DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

ANALYSES OF SURFICIAL DEPOSITS CENTRAL BROOKS RANGE, ALASKA

by

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With a section on Field Data

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OPEN FILE REPORT
79-228

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

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ABSTRACT

Seventy-nine sediment samples from the central Brooks Range were analyzed for grain-size distribution, shape and composition of grains, and other physical properties. Four statistical measures (sorting, mean diameter, skewness, and kurtosis) were then computed for the sand-to-clay size fraction of all samples.

Fan sediments resemble the other alluvial-gravel deposits in consisting of sand and gravel from which very fine sand and the smaller size fractions have been removed by running water. Sorting and rounding of particles is best at the distal ends of large fans. Modern alluvium is better sorted than most fan deposits, with more rounded clasts and generally higher ratios of sand to gravel. Other alluvial deposits from terraces and heavily dissected erosion remnants generally are comparable to modern alluvium. All classes of alluvial gravel are characterized by removal of fines and by decreasing values of mean ø, kurtosis, and skewness as sorting increases. Most samples also have high clay/silt ratios that probably were caused by deflation on windswept bars and floodplains.

Lacustrine deposits have clay percentages ranging from about 85 to 35, with silt predominant in more than one-half of the samples. Several samples contain sand and gravel that presumably were ice rafted. Clay-sized particles are unweathered mineral grains, implying that glacial abrasion was their primary source.

Flow-slide deposits are very poorly sorted mixtures of gravel, sand, and silt, with clay content averaging only about one percent. Clasts consist of angular fragments of local bedrock, usually schist and phyllite, and matrix materials usually are highly micaceous. Although related flow types, a mudflow and a debris-flow in till, are generally similar to flow-slide deposits,

the mudflow has been modified by running water and the debris flow reflects the composition of its parent till. Other colluvial deposits commonly have high silt and low clay contents, but one solifluction deposit has abundant clay derived from till. Several of the flow-slides and other colluvial deposits are polygenetic, having undergone several episodes of flow that incorporated different types of sediment.

Sand deposits include silty floodplain and basin-fill deposits as well as five relatively pure and well sorted dunal and river-bar sands. The silt-rich deposits probably contain large amounts of loess that fell into late-Pleistocene basin fillings and muskegs and later was redeposited on Holocene floodplains. The five dunal and bar sands are dominantly medium to fine sand; relatively well sorted, symmetric to coarse skewed, and leptokurtic. The dunal sands can be distinguished by the presence of very fine sand: wind apparently is less effective than flowing water in removing the finest sand fraction.

The glacial deposits consist of till, ice-content stratified drift, and outwash. Till is a poorly sorted mixed sediment that resembles many flow deposits but typically contains more clay. Two clay-deficient tills resemble fan deposits, implying effective washing by meltwater during glacial transport or deposition of these deposits. The ice-contact stratified drift varies in character from fan-like gravel deposits to sand accumulations nearly as well sorted as those of river bars. Almost all samples reflect some restriction in washing of fines by meltwater, probably owing to irregular topography and resulting poor drainage on and around stagnating glaciers. Most outwash deposits have less fine sand than modern alluvium, probably reflecting the generally high energy of glacial meltwater streams and the absence of vegetation from their floodplains. Samples from the southern Brooks Range are better sorted than those from northern Brooks Range valleys, and their statistical values lie close to those of modern alluvium.

Comparisons between the different classes of sediments are facilitated by combining them into (1) gravel, (2) sand, silt, and clay, and (3) mixed deposits. Deposits of unknown or uncertain origin may then be compared directly against sediments from modern streams, dunes, flow-slides and other known sources, and alternative origins of aberrant samples in each of the sediment classes can also be examined. Several samples that initially were classed as fan, lacustrine, or glacial proved to be mixed deposits created by frost-churning, frost-lifting of stones, flowage down faces of river bluffs, and other postdepositional processes.

Sorting and mean ø of matrix materials were useful in distinguishing the different sediment classes, separating them into contrasting subgroups, and identifying atypical samples. Skewness and kurtosis were generally less useful in this study.

INTRODUCTION

Representative samples of unconsolidated sediments from the central Brooks Range have been analyzed for grain-size distribution, shape and mineralogy of grains, and other physical properties. These data provided (1) quantitative descriptions for engineering purposes, (2) examples of known sediment types for comparison with Pleistocene samples of uncertain origin, and (3) useful insights into processes by which arctic and alpine sediments form. The samples include all six major categories of Quaternary deposits mapped in the central Brooks Range by Hamilton (1978a, 1978b), and were subdivided into 11 sediment classes (table 1). Ages of the deposits range from modern to late Tertiary(?), but most are Holocene to late Pleistocene and hence have not been strongly altered

Table 1. Categories, classes, and ages of sediment samples from central Brooks Range, 1977.

	Modern	Holocene	Late Pleistocene: Late Itkillik Glaciation	Late Pleistocene: Itkillik II Glaciation	Late Pleistocene: Itkillik I Glaciation	Sagavanirktok Glaciation (Middle Pleistocene)	Late Tertiary to Early Pleistocene	TOTAL
FAN DEPOSITS	1	4						5
OTHER ALLUVIAL DEPOSITS								
Modern alluvium	14							14
Alluvial-terrace Deposits		←— 3 —→						3
Other Gravel							2	2
LACUSTRINE DEPOSITS				8	2			10
COLLUVIAL DEPOSITS								
Flow-slide Deposits	10							10
Other Colluvium	4							4
SAND DEPOSITS	2*	2		1	3			8
GLACIAL DEPOSITS								
Till				4	1			5
Ice-contact Stratified Drift				1	10	1		12
Outwash Deposits			2	2	1	1		6
						TOTAL		79

* Modern dunes derived from Itkillik-age drift.

by secondary processes. Stratigraphic nomenclature follows Hamilton and Porter (1975). Field data for each sediment class are presented in a separate section at the end of this report.

Grain-size distributions of half-phi intervals were obtained by dry sieving all sand-size material and analyzing the silt fractions with a hydrophotometer (fig. 1). A single weight percentage for clay-size grains in each sample also was determined with the hydrophotometer. Sieving and hydrophotometer techniques followed those described by Folk (1974, p. 16-35) and Jordan and others (1971), respectively. The logarithmic phi (ø) scale was used because of its convenience in plotting grain-size data and computing graphic measures. Although log-probability curves are useful for emphasizing transport mechanisms (Visher, 1969), we chose to employ log-normal plots because of their more widespread use in the geological and engineering literature and their consequent greater familiarity. Folk's (1974, p. 28) textural categories were used to classify each sample (fig. 2), and graphical parameters were calculated by use of a computer program (see "Laboratory Data" at end of report).

Sediments in the gravel size range presented problems in both collecting and analysis. To avoid excessively large and unwieldy samples, the collectors usually avoided large clasts, sampled mostly matrix, and limited the mass of their samples to about 500 g. Because a sample mass of at least 1 kg generally is necessary to carry out size analyses on even small gravel (Folk, 1974, p. 16) gravel could not be included in the sieve analyses. Only a single weight percentage could be assigned to all material larger than 2 mm, and this percentage is almost certainly a minimum value. In spite of the efforts to collect primarily matrix material, many samples were still dominantly fine gravel. This means that grain-size data are lacking for large components of many

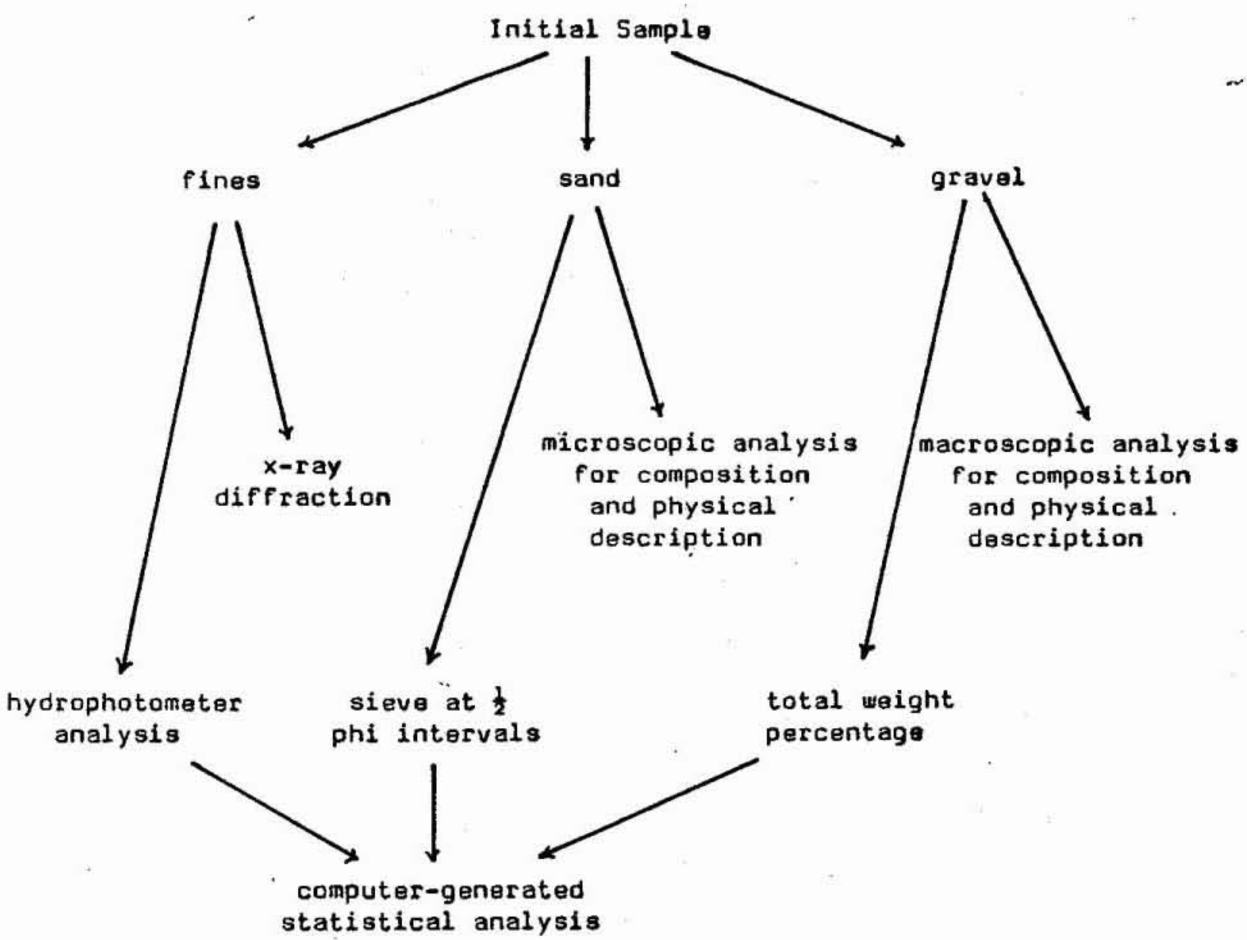

Figure 1. Flow chart of laboratory procedures, central Brooks Range samples. Analyses by J.H. Trexler, Jr.

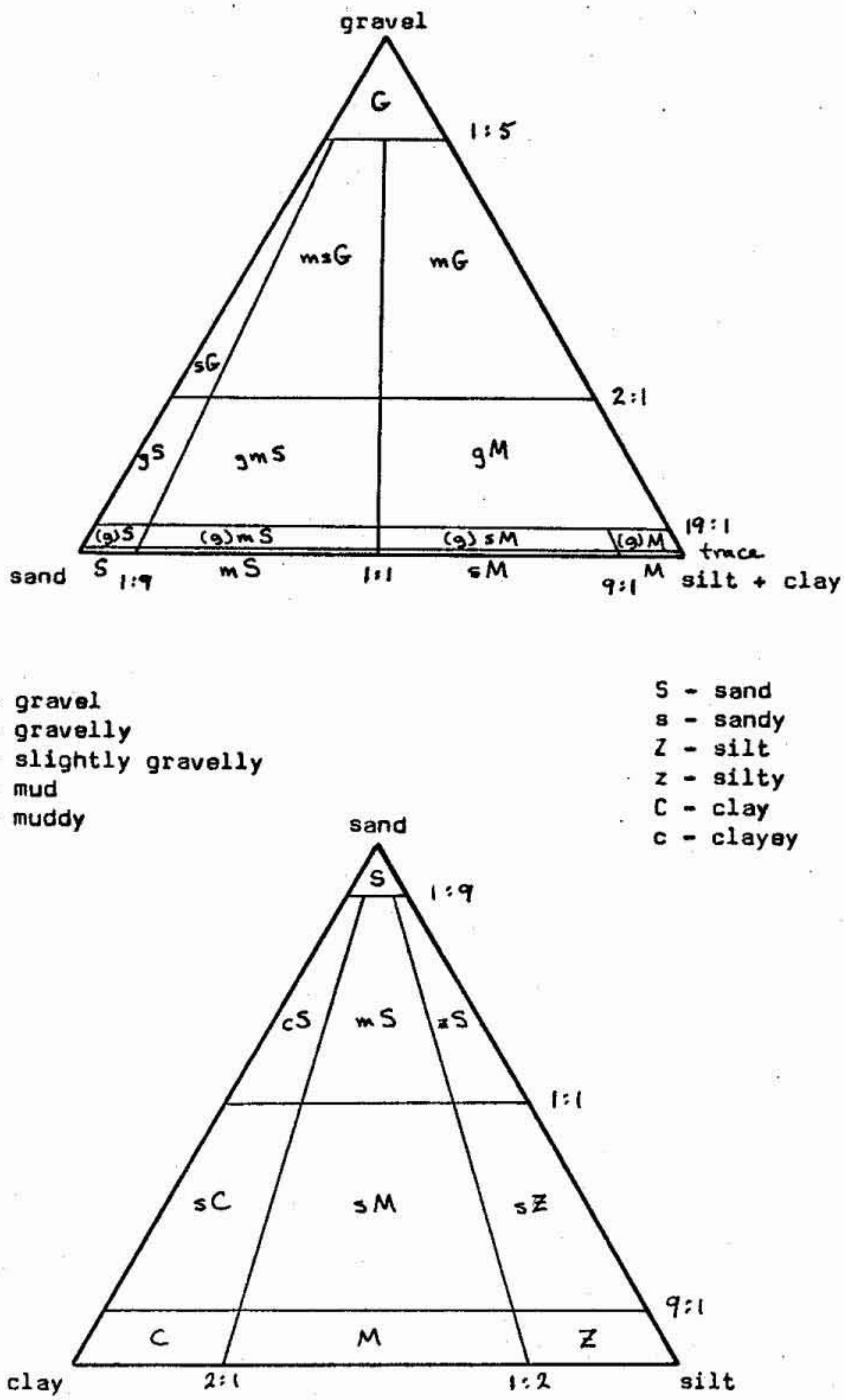

Figure 2. Textural classifications with gravel (above) and without gravel (below). From Folk, 1974, p.28

samples. Our approach to dealing with large amounts of unmeasured gravel was to carry out statistical analyses of gravelly samples as though they contained no material coarser than 2 mm. This gave a more realistic plot of the sand, silt, and clay fractions, and enabled more valid statistical measures for that size range.

The data sets usually are "open-ended" in that most samples contain either gravel (>2 mm) that is not included in the sieve analyses or clay-sized grains (<3.9 μ) that are too small to be analyzed for size distribution with the hydrophotometer. Depending on its size distribution, each sample was treated according to one of the following four approaches:

1. Sandy to silty deposits that lack gravel and have less than 2.5 percent material smaller than 62.5 μ. The weight of material finer than 62.5 μ (4 ø) was assigned to 4 ø and extrapolated to 44 μ (4.5 ø). Extrapolation of this low weight percentage caused no difficulties.

2. Clayey samples that lack gravel but have more than 2.5 percent material smaller than 62.5 μ (4 ø). The fine fraction was analyzed with the hydrophotometer which, with the associated computer program, carries measurements out to 3.9 μ (8 ø), determines a weight for all material finer than 3.9 μ, and assigns that weight to 0.006 μ (14 ø). With the exception of lacustrine deposits, few samples contained more than two percent of material finer than 3.9 μ. Lack of data in the 3.9 μ to 0.006 μ size range therefore was a problem mainly with the lacustrine samples.

3. Gravelly samples with less than 2.5 percent fines. A total weight percentage was entered for all the gravel in the sample and assigned to a generalized >2 mm fraction. Fines were dealt with as in the sandy to silty deposits.

4. Gravelly samples with more than 2.5 percent fine material. The fines were treated as in the clayey samples; the gravel as in the other gravelly samples.

Our work has benefited from the advice and encouragement of many individuals. We are particularly grateful to Gretchen Luepke, who advised us on hydrophotometer procedures and other aspects of granulometric analyses, and to A. Graig McHendrie, who wrote the computer program (U.S.G.S. program sdsz) employed in this study and introduced us to its use. Susan Bartsch-Winkler and Warren E. Yeend read an earlier draft of this paper and provided constructive editorial comments.

STATISTICAL ANALYSES

Many kinds of statistical methods and measures were made easily available through computer processing. We chose to use the graphical statistics computed according to Folk and Ward (1957). Moment measures, although quantitatively more precise, were not used because of their invalidity with open-ended data sets (Pettijohn and others, 1972, p. 72).

Mean and median diameters and modal analyses are commonly calculated from measured grain-size distributions (Pettijohn and others, 1972, p. 75). Of these three measures, mean grain size (i.e., average grain size) is the only one that provided stable and easily interpreted values. Median grain size, the mid-point between the largest and finest grains, is not determinable for the gravelly samples because of the weakness in the sampling program. Modal analysis, which identifies peaks in the size-frequency data, usually produced multiple peaks of uncertain significance when used with poorly sorted samples.

Next to graphic mean, sorting values are probably the most widely used by sedimentologists. The values calculated according to Folk and Ward (1957) (table 2) take into account a greater portion of the grain-size distribution than do values calculated by other methods. Sorting is analogous to standard deviation in that larger values indicate poorer sorting. Samples with larger sorting values therefore have broader size-frequency curves (fig. 3).

Skewness measures the asymmetry of the distribution. If the sample has more fine material than coarse, the distribution curve will be positively skewed, and by convention is said to be "fine skewed" (table 2 and fig. 3). The opposite case would give a corresponding negative or "coarse" skewness. The absolute mathematical limits of skewness are +1.0 and -1.0, and few values will exceed ±0.8.

Kurtosis, a measure of the "peakedness" of a distribution, is a comparison of the sorting near the mean with the sorting near the tails of a curve. A curve with a kurtosis value of 1.0 has pure Gaussian distribution. Leptokurtic curves, with values greater than 1.1, are better sorted in their central portions than in their tails (fig. 3). Values less than 0.9, which indicate appreciably better sorting in the tails than around the mean, characterize platykurtic curves. Although the absolute mathematical limits of kurtosis are 0.41 and infinity, measured values usually fall between 0.67 and 3.0. Kurtosis values are difficult to determine and probably cannot be used alone as environmental indicators (Pettijohn and others, 1972, p. 76).

FAN DEPOSITS

Five samples were collected from fan deposits in the central Brooks Range (see table 3 in "Field Data" at end of report). One sample (026) is from a steep alpine fan near a valley head; three samples are from larger fans in broad mountain valleys; the fifth sample (051) is from an unusually large, broad, and gently sloping fan that extends 2 to 3 km into the John Valley from the tributary valley of McKinley Creek. Only one sample (022)

Table 2. Sorting, skewness, and kurtosis values. From Folk (1974).

SORTING

value (ø)	term	example
0.35	very well sorted	beach sand
0.35 to 0.5	well sorted	dune sand
0.5 to 0.71	moderately well sorted	
0.71 to 1.0	moderately sorted	river deposits
1.0 to 2.0	poorly sorted	
2.0 to 4.0	very poorly sorted	shallow subtidal silt and clay
4.0	extremely poorly sorted	tills, mudflows

SKEWNESS

value	term	example
+1.0 to +0.3	strongly fine skewed	river and dune sand
+0.3 to +0.1	fine skewed	(river and dune sand)
+0.1 to -0.1	symmetrical	
-0.1 to -0.3	coarse skewed	beach sand
-0.3 to -1.0	strongly coarse skewed	

KURTOSIS

value	term
less than 0.67	very platykurtic
0.67 to 0.90	platykurtic
0.90 to 1.11	mesokurtic
1.11 to 1.50	leptokurtic
1.50 to 3.00	very leptokurtic
greater than 3.0	extremely leptokurtic

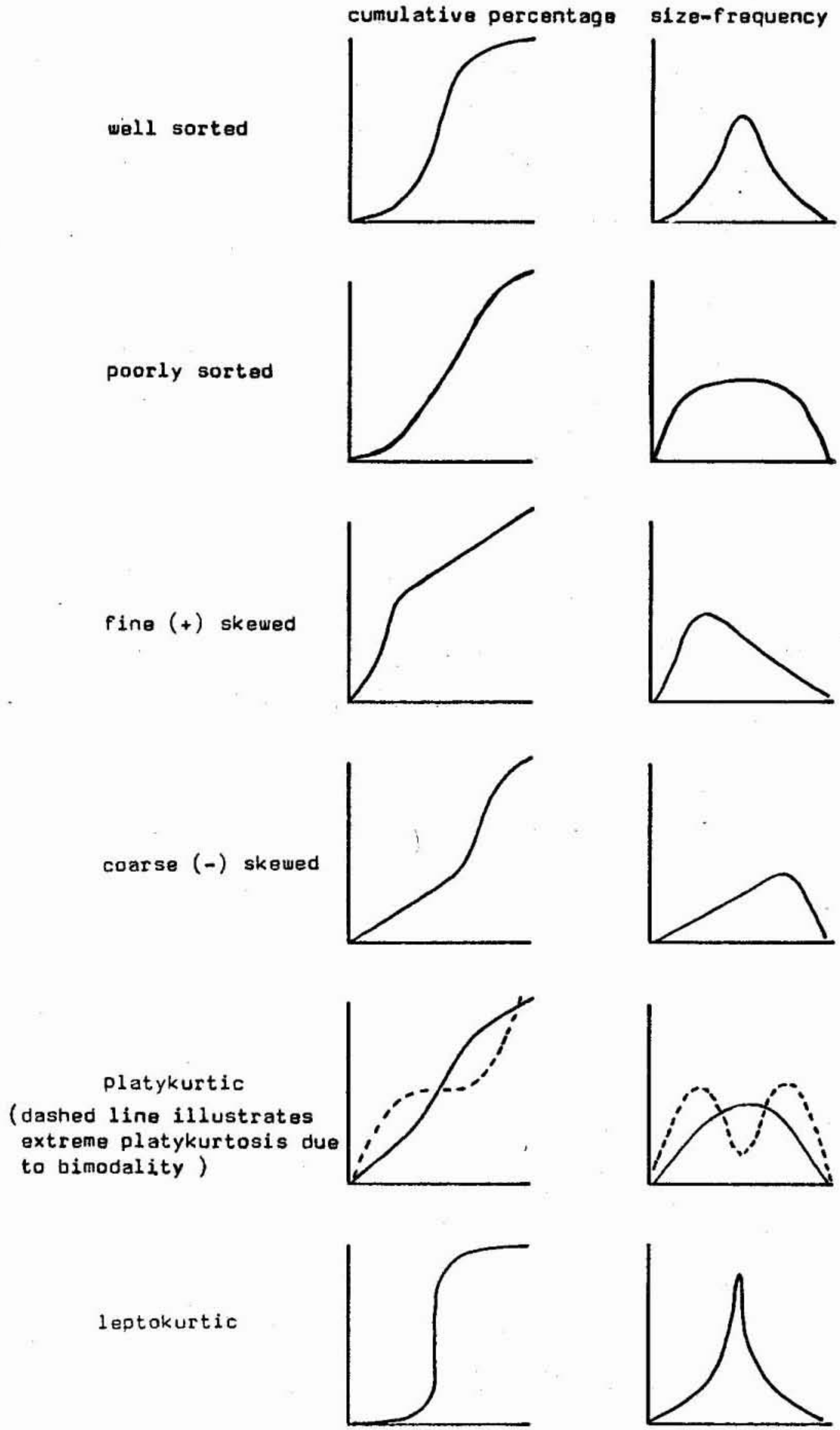

Figure 3. Idealized cumulative percentage and size-frequency curves, showing relation to graphic measures. All plots are log-normal.

is from the surface of an active fan. All of the others were taken from the stream-cut faces of stabilized and vegetated older fan segments.

All five samples are poorly sorted to very poorly sorted gravels containing less than 40 percent sand, silt, and clay (fig. 4). Gravel and sand contents are inversely related, whereas abundance of silt and clay are unrelated to either of the coarser size grades. Sand content ranges from 17 to 34 percent; silt is much less abundant and comprises less than one percent in 3 of the 5 samples. All of the samples except 062 show a wide range of roundness in both gravel and sand, and most samples contain some subangular grains (see table 13 in "Laboratory Data" at end of report). Shape of both clasts and sand is dependent on lithology. Samples 037 and 062 contain mostly tabular to platy grains of schist and phyllite, whereas the quartzite- and shale-rich samples 022 and 026 contain more diverse shapes.

Sample 026, a muddy sandy gravel, differs from all the others in its relatively poor sorting. It appears strongly bimodal, with coarse sand and coarse silt more abundant than the intervening medium to very fine sand fractions. This sample was taken from a steep alpine fan that probably is subject to slushflows and perhaps mud- or debris-flows during the spring snowmelt season.

