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PATTERNS OF COMPOSITIONAL VARIATION IN SOME GLACIOFLUVIAL SEDIMENTS IN THE LOWER PENINSULA OF MICHIGAN

By

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ABSTRACT

PATTERNS OF COMPOSITIONAL VARIATION
IN SOME GLACIOFLUVIAL SEDIMENTS IN
THE LOWER PENINSULA OF MICHIGAN

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The lower peninsula of Michigan presents an opportunity to study the relative process intensity and the orientation of vectored components of glaciofluvial sediments. Identification and examination of the patterns of compositional variation displayed by the volume frequency distributions in the pebble size range will provide the necessary information.

Analysis of the patterns indicates that, although sedimentary structure and grain size are due to the Wisconsinan glaciations and deglaciations, a considerable amount of the material has apparently been recycled from pre-existing glacial sediments. The possibility exists that, with more detailed work, energy flux and transport cycles associated with earlier glaciations might be deduced by further examination of the pebbles in these Wisconsinan deposits. Furthermore, since the Pleistocene sediments that now mantle the lower peninsula may represent the sum total of past glaciations, the contribution from each event including the Wisconsinan, was probably much less than had been supposed.

These conclusions are based on the fact that only basic igneous rock fragments present significant variation at the regional level, whereas most of the other rock types show significance only at the lower levels. Apparently, acid igneous pebbles retain enough strength to be reworked by a renewed glacial event, but the basic igneous do not persist.

More careful examination of the patterns of variation of the basic igneous indicates the outwash in the morainal uplands is more mature than in the drainage ways. This is probably due to the fact that the transport of pebbles to the morainal areas was limited in time, whereas a constant influx of fresh material was available to the deep cutting spillways, particularly from the Saginaw lobe morainal area.

Significant differences for the basic igneous between upland pits closest to the Saginaw lobe moraines suggest that the moraines were probable sources of the upland material.

At the pit level only three pits show significance for all rock types indicating a fine scale of variation which is approximately the distance between pits. Significance for homogeneous structural units within pits further corroborates this fine scale of variation. This is probably due to varying numbers of cycles of erosion and deposition at this local scale.

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INTRODUCTION

The lower peninsula of Michigan presents an opportunity to study the relative levels of process intensity from patterns of compositional variation within glaciofluvial sediments. The area provides an excellent opportunity for the studies of this type because of the geographic location, the good preservation of surface features by continental glacial events and the variety of source terrains within and adjacent to the area. The lower peninsula provides an essentially closed system bounded on three sides by a lowland channel now occupied by the Great Lakes. The multiple glaciations have moved onto the peninsular platform from the bounding troughs and drainage during deglaciation was controlled by these marginal low areas.

The Great Lakes region including Michigan contains the clearest record of deglaciation in North America (Flint, 1957). The well preserved surface features provide qualitative evidence for determining the glacial history of the area. Geomorphological reconstructions of this record are not complete enough to shed light on the detailed nature of the process history of the region that has been impressed upon the resulting glacial sediments. In particular, the degree to which glacial sediment characteristics represent a palimpsest with the record of the last glaciation-deglaciation cycle impressed over the earlier ones has never been evaluated. The object of this thesis is then to use patterns of compositional variation within the Pleistocene sediment as a means of adding to our knowledge of the nature of glaciation and deglaciation that has occurred in the lower peninsula of Michigan. It is hoped that the results of this study will be general enough to serve as a tool for use in other glaciated regions. This research is directed toward determination of sedimentological patterns and not toward establishment or corroboration of stratigraphic concepts within Michigan or other midwestern area.

REGIONAL SETTING

It is generally agreed that the lower peninsula of Michigan is veneered by Wisconsin age material. (Leverett and Taylor, 1915, Hough 1958, Wayne and Zumberge, 1965, Dorr and Eschman, 1970).

Leverett described numerous surface features of glacial origin, including the major morainic systems and the Grand River spillway. Certain of these features identified by Leverett have withstood the test of time very well. Prominent among these are the drainage ways which are expressed as sand and gravel filled valleys now containing obviously underfit streams which once served as conduits for glacial melt water.

The most prominent of these drainage ways is the old Grand river spillway (Leverett, 1915) shown in Figure 1. The spillway apparently headed near Imlay when it served as a conduit from middle Lake Maumee to Lake Chicago approximately 14,000 years ago (Kelley and Farrand, 1967). As the retreat continued the spillway head changed to a location farther north near Ubly. The spillway then served as a conduit from Lake Whittlesey through Lake Saginaw and then through essentially the same channel to Lake Chicago about 12,500 years ago (Kelley and Farrand, 1967). In addition, the lower peninsula probably contains many minor spillways. At present only a few have been identified. One used in this study is located in the southern part of Clinton county (Figure 1).

The drainage ways are bounded by topographic highs (moraines). The detailed internal composition of these is not yet known. However, from limited field observations they seem to be essentially sand and gravel with subordinate amounts of till. Sediments in these features were probably not subjected to the final paroxysm of energy flux that affected sediments in the drainage ways.

From field work and discussion with present day investigators it is clear that these upland areas deserve investigation and reevaluation in terms of composition, genesis and even relative age. It is beyond the scope of this thesis and hence presumptious for this

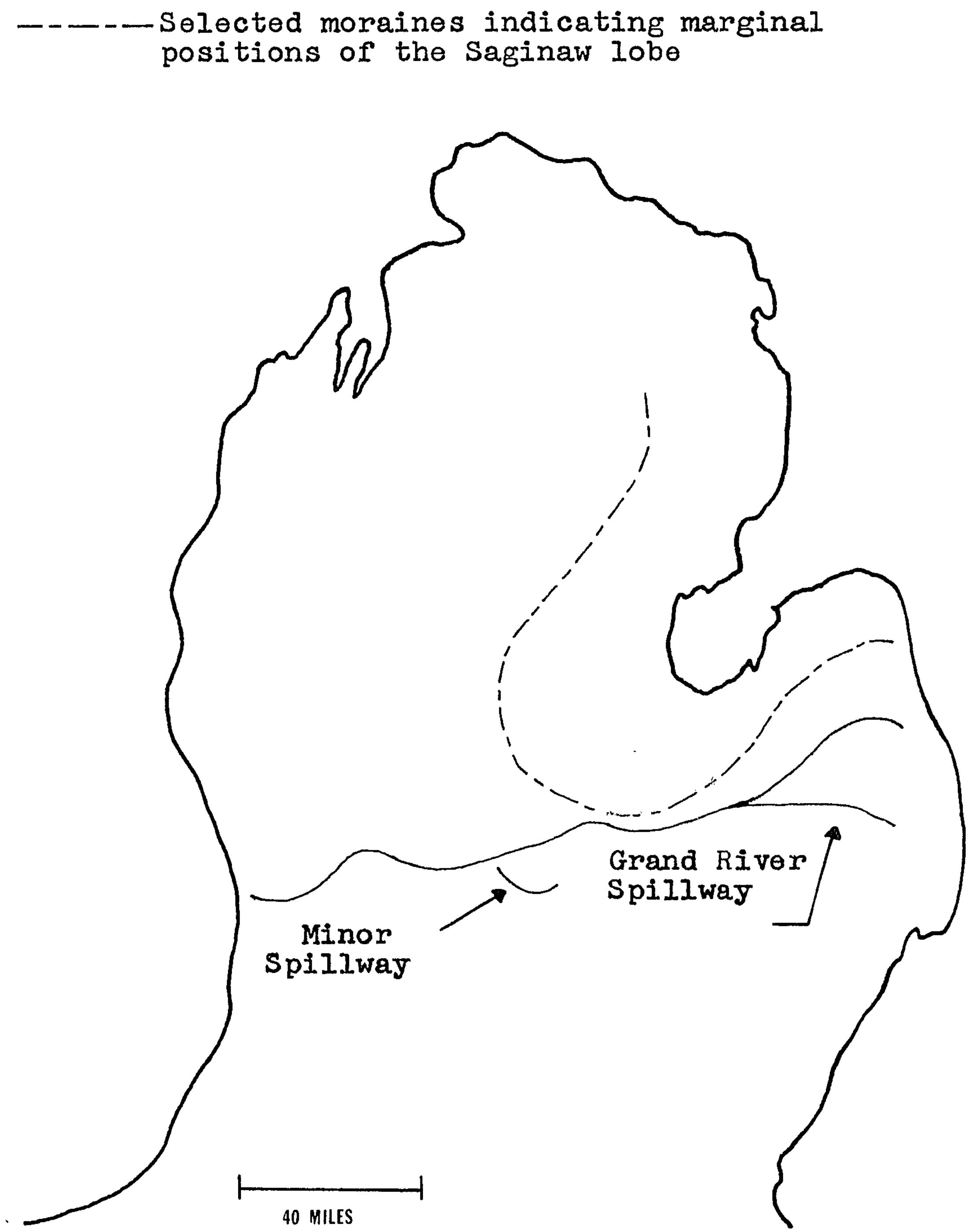


Figure 1. Adapted Surface Feature Map of the Study Area after Flint, et. al. (1959).

author at this time to discuss these areas in any more detail. The results of this thesis will contribute a small increment toward developing a new model.

PREVIOUS WORK

The general character of glaciofluvial sediments has been considered by a number of workers (Anderson 1958, Oldale 1967). The general objectives have been to determine when, from where, and in what manner they came.

Previous workers have provided a general framework which will serve as a basis for more detailed questions concerning glaciofluvial sediments. USGS Monograph 53 (Leverett and Taylor, 1915) is a report of the investigations of the glacial history of Michigan and Indiana. The maps of glacial geology included in this report contribute the major part of the present map of surface formations of Michigan. The overall contribution of Leverett to the understanding of the general glacial geology of Michigan has not been equaled to this day. Leverett described numerous surface features of glacial origin, including the major morainic systems, the Grand River spillway associated with the drainage of glacially supplied water, identification of beach features associated with past proglacial lake levels, and further indicated the major lithologic varieties present.

The precision of the surface formation map of the lower peninsula of Michigan (H.M. Martin, 1955) based on

Leverett is somewhat in doubt by a number of scholars (Winters, 1969), however, it is sufficiently precise for this study as it is only used for general reference. Figure 1 is an adapted surface feature map of the study area after Flint et al (1959). An extensive compilation of the geologic knowledge concerning the Great Lakes region is provided by Hough (1958). He is, however, mainly concerned with the evolution of the great lakes basins. In addition to the above, numerous maps that illustrate the boundaries of Wisconsin stage drift (pg. 7), the theoretical preglacial drainage (pg. 7), the principal morainic systems (pp. 8 and 9) and the principal stages in the evolution of the Great Lakes (inside front and rear cover) can be found in Kelley and Farrand (1967).

Only one reference in the literature specifically directs itself to the problem of process intensity in glaciofluvial sediments and that is by Ehrlich and Davis (1968). Their effort was concentrated on a small-scale area adjacent to an active ice front. This study is one of the first to take into account the problem of using number frequency where volume frequency is more appropriate. They demonstrated that the variation in size (volume) frequency distribution by compositions provided a measurement of change in process intensity. Following their lead this study concentrates on an area of intermediate scale, a few orders of magnitude larger and not adjacent to an active ice front.

Although in many instances we may be unable to determine the entire genetic history of a sediment, the effects of certain events tend to be progressive or additive. For instance, once particles that are either chemically or physically unstable leave their source terrain they can only suffer degradation not reconstruction. Therefore evaluation by careful sampling and careful choice of detrital species one can compare one sample with another with respect to the total amount of physical and chemical degradation the samples have endured. If we consider the degradation to be principally physical, such as result from the hydrodynamics of glaciofluvial events, then we might consider a sample rich in physically and chemically resistant detrital species to have undergone a greater total process intensity, all other effects being held constant by design or extracted mathematically. Thus, as used in this thesis "process intensity" is defined to mean the relative amount of degradation experienced by the detrital particles in the glaciofluvial environment. At this time we must talk in terms of relative rather than absolute process intensity.

This process intensity may or may not exhibit a uniform pattern of variation. That is, the differences in process intensity might reflect purely local vagaries of depositional environments. However, it is possible in Michigan, knowing the source of the melt waters and the direction to the source of the sediments, that the effects on the sediments as they are acted upon may indicate a regional pattern imposed on the local patterns. Such a pattern representing a "progressive cleaning up of the sediment" could be represented by a vector pointing away from the areas of less process intensity to areas of greater process intensity. In a study such as this which is restricted by accessibility of proper sampling sites and other considerations, it is possible only to establish the presence or absence of vectors rather than the entire field of variation.

There have been a number of investigators who have addressed the general problems of vectored properties in glaciofluvial sediments (Krumbein and Lielblein, 1956, Anderson, 1958, Oldale, 1967). These studies have considered the areal distribution of rock types without respect to a specific known source. However, based on additional information, a general source area is usually indicated prior to the study.

