contains numerous granitic and andesite clasts. .23 26
C. Tan, sandy gravel. .11 27

Locality 24A

NW¼, SE¼ Sec. 25, T19N, R19E. Section within Quincillis Ranch, west off of Virginia Street after intersection with Kietzke Lane.

Poor sampling localities because of grass cover; fault scarp readily visible, and traceable from Virginia Street south to Hash Lane; maximum thickness of outwash gravel 5 feet.

Locality 25

NE¼, NE¼ Sec. 25, T29N, R29R. Measured Section east of the intersection of Kietzke Lane and Virginia Street in the office construction area.

A.	Grey, small pebbly sandy clay, few large granitic and andesite clasts between 1-5 cm.	.26	
B.	Brwon, very clayey, some granitic clasts up to 10 cm. in diameter.	.34	
C.	Brown, very clayey, some small clasts, thickens up to 45 inches to the east.	.25	
D.	Tan, clayey, contains numerous clasts up to 15 cm. in diameter.	.87	

This measured section is similar to the measured section at Locality 12.

Locality 26

SE¼, SW¼ Sec. 30, T19N, R20E. Section in a field east of Neil Road across from elementary school.

Grey, clayey sand, some small andesite clasts.	.91	28

Locality 27

SW¼, SW¼ Sec. 29, T19N, R20E. Measured Section on east Peckham Lane south of Model Dairy in an irrigation ditch.

A.	Dark grey, small andesite clasts, forms honeycomb structure.	.55	29
B.	Grey, fine clayey silt.	.57	30
C.	Dark grey, very clayey, contains small andesite clasts.	.75	

Locality 28

SE¼, SE¼ Sec. 19, T19N, R20E. Measured Section in an irrigation ditch off of Riley Road near western edge of the airport.

A.	Grey, not very compact, contains few clasts, may be fill material.	.17	31
B.	Light tan, blocky, clayey silt, residue in ditch is slightly sandy.	1.2	32

Locality 29

NE¼, NW¼ Sec. 30, T19N, R20E. Measured Section in a ditch north of Parkview Street.

A.	Brown to grey, very small clasts, very clayey, possible fill material.	.25	
B.	Light brown, blocky, few small clasts, very clayey.	.32	33
C.	Light tan, small clasts of altered volcanics, minor bedding features present.	.76	34
D.	Tan, silty sand.	1.1	

Locality 30

SW¼, NE¼ Sec. 19, T19N, R20E. Measured Section in a ditch north off of National Guard Way.

A.	Light tan, clayey sandy silt, few clasts, some iron stain.	.34	35
B.	Sandy silt, contains numerous andesite clasts.	.66	

Locality 31

SE¼, NW¼ Sec. 19, T19N, R20E. Measured Section in a ditch west of National Guard Way.

A.	Brown to dark grey, clayey sand, no large clasts, iron stains present.	.21	36
B.	Tan to light brown, silty sand, very sandy, with numerous small andesite clasts, thin ½ in. to 2 in. clay lenses.	.35	37
C.	Light grey, clay, slightly bedded, some beds are more sandy, changes to a light brown within 100 yards south.	.49	

Locality 32

SW¼, SW¼ Sec. 19, T19N, R20E. Measured Section in same ditch as Locality 20 off of Kietzke Lane.

A.	Dark brown, no soil horizon, clayey.	.02	
B.	Brown, clayey, some small clasts up to 2 cm. in diameter.	1.3	40

Locality 33

SE¼, NW¼ Sec. 19, T19N, R20E. Section in a small ditch at the southeast corner of Linden Street and Harvard Way.
Light tan, silty sand. 41

Locality 33A

SW¼, NE¼ Sec. 20, T19N, R10E. Section in a ditch north and east of the Brookside Golf Course.
Southern end is dark grey, very clayey silt, large number of clasts may indicate fill material. Northern end is a grey, clayey silt, with few clasts.

Locality 34

NW¼, NE¼ Sec. 29, T19N, R20E. Measured Section on Bounton Lane across from the city impound lot.

A.	White to light grey, clayey, blocky, no clasts.	.15
B.	Light grey, silty clay, no clasts.	.27
C.	Thin gravel bed, average clast size is 10 mm.	.16
D.	Tan, clayey silt, no clasts.	.62

Locality 34A

SE¼, SE¼ Sec. 20, T19N. R20E. Section north along the ditch parallel to Boynton Lane.
Clayey silt, 10-15 inches thick, becomes more sandy with pebbles southward, similar to Locality 30.