The remaining four samples are generally similar to each other in grain-size distribution, and all reflect effective removal of the fine sand, silt, and clay fractions from fan deposits. However, some variations between them probably are controlled by terrain, geology, and other environmental factors. Sample 051, which exhibits the best sorting in the sand and silt fractions, is from the distal end of the unusually large and gently sloping fan. Samples 037 and 062, which are nearly identical to each other, were taken from smaller fans that resemble each other in size, steepness, and age, and

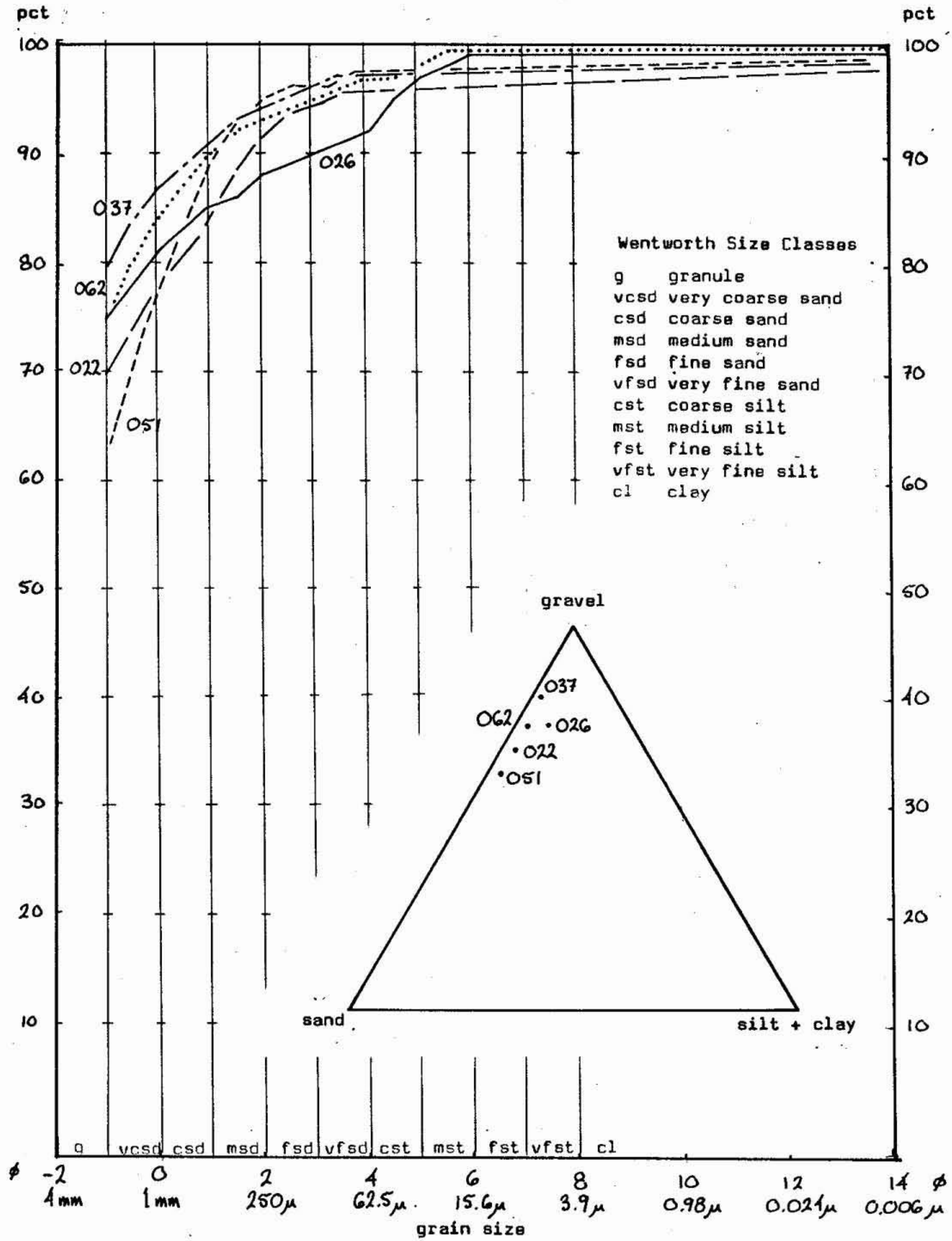

Figure 4. Cumulative percentage plots and ternary diagram, fan deposits.

occupy forested valley segments within schist and phyllite terrane. Sample 022 is from a fan intermediate in size and gradient between the large fan from which Sample 051 was taken and the two smaller fans. Only one sample (022) was taken from the surface of a currently active fan, and its statistical values do not vary systematically from the deposits of inactive fans.

MODERN ALLUVIUM

Fourteen samples were collected from modern alluvial sand and gravel deposits (see "Field Data, table 4). Two samples (005 and 043) are from unvegetated sand bars; the remaining 12 are from unvegetated gravel bars of meandering streams or the active floodplains of braided streams.

All of the samples contain abundant sand, and all samples but one (043) contain 2.6 percent or less of the silty and clay fraction (fig. 5). Clay appears to be more abundant than silt in 11 of the 14 samples, possibly reflecting winnowing by wind of bar and floodplain surfaces. Most gravel is subrounded to either rounded or well rounded, and sand grains tend to be subangular to subrounded (see "Laboratory Data, table 14).

The two sand samples are very similar, consisting dominantly of medium to fine sand with nearly symmetric, mesokurtotic size distributions. Sample 043 has a slightly smaller mean size and poorer sorting than 005; its grains exhibit a wider range of roundness and consist almost entirely of rock fragments whereas sample 005 contains roughly equal amounts of subangular mineral grains and subangular rock fragments. The two samples were taken from similar localities: meandering streams of comparable discharge in forested valleys.

The twelve gravel samples show extremely rapid attenuation through the coarse to medium sand range, with very fine sand almost as rare as silt and clay in most cases. Sample 029 is unique in its high gravel content, virtual

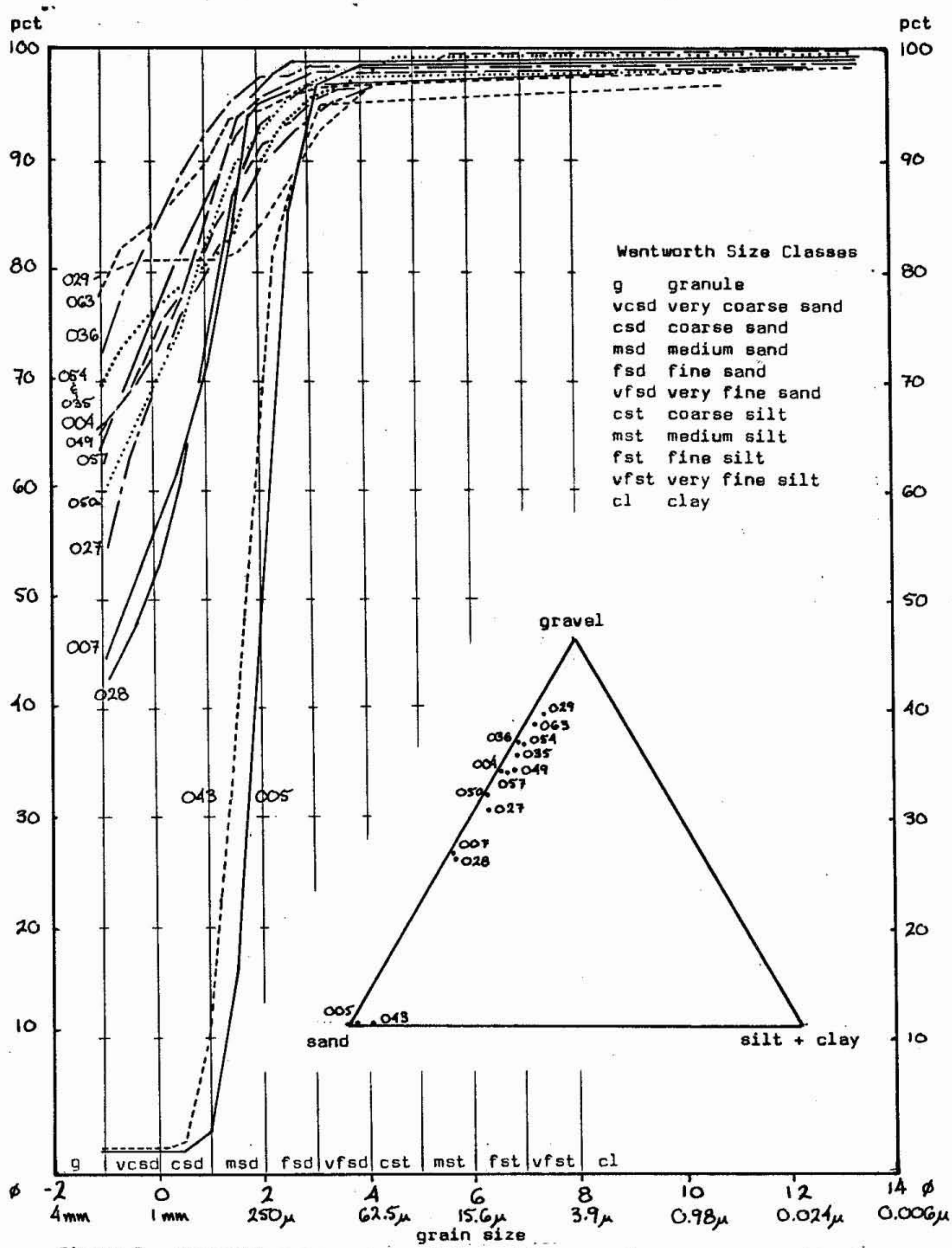

Figure 5. Cumulative percentage plots and ternary diagram, modern alluvium.

absence of coarse to medium sand, and abundance of the fine to very fine sand fraction. Its unusual size distribution may be the result of some error in sampling or analysis. Two mutually similar samples (007 and 028) are unusually sandy, with coarse and medium sand about equal to gravel in abundance. Sample 063 differs from the others in its high percentage of gravel and in its high sorting, skewness, and kurtosis values. Most of the remaining eight samples are similar to each other, and their properties tend to range through a narrow set of values rather than cluster in separate groups.

No distinct relationship is apparent between physical properties and geologic settings of the 12 gravel samples. The nearly identical samples 007 and 028 are from entirely different settings: sample 007 is from a large stream meandering at low gradient through a forested floodplain, whereas sample 028 was taken from an aufeis zone along a smaller, steeper, braided stream in the arctic tundra. Sample 063, which is unique in several respects, is from a small meandering river in the southern Brooks Range that is similar to the streams that yielded samples 036, 050, and 057.

The individual size-distribution curves seem to provide little information that can be used for such specific environmental interpretations as gradient, channel pattern, or local vegetation. Variance in sediments along most streams (between pools and riffles, for example) probably is nearly as great as the total range of values between the gravel samples. However, all of the alluvial deposits are characterized by deficiency of particles smaller than fine sand, and the sandy and gravelly samples form two distinctive sets of values for comparison against other sand and gravel deposits of uncertain origin.

ALLUVIAL-TERRACE AND OTHER GRAVEL DEPOSITS

Three samples of late Quaternary river gravels were collected from alluvial terraces in the John Valley drainage system (see "Field Data", table 5). Two of the terraces occur upvalley from the Itkillik II end moraine and therefore are younger than that glacial advance. They possibly are related to late Itkillik glacial stillstands farther upvalley. The third terrace (sample 042) occurs in a tributary valley that was not glaciated during Itkillik II time, but probably was alluviated during that interval. All three terraces most likely were created by latest Pleistocene to early Holocene downcutting through the thick Itkillik deposits of the John Valley system.

Two additional samples were collected from weathered alluvium of late Tertiary or early Pleistocene age in positions well above modern valley floors. Sample 002 is from residual gravel knobs at the south flank of the Brooks Range; sample 021 is from a widespread high terrace that lies beyond the outer limits of northern Brooks Range glaciations.

Sample 021 is unusual in its relatively poor sorting, bimodal size distribution, and relatively abundant silt and fine to very fine sand (fig. 6). Stones show a wide range of rounding, shape, and compositions; sand grains range from fresh and angular to well rounded and frosted (see "Laboratory Data", table 15). Graphic measures indicate a relatively small mean size, very poor sorting, and a low kurtosis value. This sample was taken from gravel that has been subjected to weathering and other postdepositional processes for at least several hundred thousand years. Its unusually high silt content could be the result of weathering of the parent material and perhaps admixture of loess.

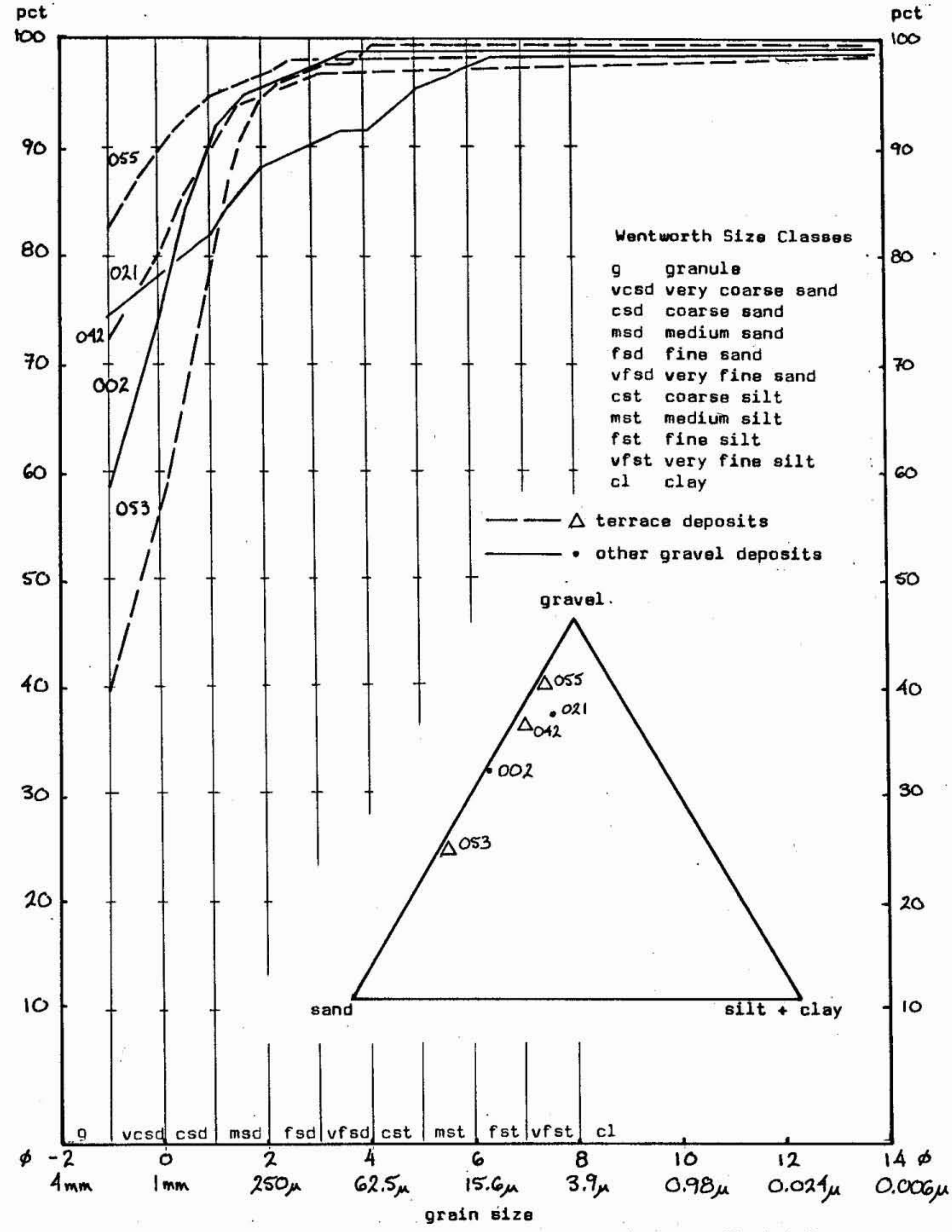

Figure 6. Cumulative percentage plots and ternary diagram, alluvial-terrace and other gravel deposits.

All other samples consist of sand and gravel with five percent or less fine sand, silt, and clay (fig. 6). Although percentages are very small, clay content appears consistently to be 3 to 4 times greater than silt content (see "Laboratory Data", table 15). The sandiest and least silty of the samples (053) is the best sorted and has the most symmetric size distribution; it contains the most angular clasts and also the most angular sand grains. Sample 042 has the most abundant clay, and as a result is the most poorly sorted of the group and has strongly positive skewness. The most gravel-rich sample (055) is similar to sample 042 in its very poor sorting, positive skewness, and high kurtosis value; some clasts are well rounded, and many show secondary breakage surfaces. Sample 002, the oldest in this group, is a clean sandy gravel with rounded to well rounded stones that are compact in shape and commonly are fractured. The sand fraction is at least 50 percent quartz and is somewhat more angular than the gravel; it contains a few well rounded and frosted grains.

Samples 002, 042, and 053 resemble modern alluvium in grain-size distribution, rounding, composition, and statistical measures. Sample 055, which has unusually high gravel content, also contains exceptionally well-rounded grains and, locally, a very well washed granule-small pebble matrix (see "Field Data", table 5). This sample was obtained from a locality where two valleys join and where complex late-Pleistocene drainage changes took place. It may be polygenetic in origin, including lacustrine or basin-fill sediments and alluvial-fan deposits in addition to alluvium.

LACUSTRINE DEPOSITS

Lacustrine sediments were sampled at eight localities where Itkillik-age glaciers or their moraines dammed valleys within the Brooks Range and its foothills (see "Field Data", table 6). In five cases (samples 040, 044, 048, 058, and 178), glacier ice moving through main valleys dammed lakes in the lower courses of unglaciated tributaries. At two other localities (samples 032 and 061), lakes formed in glaciated main valleys as ice fronts retreated from terminal moraines. At the remaining locality (sample 011), a proglacial lake was formed during advance of an Itkillik I glacier into foothills beyond the south margin of the Brooks Range. Two additional samples (136 and 137) define the coarsest and finest lacustrine beds at a site where a representative sample (048) was also taken.

Most of the lacustrine samples show possible effects of ice rafting. All samples are poorly sorted to extremely poorly sorted, and 6 of the 10 contain sand and gravel in amounts ranging from traces to about 50 percent (fig. 7). Silt-clay ratios range from 9:1 to 1:5 (fig. 8), and silt is the predominant size class in six samples. The sand grains range from angular to rounded, in most cases tending toward angular with some euhedral grains (see "Laboratory Data", table 16). Quartz is the dominant mineral in the sand fractions, with calcite, micas, pyroxenes, and amphiboles also present, but rock fragments occur in all sandy samples and dominate the sand fractions of samples 040 and 061. Fine gravel, present in four samples, ranges from subangular to rounded and consists entirely of rock fragments.

Two samples were analyzed by x-ray diffraction to determine composition of the fine fractions. Sample 044 was selected as representative of the silt-rich samples, and sample 137 was chosen as the most plastic and the richest in clay-sized mineral grains. Analyses of both samples show that all of the fine constituents are primary mineral grains and that no expandable clay minerals are present (see "Laboratory Data").

Samples 044, 048, and 058 are similar to each other in their abundant clay and very fine silt percentages and in their skewness, sorting, and kurtosis

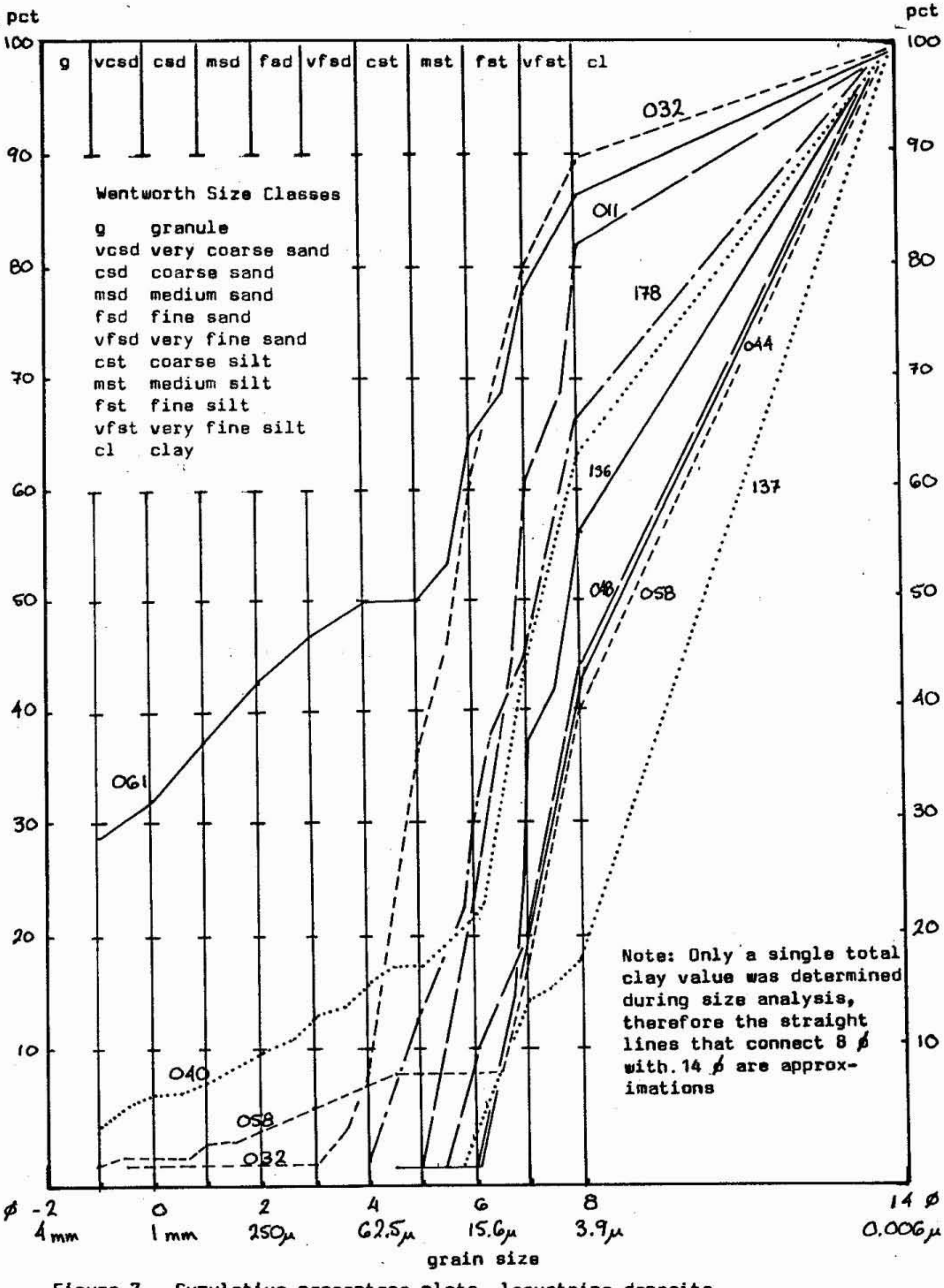

Figure 7. Cumulative percentage plots, lacustrine deposits.

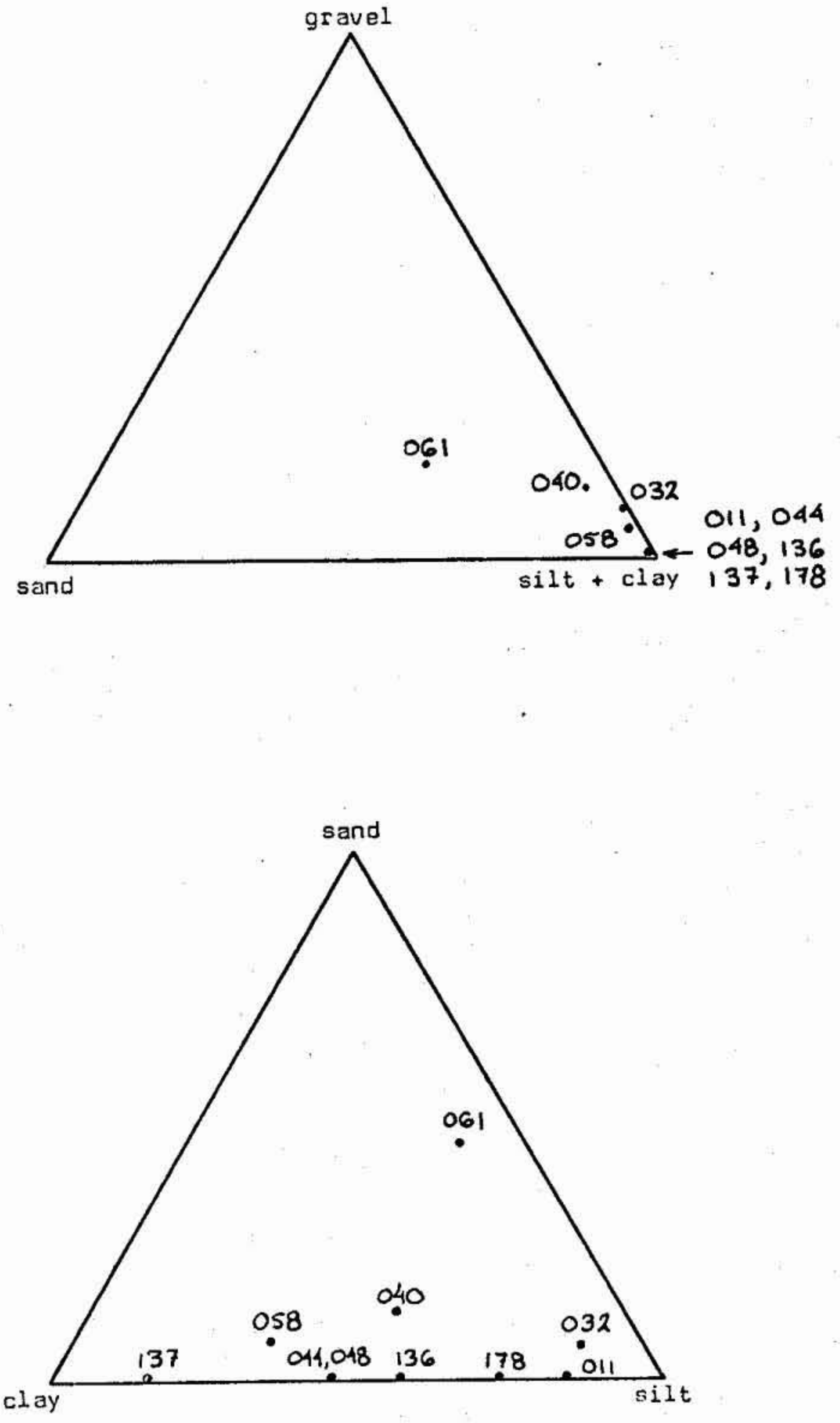

Figure 8. Ternary diagrams with gravel (above) and without gravel (below), lacustrine deposits.

values. All three samples formed in tributary valleys that were dammed by Itkillik II glaciers. Samples 048 probably formed while ice was advancing, and was later buried under a till deposit. Sample 044 formed just beyond the ice limit during the time of maximum glaciation. The relatively sandy sample 058 formed within the Itkillik drift sheet during a stillstand or minor readvance of the ice front. The size-frequency curves of samples 136 and 137 form silt-rich and clay-rich end members that enclose the other three curves.