The use of largest particles (Krumbein and Lielblein, 1956) must account for the fact that the nature of the largest particle is a function of how long and how far one looks, thus the nature of the underlying population is difficult to deduce. The use of pebble counts (Anderson, 1958, Oldale, 1967) to ascertain relative proportion of lithologic types have limited usefulness due to the bias arising from the use of number frequency where volume frequency would be more appropriate (Griffiths, 1967). An additional area which would provide background is that which concerns stream transport of detrital particles.

The work of Plumley (1948) on the Black Hills terrace gravel is one of the more exhaustive accounts concerning the effects of energy on sedimentary particles of various compositions during transport in natural streams. Plumley suggests that size reduction of pebble size material in streams is effected by two processes: (1) selective transport and (2) abrasion and breakage.

By dividing the lithologic species into two groups (1) hard rocks (chert, quartz, quartzite) and (2) soft rocks (sandstone, limestone, metamorphics), Plumley was able to assess the role of abrasion and breakage versus selective transport. He found that in a distance of 30 miles the volume of soft rocks decreased from 60% to 10%. Plumley concludes (1948): (1) initial lithologic frequency distribution is directly related to the source area; (2) short distance stream transport removes most soft rock lithologies by abrasion and breakage; (3) loss of the soft rocks during transport is a function of rigor of transport and size and composition of associated particles; (4) decrease in mean size results from decreasing competence of the stream as the gradient decreases; (5) skewness of the size distribution decreases with distance of transport; and (6) the standard deviation or sorting shows no systematic change with distance of transport.

Although this represents a major contribution to understanding the attrition of clastics, some of his conclusions should be accepted with caution. Plumley maintains that the choice of an appropriate sample was limited by the nature of the deposits and their exposures. The material being sampled was cemented in varying degrees by calcium carbonate. In addition, as a result of practical considerations the available population for sampling was limited. Possibly of far more importance he was only able to obtain channel samples which, of course, would not allow assessment of variation to the degree offered by sedimentation unit sampling (Otto, 1938, Apfel, 1938, Ehrlich, 1964). The advantage of sedimentation unit sampling is that the variation within the unit ideally is of common origin. This is not necessarily true where the sample taken incorporates a number of units (a channel sample). In the latter case the variation can be attributed to many more unknown circumstances concerning the evolution of the sampled sediment. Thus the nature of the deposit (consolidated by cementation) and the inability to assess the constituent components of variation within a channel sample are the main reasons for cautious consideration of the conclusions.

Plumley's conclusions suggest criteria for interpretation that are useful in this study. The assumption of the relative importance of abrasion relative to chemical weathering should be considered since the pebble fraction "in transport" spends the majority of time immobile according to the vagaries of the seasons and patterns of local turbulence. Notwithstanding this objection it seems reasonable that the larger particles are vulnerable to abrasion causing loss of the coarse tail of the distribution thus explaining the observed skewness variation.

Both Ehrlich and Davis (1968) and Plumley (1948) selected the scale and the place to test an analytical tool whereas this thesis will use this research approach to solve a problem. Because this considers a much larger scale than the Ehrlich and Davis (1968) study the precision of the results is lower. However, the tradeoff in precision is justified because formulation of needed models requires information at the larger scale.

DISCUSSION OF THE PROBLEM

There have been few unambiguous studies concerning quantitative patterns of detrital species within Pleistocene sediments. In order to minimize readily apparent sources of ambiguity, it is necessary to characterize each detrital particle in terms of at least three parameters; species, volume, and aggregate volumetric proportion of that species to other species through volume classes.

Sediment is a product of both source and process. The less the source material is affected by the processes of erosion, transportation or deposition the less these materials will reflect these processes. As process acts more on the source material in terms of intensity and duration the less accurately will the source be mirrored and, concomitantly, the more accurately will the processes be reflected. Most sediments bear to a lesser or a greater degree both information on source and process. Determination of the relative proportion partitioned between source and process is the purpose of this thesis.

In the present instance the source terrain for most of the compositions lies beyond the area of study, particularly for contributions during the Wisconsinan which would have come mainly from north of Lake Huron (Canada). After transport from the source terrain each rock type is affected more or less according to its chemical and physical stability.

Precise distinctions based on resistance to chemical and physical change are not practical except in a relative sense, mainly because most often the substance being considered (especially in the pebble size range) is polymineralic. Even in the case of a monomineralic specimen it is not often straightforward because the result of mechanical and chemical stresses may exhibit wide variations.

However, we do know some general durability characteristics such as hardness and relative chemical stability in various environments (Goldich, 1938). This will be discussed further in the section on generation of data.

Recognizing that the appearance or disappearance of more or less resistant species can give us a clue to widespread energy flux patterns it must be made clear that without the concomitant determination of volume of each clast and the aggregate volume of clasts by species the results will be ambiguous. This approach solves the problem of using number frequency (pebble counts) where volume frequency is more appropriate (Griffiths, 1967).

The identified pattern will, assuming valid sampling, allow interpretation of an unique cause or a small number of causes. Detailed discussion of the sampling plan will be found below.

Based on the above discussions this investigation relies on a number of assumptions. These are: (1) glaciofluvial sediments undergo change during transportation and deposition; (2) these changes are reflected as patterns of compositional variation; (3) detrital species can be classified according to their relative chemical and mechanical resistance. For example if one particle each of two rock types of equal volumes, one soft and one hard, are placed in a glaciofluvial environment, after a time the weaker will be volumetrically diminished compared to the stronger. On a pebble count basis the above situation would result in both pebbles being present in equal. Thus the volume proportion of detrital particles ranked according to relative resistance is an indicator of relative process intensity.

The objective thus is to identify and study the pattern of variation displayed by the volume frequency distributions for various compositions in the pebble size range.

Particles in the pebble range were studied because they offer the greatest spectrum of compositional diversity and can be examined with relative ease.

EXPERIMENTAL DESIGN

In order to identify the pattern of variation a strategy which will allow assessment of changes due to the processes and estimation of vectored components is needed. This necessitates the use of a design which is multilevel and geometrically sensitive. Sensitivity is considered as the ability to determine with adequate precision the directional relationships of the properties of the glaciofluvial sediments. The multi-level aspect is required to obtain an estimate of the regional and local scale variability.

The geometric array must be positioned so that the directions indicated by other means can be tested. For instance, observations in an established glacial spillway and observations (not in but) adjacent to the spillway yield information on direction when an appropriate geometric array is used.

By using a hierarchical design, different scales of variation can be examined. This might be referred to as partitioning the array into smaller component arrays so that the contribution of local variation to regional patterns can be assessed.

The results obtained from such a design can be evaluated in a way which considers local scale variation progressing to regional scale variation on the basis of the size frequency distributions by composition.

SAMPLING PLAN

The sampling plan must fit the design so that the desired objective can be attained. The ideal situation would be to obtain samples from an array of locations so that patterns which intersect or reside within the array could be detected efficiently. The objective of the sampling plan is to provide adequate coverage of the area of interest so that any ordered (non random) pattern can be detected.

The population to be sampled is defined as glaciofluvial sediments in the size range 1cc to 45cc in mid-Michigan. The available population for sampling is restricted to sand and gravel pits as a result of cost considerations. All accessible sand and gravel pits in the area were visited, approximately 100 individual pits. Of these pits over three-fourths were unavailable for sampling for the following reasons: (1) completely overgrown; (2) flooded; (3) all walls slumped; (4) no trespassing; and (5) only available exposure unsafe due to possible caving.

The remaining 22 pits were sampled in the following manner: The gross vertical and horizontal variation in the field was qualitatively evaluated and based on this estimate and personal field judgment individual samples were taken. Conscious effort was expended in assuring that each sample was truly representative of all the material from which it was taken. As is always the case due to problems encountered in the field it was not feasible to adhere to a strict probability sampling plan as is described by Krumbein and Graybill (1965). However, as will be seen in the results below departure from the ideal has not seriously jeopardized the results of this study. However, as will be seen, departure from a balanced design has injected some ambiguity.

In the area of interest two glacial spillways are present (based on field evidence) one major (Old Grand River Spillway) and one minor located south of and relatively parallel to the Old Grand River Spillway (Leverett and Taylor, 1915). The spillways can be considered as locations of considerable energy flux. Compositional gradients will exist along their length if sediments introduced near their head are progressively acted on. However, this contains an implicit, probably unrealistic, assumption that a major portion of the material is contributed at the head of the system with little addition along the way. Proper sampling along these spillways should enable us to choose between these two possibilities. The direction of transport in the spillways was determined to be essentially from the east to west and the more northerly spillway to be active in more recent time (Leverett and Taylor, 1915).

The region may be characterized by defining two qualitatively different terrains, drainage ways and non-drainage ways. This constitutes the top level of the hierarchical design (Figure 2). This top level compares drainage ways with non-drainage ways. In order to assess the variability within each terrain we must examine the variation at the super clusters level. Next we can assess

TERRAINS

SPILLWAY	NON SPILLWAY
SUPER CLUSTER	SUPER CLUSTER
CLUSTER	CLUSTER
PIT	PIT
HSU	HSU
SAMPLE	SAMPLE

Figure 2. Relationship Of The Various Levels Of The Hierarchy

the variation between super clusters within each terrain. Continuing down the hierarchical ladder we are able to assess the variation within the super clusters or the between cluster variation.

Each step allows estimation of the variation at a smaller, geographic scale thus reducing the generality of the results obtained. Further reduction provides an estimate of the within cluster or between pit variation. Next in the hierarchical arrangement we can look at the within pit or between homogeneous structural unit (HSU) variation. Finally we are, at the most local (smallest) scale in this investigation, looking at the within HSU or between sample variation.

Further breakdown at each level of this design is possible if a statistically significant result is obtained. This technique, an orthogonal breakdown, provides a method for identifying where in the level the significant differences reside. Application of this technique will be found at the super cluster level for the basic igneous category discussed in the results.

Each sampled unit here defined as a field observed "homogeneous structural unit" (HSU) Otto (1938), Apfel (1938) and Ehrlich (1964), consisted of two samples in standard volume (1000cc) containers level filled with pebbles in the size range 1cc to 45cc. The two samples were taken only from within the boundaries of the HSU.

These two samples permit estimation of the within HSU variation. In each sand and gravel pit one or more HSU's might be sampled thus allowing estimation of between HSU variation and within pit variation. The variation between pits which are not very far apart provides an estimate of between pit variation and a within cluster variation. The variation between clusters and a within super clusters can also be estimated. In addition the variation between super clusters can be assessed which provides an estimate of the between super cluster within terrain variation. Further the between terrain variation can be ascertained completing the hierarchical design.

The location of the pits by township, range and quarter section is given in Table 1. The relationship of the various levels in the hierarchy is illustrated in Figure 2. A cross reference by number is provided in Appendix A.

GENERATION OF DATA

Pebbles between 1cc and 45cc were evaluated. The size is considered on an individual "grain" or particle basis as the water displacement volume of the particle. The composition is identified on an individual particle basis and assigned to a rock type.

Each sample was washed and each particle identified and allocated to a compositional category, then, each

Table 1 - Location Of Pits By Township, Range And Section

Pit Number	Township	Range	Section
1	T 7 N	R 5 W	SE, SE 9
2	T 5 N	R 4 W	S½, NE, 16
3	T 5 N	R 4 W	SE, NW, 8
4	T 5 N	R 4 W	NE, SW, 6
5	T 5 N	R 3 W	NW, SW, 17
6	T 5 N	R 2 W	NW, 7
7	T 5 N	R 3 W	SE, NE, SE, 12
8	T 7 N	R 1 W	SE, SE, 11
9	T 8 N	R 1 W	SE, NW, 22
10	T 8 N	R 1 W	NW, 31
11	T 8 N	R 1 W	CNL, S½, 31
12	T 8 N	R 2 W	NE, NW, 36
13	T 8 N	R 2 W	NW, SE, 25
14	T 7 N	R 3 W	CNL, 31
15	T 7 N	R 3 W	SE, NE, 31
16	T 8 N	R 3 W	SW, NE, 7
17	T 8 N	R 4 W	SW, 11
18	T 5 N	R 5 W	NE, NE, NE, 19
19	T 4 N	R 2 W	CNL, NW, 35
20	T 9 N	R 11 E	NW, SW, 15
21	T 7 N	R 12 W	E½, 32
22	T 2 S	R 2 E	CWL, 12

identified particle was placed in a graduated cylinder and its volume measured by water displacement to plus or minus 1cc. This data was generated for all particles in each sample for all samples.

It is assumed that rock types broadly similar in composition and texture have similar resistance to communition. This assumption allows grouping of similar rock types into general compositional categories. These categories can be ranked as having low, intermediate or high resistance to mechanical and chemical breakdown. Figure 3 shows such a ranking for the compositions identified in this study. Based on the ranking and the above assumption, the rock types can be combined and placed in six general categories. These categories are: (1) limestone, (2) acid igneous, (3) basic igneous, (4) foliated metamorphic, (5) weak sediments and (6) quartzose.

LIMESTONE

The limestone category consists of limestone and dolomite. Three slightly different varieties of limestone were encountered. Correlation of any of the limestone pebbles to the parent formation is not attempted, however, some suggestions are offered. Examples containing fossils such as chain and honeycomb corals may have been derived from the Manistique Dolomite which crops out in an arc across the southern part of the upper peninsula.