Locality 35

NE¼, SE¼ Sec. 20, T19N, R20E. Measured Section at the intersection of the Boynton Slough and Boynton Lane.

A.	Grey to brown, clay, few small clasts.	.21	44
B.	Brown, silty sand, some minor bedding features.	.34	43
C.	Silty clay, contains white stain possibly from the poluted water in the Slough.	?	

Locality 36

SW¼, NE¼ Sec. 29, T19N, R20E. Section in a horse pasture on Boynton Lane.
Twenty inches of dark grey clay, no clasts over 2 cm. 45

Locality 36A

SE¼, SW¼ Sec. 30, T19N, R20E. Section in the southern pasture at the intersection of Longley and Boynton Lane.
Brown, clayey, poor exposure, surface sample. 46

Locality 37

NE¼, SE¼ Sec. 30, T19, R20E. Section at the northeast corner of Pamela and Peckham Lane in an irrigation ditch.
Twenty-five inches of tan to grey, bedded clayey silt. 47

Locality 38

SW¼, SE¼ Sec. 24, T19N, R19E. Measured Section at the northwest corner of Virginia Street and Isbell Road.

A.	Dark brown, clayey, contains large granitic and andesite clasts up to 4 cm. in diameter.	.15	38
B.	Sand, contains large clasts up to 3.5 cm. in diameter.	.46	39

Locality 39

SE¼, NW¼ Sec. 31, T19N, R20E. Measured Section off of De Lucchi Lane behind Meadow Wood Apartment complex under construction.

A.	Light grey, sandy silt, numerous andesite clasts, knobby appearance.	.27
B.	Grey to brown, clay, contains subrounded clasts, with gravel lenses of 3 mm average clast size, poorly bedded.	.33

Locality 40

Section throughout airport area.
Surface samples were randomly collected, and may be suspect.

NE¼, NE¼ Sec. 30, T19N, R20E.	40-1
SE¼, NE¼ Sec. 30, T19N, R20E.	40-2
NW¼, SW¼ Sec. 29, T19N, R20E.	40-3
NE¼, NW¼ Sec. 29, T19N, R20E.	40-4
NW¼, NW¼ Sec. 29, T19N, R20E.	40-5

Locality 41

NW¼, SE¼ Sec. 30, T19N, R20E. Section one mile east of Neil Road on Peckham Lane in an overflow ditch.

Light grey, clayey, massive, very few large clasts 42
over 1.5 cm. in diameter, possible fill material.

APPENDIX II

Preparation of Samples

Wet Sieveing

1. Approximately 650-750 grams of the sample is crumbled by hand and allowed to repose twenty-four hours in a beaker with water.

2. Lumps should be crushed and worked until all particles are separated.

3. Pour some sample on a 4Ø (phi) or 62 micron sieve, and rinse with a wash bottle of clean water. The water does not have to be distilled.

4. The water used for washing the sample should be less than one liter, and it should be retained.

5. Wash the sample until the water passing through the sieve is clear. Avoid rubbing the sample against the screen.

6. The residue on the sieve should be oven dried and prepared for dry sieveing.

7. The water and sediment passing through the sieve should be prepared for pipette analysis.

Dry Sieveing

1. If the coarse fraction of the sample weighs more than 70 grams it should be split.

2. A $\frac{1}{4}$Ø or $\frac{1}{2}$Ø interval screen set should be used.

3. Screens should be placed in order with coarsest sizes at the top and pan at the bottom. The sample is placed in the top sieve and the the sieves are securely placed in the Ro-Tap.

4. Sieveing should continue for 15 minuets.

5. The residue on each screen should be erighed to the closest 0.01 gram and examined for aggregates. If there are more than 25% aggregates on any screen the sample should be disaggregated and re-run.

Pipette Analysis

1. Material finer than 4Ø (62 microns) should be placed

in a liter cylinder and filled to exactly 1000 milliliters.

2. Five milliliters of dispersant (a calgon) should be added and the solution should be studied for possible flocculation of particles.

3. Determine the temperature of the solution.

4. A data sheet should be prepared with the desired diameters of the particles, the depths and times necessary to procure these diameters. The depths and times of withdrawal can be determined from Krumbein and Pettijohn (1938).