Samples 040 and 178 are from somewhat coarser deposits that also formed in glacier-dammed tributary valleys. The two samples are similar to each other in the fine silt through clay fractions, but 040 contains relatively abundant sand and gravel whereas 178 has a higher silt content. Sample 040 formed while ice was advancing, and was later buried under a till. It might contain some outwash from the ice front. Sample 178 formed at the mouth of a small stream several km up a tributary valley from the ice dam at its mouth, and may represent the distal portion of a delta.

Samples 011 and 032 are the best sorted of the ten samples, with a silt percentage greater than 80 in each case. In contrast to all other lacustrine samples, these two are from deposits that formed in very poorly drained basins of Itkillik I age that experienced several later episodes of eolian, fluvial, thaw-lake, or muskeg deposition and reworking. Sample 011 is from a shallow auger hole into a muskeg-thaw lake complex of Holocene age; sample 032 is from a poorly drained Holocene floodplain. In both cases, the sediments are relatively enriched in silt that may have originated as loess during the Itkillik II glaciation and then been intermixed with younger organic matter during subsequent thaw-lake or muskeg development.

Sample 061 was taken from the face of a river bluff where downslope flowage had caused some mixing of sediments. Its unusually high gravel and sand content probably resulted from secondary mixture rather than primary ice rafting. Its stones are unusually well rounded compared to the other gravel-rich samples, suggesting possible incorporation of alluvium that perhaps once formed a thin cap above the lacustrine deposit.

FLOW-SLIDE DEPOSITS

Flow slides--large lobate bodies of slowly flowing and(or) sliding rock debris--are particularly abundant on valley walls oversteepened by glacial erosion of the weakly resistant schists and phyllites that underlie much of the south-central Brooks Range (Hamilton, 1978a). Such lithologies weather readily to yield platy rock fragments and micaceous matrix that are readily susceptible to sliding and flowage. Eight samples were taken from active flow-slide lobes; a mudflow in phyllite (sample 056) and a debris flow in till (sample 085) also were sampled for comparative study (see "Field Data", table 7).

The eight flow-slide deposits are very poorly sorted mixtures of gravel, sand, and finer particles (fig. 9). Gravel predominates in most samples, with sand usually second in abundance. Silt percentages range between about 13 and 30 in most cases, whereas clay usually averages about 1 percent. Gravel and sand particles are angular to subangular and usually tabular (see "Laboratory Data", table 17). Stones are dominantly schist and phyllite; sand grains are composed of quartz, mica, and tabular metamorphic rock fragments. Most samples show a moderate to strong size peak in the very fine sand to coarse silt range.

Samples 041 and 149 are end members of a range of size distributions that shows little clustering (fig. 9). As the gravel percentages decrease,

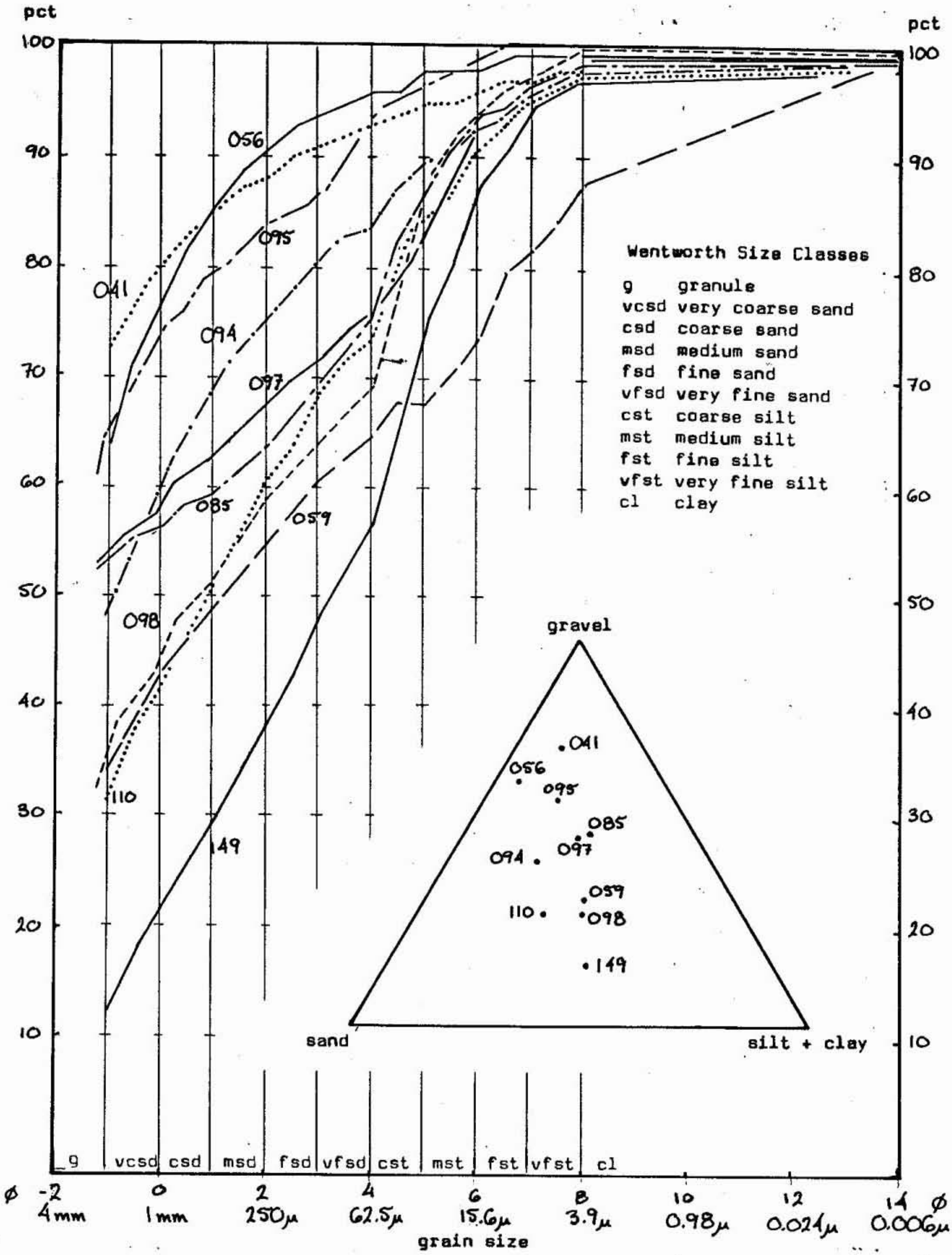

Figure 9. Cumulative percentage plots and ternary diagram, flow-slide deposits.

the coarse-silt peaks tend to become stronger and sorting becomes generally poorer. Gravel-rich samples such as 041 tend toward positive skewness whereas gravel-deficient samples such as 149 tend to be negatively skewed. Most samples have platykurtic size distributions, with kurtosis values showing little relation to gravel content. Properties of the flow-slide deposits show close relationships to their geologic settings. The gravel-rich samples 041, 094, 095, and 097, from typical flow lobes developed on schist and phyllite, were sampled where incised by axial streams along the centers of narrow mountain valleys. Samples 059 and 098, which are similar to each other in their relatively low gravel and high silt contents, were taken from remobilized flow deposits in which fines apparently became concentrated. Sample 059 is from a secondary flow generated from a landslide deposit on the floor of a relatively broad valley. The flow may contain valley-fill deposits admixed with the landslide debris, and the unusually high clay content of this sample (12 percent) could be due to incorportated lacustrine sediments. Sample 098 is from a muddy debris apron at the base of an active lobe front. This apron apparently represents a concentration of fine-grained matrix material washed from the lobe front by rainfall and meltwater. Sample 110 has a low gravel content similar to those for samples 059 and 098, but contains more sand and has an unusually even size gradation through all fractions of the sand-to-silt range. This sample is from a shear zone in bedrock along the headwall of an active rubble deposit that appears transitional in character between rock glaciers and flow-slides. Granulation of vein quartz along the shear zone might account for the unusually abundant and well-graded sand in this sample. Sample 149, which differs from all of the others in its very high content of organic-rich silt, was taken from the lower wall of a valley that was icefree but dammed at its mouth by a glacier during Itkillik II time. Lacustrine sediments, exposed at and near the valley center near the sample site, possibly extend up the valley wall to the altitude where sample 149 was taken.

Samples 056 and 085, from a mudflow and a debris flow in till, show general similarity to the four typical flow-slide deposits but lie at the two extremes of their range of values (fig. 9). The fanlike mudflow deposit from which sample 056 was taken contains surprisingly abundant sand and gravel, with total silt plus clay content less than four percent. Fines may have been washed from this deposit during or after the time of its formation. Sample 085, from a debris flow on the flank of a moraine, is relatively deficient in coarse to medium sand but contains abundant sediment in the fine sand through medium silt fractions. This size distribution may reflect composition of the parent till.

OTHER COLLUVIAL DEPOSITS

Four samples representing three separate types of colluvium are combined in this category. Samples 031 and 114 are matrix materials from rock-glacier rubble, sample 064 is from a solifluction deposit, and sample 020 is from a small flow lobe at the base of an abandoned river bluff (see "Field Data", table 8).

Both of the rock-glacier samples are very poorly sorted silty sandy gravel with virtually no clay-size material (fig. 10), and consist mainly of schist and phyllite fragments (see "Laboratory Data", table 18). Both clasts and sand grains are angular, having tabular to elongate shapes that reflect cleavage planes. Sample 031 is very micaceous and contains a sulpherous alteration mineral, whereas sample 114 consists of non-micaceous rock fragments.

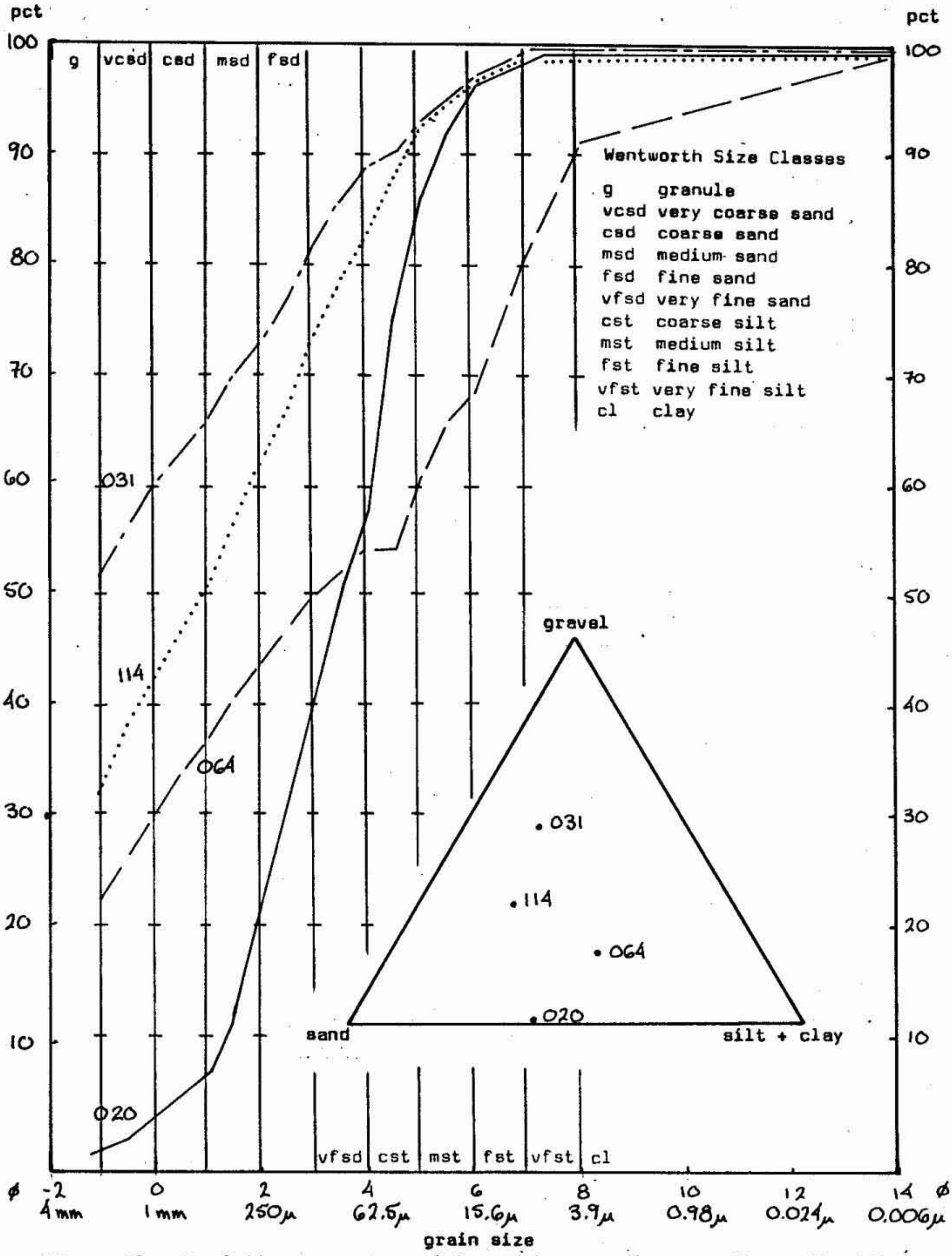

Figure 10. Cumulative percentage plots and ternary diagram, other colluvial deposits.

The solifluction sample (064) is very poorly sorted gravelly mud with an unusually high content of fine silt and clay. Both gravel and sand particles are angular and schistose, with quartz and mica also abundant in the sand and silt fractions. Grain-size distribution is negatively skewed and platykurtic, and the size-frequency plot shows distinct modes at 5 and 7 ø. Sample 064 was taken from a glaciated mountain valley, where the solifluction apron may include redeposited clayey till as well as the products of postglacial weathering.

Sample 020, taken from a highly organic flow lobe, is a very silty sand with more than 40 percent silt, almost no clay, and no grains larger than 2 mm. The inorganic fraction is almost entirely poorly sorted subangular to subrounded quartz sand and has a symmetric and mesokurtic size distribution. The organic fraction is composed of 50 percent charcoal fragments, with wood and leaf debris making up the balance. The flow lobe terminates on a floodplain surface, and may have incorporated silty to sandy overbank deposits during its advance.

SAND DEPOSITS

Eight samples of moderately well sorted to poorly sorted sand, gravelly sand, and silty sand were collected from fluvial and eolian depostis (see "Field Data", table 9). Four of the samples (001, 009, 012, and 038) probably were deposited initially by slow-moving streams within basins partly dammed by end moraines of Itkillik age. Some of these sediments could have been reworked by wind into sand sheets on partly vegetated floodplain surfaces. Two other samples (023 and 046) are clearly eolian, and are associated with active dunes and blowouts. A final pair of samples (052A and 1952B) was taken from a sandy to silty Holocene floodplain that was in part redeposited from a late Pleistocene basin filling.

Samples 023 and 046, the dunal deposits, are relatively well sorted, medium to find sands containing little silt (fig. 11). Sample 023 contains some clay-size material, and its sand grains are predominantly subangular to subrounded phyllitic rock chips (see "Laboratory Data", table 19). Sample 046 is a calcareous sand with almost no silt or clay, and its grains are more rounded than those of sample 023. Both samples are moderately sorted to moderately well sorted and leptokurtic.

One of the basin-fill deposits (009) is nearly identical to the two dunal samples in its grain-size distribution and in most graphic measures. It has slightly more silt than either of the dunal samples, and its sand grains are relatively angular and consist primarily of mineral rather than rock fragments. Although sample 009 is from a bluff exposure cut into an inferred basin filling, its similarity to the two dunal samples suggests that the deposit may have been of eolian origin where sampled near the crest of the bluff.

Samples 001, 012, 052A, and 052B are extremely silty in comparison to the group of dunal samples, and consist dominantly (40 to 60 percent) of grains in the very fine sand to coarse silt range. Two of the samples (001 and 012) are relatively well sorted and nearly devoid of clay-sized grains; the other samples (052A and 052B) are more poorly sorted and contain 5 or 6 percent clay. Sand and silt grains are more angular than those of the dunal samples, and quartz is a more important constituent. Samples 052A and 052B contain more fine silt and clay than any of the other samples and are more poorly sorted. These characteristics are compatible with their origin on a Holocene floodplain, where a complex of Pleistocene-age sediments was redeposited in the presence of silt-trapping vegetation. Samples 001 and 012 are intermediate between the floodplain and dunal samples in grain size,

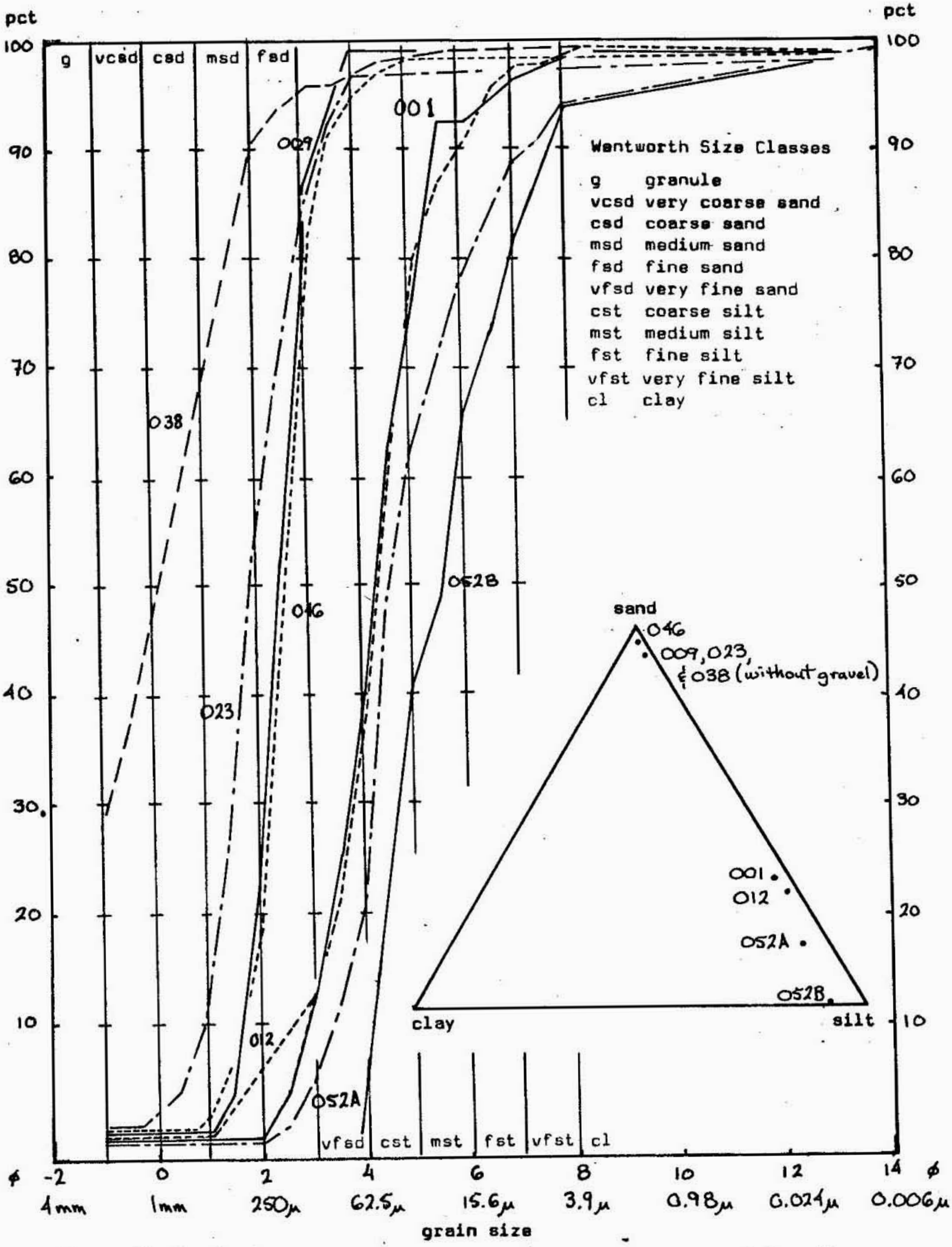

Figure 11. Cumulative percentage plots and ternary diagram, sand deposits.

sorting, and other physical characteristics. This is compatible with their inferred deposition in barren windswept depositional basins that formed behind Itkillik-age moraines during glacial recession.

Sample 038 is unique among the sand samples in its high gravel content combined with its very low abundance (6 percent) of fine to very fine sand. Stones are rounded to subrounded, commonly fractured, and consist mainly of schist and phyllite. The sand fraction is primarily quartz, and grains commonly are angular. This sample was taken from a soil pit, and its gravel content plus fractured stones suggests that it may have been subjected to frost mixing and other freeze-thaw processes. However, the low abundance of particles finer than medium sand indicates that the original deposit probably was not a basin fill similar to any of those from which samples 001, 009, or 012 were taken.

TILL DEPOSITS

Five samples of till were taken from drift of Itkillik age (see "Field Data", table 10). Sample 010 is from the crest of an Itkillik I end moraine; sample 014 is from the inner flank of an Itkillik II lateral moraine. Sample 017 is from the actively caving margin of a kettle pond, and both 018 and 030 are from deep stream cuts that expose basal tills.

All of the samples are poorly sorted to very poorly sorted mixtures of gravel, sand, and silt, with less than three percent clay in 4 of the 5 specimens (fig. 12). Most gravel is rounded to subrounded, and many particles are fractured (see "Laboratory Data", table 20). They consist primarily of metamorphic rock fragments, whereas sand grains consist of quartz and rock fragments in more nearly equal amounts. Sample 014 has a double mode at 3 ∅ and 5 ∅; all other samples have a single mode near 4 ∅.

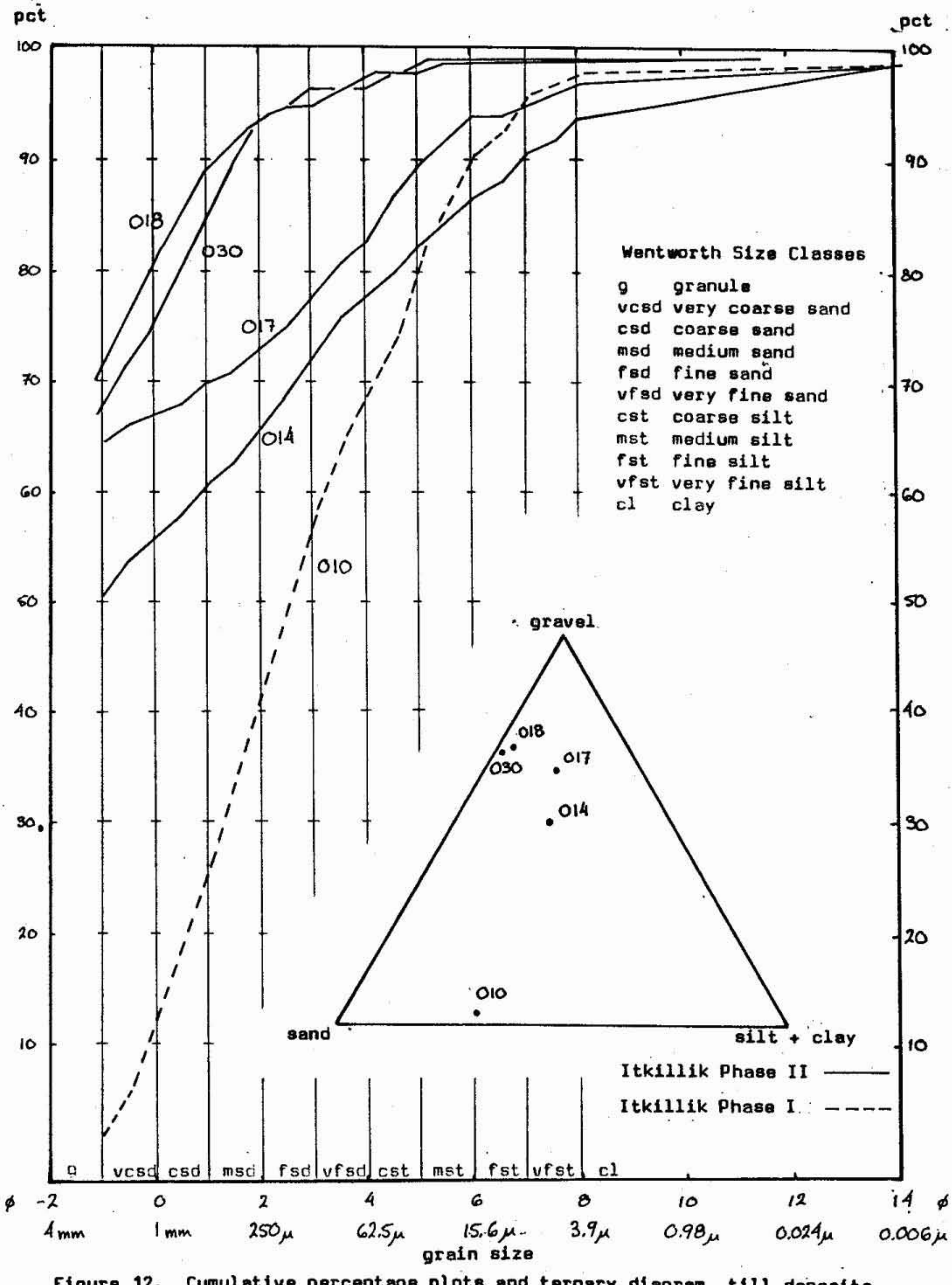

Figure 12. Cumulative percentage plots and ternary diagram, till deposits.