MECHANICAL RESISTANCE

	Low	Intermediate	High
High	Sandstone Quartz conglomerate		Quartz Quartzite Chert
Intermediate		Dolomite	Granite gneiss Granite Rhyolite Granodiorite
Low	Greywacke Shale Siltstone Coal	Limestone Quartz-biotite schist Quartz-biotite, muscovite schist	Gabbro Diorite Basalt

Figure 3. Ranking Of Relative Resistance

Examples that suggest the Traverse Limestone are based on the occurrence of pebbles containing the colonial coral Hexagonaria, often called "Petoskey" stone. The Traverse Limestone forms a wide belt below the drift in the northern part of the lower peninsula. Some samples contained pebbles of a cherty limestone breccia; these are probably from the Mackinaw City, St. Ignace and Mackinac Island region, however, positive correlation is not made. It is a reasonable assumption that most of the limestone is not far traveled as ample local source is available.

ACID IGNEOUS

The acid igneous category consists of granite, granodiorite, rhyolite and granite gneiss. Although all of these are not igneous they will be considered together as they are similar enough in their properties for this study.

Rhyolite occurred in very few samples (59 and 60, HSU 30); the source is probably from north of Lake Huron. Granodiorite and granite are present in a number of different varieties.

Some of the granite probably derived from the upper peninsula of Michigan, the rest from Canada. Neither granite nor other igneous and metamorphic rock types occur in the lower peninsula as bedrock.

BASIC IGNEOUS

The basic igneous category consists of gabbro, diorite and basalt. Diorite has not been found as bedrock in Michigan, thus, its source is probably Canada. Gabbro and basalt both are found in outcrop in the upper peninsula and are most likely derived from there and Canada.

FOLIATED METAMORPHIC

The foliated metamorphic category consists of a quartz-biotite gneiss and quartz-biotite-muscovite schist. Both compositions are considered to be from the upper peninsula and Canada. Schist is the most common metamorphic rock type in the western half of the upper peninsula and is also common on the north shore of Lake Huron.

WEAK SEDIMENTS

The weak sediments category is made up of shale, sandstone, coal, siltstone, quartz conglomerate and greywacke. No attempt was made to ascertain which formation a particular sedimentary rock fragment came from, however, in some instances, a general suggestion is offered. The important thing is that all of the above are probably locally derived with the exception of the greywacke which may have come from a few areas in the western part of the upper peninsula. It does not occur in the lower peninsula.

It is possible that a few samples contain representatives of the Jacobsville sandstone which occurs in the upper peninsula as a distinctly red sandstone and was identified in very small amounts in a few samples. The only other possible specific sandstone identification may be from a few samples which contained a mottled variety ranging in color from brown to yellow to red and purple which fits the description of the Ionia sandstone. This is most definitely a local derivative as it occurs in outcrops along the Grand River valley and in the vicinity of Ionia and Grand Ledge. The coal and shale which are very sparse are probably from more northern subcrops of the Coal Measure shales of the Saginaw Sandstone which are exposed in the vicinity of Grand Ledge, Jackson, Corunna and Williamston. The quartz conglomerate may be from the Marshall sandstone (Huron County), however, a positive correlation is not made.

QUARTZOSE

The quartzose category consists of quartz, chert and quartzite. The quartz may be from the pegmatites or quartz veins of the upper peninsula, however, a definite correlation is not made. Possible source of the chert is from the chert beds which underlie the Bayport Limestone in Arenac County. Quartzite is a common rock in the iron ranges area of the upper peninsula and probably the specimens found in the study area are derived from there.

Each of the above categories is considered as a composition for analysis. The data is then reduced on a compositional basis for each sample. The resultant data is in the form of size frequency distributions by composition.

The reduction makes use of five cubic centimeter classes. Particles larger than 45cc were purposely excluded in the samples. The data in this form was submitted for analysis.

This censored distribution is suitable because with overall reduction in size when particles get so small that they fall out the larger particles will fall into the range of the distribution.

ANALYSIS

The object of the analysis and of this thesis is to identify the pattern of variation displayed by the size frequency distribution for various compositions throughout the study area and also to determine if these patterns of variation can be used to better understand the general process of glaciofluvial accumulation. The appropriate statistical analysis to achieve the objective must provide for comparison of the size frequency distributions for each compositional category at the local and regional levels and estimation of the variation at those levels.

The analysis must be compatable with the sampling plan and the nature of the data. The sampling plan is a nested or hierarchical type and the data is essentially enumeration. In addition the large amount of data requires an economical means of analysis. This type of data in the hierarchical arrangement is most suitably portrayed and analyzed in contingency tables. Contingency tables provide a convenient way of displaying data which considers a number of criteria which have been divided into classes. The statistical objective is to determine if two or more properties are manifested independently. Thus a statistical test which tests independence for enumeration data is appropriate.

The G-test (Sokal and Rohlf, 1969), is chosen because it uses enumerative data arranged in contingency tables. The G-statistic provides a closer approximation to the chi-square distribution than the traditional chi-square statistic. The G-test is computationally simpler for tests of independence. (Sokal and Rohlf, 1969).

The statistical analysis answers the following questions. Does a pattern of variation exist and, if so, at which level or levels does it reside?

Figure 2 illustrates the hierarchical arrangement. The lowest level is the individual sample, the next higher level is the HSU; then the pit; cluster and super cluster complete the arrangement.

The components of variation arising at each level are shown by the familiar analysis of variance table.

Source of Variation	Components of Variation
Super Clusters (SC)	S + H + P + C + SC
Clusters (C)	S + H + P + C
Pit (P)	S + H + P
HSU (H)	S + H
Samples (S)	S

Using the G-test it is possible to compute a G-statistic which is an estimate of the total variation. G-statistics are computed for each level of the design obtaining an estimate of the variation at each level and identifying where in the design significant difference resides. One definite advantage with this form of analysis is that if there is significance at a lower level it does not require significance at successively higher levels.

The G-statistic is computed by the following relationship:

$$G = 2\left[(\sum f \ln f \text{ for the cell frequencies}) - (\sum f \ln f \text{ for the row and column totals}) + (n \ln n)\right]$$

Where G is the statistic, f is the individual cell frequency, ln is the natural logarithm and n is the grand total.

The G-statistic which estimates the total variation is based on the size frequency distribution for all samples for one composition at a time. Table 2 is an

TABLE 2. TOTAL VARIATION FOR LIMESTONE CATEGORY

Volume Class

1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
81	58	54	60	25	0	0	0	0
95	46	30	40	25	60	0	0	0
140	65	72	20	0	0	0	0	45
130	58	45	57	0	0	0	0	45
100	42	15	44	25	0	0	0	0
145	41	15	0	0	0	0	0	0
89	105	60	40	0	0	0	0	0
197	58	0	0	0	0	0	0	0
115	19	12	0	0	0	35	0	0
140	56	39	20	0	30	0	0	0
158	84	12	20	0	0	0	0	0
122	62	0	60	0	60	0	0	0
194	50	12	0	0	0	0	0	0
125	77	30	15	0	0	35	0	0
127	123	43	0	25	0	0	0	0
161	76	15	20	0	0	0	0	0
241	69	39	0	25	0	0	0	0
166	46	0	0	25	0	0	0	0
89	0	29	66	25	0	33	0	45
97	63	56	20	0	0	35	40	0
160	49	0	40	0	0	0	0	0
193	60	27	40	25	0	0	0	0
144	58	45	20	0	30	0	0	0
177	117	30	20	0	0	0	0	0
104	45	30	40	0	30	0	0	0
71	60	98	60	0	0	0	0	0
94	86	45	20	0	0	0	0	0
176	49	0	0	25	0	0	0	0
111	36	0	20	25	0	0	0	0
169	82	27	0	0	30	0	0	0
231	42	0	0	0	0	0	0	0
175	42	12	0	0	0	0	0	0
73	46	87	53	50	0	0	0	0
131	82	30	20	0	0	0	0	0
101	51	24	58	0	30	0	0	0
125	55	78	21	25	0	0	0	0
90	54	42	41	25	0	33	0	0
116	83	15	0	25	60	70	0	0
115	114	114	40	50	0	0	0	0
91	72	54	60	0	0	0	40	0
133	100	54	40	25	0	0	0	0
152	58	54	20	25	0	0	0	0
202	86	23	20	0	0	0	0	0
184	73	27	33	0	0	35	0	0
139	30	27	20	25	0	0	0	0
171	29	45	0	23	0	0	0	0
173	102	0	20	0	0	0	0	0
136	79	0	0	0	0	0	0	0
111	54	12	40	0	0	0	0	0
59	70	15	60	25	0	0	0	0
132	76	30	0	25	0	0	0	0
143	38	42	37	0.	0	35	0	0
106	71	27	40	47	0	0	0	0
114	57	15	0	0	0	0	0	0
137	44	54	0	25	0	0	0	0
221	71	45	0	0	0	0	0	0
82	51	12	18	25	0	0	0	0
152	101	15	0	0	0	0	0	0
98	39	15	0	25	30	0	0	0
108	64	15	40	0	0	0	0	0
205	61	30	0	0	0	0	0	0
204	119	15	20	0	0	0	0	0
145	175	66	20	0	0	0	0	0
143	158	27	0	47	0	0	0	0

G = 9422.9613 FOR TOTAL SET

example of the contingency table which contains the total variation. Thus there is a total G for each composition. Next the two samples in each HSU are combined and a new G-statistic is computed. This estimate contains the variation due to the HSU and the individual samples. This procedure is repeated at each successive level of the design. Then the separate G values for each level for one composition may be subtracted from the next higher level resulting in an estimate of the variation due to that level. The resulting values are the estimates of the variation arising at each individual level. These values are divided by the appropriate degrees of freedom and the resulting value treated as the variance for the individual level. Levels which show significant differences can be broken down into comparisons within that level. This allows identification of the significant set or sets for that level. Breakdown at the super cluster level provides an example. The comparisons are determined apriori. The comparisons are for the relationship of the spillways and the non spillways, in addition the north versus south and the east versus west directions. These comparisons test the regional scale variation.

Variance ratios are obtained by collapsing from the lowest level to successively higher levels and comparing the result to the F distribution. This is possible by the following relationship:

$$\frac{G_1/df_1}{G_2/df_2} = F_{df1,\ df2}$$

Where G_1 and G_2 are the G statistics for the appropriate levels and df_1 and df_2 are the respective degrees of freedom and F is the variance ratio for reference to an F-table.

This is the same procedure as with individual degrees of freedom in analysis of variance. The relationship between the chi square and F distributions which allows for the above manipulation is explained in most general statistics texts (li, 1966). The results of the analysis are given in Tables 3, 4, 5 and 6. Appendices B and C contain the F values at each level plus the breakdowns and the original contingency tables respectively.

Table 3. Statistical Summary for All Levels of the Design

Level	Compositional Category					
	Weak Sediments	Quartzose	Acid Igneous	Foliated Metamorphic	Limestone	Basic Igneous
Super Cluster						*
Cluster						
Pit	*	*	*	*	*	
HSU	*	*	*	*		*

* Significant at the 0.05 level ($\alpha = .05$)

Table 4. Orthogonal Breakdown At The Super Cluster Level For The Basic Igneous Category

Source	Degrees of Freedom	G/df	F
Super Clusters	36	16.71	2.78*
Spillway versus Non-spillway	6	15.73	2.619*
Major spillway versus Minor spillway	6	34.76	5.77*
East plus central versus West within major spillway super clusters	6	4.192	0.696 ns
East versus central within major spillway super clusters	6	16.86	2.80*
North versus South non-spillway super clusters	6	5.78	0.962 ns
East versus West non-spillway super clusters	6	23.38	3.87*
Clusters	66	6.01	

* Significant at 0.05 level ($\alpha = .05$)

ns non significant

Table 5. Summary for Breakdown Between Pits

Source	Compositional Category					
	Limestone	Weak Sediments	Quartzose	Acid Igneous	Basic Igneous	Foliated Metamorphic
Pits	*	*	*	*		*
Pit 6 versus Pit 7				*		
Pit 12 versus Pit 13	*	*	*			*
Pit 14 versus Pit 15	*			*		

* Significant at 0.05 level
($\alpha = .05$)

Table 6. Summary of Breakdown Between HSU's

Source	Compositional Category					
	Limestone	Weak Sediments	Quartzose	Acid Igneous	Basic Igneous	Foliated Metamorphic
HSU's		*	*	*	*	*
HSU 5 versus HSU 6		*			*	*
HSU 13 versus HSU 14		*		*		
HSU 15 versus HSU16		*		*		*
HSU 17 versus HSU 18		*	*		*	*
HSU 22 versus HSU 23 versus HSU 24			*		*	*
HSU 25 versus HSU 26		*	*	*	*	

* Significance at the .05 level ($\alpha = .05$)

RESULTS

INTRODUCTION

The results of the statistical analyses answer the questions: Does a nonrandom pattern of variation exist and at which levels does it reside? Examination of the basic descriptive statistics for the levels which are significantly different provides more detailed information on the patterns of variation. Reference to the relative resistance of each species (Figure 3) provides a basis for interpretation of the process intensity. If a comparison yields a nonsignificant result, then the size frequency distributions are not distinguishably different. It indicates that the geologic history of the materials for each case has produced the statistically indistinguishable size frequency distributions but it does not necessarily indicate that the geologic history in each case was the same. Significant differences cannot arise from compositional differences arising entirely from grain size effects. That is, spasmodic changes in water velocity at a single time and space favoring different sectors of the size frequency distribution will yield different total volumes of a detrital species. However, the proportional volumes between size classes from sample to sample should be similar. The analytic method chosen is only sensitive to disproportional differences. The results of the analysis indicate that a pattern of significant variation is present.