5. Oven dry and pre-weigh several 50 milliliter beakers.

6. The sample in the 1000 millileter cylinder should be stirred from the bottom up until all the material is evenly distributed throughout the cylinder.

7. When all the particles are in suspension remove the stirrer, and at the end of 20 seconds withdraw exactly 20 ml of solution, with a pipette at a depth of 20 cm, and place in a previously labled 50 ml beaker.

8. Other withdrawals are timed from the time of the first withdrawal.

9. Dry and weigh the 50 ml beakers to determine the weight percent of each grain size desired.

APPENDIX III

Computation of Sieve and Pipette Analysis

Pipette Analysis

Sample Size	Weight of Sample	Minus Dispersant 0.0024	Weight Times Fifty
Bulk	1.0024	1.0000	50.0
Ø Size	0.1124	0.1100	5.5

$$\text{Weight of Ø Sample} = \frac{\text{(wt. of Bulk wt. of Ø sample) Total wt.}}{\text{weight of Bulk}}$$

Sieve Analysis

Grain-size	Raw Weight of each Sieve	Weight Percent	Cumulative Percent

The Cumulative Percent is plotted on semi-log paper and the different Ø sizes are taken from this plot and used in the statistical analyses.

APPENDIX IV

Basic Computer Program for Determination of Statistical Parameters

```
AUTO    10,10
010     REM LET ALL P VALUES REPRESENT PHI SIZES
020     INPUT N1
030     INPUT P1,P2,P3,P4, P5,P6,P7
040     DATA
050     DATA
060     REM CALCULATE GRAPHIC MEAN, M1
070     M1=(P6+P4+P2)/3
080     REM CALCULATE INCLUSIVE STANDARD DEVIATION, S1
090     S1=((P2-P6)/4)+((P1-P7)/6.6)
100     REM CALCULATE INCLUSIVE GRAPHIC SKEWNESS, I1
110     I1=(((P6+P2)-(2*P4))/(2*(P2-P6)))+(((P7+P1)-
           (2*P4))/(2*(P1-P7)))
120     REM CALCULATE KURTOSIS, K1
130     K1=(P1-P7)/(2.44*(P3-P5))
140     REM CALCULATE GRAPHIC STANDARD DEVIATION, S2
150     S2=(P2-P6)/2
160     REM CALCULATE PHI QUARTILE DEVIATION, Q1
170     Q1=(P3-P5)/2
180     REM CALCULATE PHI QUARTILE SKEWNESS, I2
190     I2=((P5+P3)-(2*P4))/2
200     REM CALCULATE GRAPHIC SKEWNESS, I3
210     I3=((P6+P2)-(2*P4))/(P2-P6)
220     PRINT
230     PRINT   "SAMPLE NUMBER  "N1
240     PRINT
250     PRINT   "GRAPHIC MEAN  "M1
260     PRINT
270     PRINT   "INCLUSIVE STANDARD DEVIATION  "S1
280     PRINT
290     PRINT   "INCLUSIVE GRAPHIC SKEWNESS  "I1
300     PRINT
310     PRINT   "KURTOSIS  "K1
320     PRINT
330     PRINT   "GRAPHIC STANDARD DEVIATION  "S2
340     PRINT
350     PRINT   "PHI QUARTILE DEVIATION  "Q1
360     PRINT
370     PRINT   "QUARTILE SKEWNESS  "I2
380     PRINT
390     PRINT   "GRAPHIC SKEWNESS  "I3
400     PRINT
410     GO TO 020
420     STOP
RUN
```