Sample 010 differs from the other four in its low gravel content, abundant sand and coarse silt, and presence of concretions that have formed as weathering products. This sample was taken from a soil pit along the crest of a moraine, where meltwater activity probably caused appreciable sorting. Postdepositional weathering and soil formation probably have affected grain-size distribution in this sample.

The remaining four samples comprise two sets with contrasting characteristics. Samples 018 and 030 are relatively well sorted and deficient in fine sand, silt, and clay. Pebbles are subangular to well rounded, and both gravel- and sand-size particles are dominantly rock fragments. Samples 014 and 017, in contrast, have somewhat less gravel and considerably more silt and clay. Their stones are somewhat more angular, and sand fractions consist predominantly of quartz grains. The nearly identical samples 018 and 030 are both from deep exposures within the Killik Valley, and are derived from relatively quartzose lithologies. Other aspects of their geologic settings are radically different however. Sample 018 was obtained from a broad piedmont drift lobe at the north flank of the Brooks Range whereas sample 030 came from a confined mountain valley with a relatively steep gradient and relatively uniform lithology. The siltier, less sorted, and less uniform samples 014 and 017 were obtained from the upper Nigu Valley, where lithologies are dominantly shale and sandstone. Sample 014 was taken near the upper contact of a till deposit exposed on a slope where solifluction has been active. Its very poor sorting, high silt and clay content, and bimodality may be due to admixture of the till with late-glacial loess and postglacial solifluction deposits. Sample 017 is from a broad low pass where glacial meltwater would tend to become ponded rather than flow actively. Its relatively high silt and clay content probably reflect this low-energy environment.

ICE-CONTACT STRATIFIED DRIFT DEPOSITS

The twelve samples of ice-contact stratified drift represent a broad spectrum of glacial deposits (see "Field Data", table 11). Sample 013 is from a probable outwash sheet deposited on top of a stagnant glacier; samples 033 and 060 are from probable eskers; samples 016A, 016B, and 019 are from massive deposits of superglacial drift. Samples 039 and 045 are from stream deposits laid down in slowly moving to standing water bodies along the margins of valley glaciers; samples 034 A through D are from a bluff exposure cut into a diverse assemblage of stagnant-ice deposits. Ten of the samples are of Itkillik II age. One of the others (039) dates from the Itkillik I Glaciation and the remaining sample (060) is of late Itkillik age.

Three samples (016B, 034C, and 045) contain little or no gravel, and are better sorted than most of the others (fig. 13). Skewness values are near symmetry, and all three samples are leptokurtic (see "Laboratory Data", table 21). Samples 016B and 034C are fine-skewed silty sands with no gravel and with less than four percent fine silt and clay, whereas sample 045 is coarse-skewed, less well sorted, and contains about 50 percent silt as well as a small amount of gravel.

Sample 039 also is relatively well sorted, and has skewness and kurtosis values very close to those of samples 016B, 034C, and 045. Both 039 and 045 were taken from deposits probably laid down in standing to sluggishly moving water along former glacier margins. Samples 016B and 034C could reflect similar environments, although both are from subsurface stratigraphic units that cannot be related to contemporaneous surface morphology.

Seven of the eight remaining samples have gravel contents greater than 62 percent, poor to very poor sorting, and relatively little matrix material in the fine sand to coarse silt range. Gravel and sand grains are subangular

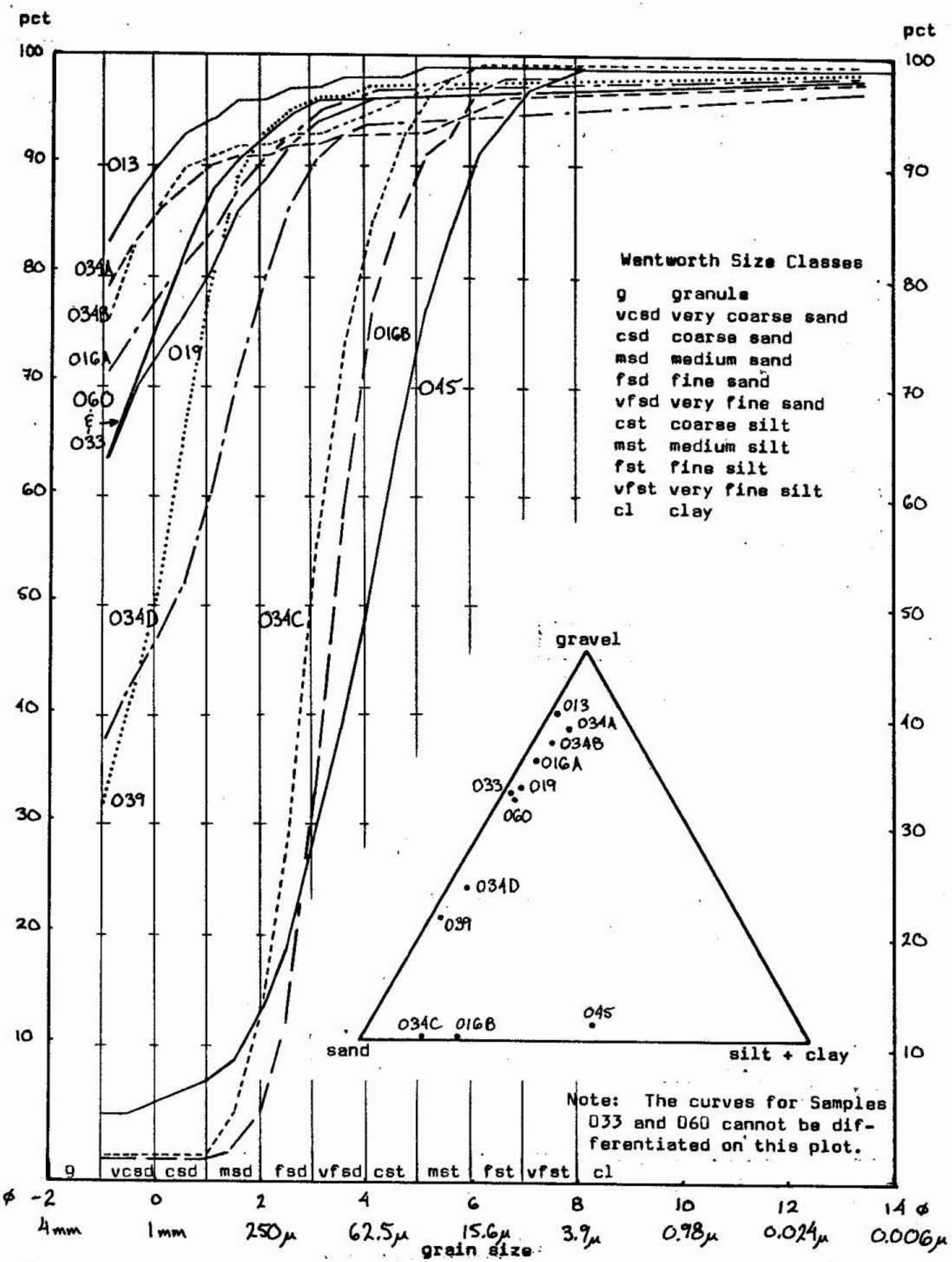

Figure 13. Cumulative percentage plots and ternary diagram, ice-contact stratified drift deposits.

to rounded, and stones commonly are fractured. Sample 013 is from probable superglacial outwash, and samples 033 and 060 are from esker-like ridges that probably were deposited by meltwater streams flowing beneath stagnating glacier ice. These three samples may define a range of grain-size values characteristic of superglacial to subglacial meltwater streams. Four somewhat similar samples (016A, 019, and 034 A and B) may have formed under comparable environments. Sample 016A is from a geologic setting similar to that of 013, although gradients are gentler and stream energy presumably was less. Samples 034 A and B are from superglacial drift that may have been further washed by meltwater as glacier ice retreated. Sample 019 is from a massive deposit of superglacial drift that underwent an unknown amount of reworking by meltwater.

Sample 034D, a bedded and presumably water-laid gravel, is intermediate in character between the sandy and gravelly end members of the ice-contact stratified drift deposits.

OUTWASH DEPOSITS

Six samples were taken from outwash terraces that range in height between 11 and 30 m. One of the outwash deposits is of Sagavanirktok age; the others range in age from Itkillik I through late Itkillik (see "Field Data", table 12).

All six samples are remarkably similar in grain-size distribution of matrix materials (fig. 14). Compositions range from sandy gravel (3 samples) to muddy sandy gravel (3 samples), with sand abundance between 25.6 and 41.2 percent. Combined clay, silt, and very fine sand is five percent or less in all cases. The samples also are very similar in texture, with gravel rounded to subrounded and sand grains somewhat more angular (see "Laboratory Data", table 22). Only sample 006, of pre-Itkillik age, contains fractured

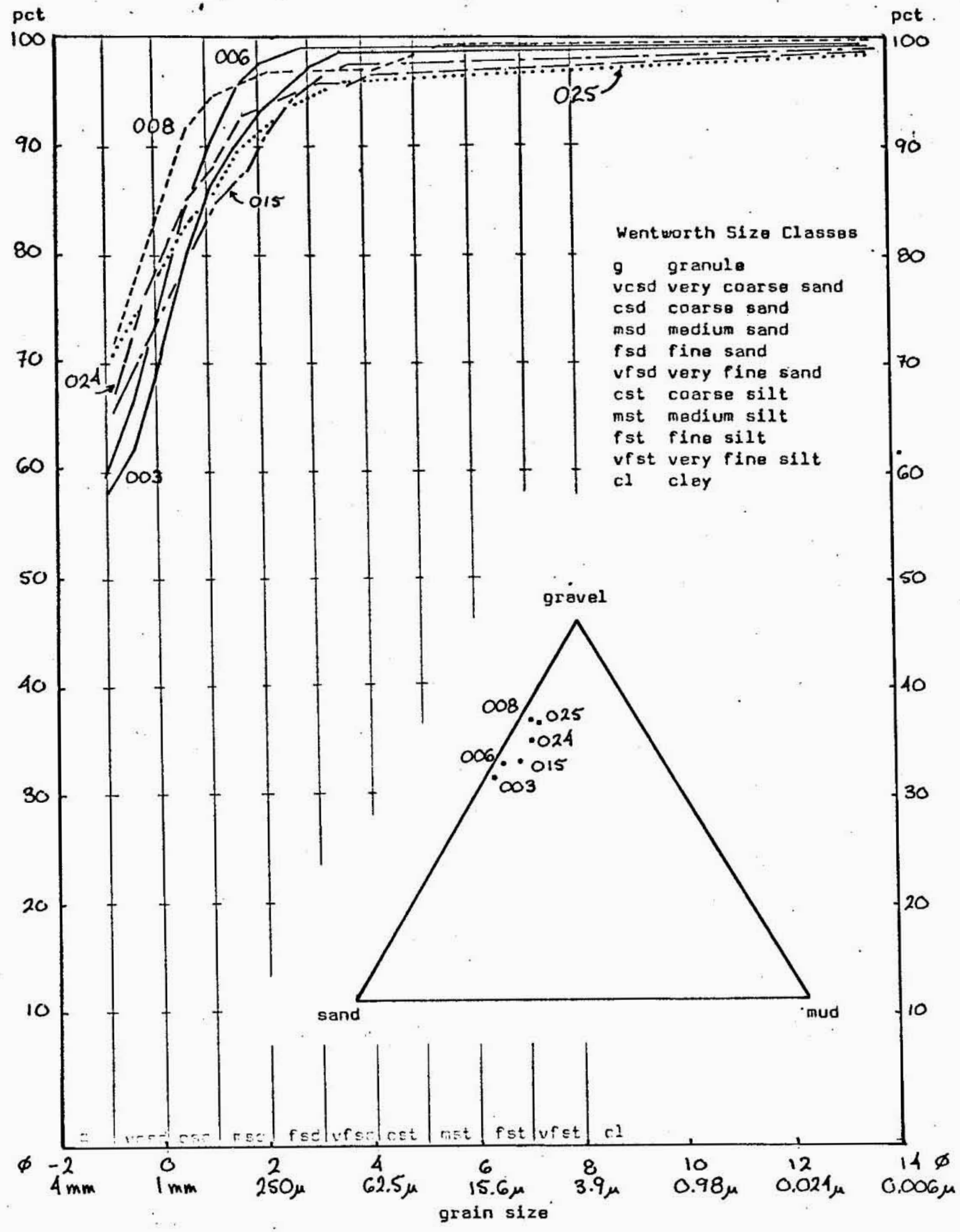

Figure 14. Cumulative percentage plots and ternary diagram, outwash deposits.

stones. Rock fragments are an important component of both gravel and sand grains. Quartz also is present in every sample, and dominates the sand fraction of samples 006 and 008.

Samples 003 and 006 differ from the others in their lower gravel contents and lower values for combined silt and clay. These relatively sandy samples are better sorted, more mesokurtic, and more nearly symmetrical than any other outwash samples. Samples 015, 024, and 025 form a contrasting group that is characterized by relatively poor sorting, strong positive skewness, and high kurtosis values. Sample 008, like 003 and 006, is relatively well sorted and deficient in very fine sand, silt, and clay; but it has intermediate skewness and kurtosis values.

The three relatively well sorted sandy gravel samples (003, 006, and 008) are all from valleys at and beyond the south flank of the Brooks Range that lie at low altitudes and have relatively gentle gradients. The better sorting of these samples and their relative deficiency in fine sand, silt, and clay probably reflect relatively effective size segregation by meltwater streams during sediment transport. The three less sorted samples (015, 024, and 025) are all from mountain valleys within the northern Brooks Range where gradients are relatively steep and source areas may have been close. The most poorly sorted among these samples (025) is from an outwash terrace that probably was deposited close to or in contact with stagnating glacier ice.

COMPARISONS BETWEEN SEDIMENT CLASSES

Gravel Deposits

Gravel is the dominant size fraction in 6 of the 11 sediment classes discussed in previous sections. Three of these classes (modern alluvium, fan sediments, and outwash) comprise deposits of known origin and fairly well defined environmental controls. The remaining three classes (ice-contact stratified drift, alluvial-terrace deposits, and other gravel deposits) consist of sediments that formed under less certain depositional environments. In this section, we compare grain-size statistics of modern alluvium against those of fan sediments and outwash, then use these values as standards against which the other three classes of deposits can be evaluated.

Modern alluvium, fan deposits, and outwash contain abundant gravel (40 to 80 percent) and coarse to medium sand (15 to 50 percent). With two exceptions (007 and 028), all samples contain 20 percent or less of particles in the medium sand and finer fractions (fig. 15). Total content of very fine sand, silt, and clay is less than five percent in nearly all cases, attesting to the effective winnowing of fine particles by flowing water.

Excluding samples 007 and 028, modern alluvium forms an envelope of values that nearly coincides with the combined sets of values for fan deposits and outwash. The six outwash samples show a very close grouping of values, with consistently good sorting through the sand range and relatively low percentages (four or less) of the very fine sand through clay fractions. Outwash values lie generally within the range of modern alluvium, but differ slightly in the relative scarcity of fine to very fine sand in the outwash. Highly effective winnowing of fines from outwash probably is a consequence of the higher energy of glacial meltwater streams and general absence of silt-trapping vegetation from their floodplains. The fan deposits show generally poorer sorting through the sand range, and contain more gravel and fine to very fine sand than is present in typical samples of outwash and modern alluvium. Most fan deposits lie within the range of values for modern alluvium, but sample 037 contains more gravel and proportionally less sand.

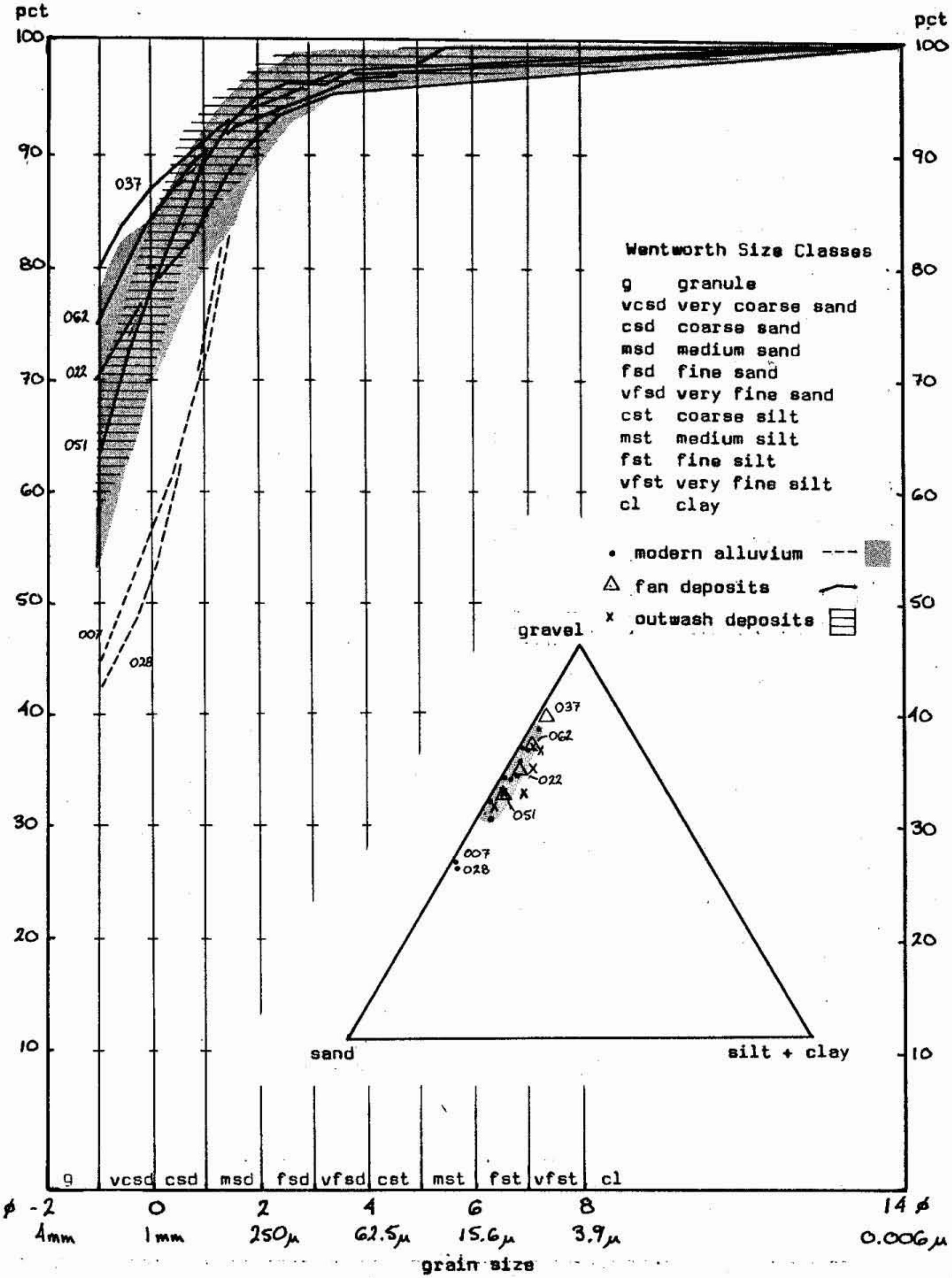

Figure 15. Comparative plots; fan, modern alluvium, and outwash deposits.

The nine samples of gravelly ice-contact stratified drift show a range of values somewhat greater than the combined values for modern alluvium, fan deposits, and outwash (fig. 16). Sample 034D, which contains about 15 percent fine to very fine sand and more than 5 percent silt and clay, may have formed where meltwater velocity was abruptly checked--perhaps in a deeper body of sluggishly moving water. The gravel-rich samples 034A and 034B show similar poor sorting and abundant fine fractions, resembling fan deposits rather than typical alluvium or outwash. These three samples, together with the sand sample 034C (see following section), suggest that the 034 sample series possibly was taken from drift deposited in a fan-delta complex on a stagnating glacier. Sample 013 differs from the other gravel samples in its very high gravel content combined with negligible amounts (1.6 percent total) of silt and clay. Sorting through the fine sand range is poorer than in most outwash deposits, and more closely resembles that of several of the alluvial-fan samples. Despite its field setting, sample 013 clearly is not typical outwash; it possibly formed where meltwater flow abruptly became blocked or depleted. Sample 039, which has the lowest gravel content, has abundant coarse to medium sand but very low percentages of fine sand and the smaller size fractions. Although formed in an embayment along the margin of a glacier (see "Field Data", table 11), the deposit clearly was washed by water flowing with sufficient velocity to carry away most of the fine particles from the incoming sediments. The other four samples of ice-contact stratified drift have values close to the average for outwash and alluvium, but have slightly less effective washing of grains in the fine sand range. They are better sorted than two of the fan deposits, but are virtually indistinguishable from the two samples taken from distal portions of large fans.

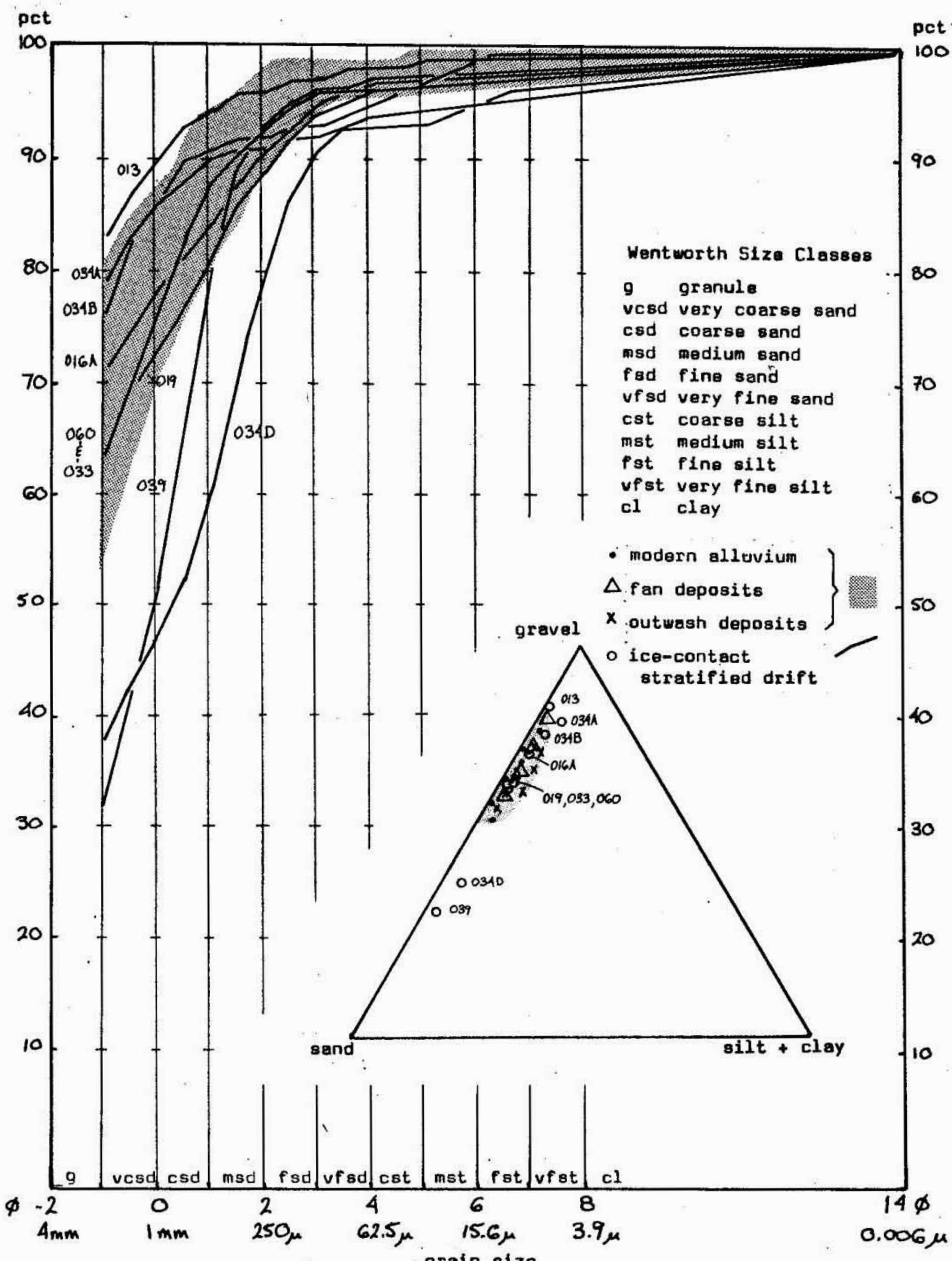

Figure 16. Comparative plots; ice-contact stratified drift vs. fan, modern alluvium, and outwash deposits.