SUPER CLUSTERS

Significance at the super cluster level identifies a pattern of regional scale variation. Only the basic igneous category of all the compositional categories is significant at the super cluster level.

Reference to Figure 3 indicates that the basic igneous, acid igneous and quartzose categories are all considered to have high mechanical resistance. Of these three nonlocally derived categories the basic igneous are the least chemically resistant. In addition to the above considerations this investigator found in the field that the acid igneous compositions have maintained considerable integrity over an estimated period in excess of 1000 years, whereas the basic igneous compositions are falling apart due to weathering. This strongly suggests that the basic igneous compositions could not have survived for very long. Thus it appears that the acid igneous compositions are the result of past accumulations mixed with renewed influx, whereas the basic igneous compositions indicate only the latest episode.

The implications of this result cast the glacial sediment in quite a different light than heretofore mentioned. Many have argued in the past whether a given volume of sediment was a product of a particular stage, as resolved above. The last processes which moved the sediment may well have been due to the Wisconsinan stage. However, the material itself may have been progressively brought into the area by preceding glaciations. Thus, although land forms and the sedimentary structures and the patterns of grain size variation may be properly attributed to the Wisconsinan stage, a great proportion of the component clasts might well be Illinoian or Kansan in terms of the glacier that delivered them to the lower peninsula. Situations such as this have long been observed in purely fluvial systems where transport of the coarse fraction is quite slow and the major source of contribution is from the banks.

SPILLWAYS VERSUS NON SPILLWAYS

Super clusters 1, 2 and 3 within the old Grand River spillway and super cluster 4 within a smaller parallel spillway are compared with the non spillway locations, super clusters 5, 6 and 7 (Figure 4).

Results are significant from analysis of the basic igneous category. This result is not unexpected, as it reflects the shift in the size frequency distribution of the basic igneous toward the small sizes in the spillways (Table 7A). Inspection of the descriptive statistics associated with these distributions provide another means of verifying the results from the contingency tables.

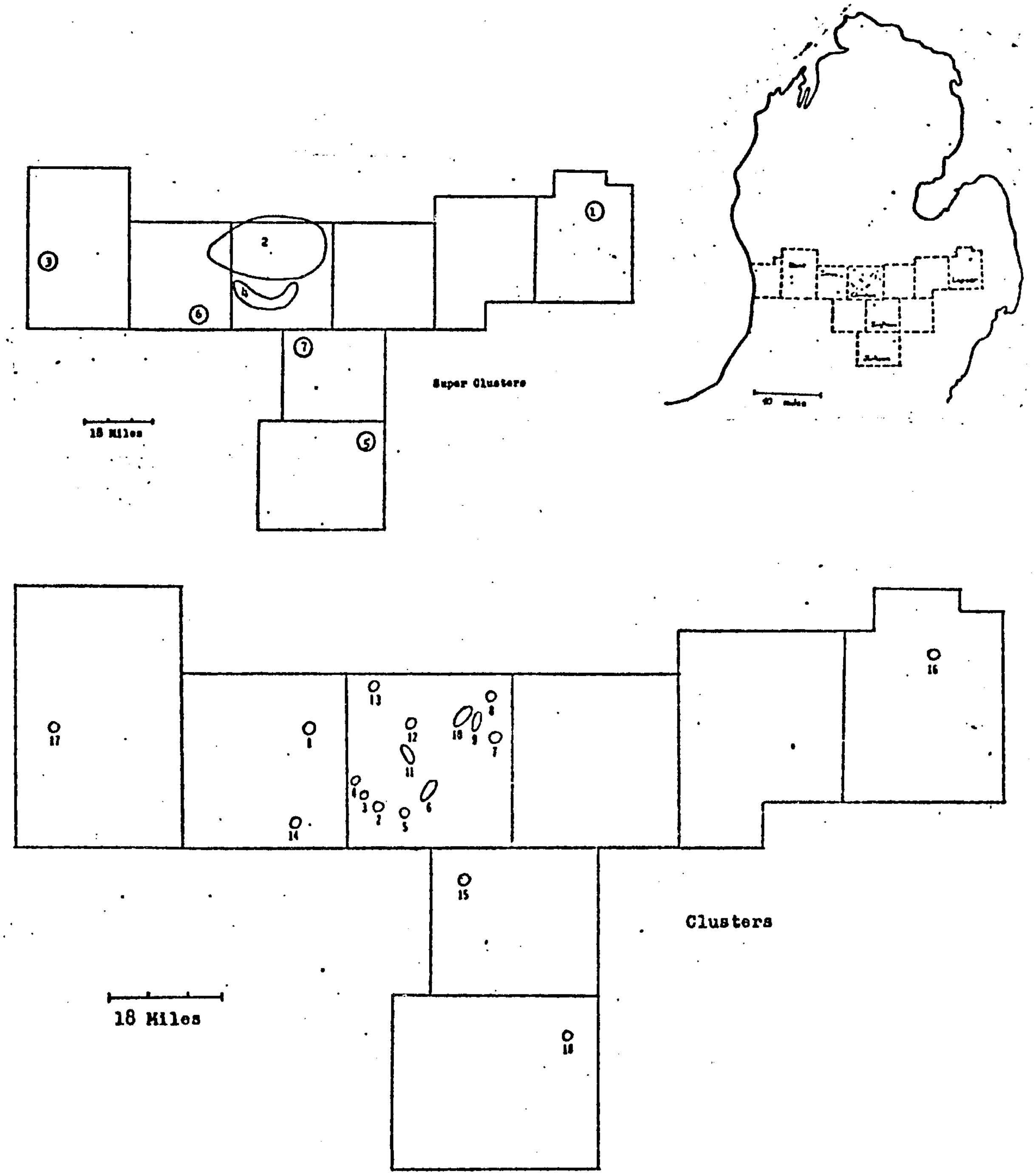
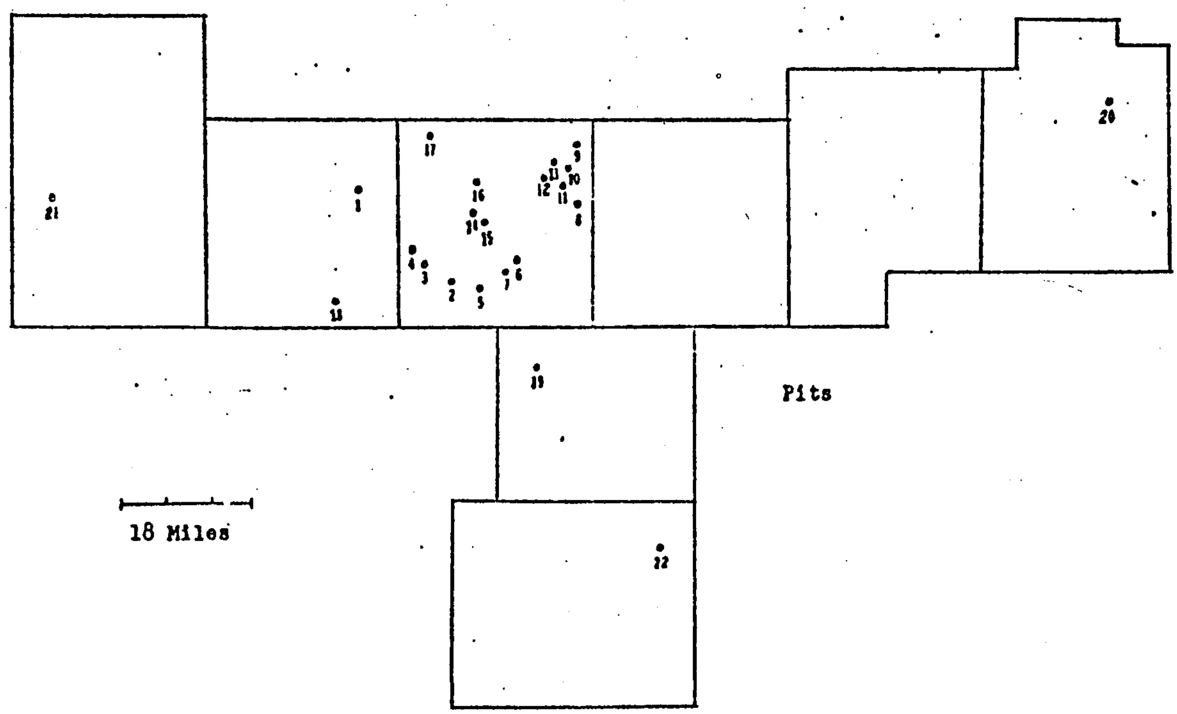


Figure 4. REFERENCE FOR GEOGRAPHIC LOCATION WITHIN THE VARIOUS LEVELS OF THE DESIGN



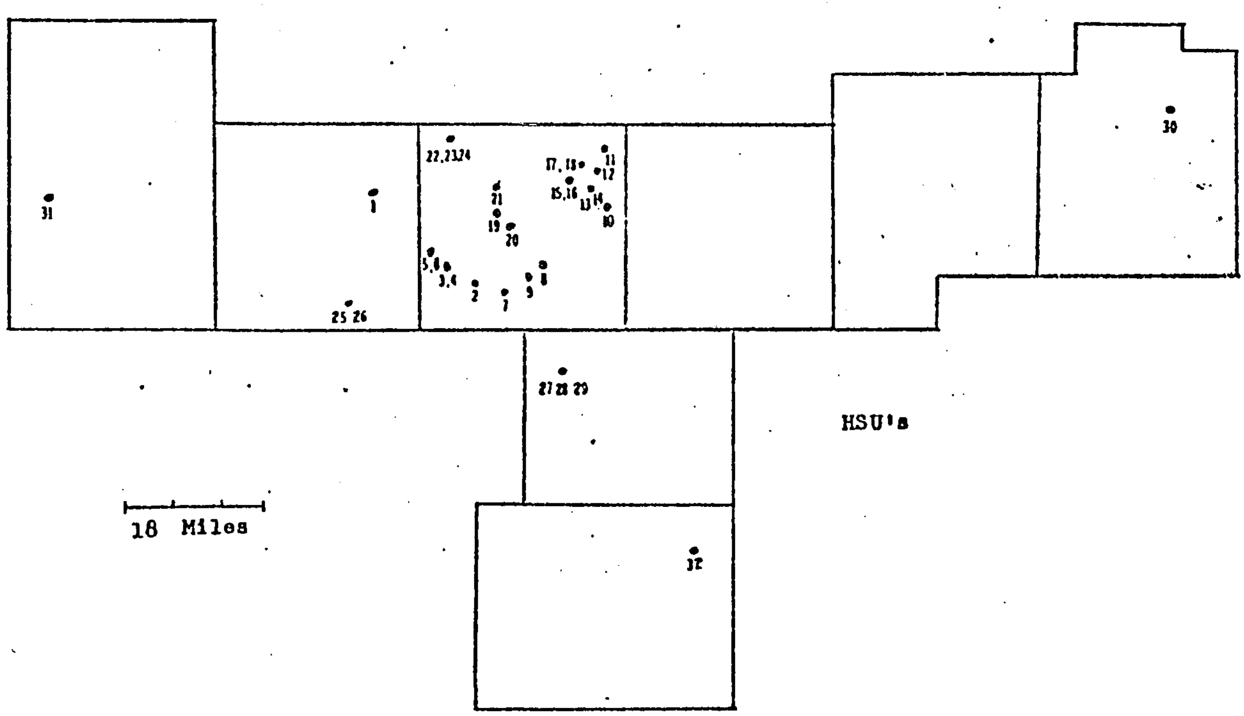


Figure 4. Continued

Table 7. SIZE FREQUENCY DISTRIBUTION, BASIC IGNEOUS

	Volume Class							
ID	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40
501	1081	582	194	20	75	60	0	40
502	232	157	81	40	25	0	0	0

G = 125.8772 for Total Set

7A

	Volume Class							
ID	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40
503	722	412	182	20	75	60	0	0
504	359	170	12	0	0	0	0	40

G = 278.1476 for Total Set

7B

	Volume Class							
ID	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40
505	680	399	182	20	75	60	0	0
517	42	13	0	0	0	0	0	0

G = 33.5404 for Total Set

7C

	Volume Class							
ID	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40
516	47	26	27	20	0	0	0	0
506	633	373	155	0	75	60	0	0

G = 134.9434 for Total Set

7D

	Volume Class							
ID	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40
518	42	44	54	0	0	0	0	0
504	104	83	27	40	25	0	0	0

G = 46.2939 for Total Set

7E

	Volume Class							
ID	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40
514	86	30	54	40	25	0	0	0
515	104	83	0	0	0	0	0	0

G = 187.0463 for Total Set

7F

Of the descriptive statistics, only the skewness is relevant because the mean is very sensitive to local hydrodynamics and because the standard deviation is proportional to the skewness, it is redundant. The skewness statistic, as discussed above in regard to the loss of the tail, provides for the most straight forward interpretation.