APPENDIX V

Weight Percentiles from Cumulative Curves

Sample	Ø5	Ø16	Ø25	Ø50	Ø75	Ø84	Ø95
1	-6.0	-3.9	-1.4	+0.3	+3.0	+5.3	+6.6
2	-1.7	-0.5	-0.2	+0.3	+0.8	+1.1	+1.6
3	-5.4	-5.4	-5.4	+2.2	+4.3	+5.2	+6.4
5	-0.1	+1.9	+2.7	+4.6	+6.1	+6.4	+7.1
6	-2.2	-0.8	-0.8	+1.2	+5.7	+6.4	+7.1
7	-3.3	-1.1	-0.6	+0.4	+1.5	+2.3	+5.2
8	-5.4	-5.4	-5.4	-2.3	+2.2	+4.4	+6.3
9	-5.2	-5.2	-2.8	-0.4	+1.9	+3.0	+6.0
10	-4.9	-2.0	-0.5	+0.8	+1.5	+1.9	+2.8
11	-1.3	-0.3	+0.2	+1.4	+5.0	+5.8	+6.6
12	-6.0	-6.0	-5.8	-1.1	+-.9	+1.4	+2.6
13	-4.2	-1.5	-1.0	-0.2	+0.6	+0.8	+1.6
14	-6.0	-5.2	-3.5	+0.2	+3.1	+5.8	+7.4
14A	-1.6	-0.5	+0.2	+2.4	+6.0	+6.5	+7.4
15	-5.-	-4.8	-1.3	+1.0	+1.8	+2.3	+3.6
16	-1.0	-1.0	-1.0	+0.5	+4.6	+5.7	+6.7
17	-6.0	-5.9	-5.7	-4.6	-0.9	0.0	+1.2
18	-3.9	-1.8	-1.4	-0.8	0.0	+0.3	+1.1
19	-0.3	+0.8	+1.5	+4.3	+6.1	+6.5	+7.2
20	-4.0	-2.0	-1.2	-0.2	+1.5	+2.6	+5.2
21	0.0	+0.9	+1.2	+2.0	+4.6	+6.0	+6.6
23	-2.9	-1.5	-0.2	+2.2	+3.7	+4.8	+6.4
24	-1.2	-1.0	+1.8	+3.0	+4.4	+5.2	+6.8
25	-3.8	-1.6	-0.8	+0.8	+2.5	+3.6	+6.2
26	-1.7	-0.4	+0.8	+2.9	+5.5	+6.3	+7.0
27	-4.0	-2.2	-1.5	+0.2	+2.3	+3.2	+5.4
28	-1.4	0.0	+0.8	+2.6	+4.5	+5.6	+6.9
29	-0.8	+1.7	+2.6	+4.0	+6.1	+6.6	+7.2

Sample	ø5	ø16	ø25	ø50	ø75	ø84	ø95
30	-0.7	+2.7	+3.5	+5.9	+6.4	+6.6	+7.0
31	-0.2	+2.8	+4.2	+5.8	+6.6	+6.9	+7.2
32	-1.7	+0.8	+2.6	+5.6	+6.4	+6.6	+7.1
35	+0.1	+1.4	+2.2	+3.9	+5.3	+6.6	+6.8
36	+0.5	+1.5	+2.0	+3.3	+4.7	+5.5	+6.7
37	-0.4	+0.4	+0.7	+1.5	+3.0	+4.5	+6.2
38	+3.0	+4.0	+5.0	+6.0	+6.5	+6.7	+7.1
39	-0.2	+2.6	+4.3	+5.3	+6.3	+6.6	+7.0
40	+0.3	+2.6	+3.2	+4.4	+5.6	+6.1	+6.6
401	-0.1	+1.6	+2.3	+3.2	+5.1	+6.1	+6.7
402	+1.5	+3.3	+4.1	+5.5	+6.3	+6.7	+7.1
403	-1.4	+0.6	+1.5	+3.2	+5.1	+5.9	+6.7
404	-1.9	0.0	+0.6	+1.9	+3.5	+4.6	+6.5
405	-0.7	+1.0	+1.9	+3.6	+5.4	+6.0	+6.6
41	+0.1	+1.4	+2.1	+3.2	+5.0	+5.9	+7.2
42	+0.8	+2.6	+3.2	+4.5	+6.0	+6.3	+6.8
43	+2.6	+3.9	+4.5	+5.7	+6.5	+6.7	+7.0
44	+3.1	+4.5	+4.9	+6.2	+6.7	+6.9	+7.2
45	-0.4	+0.7	+1.2	+2.8	+6.0	+6.6	+7.4
46	+1.6	+2.9	+3.3	+4.4	+5.6	+6.1	+6.7
47	-2.0	+0.6	+1.4	+3.2	+5.3	+6.0	+6.6
48	-5.0	-4.6	-2.6	-0.1	+2.2	+4.8	+6.6
49	-6.0	-6.0	-5.8	-1.9	-0.7	-0.2	+0.6