The remaining four gravel deposits also have a range of values that generally is comparable to the envelope of values for modern alluvium, fan deposits, and outwash (fig. 17). Gravel content is highly variable (about 42 to 84 percent), but all four samples show similar depletion of particles in the fine sand, silt, and clay fractions. Total content of particles finer than medium sand is less than five percent in all four cases, indicating a degree of water-washing as effective as that among the outwash samples and the best sorted samples of modern alluvium. Sample 053 has a gravel content as low as the two gravel-deficient samples of modern alluvium, but is better sorted through the fine sand fractions; samples 022 and 042 lie within the most common range of modern alluvial samples and also generally coincide with values for outwash and for the two better-sorted fan deposits. These three deposits appear to consist entirely of alluvium. Sample 055, of possible polygenetic origin, lies partly outside of the values for all other gravel deposits owing to its very high gravel content (83.5 percent) combined with relatively low percentages of fine sand and silt. It is similar only to one sample of ice-contact stratified drift (013).

Comparisons of mean diameters, sorting, skewness, and kurtosis of matrix materials show additional relationships between the gravel samples (fig. 18). Sorting increases progressively as mean diameter increases in all classes of samples (fig. 18A), reflecting the relative scarcity of the fine fractions in the better-washed deposits. Skewness and kurtosis show corresponding relationships, with the best sorted samples generally exhibiting the greatest symmetry and relatively mesokurtic values (fig. 18B). The most poorly sorted samples generally are strongly fine skewed and extremely leptokurtic.

With the exception of the gravel-rich sample 063, the modern alluvium forms an assemblage characterized by relatively good sorting, large mean

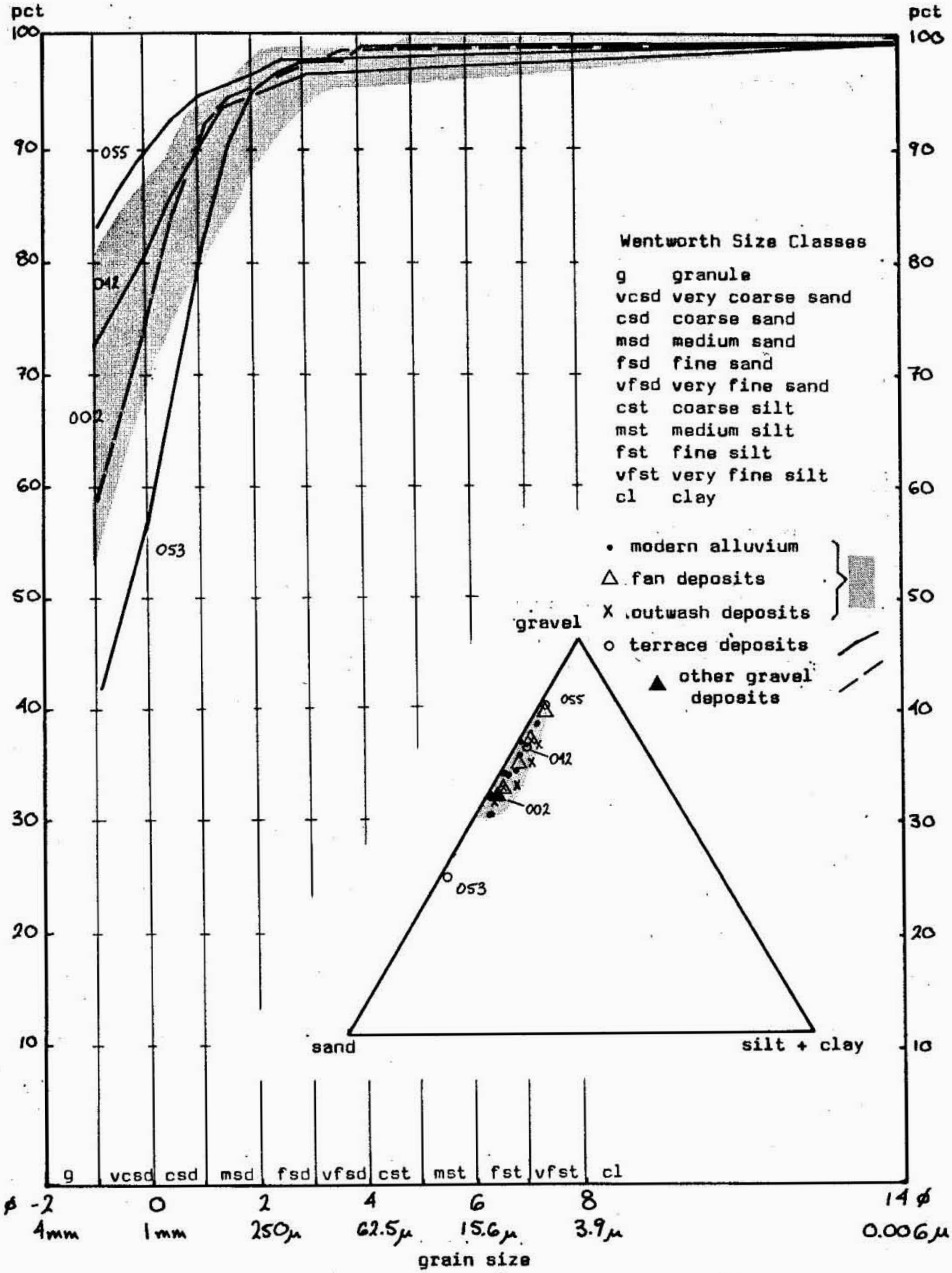

Figure 17. Comparative plots; alluvial-terrace and other gravel vs. fan, modern alluvium, and outwash deposits.

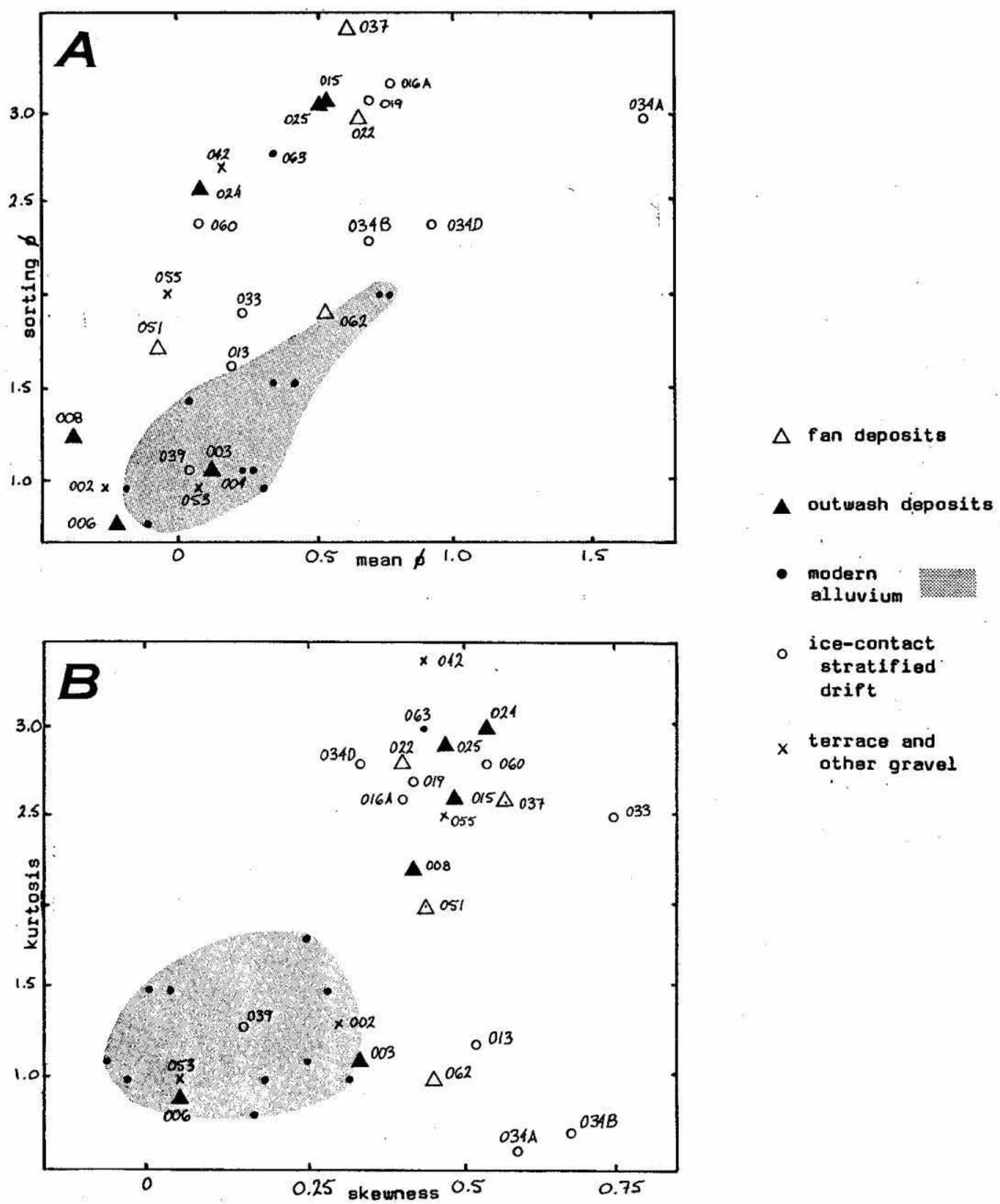

Figure 18. Bivariate plots of statistical measures, gravel deposits.

diameters, low positive skewness, and very platykurtic values (shaded on fig. 18). Fan deposits have the poorest average sorting of any group, but 2 of the 4 samples have values close to those of the less well sorted samples of modern alluvium. All fan deposits are strongly fine skewed, with values lying outside of the cluster of values for modern alluvium, but kurtosis values are highly scattered. The outwash samples are divisible into a very poorly sorted, fine-grained, northern Brooks Range assemblage and a better-sorted cluster of southern Brooks Range sediments with generally coarser matrix. The three northern Brooks Range samples are strongly fine-skewed and highly leptokurtic, with values close to those of the two less well sorted fan deposits and the aberrant alluvial sample 063. Two of the southern Brooks Range samples (003 and 006) usually lie within the range of values for modern alluvium whereas sample 008 lies slightly outside it.

The widely scattered values for ice-contact stratified drift resemble modern alluvium in the rate at which sorting increases with increasing mean diameter. Skewness and kurtosis show no apparent inter-relationship however. Kurtosis tends to be higher among the better-sorted samples, but with several pronounced exceptions. The ice-contact deposits generally are less well sorted than modern alluvium, and 5 of the 9 samples are more leptokurtic. Most samples are slightly finer-skewed than modern alluvium, but values of the two groups overlap slightly. Sample 034C lies well within the cluster of modern-alluvium values in all cases, and 013 always lies close to its margin.

The three terrace deposits and the preglacial(?) gravel also have widely scattered values. Among the terrace deposits, sample 053 lies entirely within the normal range for modern alluvium, whereas 042 more closely resembles the most poorly sorted outwash deposits and 055 has intermediate sorting and kurtosis values. The preglacial(?) gravel sample lies near the best-sorted and coarsest-matrix end members of the modern alluvium assemblage, and also has skewness and kurtosis values typical of modern alluvium.

Sand, Silt, and Clay Deposits

The medium sand through clay fractions are dominant in 21 samples which are divisible into seven general groups (figs. 19 and 20). Three samples of moderately well sorted nearly pure sand are from dunal deposits, and two similar samples are from sand bars in modern rivers. Seven samples containing more than 50 percent clay and very fine silt are from deposits that formed in standing water within former lake basins. The remaining nine samples are intermediate in texture, ranging from silty fine sand to sily clay. Three of these samples are from ice-contact stratified drift, and three samples are from Holocene floodplains. Two other samples are from basin-fill deposits, and the final sample was taken from a muskeg.

All three dunal samples are characterized by dominance of medium to fine sand, with lesser amounts of very fine sand (about 15 percent) and coarse sand (about 5 percent). Minor quantities of silt and clay also are present, and some very coarse sand occurs in one sample. Mean diameter is consistently high for all samples, and sorting is relatively good (fig. 21A). Neither skewness nor kurtosis values appear to be distinctive for the dunal samples (fig. 21B).

The two samples taken from sand bars in modern rivers show good to moderate sorting comparable to the dunal deposits, and mean grain size values also lie within the dunal range (fig. 21A). Winnowing of the very fine sand fraction from the fluvial deposits has been more effective than among the dunal samples, but abundance of the other sand fractions is about the same.

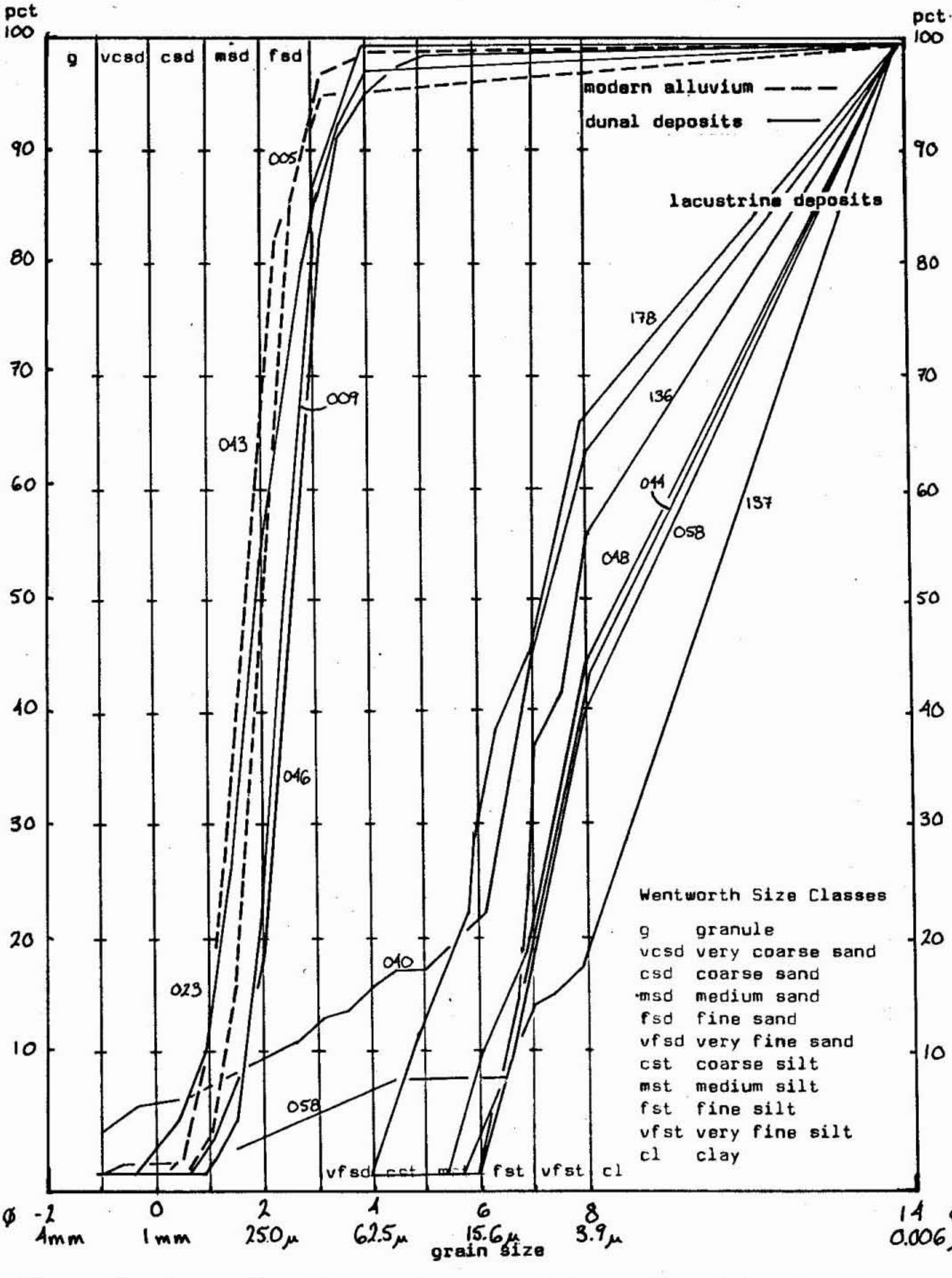

Figure 19A. Comparative plots; sand-dune, sand-bar, and lacustrine deposits.

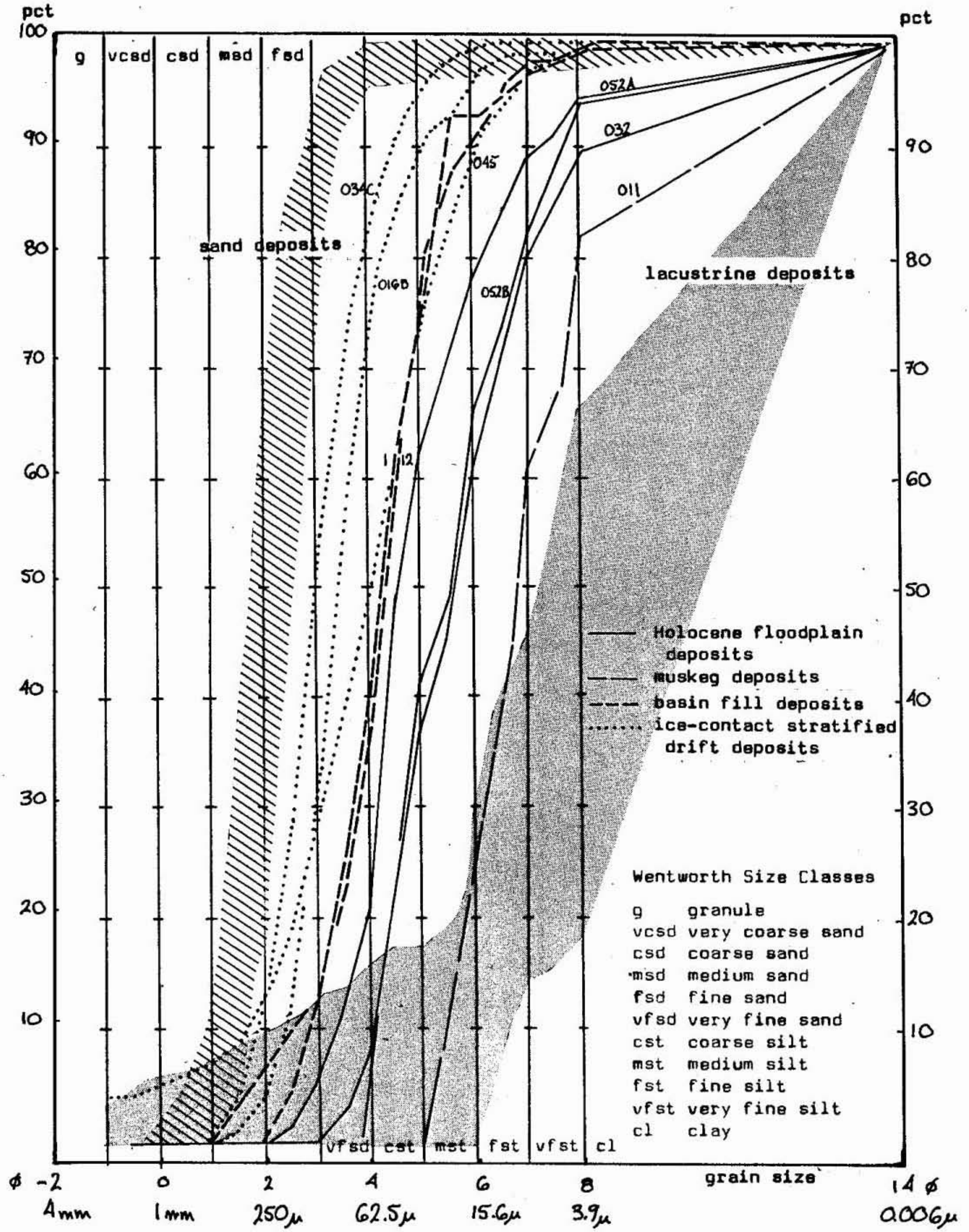

Figure 19B. Comparative plots; other sand, silt, and clay vs. dune, bar, and lacustrine deposits.

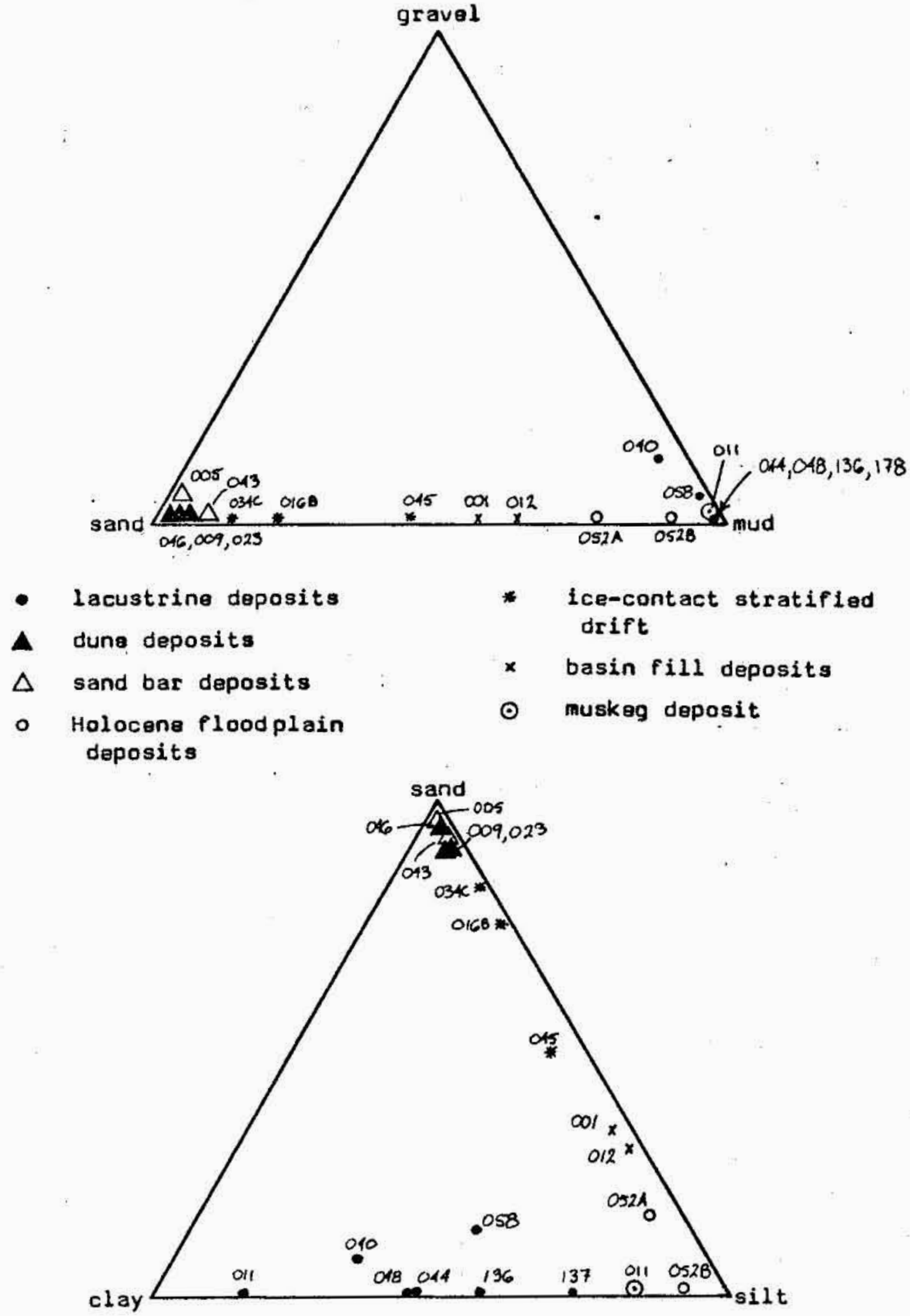

Figure 20. Ternary diagrams with gravel (above) and without gravel (below); sand, silt, and clay deposits.