Inspection of Table 8 shows the difference in skewness between the spillways and non spillways.

The skewness values are four to six times greater, with the exception of the east end of the major spillway, for the spillways than the non spillways. This is contrary to that expected from the Plumley (1948) conclusions.

Assuming Plumley's (1948) argument is correct, we must suspect the upland sediment to be more mature. In view of the greater energy flux down the spillways, this result would at first glance seem paradoxical. However, once the basic igneous clasts were delivered to the uplands, the source of additional basic igneous pebbles was terminated. Then the material of the region was acted on by a complex of erosional and deposition processes due to the stablishment and evolution of the consequent drainage. At that time, as now, streams migrate across their floodplains eroding and depositing in an almost random fashion. Thus the net down valley

Table 8. Skewness Values for the Basic Igneous Category at the Super Cluster Level

Spillways			Non-spillways	
	Super Cluster	Skewness	Super Cluster	Skewness
Major	1	0.38	5	0.23
	2	1.55	6	0.32
	3	1.27	7	0.22
Minor	4	2.91		

Table 9. Skewness Values at the Pit Level

Compositional Category	Pits					
	6	7	12	13	14	15
Limestone	1.50	1.99	2.47	0.72	0.53	1.39
Weak Sediments		0.12	1.00	-0.59		1.48
Quartzose	-0.13	-0.41	1.36	-0.36	-0.22	-1.09
Acid Igneous	-0.89	0.71	0.88	0.024	-0.39	0.63
Foliated Metamorphic				-0.28	-1.91	

transport of the coarse fraction is almost nil. Kuenen (1950) estimates that in an alluvial plain it takes one million years for the average sand grain to move one mile. In contrast to the upland, where the contribution of basic igneous material ceased, the spillways could have remained open, thus continually receiving additional basic igneous material. Rather than the evolution of a drainage pattern, we have a fixed course drainage east to west with the head situated in glacial lakes, which being relatively still water would contribute little coarse sediment. Thus, in the drainage way, the water was contributed by the lakes and the material from the bed and sides of the drainage way.

The above suggests that much material resulted from major erosion in the materials through which the drainage way first passed. The rest of the material was derived from along its course.

Examination of Table 8 indicates that the most mature sediment in the spillway exists at the head. This is consonant with the theory that lake waters act most vigorously on the materials at the beginning portion of a developing channel.

Further down the spillway course the features (considered to be peripheral moraines of the Saginaw lobe) have provided a continual source of additional material.

It is in this way that the very low skewness values at the head and the very high skewness values in the central portion are explained.

Another lower skewness value at the mouth where the width of the spillway has decreased from greater than a mile in the central area to less than a mile is probably due to the concentration of fluvial energy by decreased channel size.

BETWEEN SPILLWAYS

Breakdown of the "between spillway super clusters" compares the major spillway (super clusters 1, 2 and 3) with the minor spillway (super cluster 4) (Figure 4). The significant result indicates a difference between the major and minor spillways. There appears to be a definite shift in the size frequency distribution of the basic igneous toward the smaller sizes in the major spillway (Table 7B). The higher skewness value for the minor spillway (2.91) is suggestive of the probable short life of this feature as a drainage way compared to the longer occupation of active channeled energy flux in the major spillway.

WITHIN THE MAJOR SPILLWAY

The next two comparisons in the breakdown examine the within major spillway variation. The first compares the central and eastern super clusters (1 and 2) with the eastern (super cluster 1, Table 7D) (Figure 4). The first comparison does not yield a significant result. This indicates a certain degree of homogeneity and uniformity within the drainage way. This conclusion could be tempered by the other comparison.

The second comparison does yield a significant result. This might have been expected; although the skewness values are apparently quite different (1.55 versus 0.38 respectively), the two locations have much in common. Both are situated at or near a lake water source. Thus, they might well be expected to reflect similar characteristics as their environmental conditions were probably very much alike. The difference which the skewness value is emphasizing is a function of the position in the spillway and availability of additional basic igneous material from the banks and bed of the spillway. However, because this result relies on such a small sample, it should be treated circumspectly. If the pattern of differences are truly regional differences, this again could be interpreted as the intense reworking at the head where the supply of additional material is limited.

NON-SPILLWAY SUPER CLUSTERS

The breakdown of the non-spillway super clusters first considers the north south comparison. This comparison (super cluster 6 plus 7 versus 5, Table 7E)

(Figure 4), does not yield a significant result. This demonstrates that over an area this size the complex events yield a uniform result. The material ultimately came from the north. Thus, the absence of a north-south direction clearly indicates the homogeneity. However, the comparison of the east (super cluster 7) versus west (super cluster 6) non spillway super cluster (Table 7F) (Figure 4), provides a significant result. The western super cluster (6) is proximal to a major morainal feature, thus emphasizing the differences due to a slightly different source.

It appears that the differences between spillways and within the uplands arise from a perturbing source within the lower peninsula. This is apparently the Saginaw lobe moraine.

SUMMARY AT THE SUPER CLUSTER LEVEL

Therefore, examination of the patterns at the super cluster level for the basic igneous category suggests that the differences between spillways and uplands (non spillways) is apparently due to local character in the uplands and constantly renewed source in the spillways. This also points up the importance of morainal material as a source.

INTRODUCTION TO REMAINDER OF HIERARCHY

As mentioned earlier, only the basic igneous category showed significance at the super cluster level.

In general, at the lower levels, many categories show significance, excepting the basic igneous category. The reasons for this were discussed above. Thus, significant patterns of the other rock types must be interpreted in light of patterns impressed by the latest energy cycle upon materials that have experienced earlier episodes. At the pit level (Table 5) rock types, except the basic igneous show significance. At the next level, the HSU level (Table 6), significant differences for the basic igneous reappears.

CLUSTERS WITHIN SUPER CLUSTERS

Variation between clusters, within super clusters, is a measure only of the variation between clusters within each super cluster. Only two super clusters contain more than one cluster. Both of these reside in the central portion of the study area (Figure 4). They both contain only spillway locations, no upland locations. The comparisons show nonsignificance, indicating process homogeneity at this scale. Because there were not enough clusters available in the upland regions, comparisons were not possible.

PITS WITHIN CLUSTERS WITHIN SUPER CLUSTERS

Variation between pits, within clusters within super clusters, assesses only the variation between pits within a cluster. All the clusters containing more than one pit are located in the central portion of the study area. Again, as with the higher level (clusters within super clusters), we are limited by the unavailability of sufficient sampling sites to the spillway locations.

Of the comparisons made, only three showed significant results. We take this to indicate we are just moving to a scale where quirks of local history are becoming apparent. That is, differences which are sporadic at this level become more apparent at the next lower level.

The variation at the pit level is local and therefore it is felt that a detailed discussion at this point does not serve a useful purpose. Detailed discussion at this level is contained in Appendix D.

HSU'S WITHIN PITS WITHIN CLUSTERS WITHIN SUPER CLUSTERS

The HSU's represent the lowest scale of variation investigated and analysed in this study. The results apply only between HSU's within a pit within a cluster within a super cluster and, thus, are relevant to the pattern of local scale variation only. Interpretation relies, in part, on the "law of superposition".

Of the six HSU comparisons showing significant results, one is located in the minor spillway, four are located in the central portion of the major spillway and one is located in the upland area south of the two spillways.

Because the variation at the HSU level is also at a local scale a detailed discussion at this point does not serve a useful purpose and therefore has been deferred to Appendix E.

CONCLUSIONS

Patterns of compositional variation do exist in the area studied. The method of analysis assures that these differences are not due to grain size and are also greater in magnitude than differences expected from chance variation.

Analysis of the patterns indicate, in general, that the record contained in the glaciofluvial sediments is not unlike a palimpsest in that, although the physiography, sedimentary structure and grain size are due to the Wisconsinan glaciations and deglaciations, a considerable amount of the material has apparently been recycled from pre-existing glacial sediments. The possibility exists that, with more detailed work, energy flux and transport cycles associated with earlier glaciations might be deduced by further examination of the pebbles in these Wisconsinan deposits. Furthermore, since the Pleistocene sediments that now mantle the lower peninsula may represent the sum total of past glaciations, it may be that the sediment contribution of each, including the Wisconsinan, was much less than was heretofore supposed.

These conclusions are based on the fact that only basic igneous rock fragments present significant variation at the regional level, whereas most of the other rock types show significance only at the lower levels. Mechanisms proposed to explain this concerns the comparatively like mechanical resistance of the basic and acid igneous rocks to their disparate chemical resistance. Whereas the acid igneous retain enough strength to be reworked by a renewed glacial event, the basic igneous do not last.

More careful examination of the patterns of variation of the basic igneous indicates the outwash in the morainal uplands is more mature than in the drainage ways. This is probably due to the fact that the transport of pebbles to the morainal areas was limited in time, whereas a constant influx of fresh material was available to the deep cutting spillways, particularly from the Saginaw lobe morainal area.

The Saginaw moraine prominent in the discussion of the provenance of the spillway material also are probable sources of upland material, as evidenced by the significance for upland pits closest to the moraines.

From analysis at the pit level, all rock types exhibit significant difference in only three pits. This indicates that a fine scale of variation exists which is approximately the distance between pits. Existence of significant variation of HSU's within pits further corroborates this fine scale of variation, probably due to local energy flux involving varying numbers of cycles of erosion and deposition, or at least varied energy fluxes during a single episode.

The conclusions of this thesis should offer encouragement to those who would like to supplement knowledge based on stratigraphy and geomorphology with sedimentological data in order to more clearly understand the nature of continental glaciation.

This study demonstrates that valid use of the pebble fraction can yield satisfying results without resort to great operational complexity or extremes in data reduction and analysis.

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APPENDICES

APPENDICES

APPENDIX A, CROSS REFERENCE FOR THE HIERARCHY

APPENDIX A

Cross Reference for the Hierarchy

SUPER Cluster	CLUSTER	PIT	HSU	SAMPLE
2	1	1	1	1 + 2
	2	2	2	3 + 4
	3	3	3	5 + 6
			4	7 + 8
4	4	4	5	9 + 10
			6	11 + 12
	5	5	7	13 + 14
	6	6	8	15 + 16
		7	9	17 + 18
	7	8	10	19 + 20
	8	9	11	21 + 22
		10	12	23 + 24
	9	11	13	25 + 26
2			14	27 + 28
		12	15	29 + 30
	10		16	31 + 32
		13	17	33 + 34
			18	35 + 36
	11	14	19	37 + 38
		15	20	39 + 40
	12	16	21	41 + 42

APPENDIX A (continued)

SUPER CLUSTER	CLUSTER	PIT	HSU	SAMPLE
			22	43 + 44
2	13	17	23	45 + 46
			24	47 + 48
6	14	18	25	49 + 50
			26	51 + 52
			27	53 + 54
7	15	19	28	55 + 56
			29	57 + 58
1	16	20	30	59 + 60
3	17	21	31	61 + 62
5	18	22	32	63 + 64

APPENDIX B, F VALUES AT EACH LEVEL PLUS THE BREAKDOWNS

Table B1. F Values for Limestone, All Levels

Source	df	G	"Corrected" G	"Corrected" df	G/df	F	df1	df2
Super Clusters	48	1066.70	1066.70	48	22.22	0.597	48	88
Clusters	136	4181.07	3114.37	88	37.20	1.424	88	32
Pits	168	5018.59	837.52	32	26.19	1.72*	32	80
HSU	248	6242.95	1224.36	80	15.3	1.25	80	256
Samples	504	9422.96	3180.01	256	12.42			

*Significant at 0.05 level
($\alpha = 0.05$)

Table B2. F Values for Weak Sediments, All Levels

Source	df	G	"Corrected" G	"Corrected" df	G/df	F	df1	df2
Super Clusters	36	556.09	556.09	36	11.58	1.069	36	66
Clusters	102	1507.50	951.41	66	10.81	1.218	66	24
Pits	126	1791.97	284.47	24	8.89	1.637*	24	60
HSU	186	2226.56	434.59	60	5.43	2.784*	60	192
Samples	378	2725.85	499.29	192	1.948			

* Significant at 0.05 level
($\alpha = 0.05$)

Table B3. F Values for Quartzose, All Levels

Source	df	G	"Corrected" G	"Corrected" df	G/df	F	df1	df2
Super Clusters	42	566.86	566.86	42	11.80	0.734	42	77
Clusters	119	1982.49	1415.63	77	16.09	0.869	77	28
Pits	147	2574.02	591.53	28	18.5	1.929*	28	70
HSU	217	3340.58	766.56	70	9.6	1.56*	70	224
Samples	441	4913.50	1572.92	224	6.15			

* Significant at 0.05 level ($\alpha = 0.05$)

Table B4. F Values for Acid Igneous, All Levels.