APPENDIX VI

Computer Results

Sample	Mean Value	Inclusive Standard Deviation	Inclusive Graphic Skewness	Kurtosis	Phi Quartile Deviation	Graphic Standard Deviation	Quartile Skewness	Graphic Skewness
Outwash Gravel								
1	2.27	3.21	0.34	0.64	2.95	3.69	1.52	0.43
6	2.30	2.72	0.37	0.67	2.40	3.05	1.20	0.44
8	2.80	3.08	0.13	0.62	2.90	3.50	0.70	0.17
11	1.73	2.84	0.58	0.56	2.80	3.35	1.30	0.55
14A	-3.5	2.56	0.58	0.61	2.40	2.95	1.30	0.56
16	2.96	2.27	0.48	0.79	1.70	2.55	0.90	0.56
17	-1.1	4.22	0.42	0.63	3.88	4.90	0.70	0.36
21	0.56	4.21	0.04	1.20	2.15	4.60	0.55	0.08
Alluvium Deposits								
10	0.23	2.14	-0.46	1.57	1.00	2.25	-0.30	-0.44
14	0.26	4.78	0.04	0.83	0.30	5.50	-0.40	0.01
19	3.86	2.56	-0.23	0.67	2.30	2.85	-.50	-0.23
23	1.83	2.98	-0.13	0.97	1.95	3.15	-0.45	-0.17
25	0.93	2.81	0.07	1.24	1.65	2.60	0.05	0.07
40	4.36	1.83	-0.16	1.07	1.20	1.75	-0.01	-0.02
42	4.48	1.84	-0.12	0.87	1.40	1.87	0.10	-0.01
45	3.36	2.56	0.23	0.66	2.40	2.88	0.80	0.28
46	4.50	1.57	0.01	0.88	1.17	1.60	0.07	0.09
47	3.26	2.65	-0.08	0.91	1.65	2.60	0.05	0.04
48	0.03	4.10	0.09	0.00	2.40	4.60	-0.10	0.04
Lacustrine Deposits								
31	5.16	2.08	-0.53	1.19	1.20	2.05	-0.40	-0.46
35	3.76	2.15	-0.12	0.88	1.55	2.30	-0.15	-0.08
36	3.42	1.94	0.12	0.95	1.32	2.00	0.07	0.13

Sample								
41	3.63	2.20	0.16	1.10	1.45	2.25	0.35	0.20
43	5.43	1.36	-0.34	0.91	1.00	1.40	-0.20	-0.28
44	5.85	1.22	-0.42	0.93	0.90	1.20	-0.35	-0.37
401	3.63	2.15	0.16	0.99	1.40	2.25	0.50	0.28
402	5.16	1.69	-0.36	0.97	1.17	1.70	-0.23	-0.29
403	3.20	2.53	-0.06	0.92	1.80	2.60	0.10	0.0
404	2.16	2.42	0.13	1.18	1.45	2.30	0.15	0.17
405	3.53	2.35	-0.11	0.85	1.75	2.50	0.05	-0.04
Under Outwash Gravel								
2	0.35	0.89	-0.31	1.37	0.50	0.77	-0.20	-0.29
7	0.53	2.12	0.13	1.67	1.05	1.70	0.05	0.12
9	-0.86	3.74	-0.01	0.97	2.35	4.10	-0.05	-0.17
13	-0.30	1.45	-0.25	1.48	0.80	1.15	0.01	-0.13
15	-0.50	3.07	-0.52	1.14	1.55	3.55	-0.75	-0.63
18	-0.76	2.12	0.13	1.64	1.05	1.70	0.05	0.12
Under Alluvium Depsoits								
5	3.99	2.21	-0.29	0.86	1.70	2.25	-0.3.	-0.24
20	0.13	2.54	0.19	1.39	1.35	2.30	0.35	0.22
24	3.06	2.26	-0.01	1.26	1.30	2.10	0.10	0.47
Under Lacusterine Deposits								
32	4.33	2.10	-0.43	1.41	1.05	2.13	0.05	-0.33
37	2.11	2.03	0.44	1.15	1.17	2.07	0.33	0.44
38	5.66	1.29	-0.47	1.12	0.75	1.35	-0.25	-0.48
39	4.85	2.10	-0.43	1.41	1.05	1.99	0.05	-0.33