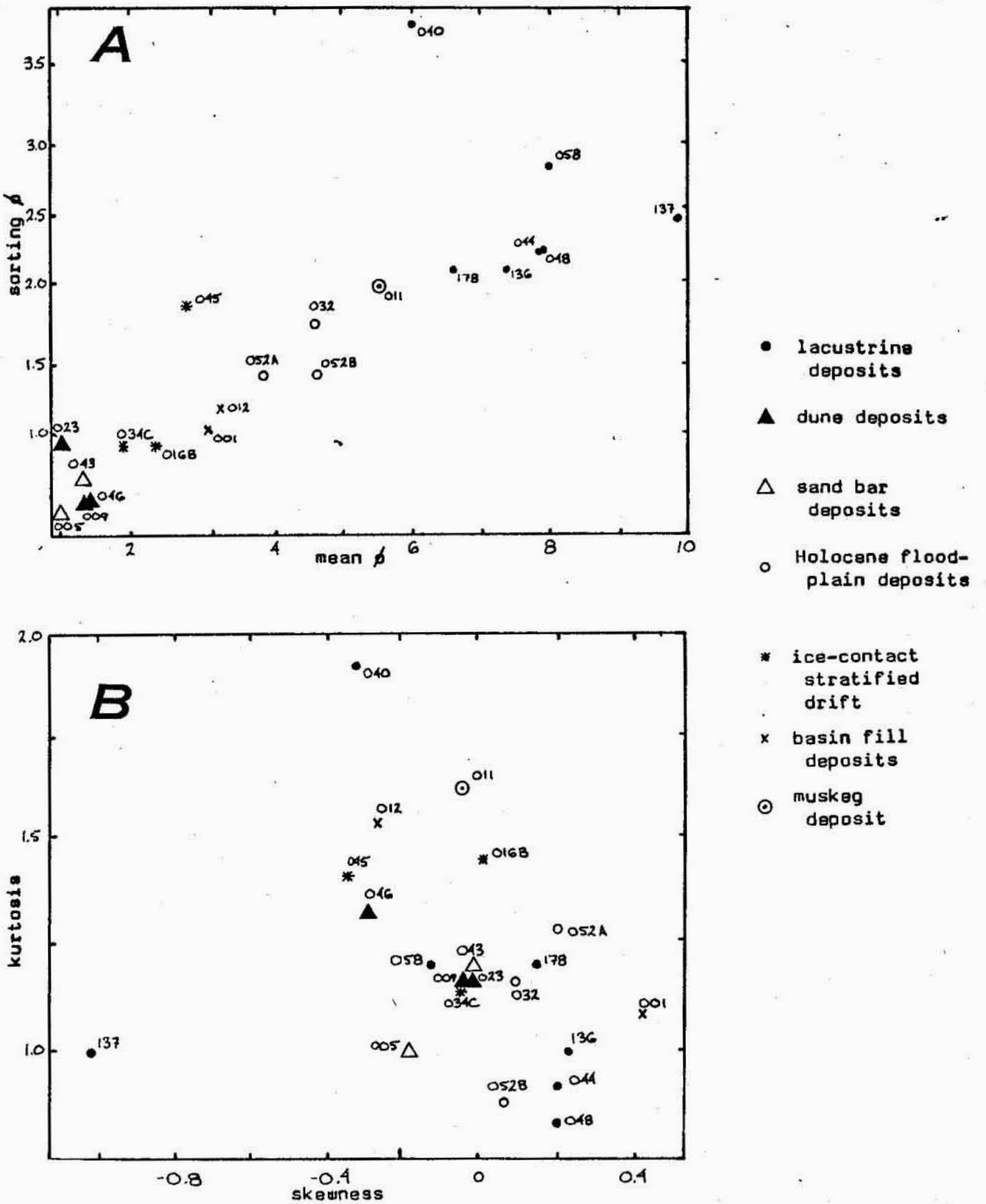

Figure 21. Bivariate plots of statistical measures; sand, silt, and clay deposits.

Skewness and kurtosis values tend to cluster with those of the dunal samples, lying close to symmetry and in the mesokurtic to leptokurtic range (fig. 21B). However, neither skewness nor kurtosis alone is significantly different from values of the other types of fine-grained deposits. One of the alluvial samples (043), which resembles alluvial gravel in its high ratio of clay to silt, may be a normal wind-winnowed stream deposit. The other sample, which contains silt and clay percentages as low as those of the best sorted dunal deposits, may have been taken from a river bar that was built wholly or in part by the wind.

The seven lacustrine deposits, which range texturally from clay to gravelly mud, are distinguished by dominance of clay and very fine silt, with most remaining particles in the fine to medium silt range. Sand and gravel, presumably of ice-rafted origin, are present in four of the samples (fig. 20). Mean diameters are smaller than for any other fine-grained samples, and sorting is relatively poor (fig. 21A)[1/]. Skewness and kurtosis values are broadly scattered, but most samples are symmetrical to strongly skewed and platykurtic to mesokurtic (fig. 21B).

The three floodplain deposits contain abundant silt (70 to 80 percent). 5 to 10 percent clay, and have similar mean-diameter, sorting, and skewness values. They differ from the five dunal and sand-bar deposits not only in their higher percentages of silt and clay (fig. 20) but also in their poorer sorting and relatively more positive skewness (fig. 21). They differ from the lacustrine deposits in their relatively low clay, high silt, and generally better sorting. The small amounts of coarse particles in the floodplain de-

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[1/] Statistical values for samples with high clay contents may be invalid owing to lack of measurements on size divisions within the 8 ø to 14 ø range.

posits may have been carried in suspension by floodwaters or transported by river ice during spring floods. The clay-sized particles probably settled out from shallow pools of standing water following floods.

Two samples of sandy to silty ice-contact stratified drift resemble dune and sand-bar deposits; a third sample (045) more closely resembles floodplain deposits (fig. 19B). Samples 016B and 034C consist dominantly of sand, with lesser amounts of coarse to medium silt. Sorting is nearly as good as for the dune and sand-bar deposits (fig. 21A), and virtually no particles finer than medium silt or coarser than medium sand are present. Skewness values also lie close to those of the other sand deposits (fig. 21B). The association of coarse to medium silt with sand argues against eolian sorting, therefore samples 016B and 034C probably were deposited in sluggishly flowing water bodies where flow rates were adequate to carry away the fine silt to clay fractions but were sufficiently slow and steady to prevent influx of particles coarser than medium sand. Sample 045 differs from the others in its poorer sorting, abundant (50 percent) silt, and presence of gravel and coarse sand particles. Sorting resembles that of floodplain deposits, but mean grain size is coarser and neither skewness nor kurtosis show any agreement (fig. 21). This deposit possibly formed on an unvegetated late Pleistocene floodplain that was subject to effective winnowing of fine silt and clay and to periodic influx of sediment carried by river ice, fragments of glacier ice, or slides and flows from the margin of a glacier.

The two basin-fill deposits are intermediate in size and sorting between the floodplain and ice-contact deposits. Both samples contain about 40 percent sand and 60 percent silt, with no particles coarser than medium sand and only minor amounts of clay. Absence of coarse particles indicates that the site of deposition was protected from severe flooding and from influx of ice, turbidity flows, or other mass-wasting processes; the rapid decrease in particle abundance across the silt-clay boundary reflects either washing of the deposit by gently flowing water or strong size-selection among incoming particles. Loess may have been an important component of late Pleistocene basin fillings.

The final sample, taken from a muskeg deposit within a lake basin of Itkillik I age, is intermediate in character between floodplain and lacustrine deposits. Clay content is about 18 percent, and all remaining material consists of medium to very fine silt. Total absence of gravel, sand, and coarse silt contrasts with their relative abundance in floodplain deposits and in about half of the lacustrine samples, whereas the clay fraction is much less abundant than in even the siltiest of the lacustrine beds. The predominance of medium to very fine silt possibly is due to influx of loess from relatively distant glaciers and outwash trains; these lay no closer to the site than 15 to 20 km during Itkillik II time.

Mixed Deposits

Mixtures of gravel, sand, and silt are characteristic of 23 samples, and five members of this group also contain appreciable clay. The mixed deposits are mostly colluvial in origin, representing eight flow-slides, two rock glaciers, and four other varieties of flows. In addition, four till samples and four apparent mixtures of primary deposits with products of mass wasting and soil genesis are included in this category.

Six of the flow-slide deposits contain about 30 to 75 percent gravel, with equal or lesser amounts of sand, 30 percent or less silt, and very small amounts of clay (fig. 22). One other sample (149) contains little gravel but very abundant sand and coarse silt. The eighth sample (059) has unusually

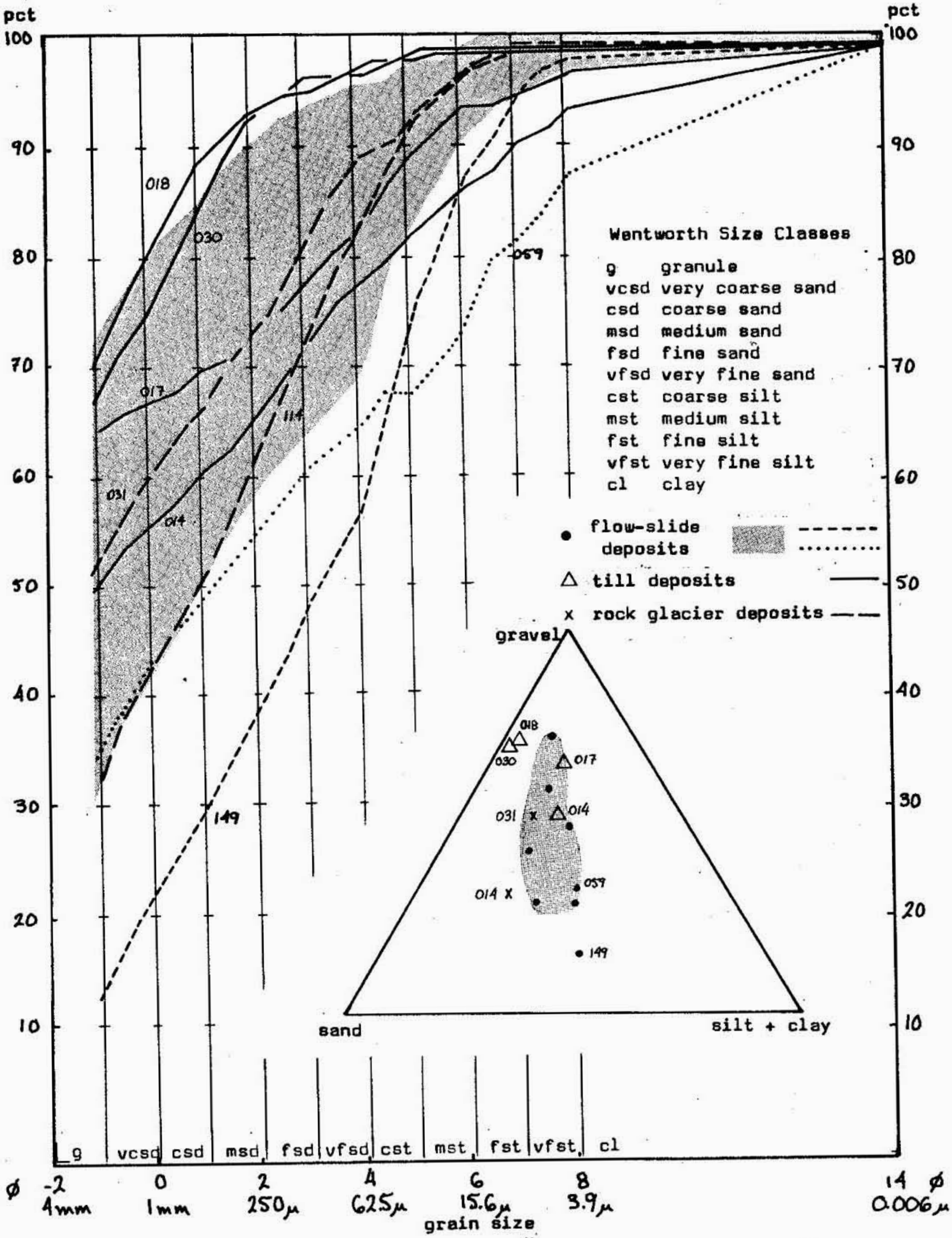

Figure 22. Comparative plots; flow-slide, rock-glacier, and till deposits.

abundant grains in the medium silt through clay fractions. All samples are very poorly sorted, and all samples except 059 are platykurtic (fig. 23). Skewness is highly variable.

The two rock-glacier deposits lie within the envelope of values that characterizes normal flow-slides. Both samples have abundant gravel and sand, but contain less medium to fine silt than most of the flow-slide deposits and have negligible amounts of very fine silt and clay. All statistical values for rock-glacier samples cluster closely together (fig. 23). Sorting is slightly better than among the flow-slide deposits, kurtosis values are lower, and mean diameters lie at the coarse end of the flow-slide range.

All four till deposits contain abundant sand and gravel, but two tills have less than five percent very fine sand, silt, and clay whereas the other two samples are relatively enriched in these fine fractions. Mean diameter and sorting values form two corresponding groups. One pair of till samples (018 and 030) has coarser and better sorted matrix material than all flow-slide and rock-glacier samples; the matrix of the other pair of samples (014 and 017) lies at the fine-grained and poorly sorted limit of the flow-slide distribution (fig. 23). The two pairs of till samples show overlapping kurtosis and skewness values (fig. 23B); all are mesokurtic and range from symmetrical to fine skewed. The two better sorted till samples resemble alluvial gravel and outwash in their rapid decrease in particle abundance at the medium-fine sand boundary (compare fig. 16). These deposits probably were sorted by subglacial meltwater whereas samples 014 and 017 apparently were not subjected to such sorting.

The solifluction sample (064) contains less gravel and sand than 7 of the 8 flow-slide deposits, but has relatively abundant silt and contains

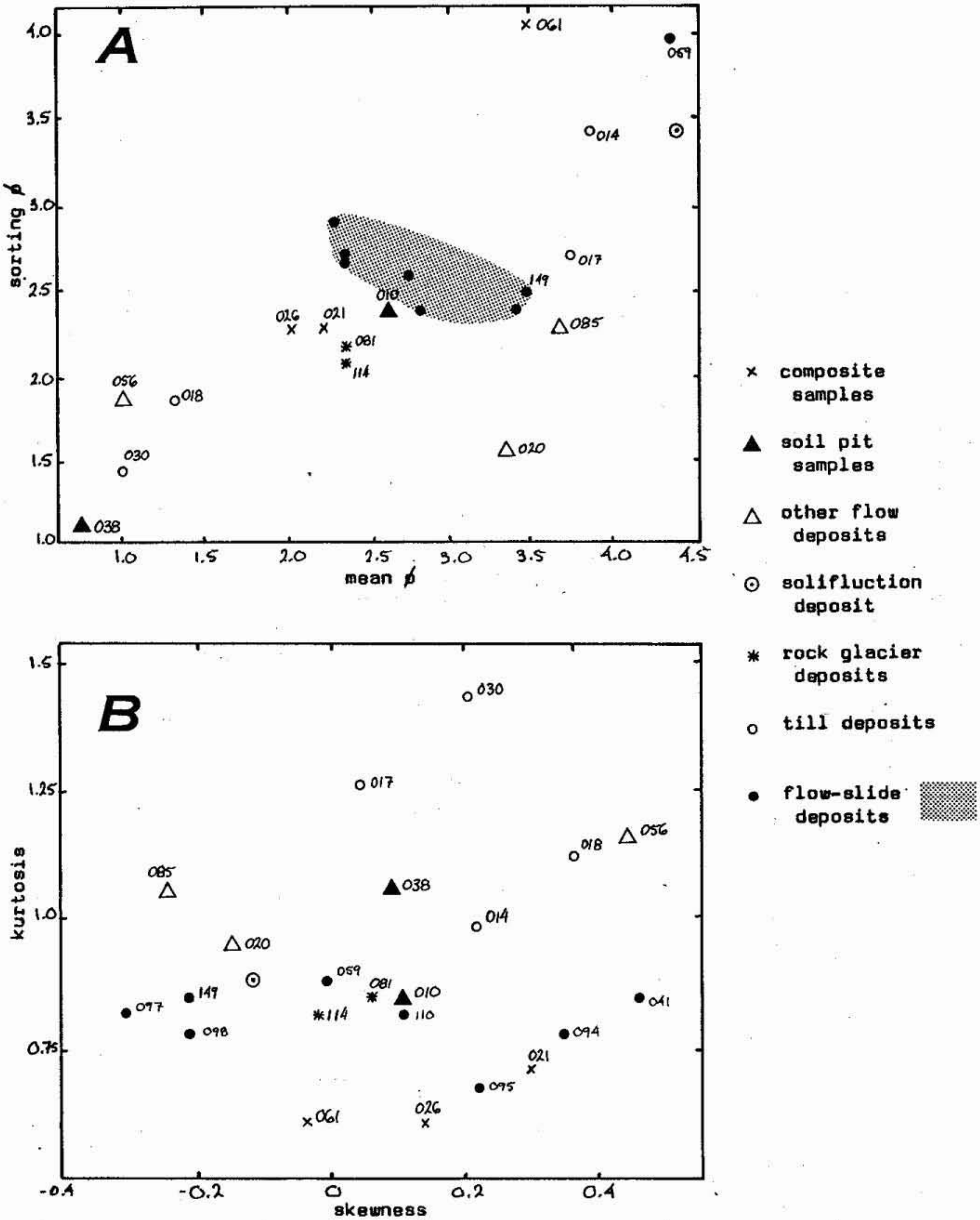

Figure 23. Bivariate plots of statistical measures; mixed deposits.

somewhat more clay (fig. 24). Sorting is relatively poor (fig. 23A). Skewness and kurtosis lie within the flow-slide range, but values are distinctly less than those for the tills (fig. 23B). The relatively high content of medium to very fine silt suggests that this sample may be a mixture of loess with an older deposit such as till that contributed gravel, sand, and clay to the solifluction apron.

The mudflow sample (056) is distinctive in its abundant gravel and coarse sand combined with very low percentages (less than 5) of silt and clay. Matrix material is as coarse and well sorted and skewness and kurtosis values are similar to those of the two best sorted tills. Both grain-size distribution and statistical values are comparable to those of the more poorly sorted modern alluvial gravel, indicating that running water probably flushed much of the fine sediment from the mudflow lobe.

Sample 085, from a flow developed on till, is very similar to the two poorly sorted till deposits, but contains slightly higher amounts of coarse to medium silt (compare figs. 22 and 24) and shows slightly better sorting values (fig. 23A). Kurtosis also lies within the range for poorly sorted tills (fig. 23B). This flow deposit appears to consist of unsorted basal till to which some loess has been added.

The remaining flow deposit (020), an organic-rich lobe at the base of an abandoned river bluff, consists primarily of the medium sand through medium silt fractions. The sharp division between abundant medium sand and relatively scarce coarse sand resembles that of the dunal deposits (fig. 19A), whereas the corresponding sharp division at the fine silt boundary is comparable to that for loess. This flow deposit appears to consist largely of eolian sand and silt, part of which may have been incorporated from Holocene floodplain deposits at the base of the bluff.

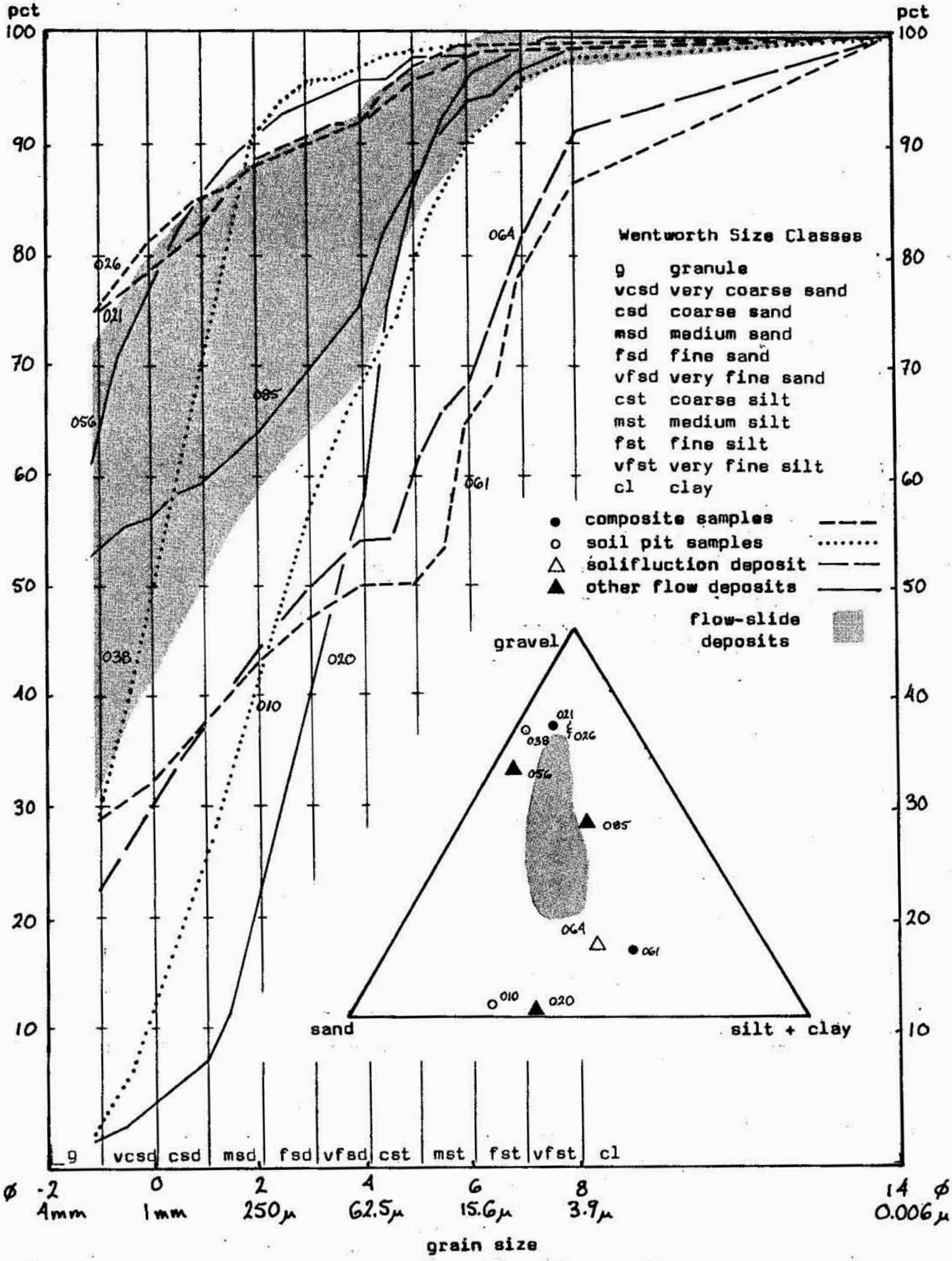

Figure 24. Comparative plots; other mixed deposits vs. flow-slide deposits.

Two other samples are from soil pits in which sediments of different ages and origins may have been mixed by soil processes. Sample 010, on the crest of a moraine, differed from all other till deposits in its low gravel content combined with high percentages of sand and coarse silt (fig. 12). Percentages of medium and fine silt are about the same as for the two poorly sorted till samples (fig. 22), but only small amounts of very fine silt and clay are present. The morainal sample also differs from all sandy ice-contact stratified drift deposits in its relatively poor sorting through the sand and silt range. The deposit may initially have been a thin cap of sandy ice-contact sediment that later became mixed with till and enriched in loess through such processes as frost churning, tree throw, and frost-heaving of stones. The second soil-pit sample (038) is a basin-fill deposit that differs from the other basin fillings in its more abundant gravel and coarse sand and virtual absence of very fine sand (see fig. 11). This sample is much better sorted than any other mixed deposit (fig. 23A), and is almost unique in its very low content of fine sand and the smaller fractions. It resembles modern alluvium in its low percentages of fine sand (about 5) and very fine sand, silt, and clay (less than 5). Although the deposit may have formed in a basin dammed by Itkillik ice (see "Field Data"), basin-filling apparently was by stream alluviation rather than by deposition into a standing or sluggishly flowing water body.

One of the fan samples (026) and one other alluvial gravel (021) differed from the other members of their classes in having relatively low percentages of sand and high amounts of coarse to medium silt (see figs. 4 and 7). These samples were inferred to be composite in origin: the fan possibly originating in part from mudflows or slushflows and the alluvium possibly intermixed with younger eolian deposits on the inclined face of a river bluff. The cumulative curves of these two samples are almost identical, and lie along the upper margin of the envelope of values for normal flow-slide deposits (fig. 24). Matrix materials are slightly better sorted and somewhat coarser than those of the flow-slide samples, but sorting values are close to those for the till-flow and the mudflow (fig. 23). Samples 021 and 026 are almost certainly composite, but their exact origins remain uncertain.

Sample 061, a lacustrine deposit, differed from the other lacustrine samples in having high percentages of gravel and sand and relatively low silt and clay (see fig. 7). This sample also was inferred to probably be composite, with the lacustrine sediments perhaps intermixed with alluvium during flowage down the face of a river bluff. Sample 061 is similar to the solifluction deposit in its relatively abundant medium to very fine silt (fig. 24). It is least sorted of all the mixed deposits (fig. 23A), and more strongly platykurtic (fig. 23B). Neither skewness nor mean diameter are distinctive. The sample could represent a mixture of sandy stream gravel with silty lacustrine sediment, or the high silt content could have been caused by additional incorporation of loess.

SUMMARY AND CONCLUSIONS

Although sediments collected from the central Brooks Range represent 11 different surficial geologic map units, they can be grouped into three broad assemblages with contrasting physical properties: gravel deposits; sand, silt, and clay deposits; and mixed deposits.

The gravel deposits consist of gravel and sand from which most finer particles have been removed by running water. Gravel ranges in abundance up to about 85 percent, and particles typically are subrounded to rounded. Total content of very fine sand and the smaller fractions usually is less than five percent. Fan deposits typically show the poorest sorting and least rounding, but the distal portions of large fans closely resemble modern alluvium. Winnowing is particularly effective in the outwash samples, which show uniformly good sorting through the sand range and commonly contain less than three percent of the very fine sand and smaller fractions. However, the properties of the better sorted samples of modern alluvium overlap those of outwash to such a degree that they cannot be differentiated on the basis of sediment characteristics alone. Many other Pleistocene-age samples (e.g., terrace alluvium and some ice-contact stratified drift) clearly were deposited by running water, and resemble modern river-channel or fan deposits. Other deposits of ice-contact stratified drift must have formed under conditions of more restricted drainage.

Clay is more abundant than silt in nearly three-fourths of the gravel deposits:

	Silt > Clay	Silt < Clay
Modern alluvium	3	11
Fan deposits	2	3
Outwash	2	4
Other gravel	1	3
Totals	8	21

This relationship probably is due to winnowing of sediments on windswept floodplains, and may be a useful indicator of alluvial deposits. In three of the eight cases where silt is more abundant than clay, the high silt content could be the result of faulty laboratory analysis (sample 029), influx of mudflow or slushflow sediments (sample 026), or postdepositional admixture of loess or weathering products (sample 021). Relatively abundant silt therefore might be an indicator of postdepositional mixing in an alluvial gravel deposit.