Source	df	G	"Corrected" G	"Corrected" df	G/df	F	df1	df2
Super Clusters	42	954.16	954.16	42	19.87	0.805	42	77
Clusters	119	3120.98	2166.82	77	24.62	1.148	77	28
Pits	147	3806.19	685.21	28	21.45	2.127*	28	70
HSU	217	4615.06	808.87	70	10.1	1.73*	70	224
Samples	441	6110.61	1495.55	224	5.845			

* Significant at 0.05 level ($\alpha = 0.05$)

Table B5. F Values for Basig Igneous, All Levels

Source	df	G	"Corrected" G	"Corrected" df	G/df	F	df1	df2
Super Clusters	36	802.39	802.39	36	16.71	2.78*	36	66
Clusters	102	1325.35	522.96	66	6.01	1.443	66	24
Pits	126	1458.58	133.23	24	4.16	0.825	24	60
HSU	186	1862.87	404.29	60	5.05	2.88*	60	192
Samples	378	2478.82	615.95	192	2.41			

* Significant at 0.05 level
($\alpha = 0.05$)

Table B6. F Value for Foliated Metamorphic, All Levels

Source	df	G	"Corrected" G	"Corrected" df	G/df	F	df1	df2
Super Clusters	24	198.66	198.66	24	4.138	0.967	24	36
Clusters	60	506.43	307.77	36	4.27	0.775	36	8
Pits	68	586.91	80.84	8	5.5	2.8*	8	24
HSU	92	685.37	94.46	24	1.965	5.04*	24	44
Samples	136	719.67	34.30	44	0.39			

* Significant at 0.05 level
($\alpha = 0.05$)

Table B7. F Values for Limestone, Between Pits

Source	df	"Corrected" G/df	F	df1	df2
Between Pits Within Clusters	32	26.19	1.72*	32	80
Cluster 6 Pit 6, 7	8	10.19	0.6661	8	80
Cluster 9 Pit 10, 11	8	6.724	0.4396	8	80
Cluster 10 Pit 12, 13	8	42.02	2.7470*	8	80
Cluster 11 Pit 14, 15	8	45.74	2.9899*	8	80
HSU's	80	15.3			

* Significant at 0.05 level ($\alpha = 0.05$)

Table B8. F Values for Weak Sediments, Between Pits

Source	df	"Corrected" G/df	F	df1	df2
Pits	24	8.89	1.637*	24	60
Cluster 6 Pit 6, 7	6	3.584	0.6604	6	60
Cluster 9 Pit 10, 11	6	2.336	0.4305	6	60
Cluster 10 Pit 12, 13	6	19.432	3.5789*	6	60
Cluster 11 Pit 14, 15	6	10.205	1.8797	6	60
HSU's	60	5.43			

* Significant at 0.05 level ($\alpha = 0.05$)

Table B9. F Values for Quartzose, Between Pits

Source	df	"Corrected" G/df	F	df1	df2
Pits	28	18.5	1.929*	28	70
Cluster 6 Pit 6, 7	7	14.9143	1.5536	7	70
Cluster 9 Pit 10, 11	7	15.148	1.5779	7	70
Cluster 10 Pit 12, 13	7	29.968	3.1218*	7	70
Cluster 11 Pit 14, 15	7	13.910	1.449	7	70
HSU's	70	9.6			

* Significant at 0.05 level ($\alpha = 0.05$)

Table B10. F Values for Acid Igneous, Between Pits

Source	df	"Corrected" G/df	F	df1	df2
Pits	28	21.45	2.127*	28	70
Cluster 6 Pit 6, 7	7	30.827	3.0522*	7	70
Cluster 9 Pit 10, 11	7	20,622	2.0419	7	70
Cluster 10 Pit 12, 13	7	12.568	1.2445	7	70
Cluster 11 Pit 14, 15	7	21.633	2.1419*	7	70
HSU's	70	10.1			

* Significant at 0.05 level ($\alpha = 0.05$)

Table B11. F Values for Foliated Metamorphic, Between Pits

Source	df	"Corrected" G/df	F	df1	df2
Pits	8	5.5	2.8*	8	24
Cluster 9 Pit 10, 11	4	2.562	0.6475	4	24
Cluster 10 Pit 12, 13	4	8.787	4.4727*	4	24
HSU's	24	1.965			

*Significant at 0.05 Level
(α = 0.05)

Table B12. F Values for Weak Sediments, Between HSU's

Source		df	"Corrected" G/df	F	df1	df2
HSU's		60	5.43	2.784*	60	192
Pit	HSU					
3	3, 4	6	2.099	1.0783	6	192
4	5,6	6	12.107	6.2157*	6	192
11	13, 14	6	5.624	2.8879*	6	192
12	15, 16	6	6.399	3.2858*	6	192
13	17, 18	6	13.315	6.8358*	6	192
17	22, 23, 24	12	2.907	1.4928	12	192
18	25, 26	6	6.71	3.4497*	6	192
19	27, 28, 29	12	1.1212	.5758	12	192
	Samples	192	1.948			

* Significant at 0.05 level
($\alpha = 0.05$)

Table B13. F Values for Quartzose, Between HSU's

Source		df	"Corrected" G/df	F	df1	df2
HSU's		70	9.6	1.56*	70	224
Pit	HSU					
3	3, 4	7	1.02	0.1661	7	224
4	5, 6	7	5.782	0.9404	7	224
11	13, 14	7	11.042	1.7957	7	224
12	15, 16	7	7.423	1.2072	7	224
13	17, 18	7	13.693	2.2268*	7	224
17	22, 23, 24	14	11.189	1.8195*	14	224
18	25, 26	7	14.098	2.2926*	7	224
19	27, 28, 29	14	10.189	1.6569	14	224
	Samples	224	6.15			

* Significant at 0.05 level
($\alpha = 0.05$)

Table B14. F Values for Acid Igneous, Between HSU's

Source		df	"Corrected" G/df	F	df1	df2
HSU's		70	10.1	1.73*	70	224
Pit	HSU					
3	3, 4	7	11.113	1.9011	7	224
4	5, 6	7	8.950	1.5315	7	224
11	13, 14	7	23.433	4.0092*	7	224
12	15, 16	7	12.093	2.0692*	7	224
13	17, 18	7	8.046	1.3768	7	224
17	22, 23, 24	14	6.146	1.0517	14	224
18	25, 26	7	12.970	2.2192*	7	224
19	27, 28, 29	14	6.104	1.0445	14	224
	Samples	224	5.845			

* Significant at 0.05 level
($\alpha = 0.05$)

Table B15. F Values for Basic Igneous, Between HSU's

Source		df	"Corrected" G/df	F	df1	df2
HSU's		60	5.5	2.88*	60	192
Pit	HSU					
3	3, 4	6	0.059	0.0246	6	192
4	5, 6	6	4.90	2.0334*	6	192
11	13, 14	6	4.533	1.8811	6	192
12	15, 16	6	2.330	0.9672	6	192
13	17, 18	6	12.776	5.3014*	6	192
17	22, 23, 24	12	4.880	2.0044*	12	192
18	25, 26	6	13.373	5.5494*	6	192
19	27, 28, 29	12	1.451	0.6023	12	192
	Samples	192	2.41			

* Significant at 0.05 level
($\alpha = 0.05$)

Table B16. F Values for Foliated Metamorphic, Between HSU's

Source		df	"Corrected" G/df	F	df1	df2
HSU's		24	1.965	5.04*	24	44
Pit	HSU					
4	5, 6	5	4.739	12.1530*	5	44
12	15, 16	5	2.782	7.1342*	5	44
13	17, 18	5	1.698	4.3550*	5	44
17	22, 23, 24	9	1.544	3.9600*	9	44
	Samples	44	0.39			

* Significant at 0.05 level
($\alpha = 0.05$)

APPENDIX C, ORIGINAL CONTINGENCY TABLES

Note: All zero columns are not used in the computation of the degrees of freedom.

Table C5 Limestone Super Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
116	206	123	30	40	25	30	0	0	0
100	4299	2009	1157	900	423	240	206	40	45
117	409	180	45	20	0	0	0	0	0
140	2412	1349	425	315	175	90	70	0	80
118	288	333	93	20	47	0	0	0	0
114	445	238	99	137	50	0	35	0	0
115	812	395	198	58	97	0	0	0	0

G = 1066,7094 FOR TOTAL SET

GSTAT/DEGREES OF FREEDOM 22,2231

Table C10 Weak sediments, Super Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
216	31	20	-0	-0	-0	-0	-0	-0	-0
220	260	138	18	60	75	57	35	-0	-0
217	41	16	-0	-0	-0	-0	-0	-0	-0
240	191	64	69	20	22	-0	-0	-0	-0
218	18	57	-0	-0	-0	-0	-0	-0	-0
214	25	0	0	20	50	30	0	0	0
215	23	35	0	0	0	0	0	0	0

G = 556,0906 FOR TOTAL SET

GSTAT/DEGREES OF FREEDOM 11,5852

Table C15 Quartzose Super Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
316	55	62	65	20	-0	-0	-0	-0	-0
320	581	377	140	195	94	90	70	0	42
317	46	20	15	-0	-0	-0	-0	-0	-0
340	312	118	81	84	50	60	-0	-0	-0
318	29	32	22	40	25	-0	-0	-0	-0
314	52	40	53	20	25	30	-0	-0	-0
315	99	83	84	40	25	-0	-0	-0	-0

G = 566,8604 FOR TOTAL SET

GSTAT/DEGREES OF FREEDOM 11,8096

Table C20 Acid igneous, Super Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
416	47	26	27	20	=0	=0	=0	=0	=0
420	716	498	205	153	169	90	70	160	=0
417	42	13	=5	=0	=0	=0	=0	=0	=0
440	344	174	92	57	75	207	35	=0	=0
418	67	76	27	20	0	30	35	=0	=0
414	113	71	57	0	0	30	35	=0	=0
415	96	85	0	0	0	0	35	=0	=0

G = 954,1688 FOR TOTAL SET

GSTAT/DEGREES OF FREEDOM 19,8785

Table C25 Basic igneous, Super Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
516	47	26	27	20	=0	=0	=0	=0	=0
520	633	373	155	0	75	60	=0	=0	=0
517	42	13	=0	=0	=0	=0	=0	=0	=0
540	359	170	12	0	0	0	0	40	=0
518	42	44	27	=0	=0	=0	=0	=0	=0
514	86	30	54	40	25	=0	=0	=0	=0
515	104	83	=5	=0	=0	=0	=0	=0	=0

G = 802,3952 FOR TOTAL SET

GSTAT/DEGREES OF FREEDOM 16,7166

Table C1 Total variation, limestone

ID.	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
101	81	58	54	60	25	0	0	0	0
102	95	46	30	40	25	60	0	0	0
103	140	65	72	20	0	0	0	0	45
104	130	58	45	57	0	0	0	0	45
105	100	42	15	40	25	0	0	0	0
106	146	41	15	0	0	0	0	0	0
107	89	105	60	40	0	0	0	0	0
108	197	58	0	0	0	0	0	0	0
109	115	19	12	0	0	0	35	0	0
110	140	56	39	20	0	30	0	0	0
111	158	84	12	20	0	0	0	0	0
112	122	62	0	60	0	60	0	0	0
113	194	50	12	0	0	0	0	0	0
114	125	77	30	18	0	0	35	0	0
115	127	123	43	0	25	0	0	0	0
116	161	76	15	20	0	0	0	0	0
117	241	69	39	0	25	0	0	0	0
118	166	48	0	0	25	0	0	0	0
119	89	0	29	66	25	0	33	0	45
120	97	63	56	20	0	0	35	40	0
121	160	49	0	40	0	0	0	0	0
122	193	60	27	40	25	0	0	0	0
123	144	58	45	20	0	30	0	0	0
124	177	117	30	20	0	0	0	0	0
125	104	45	30	40	0	30	0	0	0
126	71	60	98	60	0	0	0	0	0
127	94	88	45	20	0	0	0	0	0
128	176	49	0	0	25	0	0	0	0
129	111	36	0	20	25	0	0	0	0
130	169	82	27	0	0	30	0	0	0
131	231	42	0	0	0	0	0	0	0
132	175	42	12	0	0	0	0	0	0
133	73	46	87	58	50	0	0	0	0
134	131	82	33	20	0	0	0	0	0
135	101	51	24	58	0	30	0	0	0
136	125	55	78	20	25	0	0	0	0
137	90	54	42	40	25	0	33	0	0
138	116	83	15	0	25	60	70	0	0
139	115	114	114	40	50	0	0	0	0
140	91	72	54	60	0	0	0	40	0
141	133	100	54	40	25	0	0	0	0
142	152	58	54	20	25	0	0	0	0
143	202	86	23	20	0	0	0	0	0
144	184	73	27	38	0	0	35	0	0
145	139	30	27	20	25	0	0	0	0
146	171	29	45	0	23	0	0	0	0
147	173	102	0	20	0	0	0	0	0
148	136	79	0	0	0	0	0	0	0
149	111	54	12	40	0	0	0	0	0
150	59	70	15	60	25	0	0	0	0
151	132	76	30	0	25	0	0	0	0
152	143	38	42	37	0	0	35	0	0
153	106	71	27	40	47	0	0	0	0
154	114	57	15	0	0	0	0	0	0
155	137	44	84	0	25	0	0	0	0
156	221	71	45	0	0	0	0	0	0
157	82	51	12	18	25	0	0	0	0
158	152	101	15	0	0	0	0	0	0
159	98	39	15	0	25	30	0	0	0
160	108	84	15	40	0	0	0	0	0
161	205	61	30	0	0	0	0	0	0
162	204	119	15	20	0	0	0	0	0
163	145	175	66	20	0	0	0	0	0
164	143	158	27	0	47	0	0	0	0

G = 9422,9613 FOR TOTAL SET

Table C2 Limestone HSU's

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
101	176	104	84	100	50	60	0	0	0
102	270	123	117	77	0	0	0	0	90
103	246	83	30	40	25	0	0	0	10
104	286	163	60	40	0	0	0	0	10
105	255	75	51	20	0	30	35	0	0
106	280	146	12	80	0	60	0	0	0
107	319	127	42	18	0	0	35	0	0
108	288	129	58	20	25	0	0	0	0
109	407	117	39	0	50	0	0	0	0
110	186	63	85	86	25	0	68	40	45
111	353	109	27	80	25	0	0	0	0
112	321	175	75	40	0	30	0	0	0
113	175	105	128	100	0	30	0	0	0
114	270	137	45	20	25	0	0	0	0
115	280	118	27	20	25	30	0	0	0
116	406	84	12	0	0	0	0	0	0
117	204	128	117	78	50	0	0	0	0
118	226	106	102	78	25	30	0	0	0
119	206	137	57	40	50	60	103	0	0
120	206	186	165	100	50	0	0	40	0
121	285	158	109	60	50	0	0	0	0
122	386	159	50	58	0	0	35	0	0
123	310	59	72	20	48	0	0	0	0
124	309	181	0	20	0	0	0	0	0
125	170	124	27	100	25	0	0	0	0
126	275	114	72	37	25	0	35	0	0
127	220	126	42	40	47	0	0	0	0
128	358	115	129	0	25	0	0	0	0
129	234	152	27	18	25	0	0	0	0
130	206	123	30	40	25	30	0	0	0
131	409	180	45	20	0	0	0	0	0
132	288	333	93	20	47	0	0	0	0

G = 6242,9583 FOR TOTAL SET

Table C3 Limestone Pits

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
101	176	104	84	100	50	60	0	0	0
102	270	123	117	77	0	0	0	0	90
103	532	246	90	80	25	0	0	0	0
104	535	221	63	100	0	90	35	0	0
105	319	127	42	18	0	0	35	0	0
106	288	199	58	20	25	0	0	0	0
107	407	117	39	0	50	0	0	0	0
108	186	63	85	86	25	0	68	40	45
109	353	109	27	80	25	0	0	0	0
110	321	175	75	40	0	30	0	0	0
111	445	242	173	120	25	30	0	0	0
112	686	202	39	20	25	30	0	0	0
113	430	234	219	156	75	30	0	0	0
114	206	137	57	40	50	60	103	0	0
115	206	186	168	100	50	0	0	40	0
116	285	158	108	60	50	0	0	0	0
117	1005	399	122	98	48	0	35	0	0
118	445	238	99	137	50	0	35	0	0
119	812	395	198	58	97	0	0	0	0
120	206	123	30	40	25	30	0	0	0
121	409	180	45	20	0	0	0	0	0
122	288	333	93	20	47	0	0	0	0

G = 5018,5942 FOR TOTAL SET

Table C4 Limestone Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
101	176	104	84	100	50	60	0	0	0
102	270	123	117	77	0	0	0	0	90
103	532	246	90	80	25	0	0	0	0
104	535	221	63	100	0	90	35	0	0
105	319	127	42	18	0	0	35	0	0
106	695	316	97	20	75	0	0	0	0
107	186	63	85	86	25	0	68	40	45
108	353	109	27	80	25	0	0	0	0
109	766	417	248	160	25	60	0	0	0
110	1116	436	258	176	100	60	0	0	0
111	412	323	225	140	100	60	103	40	0
112	285	158	108	60	50	0	0	0	0
113	1005	399	122	98	48	0	35	0	0
114	445	238	99	137	50	0	35	0	0
115	812	395	198	58	97	0	0	0	0
116	206	123	30	40	25	30	0	0	0
117	409	180	45	20	0	0	0	0	0
118	288	333	93	20	47	0	0	0	0

G = 4181,0744 FOR TOTAL SET

Table C6 Total variation, weak sediments

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
201	1	0	0	0	0	0	0	0	0
202	0	44	0	0	0	0	0	0	0
203	9	0	0	0	0	0	0	0	0
204	1	0	0	0	0	0	0	0	0
205	11	20	0	0	0	0	0	0	0
206	13	16	0	0	0	0	0	0	0
207	15	6	0	0	0	0	0	0	0
208	13	0	0	0	0	0	0	0	0
209	6	0	43	20	0	0	0	0	0
210	9	0	0	0	0	0	0	0	0
211	17	0	0	0	0	0	0	0	0
212	14	10	0	0	0	0	0	0	0
213	18	0	0	0	0	0	0	0	0
214	19	12	0	0	0	0	0	0	0
215	8	0	0	0	0	0	0	0	0
216	12	0	0	0	0	0	0	0	0
217	18	0	0	0	0	0	0	0	0
218	8	0	15	0	22	0	0	0	0
219	0	0	0	20	0	0	0	0	0
220	8	0	0	0	0	0	0	0	0
221	18	8	0	0	25	0	0	0	0
222	2	0	0	0	0	0	0	0	0
223	9	0	0	0	0	0	0	0	0
224	7	0	0	0	0	0	0	0	0
225	5	0	0	0	0	0	0	0	0
226	15	8	0	0	0	0	0	0	0
227	1	0	0	0	0	0	0	0	0
228	13	0	0	0	25	0	0	0	0
229	17	17	15	0	0	27	0	0	0
230	9	16	0	0	0	0	0	0	0
231	13	0	0	0	0	0	0	0	0
232	10	0	0	0	0	0	0	0	0
233	4	0	0	20	0	0	0	0	0
234	8	7	15	20	0	0	0	0	0
235	3	0	0	0	25	0	0	0	0
236	7	0	0	0	0	0	0	0	0
237	14	0	0	0	0	0	0	0	0
238	11	0	0	0	0	0	0	0	0
339	2	8	0	0	0	0	0	0	0
240	5	0	0	0	0	30	35	0	0
241	4	0	0	0	0	0	0	0	0
242	4	13	0	0	0	0	0	0	0
243	20	0	0	0	0	0	0	0	0
244	27	10	0	0	0	0	0	0	0
245	9	0	0	0	0	0	0	0	0
246	2	0	0	0	0	0	0	0	0
247	5	0	15	0	0	0	0	0	0
248	7	7	0	0	0	0	0	0	0
249	7	0	0	0	25	0	0	0	0
250	3	0	0	20	0	30	0	0	0
251	8	0	0	0	0	0	0	0	0
252	7	0	0	0	25	0	0	0	0
253	0	0	0	0	0	0	0	0	0
254	8	0	0	0	0	0	0	0	0
255	4	13	0	0	0	0	0	0	0
256	4	0	0	0	0	0	0	0	0
257	5	6	0	0	0	0	0	0	0
258	2	16	0	0	0	0	0	0	0
259	14	8	0	0	0	0	0	0	0
260	17	12	0	0	0	0	0	0	0
261	16	0	0	0	0	0	0	0	0
262	25	16	0	0	0	0	0	0	0
263	13	17	0	0	0	0	0	0	0
264	5	0	0	0	0	0	0	0	0

G = 2725.8516 FOR TOTAL SET

Table C7 Weak sediments HSU's

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
201	1	44	-0	-0	-0	-0	-0	-0	-0
202	10	-0	-0	-0	-0	-0	-0	-0	-0
203	24	36	-0	-0	-0	-0	-0	-0	-0
204	28	6	-0	-0	-0	-0	-0	-0	-0
205	15	0	45	20	-0	-0	-0	-0	-0
206	31	10	-0	-0	-0	-0	-0	-0	-0
207	37	12	-0	-0	-0	-0	-0	-0	-0
208	20	-0	-0	-0	-0	-0	-0	-0	-0
209	26	0	15	0	22	-0	-0	-0	-0
210	8	0	0	20	-0	-0	-0	-0	-0
211	20	8	0	0	25	-0	-0	-0	-0
212	16	-0	-0	-0	-0	-0	-0	-0	-0
213	20	8	-0	-0	-0	-0	-0	-0	-0
214	14	0	0	0	25	-0	-0	-0	-0
215	26	33	15	0	0	27	0	0	0
216	23	-0	-0	-0	-0	-0	-0	-0	-0
217	12	7	15	40	-0	-0	-0	-0	-0
218	10	0	0	0	25	-0	-0	-0	-0
219	25	-0	-0	-0	-0	-0	-0	-0	-0
220	7	8	0	0	0	30	35	-0	-0
221	8	13	-0	-0	-0	-0	-0	-0	-0
222	47	10	-0	-0	-0	-0	-0	-0	-0
223	11	-0	-0	-0	-0	-0	-0	-0	-0
224	12	7	15	-0	-0	-0	-0	-0	-0
225	10	0	0	20	25	30	-0	-0	-0
226	15	0	0	0	25	-0	-0	-0	-0
227	8	-0	-0	-0	-0	-0	-0	-0	-0
228	8	13	-0	-0	-0	-0	-0	-0	-0
229	7	22	-0	-0	-0	-0	-0	-0	-0
230	31	20	-0	-0	-0	-0	-0	-0	-0
231	41	16	-0	-0	-0	-0	-0	-0	-0
232	18	17	-0	-0	-0	-0	-0	-0	-0

G = 2226.5625 FOR TOTAL SET

Table C8 Weak sediments Pits

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
201	1	44	-0	-0	-0	-0	-0	-0	-0
202	10	-0	-0	-0	-0	-0	-0	-0	-0
203	52	42	0	0	0	0	0	0	0
204	46	10	45	20	0	0	0	0	0
205	37	12	-0	-0	-0	-0	-0	-0	-0
206	20	-0	-0	-0	-0	-0	-0	-0	-0
207	26	0	15	0	22	-0	-0	-0	-0
208	8	0	0	20	-0	-0	-0	-0	-0
209	20	8	0	0	25	-0	-0	-0	-0
210	16	-0	-0	-0	-0	-0	-0	-0	-0
211	34	8	0	0	25	0	0	0	0
212	49	33	15	0	0	27	0	0	0
213	22	7	15	40	25	0	0	0	0
214	25	-0	-0	-0	-0	-0	-0	-0	-0
215	7	8	0	0	0	30	35	-0	-0
216	8	13	-0	-0	-0	-0	-0	-0	-0
217	70	17	15	0	0	0	0	0	0
218	25	0	0	20	50	30	0	0	0
219	23	35	0	0	0	0	0	0	0
220	31	20	-0	-0	-0	-0	-0	-0	-0
221	41	16	-0	-0	-0	-0	-0	-0	-0
222	18	17	-0	-0	-0	-0	-0	-0	-0

G = 1791,9775 FOR TOTAL SET

Table C9 Weak sediments Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
201	1	44	-0	-0	-0	-0	-0	-0	-0
202	10	-0	-0	-0	-0	-0	-0	-0	-0
203	52	42	0	0	0	0	0	0	0
204	46	10	45	20	0	0	0	0	0
205	37	12	-0	-0	-0	-0	-0	-0	-0
206	46	0	15	0	22	0	0	0	0
207	8	0	0	20	-0	-0	-0	-0	-0
208	20	8	0	0	25	-0	-0	-0	-0
209	50	8	0	0	25	-0	-0	-0	-0
210	71	40	30	40	25	27	0	0	0
211	32	8	0	0	0	30	35	0	0
212	8	13	-0	-0	-0	-0	-0	-0	-0
213	70	17	15	0	0	0	0	0	0
214	25	0	0	20	50	30	0	0	0
215	23	35	0	0	0	0	0	0	0
216	31	20	-0	-0	-0	-0	-0	-0	-0
217	41	16	-0	-0	-0	-0	-0	-0	-0
218	18	17	-0	-0	-0	-0	-0	-0	-0