Sand, silt, and clay deposits formed under a range of conditions that generally restricted the influx of gravel to depositional sites. Flowing water or wind removed fines from the sand fraction in some cases, leaving sand-rich concentrations of sediment. In other cases, silt and clay settled out of suspension in air or water and remained at the site of deposition. Among the five deposits of nearly pure sand, two samples are identical to modern alluvium in containing five percent or less of the very fine sand and finer fractions. The three eolian sand deposits, in contrast, contain relatively abundant (15 to 20 percent) very fine sand but little coarse silt or finer particles. Wind clearly is less effective than running water in removing very fine sand. The three sandy ice-contact stratified drift deposits lack the clean separation of silt from sand that characterizes the dunal and sand-bar deposits. They reflect less effective sorting on irregular surfaces associated with stagnating glacier ice.

Six samples ranging from sandy silt to clayey silt formed in late-Pleistocene basin fillings, Holocene floodplains, and a muskeg complex. Abundance of silt in these deposits may reflect the influx of loess which, except very close to source areas, is dominated by particles 100 μ to 5 μ in diameter (e.g., Péwé, 1968, fig. 3). Loess may have been an important component of late Pleistocene to early Holocene basin fillings and muskeg accumulations, and subsequently was redeposited as overbank sediments by silt-laden floodwaters during later Holocene stream incision. The presence of silt-trapping vegetation would account for the abundance of silt in floodplain deposits and its virtual absence from nearby channel and bar surfaces.

The lacustrine deposits contain 35 to 81 percent clay, and 4 of the 7 samples include presumably ice-rafted sand and gravel. X-ray diffraction analysis shows that the clay-size grains include mica, chlorite, and quartz, and that no clay minerals are present. Clay-sized mineral grains in the central Brooks Range appear to have been produced mainly by glacial abrasion rather than by interglacial or postglacial weathering. The general absence of authigenic clay minerals from arctic and subarctic soils has been noted by Tedrow (e.g., 1977, p. 180-181) and other pedologists.

The mixed deposits formed under conditions of mass transport (e.g., flow-slides, flows, or rock glaciers) or through postdepositional intermingling of different sediments. Silt is abundant in most mixed deposits, but clay usually is scarce to absent. The only clay-rich deposits are two of the tills, a solifluction apron derived from till, a mixed lacustrine deposit, and a flow-slide that may incorporate lake beds. The scarcity of clay in most of the colluvial deposits, in the soil-pit samples, and in other deposits that include weathering products provides supporting evidence for the glacial origin of most clay-sized mineral grains.

Two of the till deposits have less than five percent very fine sand and finer fractions, and resemble alluvial-fan sediments in many other respects. These drift deposits presumably were washed by subglacial meltwater during transport or deposition. Several other deposits that were initially of alluvial, glacial, or lacustrine origin appear to be mixtures that are atypical of their sediment classes. Two samples were from shallow soil pits where cryoturbation had probably caused mixing of sediments; another sample had been mixed by flowage down a bluff face, and a fourth sample had been either weathered or mixed with other sediments near the crest of a river bluff. Sampling sites must be carefully selected to avoid areas subjected to weathering, frost churning, surface flowage, and other postdepositional processes.

Four statistical measures were computed for the sand through clay fraction of all samples. Sorting and mean values are interrelated in most sample groups, with a consistent tendency for sorting to increase as mean phi increases. This seems to reflect the more efficient washing of fines from the matrix of the better sorted samples. Among gravel samples, the best sorted are relatively mesokurtic and most symmetrical; kurtosis has lower values and skewness is closer to symmetry than among the more poorly sorted samples. The best sorted deposits of sand, silt, and clay have skewness and kurtosis values that cluster near the center of this group: close to symmetry and in the leptokurtic range. Among the mixed deposits, kurtosis has relatively high values but skewness shows no consistent relations.

Clustering of values is most distinctive and consistent among sorting and mean phi measures; clusters based on skewness and kurtosis are more diffuse and show greater overlap. The strongest and most consistent clusters appear to be:

Modern alluvium (except sample 063)
Northern Brooks Range outwash
Southern Brooks Range outwash
Lacustrine deposits (except sample 040)
Sand bar and dune deposits (combined)
Holocene floodplain deposits
Rock-glacier deposits

In addition, till deposits show two weakly defined separate clusters of two samples each. Broadly scattered values rather than clusters are characteristic of fan deposits, ice-contact stratified drift, alluvial-terrace and other gravel deposits, and other flow deposits.

Sorting and mean phi of matrix materials seem to be generally useful in characterizing the different sediment classes, separating them into contrasting subgroups in some cases, and determining atypical samples that differ from the others in their groups. Skewness and kurtosis can provide useful supplementary data in some cases, but generally are less useful in characterizing and differentiating the various sediment classes.

This study has defined several serious problems in our sampling and analytical procedures. These include:

1. Absence of grain-size data for subdivisions of the gravel and clay fractions. Sampling procedures should allow for measurements of the coarser gravel fractions in the field and for collection of large samples that would permit valid laboratory measurements of the finer gravel components. Laboratory procedures should be modified to allow separation and measurement of at least the coarser clay fractions.

2. Absence of replicate samples to check analytic results and absence of suites of samples that define the range of variability. Study of relatively homogeneous sample groups (e.g., outwash) raised the problem of interpreting small differences between samples. Are these real or the result of laboratory errors? Do they represent significant differences in environments of deposition, or could they lie within the normal range of variability at any one sample locality?

3. Need for better data on environments of deposition. This was a particular problem in the case of modern alluvium, where great variability between the samples could not be accounted for by the field data. We clearly need more detailed information on stream competence and on relationship of sampling site to channel patterns, bar and channel morphology, and other environmental factors.

4. The problem of postdepositional mixing. Sample sites need to be carefully selected, avoiding soil pits and stabilized weathered bluff faces wherever possible. Loess, thaw-lake sediments, and other potential contaminants need to be sampled and their properties carefully documented to facilitate recognition of these sediments in mixed deposits.

REFERENCES CITED

Folk, R. L., 1974, Petrology of sedimentary rocks: Austin, Tex., Hemphill Publishing Company, 182 p.

Folk, R. L., and Ward, W. C., 1957, Brazos River bar; a study in the significance of grain size parameters: Journal of Sedimentary Petrology, v. 27, no. 1, p. 3-26.

Hamilton, T. D., 1978a, Surficial geologic map of the Chandalar quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-878A, scale 1:250,000.

_____1978b, Surficial geologic map of the Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-879A, scale 1:250,000.

Hamilton, T. D., and Porter, S. C., 1975, Itkillik glaciation in the Brooks Range, northern Alaska: Quaternary Research, v. 5, no. 4, p. 471-497.

Jordan, C. F., Jr., Fryer, G. E., and Hemmen, E. H., 1971, Size analysis of silt and clay by hydrophotometer: Journal of Sedimentary Petrology, v. 41, no. 2, p. 489-496.

Pettijohn, F. J., Potter, P. E., and Siever, R., 1972, Sand and sandstone: New York, Springer-Verlag, 618 p.

Péwé, T. L., 1968, Loess deposits of Alaska: XXIII International Geological Congress Proceedings, Section 8, p. 297-309.

Tedrow, J. C. F., 1977, Soils of the polar landscapes: New Brunswick, N.J., Rutgers University Press, 638 p.

Visher, G. S., 1969, Grain size distributions and depositional processes: Journal of Sedimentary Petrology, v. 39, no. 3, p. 1074-1106.

FIELD DATA

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Table 3. Field data, fan deposits.

Sample No. and Quadrangle	Location & Setting	Stratigraphy	Field Description	Remarks
77AJM 022 Killik River	Active fan, W side Killik R. 1.5 km N of L. Kanikserak	Surface sample	Subrounded, imbricated pebbles, cobbles, and small boulders in matrix of angular coarse sand and granules	Grades into fan-delta at distal end
77AJM 026 Killik River	N side Kakilivak Cr. 12 km W of confluence w/ Killik R. Vegetated fan segment 10 m above modern stream level	0.15 m Peat and silty fine sand 10 m Fan deposit	Angular to subangular imbricated platy stones 3-15 cm (occ. up to 40 cm) diam in dark grey (10YR4/1 to 4/2) silty sand + granule matrix	
77AJM 037 Wiseman (A-3)	Bluff exposure, alluvial fan, W side Wild R. 3 km SE of Gilroy Mtn.	0.5 m Silty peat and peaty sand 14 m Fan deposit	Subangular platy pebbles and cobbles in dark reddish brown (2.5YR3/4) poorly sorted granule to coarse sand matrix	Appears oxidized throughout
77AJM 051 Wiseman (B-5)	Cutbank, S side John R. along N flank of McKinley Cr fan	1 m Peat 1.5 m Frozen sand w/ice lenses 10 m Fan deposit	Rounded to subrounded pebbles and cobbles in matrix of well sorted, bedded coarse sand and granules	Near distal end of very large fan
77AJM 062 Wiseman (C-1)	Bluff exposure, E side Glacier R. 1.5 km below Sleepy Cr.	0.5 m Peaty silty sand 12 m Fan deposit	Subangular platy imbricated pebbles and cobbles in matrix of poorly sorted sand and platy granules	Some peat and rooted wood present within fan

Table 4. Field data, modern alluvium

Sample No. and Quadrangle	Location and Setting	Field Description	Remarks
77AJM 004 Wiseman (A-4)	Modern gravel bar, John R. near mouth of Malemute Fork	Sandy gravel, with clasts up to small cobble size	
77AJM 005 Wiseman (A-4)	Modern sand bar, John R. near Three-time Mtn.	Very well sorted medium sand, w/ occ. silt laminations up to 0.5 cm thick	
77AJM 007 Wiseman (A-2)	Modern gravel bar, N. Fk Koyukuk R. 5 km SW of Florence Cr. L.	Well sorted sandy gravel up to 3-5 cm diam.	
77AJM 027 Killik River	N side Kakilivak Cr. 12 km W of Killik R. Gravel from stream bed	Sandy gravel w/ occ large cobbles and small to med. boulders	
77AJM 028 Killik River	Braided stretch, Killik R. above April Cr.	Dark greyish brown (10YR3/2) imbricated sandy gravel w/stones up to small cobble size	Aufeis zone
77AJM 029 Survey Pass	Gravel bar, braided stretch of April Cr 6 km upvalley from its mouth	Dark grey (N/4), imbricated coarse sandy gravel; stones to small cobble size	
77AJM 035 Wiseman (B-2)	Gravel bar E side Glacier R. E of Delay Pass	Well sorted sandy gravel w/ stones to pebble size	
77AJM 036 Wiseman (B-4)	Gravel bar, Wild R. 1 km S of Wild L.	Well sorted sandy gravel w/ occ. stones to cobble size	
77AJM 043 Wiseman (C-4)	Sand bar, Allen R., opposite Seward Cr. Pass	Well sorted grey (N4.5) medium to coarse sand w/ silty sand interbeds	
77AJM 049 Wiseman (B-6)	Gravel bar, Mettenpherg Cr. 1.5 km below Colorado Cr.	Brown imbricated sandy gravel w/ some cobbles and occ. small boulders	
77AJM 050 Wiseman (B-5)	Sand bar, Sixtymile Cr. 1.5 km upstream from Organ Cr.	Brown very sandy gravel to gravelly sand w/ occ. stones up to 10 cm diam.	
77AJM 054 Wiseman (C-5)	Point bar, John R. opposite mouth of Wolverine Cr.	Sandy gravel, w/ stones up to small cobble size	
77AJM 057 Wiseman (C-6)	S side Shukokluk Cr. opposite pass to John R.	Imbricated gravel to small cobble size in coarse sand-to-granule matrix	
77AJM 063 Wiseman (C-1)	Glacier R. 2 km below mouth of Sleepy Cr.	Sandy gravel, with imbricated stones to cobble size in coarse sand matrix	

Table 5. Field data, alluvial terrace and other gravel deposits

Sample No. and Quadrangle	Location and Setting	Stratigraphy	Field Description	Remarks
77AJM 002 Wiseman (A-4)	Residual gravel knobs at SE end of Ninemile Hills	50-100 m Oxidized gravel	Well rounded to subrounded pebbles and small cobbles in matrix of strong brown (7.5YR5/6) coarse sand	Strongly oxidized gravel of inferred preglacial age
77AJM 021 Killik River	Bluff exposure, W side Killik R. near its mouth	15 m Sandy gravel 55 m Bedrock	Subrounded pebbles and cobbles in dark yellowish brown (10YR3/4) sandy matrix	Weathered gravel of inferred early Pleistocene age
77AJM 042 Wiseman (C-4)	Cutbank, E side Allen R. opposite Seward Cr. Pass	0.5 m Peat 15.5 m Sandy gravel	Subrounded pebbles and small cobbles in matrix of dark grey (N 4) platy coarse sand and granules	16 m terrace
77AJM 053 Wiseman (C-5)	Bluff exposure, E side John R. opposite mouth of Wolverine Cr.	5 m Covered (slip-off slope) 20 m Sandy gravel above gravelly sand	Rounded to subrounded pebbles, cobbles, and occ. very small boulders in matrix of coarse sand w/some pea gravel and medium sand interbeds	25 m terrace
77AJM 055 Wiseman (C-5)	Cutbank at confluence of Wolverine Cr. and Shukokluk Cr.	1.5 m Bedded sand w/thin cap of peaty sand 6.8 m Pebbly gravel	Subrounded pebbles, cobbles and occ. very small boulders in openwork matrix of granules and small pebbles w/ occ. lenses of coarse sand. Stones have silt coatings	8.3 m terrace

Table 6. Field Data, lacustrine deposits

Sample No. and Quadrangle	Location and Setting	Stratigraphy	Field Description	Remarks
77AJM 011 Bettles (D-6)	Muskeg terrain near head of Rocky-bottom Cr. Ponds, marshes, & peat mounds in probable lake basin formed in front of Itkillik I moraine	10 cm Peat 10 cm Decomposed org. matter >50 cm Clayey silt	Dark brown (10YR3/3) massive clayey silt	Sampled in auger hole only
77AJM 032 Wiseman (B-2)	Lacustrine plain behind Itkillik II moraine, N. Fk. Koyukuk R.	0.5 m Sod above peat 0.4-1.7 m Clayey silt 2.8-4.1 m Bedded sand w/ fine gravel lenses	Dark grey (N/4) massive clayey silt. Contains peat lenses & rooted wood	Permafrost at 30-40 cm depth
77AJM 040 Wiseman (C-4)	Flow deposit in unnamed tributary to Allen R. Lies at front of Itkillik I moraine that backfills lower trib. valley	0.3 m Peat 6 m Platy fan gravel ~25 m Flow deposit	Dark grey (N/4) clayey silt w/ scattered striated stones up to 120 cm diam.	Probable glacial-lacustrine deposit
77AJM 044 Wiseman (B-4)	Erosion remnants near mouth of McCamant Cr. Dammed by ice of Itkillik II advance	20-30 cm Peat 12 m Clayey silt & silty clay	Dark grey (5Y4/1) thin-bedded (1-5 mm) clayey silt & silty clay, alternating in units 20-25 cm thick	No stones present
77AJM 048 Wiseman (B-4)	Erosion remnants near mouth of Allen R. Valley. Dammed by ice of Itkillik II advance	20 m Till 60 m Clayey silt	Grey (N/4.5) clayey silt	Overlain by Itkillik II lateral moraine
77AJM 058 Wiseman (D-6)	Cutbank E side Kevuk Cr. Former basin within drift of Itkillik II advance	26 m Silt	Grey silt with sparse dropstones	Grades N into ice-contact deposits
77AJM 061 Wiseman (C-2)	Canyon wall of Willow Cr. where creek incised into lacustrine plain of Itkillik II age	Stony silty clay grading downward into stony clayey silt and then into probable till (all contacts obscured)	Dark grey (N/4) clayey silt	Bluff face subject to severe flowage
77AHa 136 & 137 Wiseman (B-4)	Same as 77AJM 048	Same as 77AJM 048	Dark grey (5Y4/1) clayey silt to silty fine sand (77AHa 136); grades downward into finely laminated grey (N/4.5) clay w/ pebble dropstones	Location same as for 77AJM 048
77AHa 178 Wiseman (C-1)	Bluff exposure, S side Canyon Cr. 3.5 km above its mouth. Dammed by ice of Itkillik II advance	13.5 m Fan gravel 15 m Sand and fine gravel above silt and clay 5 m Oxidized gravel	Grey clayey silt to silty clay, grading upward into interbedded sand and fine gravel	Bluff face subject to severe flowage

Table 7. Field data, flow-slide deposits

Sample No. and Quadrangle	Location and Setting	Field Description	Remarks
77AJM 041 Wiseman (C-4)	N wall Swamp Cr. Valley 5 km above its confluence with Allen R. Valley. Large flow lobe, actively advancing	Greyish purple unsorted angular phyllite fragments up to 5 m diam. in poorly sorted matrix of sand- to granule-sized phyllite chips	Sampled at active river-cut front
77AJM 056 Wiseman (C-6)	Massive mudflow deposits in pass E of Sillyasheen Mtn.	Phyllite chips 3-10 cm diam. in highly micaceous, poorly sorted sand-silt matrix	Sampled near center of fanlike mudflow deposit
77AJM 059 Wiseman (C-4)	N wall Allen R. Valley 4 km above Swamp Cr. confluence. Flows at distal end of huge landslide	Angular fragments of phyllite, schist, and quartz in matrix of dark grey (N4) silty clay with phyllite chips	Sampled at active front, N bank Allen R.
77AHa 085 Howard Pass	Tillflow, E bank Nigu R. E of Etivlik L.	Subangular to subrounded stones up to small boulder size in matrix of stony silty sand	Sampled near distal end
77AHa 094 Survey Pass	Large flow lobe, E side Kutuk R. near its head	Angular fragments of grey phyllite up to 3 m diam in silty matrix	Sampled at active river-cut front
77AHa 095 Survey Pass	Large flow lobe, E side Kutuk R. near Dalimaloak Mtn.	Angular phyllite fragments in silty matrix. Frozen; contains massive ice layers and wedges	Sampled at river-cut front
77AHa 097 Survey Pass	Large flow lobe, W side Kutuk R. about 7 km above its mouth	Phyllite, schist, and quartz fragments in silty matrix	Sampled at front of younger lobe that is overriding older lobe
77AHa 098 Survey Pass	As above. Sample from debris apron at base of younger lobe front	As above	Same locality as sample 097
77AHa 110 Wiseman (B-1)	Head wall of transitional flow-slide/ rock glacier, S Fork Rock Creek	Highly sheared schist fragments in micaceous sand-silt matrix	Sampled from flow zone on head wall
77AHa 149 Wiseman (B-6)	Active flow-slide, E wall Sixtymile Cr. Valley near its head	Sparse rock rubble (schist and quartz) in abundant matrix of highly micaceous silt	Sampled from active front of flow midway up valley side

Table 8. Field data, other colluvial deposits

Sample No. and Quadrangle	Location and Setting	Stratigraphy	Field Description	Remarks
77AJM 020 Killik River	Bluff exposure, E side Killik R. 1 km below Okpikruak R. confluence. Cuts flow deposit	12 m Colluvium 3.7 m Sand and gravel	Platy fragments of local bedrock in matrix of dark grey (10YR4/1) highly organic sandy silt. Fabric of wood and stones parallels hill slope	Flow deposit
77AJM 031 Wiseman (A-6)	Cirque basin near S range front between Mettenpherg Cr. and Malemuk Fk. of John R.	52 m Rock-glacier rubble	Angular schist blocks up to 8 m length in sparse matrix of very poorly sorted schist chips and brown micaceous sand and silt	Rock-glacier deposit
77AJM 064 Wiseman (C-1)	E side Glacier R. 4 km below mouth of Chimney Fork. Sloping solifluction apron	>0.45 cm solifluction deposit (soil pit)	Angular rubble + subrounded stones in matrix of unsorted structureless dark grey (10YR4/1) stony silt w/ trace sand	Solifluction deposit
77AHA 114 Wiseman (B-1)	Rock glacier on S Fk. of Rock Cr. Sample from steep (48°) active front	25 m Rock-glacier rubble	Openwork rubble of schist and quartzite w/ some interstitial silt	Rock-glacier deposit

Table 9. Field data, sand deposits

Sample No. and Quadrangle	Location and Setting	Stratigraphy	Field Description	Remarks
77AJM 001 Wiseman (A-4)	Bluff exposure, John R. 3 km S of Itkillik II moraine. Within basin created by Itkillik I drift	0.5 m Peat & org. silt 7.2 m Bedded sand	Grey to yellow-brown (10YR 4/1 to 5/6) medium sand to silty fine sand; weakly bedded, w/ org. silt and peat interbeds	Interstadial basin-fill deposit
77AJM 009 Wiseman (A-5)	Bluff exposure, W side Bedrock Cr. in area of massive Itkillik I ice-stagnation deposits	0.15 m Loess 35 m Sand & gravelly sand	Light grey (10YR7/2) medium sand; slightly x-bedded w/1-2 cm near-horiz. beds	Late-glacial basin-fill deposit
77AJM 012 Howard Pass	Bluff exposure W side Nigu R. upvalley from Itkillik II moraine in basin-fill stretch	0.8 m Sod above sandy silt 10 m Bedded sand & gravel 15.8 m Bedded sand	Dark greyish brown (10YR4/2) medium to fine sand, w/occ. silt partings. Bedding ranges from fine (1-2 mm) near-horiz. laminae to x-beds and climbing ripples	Late-glacial to early postglacial basin fill
77AJM 023 Killik R.	Dune deposit, E side Killik R. 7 km N of L. Kaniksrak	0.3 m Peaty sand ~20 m Dune sand w/shale granules	Dark greyish brown (10YR4/2) medium sand with granule-sized shale chips, alternating w/ 1 cm layers of grey shale chips in coarse sand to granule range	Holocene dune field
77AJM 038 Wiseman (B-3)	W side Michigan Cr. 3 km N of Fall Cr. mouth. Soil pit into old valley floor	0.35 m Frost-churned and oxidized sand 0.4+ m Pebbly sand	Brown (10YR4/3) unsorted sand and granules with scattered pebbles and occ. small cobbles	Basin-fill of Itkillik I age
77AJM 046 Wiseman (A-4)	Crest of Itkillik II moraine, John Valley at range front	6.5 m Dune sand 10+ m Drift	Dark brown (10YR4/3) well sorted medium sand w/occ. small platy granules; subhoriz. beds 15 cm thick, w/ interbeds	Longitudinal dunes, assoc. w/ blowouts
77AJM 052A & 052B Wiseman (C-5)	Cutbank, E side John R. 4 km below Eagle Cr. Holocene fluvial deposits	0.15 m Surface sod 0.8 m Silty fine sand w/ peat interbeds 0.1 m Buried peat 1.1 m Silt & org silt w/peat beds 3.6 m Micaceous fine to medium sand (samples A and B).	A. Well sorted mottled fine sand in beds ~25 cm thick B. Peaty silt and organic fine sand; horiz. bedded	Holocene flood-plain deposit, probably reworked from Itkillik II basin fill

Table 10. Field data, till deposits

Sample No. and Quadrangle	Location and Setting	Stratigraphy	Field Description	Remarks
77AJM 010 Bettles (D-6)	Crest of Itkillik I end moraine along N margin of Alatna Hills	15 cm yellow-brown silt >0.5 m till	Dark reddish brown (5YR3/4) oxidized sandy gravel. Max. clast size 15-20 cm	From soil pit on moraine crest
77AJM 014 Howard Pass	Flank of Itkillik II moraine, W side Nigu R. Exposure at head of earthflow	1 m sod, colluvium, and peat >4 m till	Faceted and striated stones up to boulder size in grey silt to sand matrix	
77AJM 017 Howard Pass	Flank of active kettle in Itkillik II drift sheet, Inyorurak Lakes area	4 m Ice-contact gravel 3.5 m Sand >7 m Till	Striated and faceted stones to boulder size in very compact silty sand matrix	Same locality as ice-contact samples AJM016 A and B
77AJM 018 Killik River	Stream cut into drift sheet near Itkillik II limit, Killik Valley	26 m Ice-contact gravel >20 m Till	Faceted and striated stones up to 1.5 m diam. in compact dark grey (N4) silty sand matrix	Same locality as ice-contact sample AJM 019
77AJM 030 Survey Pass	Bluff exposure, N side April Cr. near its mouth. Cuts valley-floor filling of Itkillik II drift	12-15 m Till 0-1.5 m Bedrock	Stones up to 1.5 m diam. in dark grey (N4) sandy matrix	

Table 11. Field data, ice-contact stratified drift deposits

Sample No. and Quadrangle	Location and Setting	Stratigraphy	Field Description	Remarks
77AJM 013 Howard Pass	Outwash(?) deposited over stagnant ice, W side Nigu Valley ~3 km above Itkillik II moraine	Massive deposit (~50 m thick) with thin cover of peaty sand	Yellow brown (10YR5/4) sandy gravel. Pebbles, cobbles, and occ. boulders (up to 65 cm) in predominantly coarse sand matrix	Forms terrace-like surface 45 m above modern river level
77AJM 016A & 77AJM 016B Howard Pass	Flank of active kettle in Itkillik II drift sheet, Inyorurak Lakes area. Possible outwash sheet above stagnant ice	4 m Ice-contact gravel (A) 3.5 m Sand (B) 7 m Till	A. Brown (10YR4/3) sandy gravel. Coarse sand to small cobble size, w/ trace medium sand B. Well sorted, well bedded brown (10YR4/3) medium sand	Samples 016A, 016B, and 017 (till) are all from same locality
77AJM 019 Killik River	Stream cut into drift sheet near Itkillik II limit, Killik Valley. Kame-like knobs with sparse litter of boulders up to 1.5 m diam.	26 m Ice-contact gravel >20 m Till	Subrounded pebbles and cobbles in dark brown (10YR4/3) coarse sand matrix	Same locality as till sample 77AJM 018
77AJM 033 Wiseman (B-2)	Cutbank W side Glacier R. near its mouth. Dissected flank of esker system	Overlain by thin cap of sod, eolian silt, and gravelly sand.	Greyish brown (10YR5/2) sandy cobble gravel with occ. boulders up to 60 cm diam.	
77AJM 034 A, B, C, D Wiseman (B-2)	Bluff exposure, E side N Fk Koyukuk ca. 23 km above Itkillik II moraine. Upper surface is old valley floor	6 m Pea gravel (B) above diamicton (A) 6 m Bedded sand (C) 6 m Bedded gravel (D)	A. Unsorted subrounded stones to small boulder size in poorly sorted silty, sandy, gravel matrix B. Well sorted openwork pea gravel (granules to small pebbles) w/silt coatings C. Finely laminated to crudely bedded greyish brown fine to medium sand D. Subrounded gravel to small boulder size in coarse sand to granule matrix	Samples A-D from 4 strat. units at same locality
77AJM 039 7/22/66-3 Wiseman (C-4)	Gravel terrace, unnamed trib to Swamp Cr. near its confluence w/ Allen R. (just W of pass at head of Tobin Cr.)	60 m Sandy gravel and gravelly sand 30 m Drift	Pebbles and occ. cobbles of schist and phyllite in matrix of dark greyish brown (10YR4/2) platy coarse sand and granules	Probably inwash against Itkillik I ice margin in main valley
77AJM 045 Wiseman (B-4)	Bluff exposure, N side McCamant Cr. ca 2 km above its mouth. W flank of Itkillik II moraine complex	18 m Sand and gravelly sand 6 m Cobble gravel 27 m Silty fine to medium sand 40 m Covered	Light yellow brown (2.5Y 6/4) well sorted fine sand w/trace silt and occ. stones	Sample from near top of exposure
77AJM 060 Wiseman (D-2)	Ice-stagnation deposits W of Chimney Pass in Clear R. valley. Soil pit in esker-like ridge	15 cm Frost-churned oxidized silt 50 cm + Oxidized pebble gravel	Dark brown (7.5YR3/2) oxidized pebble gravel in matrix of platy granules	

Table 12. Field data, outwash deposits

Sample No. and Quadrangle	Location and Setting	Stratigraphy	Field Description	Remarks
77AJM 003 Wiseman (A-4)	Bluff exposure, W side John R. immediately below Itkillik II moraine front. Edge of outwash terrace	25-30 m Outwash gravel	Imbricated subrounded pebbles and cobbles in faintly bedded to locally well bedded sandy matrix	Qtz comprises ~50% of granule-pebble fraction
77AJM 006 Bettles (D-5)	Outwash terrace of Sagavanirktok age on unnamed tributary 6 km above its confluence w/ E. Fk. Henshaw Cr.	0.3 m Peat and silt 23+ m Outwash gravel	Subrounded pebbles and small cobbles in matrix of dark brown (7.5YR4/4) coarse sand w/ trace of medium sand	Most stones show surface weathering
77AJM 008 Bettles (D-2)	Cutbank, N side S. Fk. Koyukuk R. upstream from Gold Bench. Edge of Itkillik I outwash terrace	1 m Silt + sod cap 9.5 m Outwash gravel 4 m Covered	Imbricated subrounded stones up to cobble size in light brownish grey (10YR6/2) coarse sand matrix	Upper 20 cm of outwash is weathered
77AJM 015 Howard Pass	Cutbank W side Nigu R. ca 7 km below Itkillik II moraine. Edge of outwash terrace	2.7 m Peat, laminated sand and silt, and cliffhead sand 8.5 m Outwash gravel	Weakly bedded and imbricated subrounded pebbles, small cobbles, and occ. large cobbles in poorly sorted grey (10YR5/1) sand matrix	
77AJM 024 Survey Pass	Cutbank, N side Nigu R. near its head. Edge of late Itkillik outwash terrace	11 m Outwash gravel	Subrounded to subangular pebbles and cobbles w/ rare small boulders in dark grey (N4) coarse sand-granule matrix consisting largely of shale chips	
77AJM 025 Survey Pass	Outwash terrace showing collapse features, just W of Nigu-Alatna divide	11.2 m Outwash gravel	Subrounded to subangular stones to very small boulder size (occ. 40-45 cm) in matrix of dark grey (N4) coarse to medium sand with some granules	Probably deposited on top of stagnant residual glacier ice

LABORATORY DATA

Determined by

James H. Trexler, Jr.

Table 13. Laboratory Data, fan deposits

	022	026	037	051	062			
Textural class	msG	msG	G	sG	msG			
pct gravel	70.5	75.5	80.5	63.7	75.5			
pct sand	26.4	17.3	16.9	34.0	21.6			
pct silt	0.7	7.1	0.6	0.5	2.9			
pct clay	2.4	0.1	2.0	1.8	0			
mean ø	1.14	2.02	1.11	0.42	1.02			
sorting ø	2.99	2.24	3.46	1.71	1.88			
skewness	0.41	0.15	0.57	0.45	0.46			
kurtosis	2.82	0.62	2.68	2.06	1.02			
clasts: rounding	sbrd-rd	sbang-sbrd	sbang-sbrd	sbrd-wrd	sbang			
clasts: shape			tabular	compact	tabular			
clasts: composition	qtzite & shale	qtzite & shale	phylite-schist frags	ls, qtz, schist & other rk frags	schist chips			
sand: rounding	sbang-sbrd	sbang-sbrd	sbang	sbrd-rd	sbang			
sand: shape			tabular		tabular			
sand: composition	~50 pct qtz, rk frags	>80 pct rk frags, more qtz at smaller sizes	schist chips & mica, low pct qtz	calcite, qtz, micaceous rk frags	micaceous rk frags & qtz			
remarks			brown-yellow color	some qtz grains >2 mm are frosted	mica may be biotite			

Table 14. Laboratory Data, modern alluvium

	004	005	007	027	028	029	035	036
Textural class	sG	S	sG	sG	sG	G	sG	sG
pct gravel	66.2	0	45.6	55.7	44.4	80.8	70.3	73.8
pct sand	33.0	99.6	54.3	41.7	54.6	16.6	27.7	25.9
pct silt	0.2	0.1	0	2.6	0.2	2.6	0.4	0
pct clay	0.6	0.3	0.1	0	0.8	0	1.6	0.2
mean ø	0.71	1.95	0.36	0.85	0.81	2.71	1.25	0.32
sorting ø	1.04	0.45	0.78	1.51	0.94	1.07	2.00	0.97
skewness	0.01	0.01	0.18	0.33	- 0.05	0.30	0.05	0.19
kurtosis	1.47	1.01	0.82	1.03	1.12	1.20	1.54	0.95
clasts: rounding	sbrd-wrd		sbrd-rd	sbrd-rd	rd-wrd	sbrd-rd	sbrd-rd	sbrd-rd
clasts: shape				tabular		tabular	tabular	
clasts: composition	dark fine gr rk w/some schist, vein qtz		60 pct qtz, rk frags	phyllitic, non-micaceous, few granite frags	fine gr,dark ig rk frags, qtz veins	fine gr quartzitic rk frags	schist, gneiss, small qtz pebbles	fine gr micaceous metamorphic rk frags & qtz
sand: rounding	sbang-sbrd	sbang	sbang-sbrd	rounded	sbang-rd	sbang-sbrd	sbang-sbrd	sbang-sbrd
sand: shape	tabular (frags)			tabular	tabular	tabular (phyllite)		
sand: composition	~70 pct qtz + micac rk chips, calcite	~30 pct qtz ~40 pct mic chips ~20 pct calcite	60 pct qtz 35 pct rk frags	phyllitc rk chips minor qtz	~10 pct qtz, the rest rk chips	50 pct qtz plus phyllitic rk chips	qtz, calcite mica, rk frags	30 pct qtz ~5 pct calcite, plus rk frags
remarks			some qtz pebbles are frosted				some qtz sand is rounded and frosted	

Table 14. Laboratory Data, modern alluvium (cont.)

		043	049	050	054	057	063		
	Textural class	S	sG	sG	sG	sG	msG		
	pct gravel	0	66.2	60.0	73.4	66.1	78.1		
	pct sand	95.6	31.5	39.5	24.8	32.1	19.8		
	pct silt	0.9	2.3	0.1	0.4	0.4	0.5		
	pct clay	3.4	0	0.4	1.4	1.4	1.7		
	mean ø	2.36	0.92	0.78	1.29	0.52	0.83		
	sorting ø	0.73	1.58	1.08	2.02	1.40	2.82		
	skewness	0.19	0.26	- 0.01	0.26	0.30	0.45		
	kurtosis	1.18	1.12	1.02	1.82	1.49	3.08		
clasts	rounding		sbrd-rd	sbang-rd	sbrd-w rd	sbang-sbrd	sbrd-rd		
clasts	shape		elong & compact		compact	tabular	tabular & elong		
clasts	composition		gneiss frags + 5 pct schist	gneiss, schist, qtz, and ls(?)	high grade meta rk frags, qtz pebbles all small	phyllite-schist + qtz	gneiss & schist, vein qtz		
sand	rounding	ang-sbrd	sbang-sbrd	sbang-sbrd	sbang-sbrd	sbang-sbrd	ang-sbang		
sand	shape	tabular							
sand	composition	90 pct phyllite chips 5 pct qtz 2 pct calcite	30 pct qtz 30 pct calcite + rk frags	30 pct calcite, 10 pct qtz, phyllitic rk frags	20 pct qtz 5 pct calcite + rk frags	10 pct qtz 3 pct calcite + rk frags	60 pct rk frags 20 pct qtz 5 pct calcite		
	remarks		some magnetic mineral present (<2 pct)	secondary breakage of gravel common		schist may be chloritic	calcite is euhedral		

Table 15. Laboratory Data, alluvial-terrace and other gravel deposits

		002	021	042	053	055			
	Textural class	sG	msG	msG	sG	G			
	pct gravel	60.3	75.2	73.5	41.4	83.8			
	pct sand	39.2	17.6	24.0	57.8	14.9			
	pct silt	0.1	7.1	0.54	0.17	0.25			
	pct clay	0.4	0.1	1.98	0.62	0.93			
	mean ø	0.23	2.19	0.65	0.57	0.45			
	sorting ø	0.97	2.24	2.65	0.94	2.05			
	skewness	0.32	0.31	0.45	0.07	0.47			
	kurtosis	1.27	0.71	3.45	0.99	2.48			
clasts	rounding	rd-wrd	sbrd-wrd	sbrd-rd	sbang-sbrd	sbrd-wrd			
clasts	shape	compact	some are tabular		compact				
clasts	composition	ig rk frags & qtz pebbles	rk frags dark to black aph, some chert clasts (small)	qtzose high grade meta frags, qtzite	phyllite, ls w/ vein calcite	high grade meta frags, schist			
sand	rounding	sbrd-rd w/ occ sbang	ang-wrd	sbrd	ang-sbrd	sbang-sbrd			
sand	shape			rk chips tabular					
sand	composition	~50 pct qtz, ~50 pct rk frags	~80 pct qtz rk frags (coarse sand only)	~50 pct qtz <10 pct calcite & rk chips	qtz 40 pct, calcite & ls chips and phyllite frags	30 pct qtz 60 pct rk frags (micaceous), calcite			
	remarks	clasts have some 2nd breakage. Some qtz is frosted and w rd. Strong mode at 0 ø	qtz grains are ang to wrd and frosted. bimodal: 1 ø & 5 ø		freq peak at 0 ø & 4 ø	some secondary breakage			

Table 16. Laboratory Data, lacustrine deposits

		011	032	040	044	048	058	061	136
Textural class		Z	gM	gM	M	M	(g)M	gM	M
pct gravel		0	0	4.8	0	1 pebble	0.9	29.9	0
pct sand		0	8.7	13.1	trace	trace	7.0	20.2	0
pct silt		82.4	81.8	46.6	45.9	46.0	32.5	37.1	56.9
pct clay		17.6	9.5	35.5	54.1	54.0	59.6	12.7	43.1
mean ø		6.56	5.74	7.08	8.87	8.83	9.02	3.43	8.48
sorting ø		2.02	1.73	3.81	2.25	2.26	2.89	4.06	2.18
skewness		0.16	0.29	-0.13	0.40	0.40	0.07	-0.03	0.44
kurtosis		1.58	1.15	1.86	0.91	0.85	1.19	0.63	1.01
clasts	rounding			sbang		rd	ang-rd	sbrd-rd	
	shape								
	composition			rk frags, granules only		single dropstone	rk frags w/qtz	rk frag w/ vein qtz, pea gravel predom	
sand	rounding		sbang	ang-sbang	ang	ang	ang	sbang-rd	
	shape								
	composition		~85 pct qtz, + mica & rk bits	rk frags w/ qtz, calcite	qtz & calcite, predom fine gr	fine sand: qtz, calcite, mica	qtz + 20 pct rk frags & 5 pct calcite, frags are phyllitic	rk frags + 20 pct qtz 10 pct calcite, frags are phyllitic	
remarks		high pct organics (=all material larger than 62.5µ)	some euhedral qtz	some euhedral qtz	pct* 45 chlorite 45 mica 5 qtz 0 clays				

* X-ray diffraction results.

Table 16. Laboratory Data, lacustrine deposits (cont.)

		137	178						
Textural class		C	M						
pct gravel		0	0						
pct sand		0	0						
pct silt		19.0	70.6						
pct clay		81.0	29.4						
mean ø		10.93	7.62						
sorting ø		2.49	2.14						
skewness		-0.84	0.36						
kurtosis		1.00	1.21						
clasts	rounding								
	shape								
	composition								
sand	rounding								
	shape								
	composition								
remarks		pct* 55 muscovite 40 chlorite 5 qtz trace cal- cite 0 clays							

* X-ray diffraction results.

Table 17. Laboratory Data, flow-slide deposits

		041	056	059	085	094	095	097	098
	Textural class	msG	msG	msG	mG	msG	msG	mG	msG
	pct gravel	73.9	65.9	35.5	54.3	49.7	61.7	54.2	33.5
	pct sand	19.1	30.2	30.1	22.1	34.6	24.7	22.9	36.2
	pct silt	5.8	3.7	22.4	22.6	14.2	12.8	22.6	29.6
	pct clay	1.2	0.2	12.0	1.0	1.6	0.7	0.2	0.7
	mean ø	2.28	0.96	4.39	3.65	2.37	2.32	3.39	2.82
	sorting ø	2.86	1.82	3.90	2.25	2.74	2.67	2.35	2.37
	skewness	0.47	0.46	-0.01	-0.24	0.36	0.23	-0.31	-0.22
	kurtosis	0.84	1.16	0.84	1.05	0.80	0.70	0.82	0.78
clasts	rounding	ang	sbang	ang	sbang	ang	ang	ang	ang
clasts	shape	tabular	tabular	tabular	some tabular	tabular	tabular	tabular	some tabular
clasts	composition	phyllitic rk frags	phyllite frags	micaceous rk frags, qtz veins	high grade meta with qtz veins	phyllite chips	phyllite-schist chips	schist-phyllite & other meta rk frags with qtz veins	meta rk frags
sand	rounding	ang	sbang	ang	ang-sbang	ang	ang	ang	ang
sand	shape *	tabular	tabular	tabular		tabular	tabular	tabular	tabular
sand	composition	80 pct rk frags, 15 pct qtz	rk frags + 10 pct qtz, 1 pct calcite	rk frags, mica, 2 pct qtz	rk frags, qtz (50 pct)	phyllite chips	phyllite & schist frags with low pct qtz	rock frags with low pct qtz	rock frags, qtz, mica
	remarks	purple							gravel is pea & granule size only

Table 17. Laboratory Data, flow-slide deposits (cont.)

		110	149						
	Textural class	msG	gmS						
	pct gravel	32.0	13.9						
	pct sand	42.6	43.6						
	pct silt	23.9	41.3						
	pct clay	1.5	1.1						
	mean ø	2.76	3.45						
	sorting ø	2.60	2.45						
	skewness	0.11	-0.22						
	kurtosis	0.81	0.85						
clasts	rounding	ang	ang						
	shape								
	composition	micaceous schist frags	meta rk frags (schist-phyllite)						
sand	rounding	ang	ang						
	shape								
	composition	schist frags, mica, low pct qtz	rk frags, mica, low pct qtz						
	remarks								

Table 18. Laboratory data, other colluvial deposits

	020	031	064	114				
Textural class	mS	msG	gM	msG				
pct gravel	0	52.5	23.0	33.6				
pct sand	57.7	36.5	31.6	50.1				
pct silt	42.1	10.6	36.5	16.1				
pct clay	0.2	0.3	8.8	0.1				
mean ø	3.34	2.37	4.40	2.34				
sorting ø	1.58	2.23	3.40	2.09				
skewness	-0.15	0.07	-0.12	-0.01				
kurtosis	0.95	0.86	0.87	0.83				
clasts: rounding		ang	ang	ang				
clasts: shape		tabular		elongate				
clasts: composition		schist chips and alteration minerals	qtzitic schist frags	meta rk frags				
sand: rounding	sbang-sbrd	ang	ang	ang				
sand: shape		tabular						
sand: composition	80 pct qtz + organics	50 pct schist frags + 50 pct qtz	schist-phyllite frags, qtz, mica	rk frags, 5 pct qtz				
remarks	organics: wood chips charcoal leaf bits. 50 pct charcoal	strong sulfur odor, qtz is euhedral						

Table 19. Laboratory data, sand deposits

		001	009	012	023	038	046	052A	052B
	Textural class	sZ	S	sZ	S	gS	S	sZ	Z
	pct gravel	0	0	0	0	29.89	0	0.01	0
	pct sand	41.8	96.8	39.8	97.34	67.43	99.0	21.3	0
	pct silt	57.3	3.2	59.3	0.57	2.63	0.2	73.4	94.0
	pct clay	0.86	0.02	0.9	2.08	0.04	0.8	5.3	6.0
	mean ø	4.17	2.49	4.23	2.02	0.69	2.44	4.9	5.64
	sorting ø	1.09	0.60	1.18	0.89	1.14	0.56	1.47	1.37
	skewness	0.64	0.14	-0.07	0.17	0.09	-0.11	0.39	0.26
	kurtosis	1.08	1.15	1.50	1.16	1.05	1.31	1.28	0.89
clasts	rounding					sbrd-rd			
clasts	shape								
clasts	composition					schist-phyl-lite, qtz			
sand	rounding		ang-sbang	ang	sbang-sbrd	ang-sbrd	sbrd-wrd	ang	ang-sbang
sand	shape				chips-tabular	chips-tab.			
sand	composition		50 pct-70 pct qtz, + amphiboles, pyroxenes, calcite, mica	90 pct qtz + rk frags	phyllite chips & qtz	70 pct qtz + rk chips, mica, some heavy metal-lics	50 pct cal-cite, 30 pct phyl-lite chips, 10 pct qtz	40 pct cal-cite 60 pct qtz	40 pct qtz 40 pct cal-cite + rk frags, mica
	remarks			qtz is mil-ky	more qtz at finer sizes	secondary breakage in gravel clasts		some qtz & calcite euhedral	some qtz & calcite euhedral

Table 20. Laboratory data, till deposits

		010	014	017	018	030			
Textural class		(g)mS	msG	msG	msG	sG			
pct gravel		2.3	51.6	64.9	70.2	68.9			
pct sand		66.9	26.9	18.4	25.7	28.8			
pct silt		29.5	15.4	13.7	3.8	2.0			
pct clay		1.3	5.9	2.8	0.2	0.2			
mean ø		2.62	3.85	3.70	1.28	0.95			
sorting ø		2.35	3.45	2.75	1.90	1.43			
skewness		0.12	0.23	0.05	0.38	0.21			
kurtosis		0.84	0.98	1.24	1.11	1.42			
clasts	rounding	sbrd-rd	sbang	sbrd-rd	sbrd-rd	rd-wrd			
	shape					tabular w/ some compact			
	composition	rk frags & qtz	qtzite & shale	rk frags	drk meta rk frags & qtzite (?)	drk rk frags, metamorphic			
sand	rounding	rd (qtz)	ang	sbang-sbrd	sbang-sbrd	sbang-sbrd			
	shape								
	composition	qtz, mica	50 pct qtz, 50 pct frags	>70 pct qtz + rk frags	90 pct [illegible] frags 10 pct qtz	rk frags, more qtz at smaller sizes			
remarks		contains secondary concretions w/Fe		secondary breakage	secondary breakage	secondary breakage			

Table 21. Laboratory data, ice-contact stratified drift deposits

		013	016A	016B	019	033	034A	034B	034C
	Textural class	G	msG	mS	msG	sG	msG	msG	mS
	pct gravel	83.7	71.5	0.0	63.9	63.1	79.5	76.6	0.0
	pct sand	14.7	25.3	77.8	32.2	34.1	13.9	18.8	85.5
	pct silt	1.5	0.7	21.3	0.8	0.6	6.1	4.5	14.4
	pct clay	0.1	2.5	0.9	3.1	2.1	0.5	0.1	0.1
	mean ø	0.69	1.27	3.44	1.18	0.74	2.22	1.21	2.96
	sorting ø	1.65	3.15	0.96	3.09	1.89	3.03	2.33	0.94
	skewness	0.52	0.41	0.22	0.42	0.74	0.60	0.67	0.15
	kurtosis	1.20	2.58	1.42	2.74	2.53	0.58	0.73	1.15
clasts	rounding	sbrd-rd	sbang-sbrd		sbrd-wrd	sbang-sbrd	sbang-wrd	sbrd-rd	
clasts	shape	tabular						tabular	
clasts	composition	high grade meta w/qtz veins	qtzite & meta rk frags w/qtz veins		rk frags	rk frags, granitic, aph ig & metamorphic	meta rk frags + some schist	phyllite-schist	
sand	rounding	sbang-sbrd	subang	sbang-sbrd	sbang-sbrd	sbang-sbrd	sbang-sbrd	sbang-rd	ang-sbang
sand	shape								
sand	composition	qtz-some euhedral, rk frags	>70 pct qtz + rk frags	90 pct qtz 10 pct rk frags	~70 pct qtz + rk frags	~50 pct qtz ~10 pct calcite	~40 pct qtz ~40 pct chlorite schist + mica, calcite	~30 pct qtz + mica, schist chips	~40 pct qtz, ~30 pct micas, calcite, felds
	remarks	grains are "clay" coated, secondary breakage		a few ang qtz chards	secondary breakage		no secondary breakage	sand has secondary breakge	clean

Table 21. Laboratory data, ice-contact stratified drift deposits (cont.)

		034D	039	045	060				
	Textural class	sG	sG	(g)sM	msG				
	pct gravel	38.5	32.9	4.6	62.1				
	pct sand	56.2	64.3	45.4	34.7				
	pct silt	1.1	0.6	49.3	0.7				
	pct clay	4.2	2.2	0.7	2.5				
	mean ø	1.42	0.55	3.9	0.58				
	sorting ø	2.43	1.06	1.86	2.45				
	skewness	0.34	0.17	-0.17	0.55				
	kurtosis	2.81	1.27	1.39	2.8				
clasts	rounding	sbrd-rd	ang-rd	sbrd	sbrd-rd				
clasts	shape				tabular				
clasts	composition	ig & meta rk frags	phyllite, other meta rk frags, vein qtz	qtz, ls & meta rk frags	qtz + phyl-lite, schist chips				
sand	rounding	ang-sbrd	ang-rd	ang-sbrd	sbang-sbrd				
sand	shape								
sand	composition	micaceous rk frags & qtz, calcite	50 pct qtz, 50 pct rk frags	qtz, calcite & rk frags	<50 pct qtz + rk frags				
	remarks	some second-ary break-age							

Table 22. Laboratory data, outwash deposits

		003	006	008	015	024	025		
	Textural class	sG	sG	sG	msG	msG	msG		
	pct gravel	58.0	60.7	71.6	62.0	68.2	71.1		
	pct sand	41.2	39.1	26.0	33.9	28.9	25.6		
	pct silt	0.2	0.03	2.4	0.9	0.6	0.7		
	pct clay	0.6	0.1	0	3.2	2.3	2.5		
	mean ø	0.61	0.26	0.09	1.05	0.56	1.05		
	sorting ø	1.06	0.82	1.25	3.04	2.61	3.12		
	skewness	0.35	0.06	0.42	0.49	0.55	0.48		
	kurtosis	1.06	0.91	2.19	2.62	3.03	2.94		
clasts	rounding	sbrd-rd	sbrd-rd	sbrd-rd	sbrd-rd	sbang-sbrd	sbang-sbrd		
clasts	shape	tabular			elong-tabular		tabular		
clasts	composition	rk frags w/ vein qtz	50 pct qtz 50 pct rk frags	drk fine gr rk frags	fine gr rk frags w/qtz veins	meta rk frags, shale, low pct qtz	drk fine gr rk frags, 10 pct qtz		
sand	rounding	sbang-sbrd	sbang-sbrd	ang-rd	ang-sbang	sbang-rd	ang-sbrd		
sand	shape								
sand	composition	60 pct rk frags 30 pct qtz 10 pct calcite, rk frags, schist	70 pct qtz 30 pct rk frags	60 pct qtz 35 pct rk frags; mica, calcite	50 pct qtz, rk frags, feldspar, amphiboles	80 pct rk frags, 20 pct qtz	15 pct qtz + rk frags		
	remarks		a few pebbles have secondary breakage surfaces						