G = 1507,5092 FOR TOTAL SET

Table C11 Total variation, Quartzose

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
301	9	0	0	0	0	0	0	0	0
302	31	6	0	0	0	0	0	0	0
303	23	21	0	0	0	0	0	0	0
304	14	6	12	0	0	30	0	0	0
305	15	26	15	40	0	0	0	0	0
306	43	6	24	0	0	0	0	0	0
307	18	8	15	0	0	0	0	0	0
308	29	19	0	16	0	0	0	0	0
309	14	0	0	0	0	0	0	0	0
310	23	0	0	0	0	0	0	0	0
311	22	0	0	0	25	0	0	0	0
312	13	0	0	20	0	0	0	0	0
313	17	0	0	0	0	0	0	0	0
314	23	12	0	0	0	0	0	0	0
315	15	0	15	0	0	0	0	0	0
316	2	10	0	18	0	0	0	0	0
317	20	0	0	0	0	0	0	0	0
318	21	10	0	0	25	30	0	0	0
319	11	20	0	0	0	0	0	0	0
320	9	14	0	0	22	0	0	0	42
321	3	37	0	20	0	30	0	0	0
322	16	23	15	0	0	0	0	0	0
323	25	20	15	0	0	0	0	0	0
324	19	22	0	0	0	0	0	0	0
325	6	0	0	18	0	0	0	0	0
326	12	30	12	0	0	0	0	0	0
327	17	10	15	20	0	0	35	0	0
328	9	0	0	17	0	0	35	0	0
329	16	10	15	0	0	0	0	0	0
330	29	31	0	0	0	0	0	0	0
331	64	6	0	0	0	0	0	0	0
332	44	8	0	0	0	0	0	0	0
333	3	16	0	0	0	0	0	0	0
334	7	0	15	0	0	0	0	0	0
335	11	0	0	20	22	0	0	0	0
336	9	20	0	40	25	0	0	0	0
337	2	7	0	20	0	30	0	0	0
338	2	14	0	0	0	0	0	0	0
339	7	0	15	0	0	0	0	0	0
340	1	8	15	0	0	0	0	0	0
341	15	0	12	0	0	0	0	0	0
342	21	25	0	0	0	0	0	0	0
343	31	7	23	0	0	0	0	0	0
344	29	7	0	0	0	0	0	0	0
345	41	6	0	0	0	0	0	0	0
346	52	12	27	20	0	0	0	0	0
347	13	8	0	0	0	30	0	0	0
348	17	20	15	20	25	0	0	0	0
349	5	23	26	0	23	0	0	0	0
350	11	0	0	20	25	0	0	0	0
351	29	17	15	0	0	30	0	0	0
352	7	0	12	0	0	0	0	0	0
353	5	0	30	40	0	0	0	0	0
354	16	16	12	0	0	0	0	0	0
355	21	16	5	0	0	0	0	0	0
356	27	15	27	0	25	0	0	0	0
357	8	18	0	0	0	0	0	0	0
358	22	18	15	0	0	0	0	0	0
359	25	22	24	20	0	0	0	0	0
360	30	40	42	0	0	0	0	0	0
361	29	14	0	0	0	0	0	0	0
362	17	6	15	0	0	0	0	0	0
363	18	17	22	0	0	0	0	0	0
364	11	15	0	40	25	0	0	0	0

G = 4913,5078 FOR TOTAL SET

Table C12 Quartzose HSU's

ID.	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
301	40	6	0	0	0	0	0	0	0
302	37	27	12	0	0	30	0	0	0
303	58	32	39	40	0	0	0	0	0
304	47	27	15	16	0	0	0	0	0
305	37	0	0	0	0	0	0	0	0
306	35	0	0	20	25	0	0	0	0
307	40	12	0	0	0	0	0	0	0
308	17	10	15	18	0	0	0	0	0
309	41	10	0	0	25	30	0	0	0
310	20	34	0	0	22	0	0	0	42
311	19	60	15	20	0	30	0	0	0
312	44	42	15	0	0	0	0	0	0
313	18	30	12	18	0	0	0	0	0
314	26	10	15	37	0	0	70	0	0
315	45	41	15	0	0	0	0	0	0
316	108	14	0	0	0	0	0	0	0
317	10	16	15	0	0	0	0	0	0
318	20	20	0	60	47	0	0	0	0
319	4	21	0	20	0	30	0	0	0
320	8	8	30	0	0	0	0	0	0
321	36	25	12	0	0	0	0	0	0
322	60	14	25	0	0	0	0	0	0
323	93	18	27	20	0	0	0	0	0
324	30	28	15	20	25	30	0	0	0
325	16	23	26	20	25	0	0	0	0
326	36	17	27	0	0	30	0	0	0
327	21	16	42	40	0	0	0	0	0
328	48	31	27	0	25	0	0	0	0
329	30	36	15	0	0	0	0	0	0
330	55	62	65	20	0	0	0	0	0
331	46	20	15	0	0	0	0	0	0
332	29	32	22	40	25	0	0	0	0

G = 3340,5852 FOR TOTAL SET

Table C13 Quartzose Pits

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
301	40	6	-0	-0	-0	-0	-0	-0	-0
302	37	27	12	0	0	30	-0	-0	-0
303	105	59	54	56	0	0	0	0	0
304	72	0	0	20	25	-0	-0	-0	-0
305	40	12	-0	-0	-0	-0	-0	-0	-0
306	17	10	15	18	-0	-0	-0	-0	-0
307	41	10	0	0	25	30	-0	-0	-0
308	20	34	0	0	22	0	0	0	42
309	19	60	13	20	0	30	-0	-0	-0
310	44	42	15	-0	-0	-0	-0	-0	-0
311	44	40	27	55	0	0	70	-0	-0
312	153	55	15	-0	-0	-0	-0	-0	-0
313	30	36	15	60	47	-0	-0	-0	-0
314	4	21	0	20	0	30	-0	-0	-0
315	8	6	31	-0	-0	-0	-0	-0	-0
316	36	25	12	-0	-0	-0	-0	-0	-0
317	183	60	65	40	25	30	-0	-0	-0
318	52	40	53	20	25	30	-0	-0	-0
319	99	83	84	40	25	-0	-0	-0	-0
320	55	62	65	20	-0	-0	-0	-0	-0
321	46	20	15	-0	-0	-0	-0	-0	-0
322	29	32	22	40	25	-0	-0	-0	-0

G = 2574,0265 FOR TOTAL SET

Table C14 Quartzose Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
301	40	6	-0	-0	-0	-0	-0	-0	-0
302	37	27	12	0	0	30	-0	-0	-0
303	105	59	54	56	0	0	0	0	0
304	72	0	0	20	25	-0	-0	-0	-0
305	40	12	-0	-0	-0	-0	-0	-0	-0
306	58	20	15	18	25	30	-0	-0	-0
307	20	34	0	0	22	0	0	0	42
308	19	60	15	20	0	30	-0	-0	-0
309	88	92	42	55	0	0	70	-0	-0
310	183	91	30	60	47	-0	-0	-0	-0
311	12	29	30	20	0	30	-0	-0	-0
312	36	25	12	-0	-0	-0	-0	-0	-0
313	183	60	65	40	25	30	-0	-0	-0
314	52	40	53	20	25	30	-0	-0	-0
315	99	83	84	40	25	-0	-0	-0	-0
316	55	62	66	20	-0	-0	-0	-0	-0
317	46	20	15	-0	-0	-0	-0	-0	-0
318	29	32	22	40	25	-0	-0	-0	-0

G = 1952,4918 FOR TOTAL SET

Table C16 - Total variation, Acid igneous

	Volume Class								
ID	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
401	15	12	0	0	0	0	0	0	0
402	26	36	27	0	25	0	0	80	0
403	16	12	0	0	25	0	0	0	0
404	24	16	12	0	0	30	0	0	0
405	15	0	27	17	0	0	0	0	0
406	29	21	0	0	0	0	0	0	0
407	17	10	38	0	0	0	35	0	0
408	1	0	0	0	0	0	0	0	0
409	25	24	0	0	0	0	0	0	0
410	22	18	0	20	0	0	0	0	0
411	35	14	0	0	0	0	0	0	0
412	24	6	0	0	25	0	0	0	0
413	30	0	0	0	0	30	0	0	0
414	22	13	0	0	0	30	0	0	0
415	8	16	0	0	25	60	0	0	0
416	17	18	0	0	0	57	0	0	0
417	26	6	0	0	0	0	0	0	0
418	33	0	15	20	0	0	0	0	0
419	3	6	0	0	0	0	0	40	0
420	3	0	0	0	0	0	0	40	0
421	17	22	0	0	0	0	0	0	0
422	25	10	0	0	0	0	0	0	0
423	18	50	0	0	0	30	0	0	0
424	37	0	0	0	0	0	0	0	0
425	13	7	0	0	0	30	35	0	0
426	19	8	27	0	0	0	0	0	0
427	17	10	15	20	47	0	0	0	0
428	20	0	0	0	0	0	0	0	0
429	22	51	15	38	0	0	0	0	0
430	40	0	0	18	0	0	0	0	0
431	56	24	15	0	0	0	0	0	0
432	53	0	0	0	0	0	0	0	0
433	8	6	14	0	0	0	0	0	0
434	7	0	0	0	0	0	0	0	0
435	12	68	0	0	0	0	0	0	0
436	11	18	0	0	0	0	0	0	0
437	15	14	0	0	0	0	0	0	0
438	8	6	0	0	0	30	35	0	0
439	17	15	30	0	0	0	0	0	0
440	9	26	0	0	25	0	0	0	0
441	9	0	0	0	0	0	0	0	0
442	23	10	0	0	0	0	0	0	0
443	46	27	23	17	47	0	0	0	0
444	59	6	27	0	0	0	0	0	0
445	28	6	27	40	0	0	0	0	0
446	35	14	0	0	0	0	0	0	0
447	30	24	15	0	0	0	0	0	0
448	15	22	0	20	25	0	0	0	0
449	36	24	27	0	0	30	0	0	0
450	23	24	15	0	0	0	0	0	0
451	27	17	15	0	0	0	0	0	0
452	27	6	0	0	0	0	35	0	0
453	8	16	0	0	0	0	0	0	0
454	13	20	0	0	0	0	35	0	0
455	24	0	0	0	0	0	0	0	0
456	26	13	0	0	0	0	0	0	0
457	13	23	0	0	0	0	0	0	0
458	12	13	0	0	0	0	0	0	0
459	21	8	15	0	0	0	0	0	0
460	26	18	12	20	0	0	0	0	0
461	30	6	0	0	0	0	0	0	0
462	12	7	0	0	0	0	0	0	0
463	30	6	0	0	0	0	0	0	0
464	37	70	27	20	0	30	35	0	0

G = 6110,6169 FOR TOTAL SET

Table C17 Acid igneous, HSU's

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
401	41	48	27	0	25	0	0	80	-0
402	40	28	12	0	25	30	-0	-0	-0
403	44	21	27	17	-0	-0	-0	-0	-0
404	18	10	38	0	0	0	35	-0	-0
405	47	42	0	20	-0	-0	-0	-0	-0
406	59	20	0	0	25	-0	-0	-0	-0
407	52	13	0	0	0	60	-0	-0	-0
408	25	34	0	0	25	117	-0	-0	-0
409	59	6	13	20	-0	-0	-0	-0	-0
410	6	6	0	0	0	0	0	80	-0
411	42	32	-0	-0	-0	-0	-0	-0	-0
412	55	50	0	0	0	30	-0	-0	-0
413	32	15	27	0	0	30	35	-0	-0
414	37	10	15	20	47	-0	-0	-0	-0
415	62	51	13	56	-0	-0	-0	-0	-0
416	109	24	15	-0	-0	-0	-0	-0	-0
417	15	6	14	-0	-0	-0	-0	-0	-0
418	23	86	-0	-0	-0	-0	-0	-0	-0
419	23	20	0	0	0	30	35	-0	-0
420	26	41	30	0	25	-0	-0	-0	-0
421	32	10	-0	-0	-0	-0	-0	-0	-0
422	105	33	50	17	47	-0	-0	-0	-0
423	63	20	27	40	-0	-0	-0	-0	-0
424	45	46	13	20	25	-0	-0	-0	-0
425	59	48	42	0	0	30	-0	-0	-0
426	54	23	13	0	0	0	35	-0	-0
427	21	36	0	0	0	0	35	-0	-0
428	50	13	-0	-0	-0	-0	-0	-0	-0
429	25	36	-0	-0	-0	-0	-0	-0	-0
430	47	26	27	20	-0	-0	-0	-0	-0
431	42	13	-0	-0	-0	-0	-0	-0	-0
432	67	76	27	20	0	30	35	-0	-0

G = 4615,0688 FOR TOTAL SET

Table C18 Acid igneous, Pits

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
401	41	48	27	0	25	0	0	80	-0
402	40	28	12	0	25	30	-0	-0	-0
403	62	31	65	17	0	0	35	-0	-0
404	106	62	0	20	25	-0	-0	-0	-0
405	52	13	0	0	0	60	-0	-0	-0
406	25	34	0	0	25	117	-0	-0	-0
407	59	6	15	20	-0	-0	-0	-0	-0
408	6	6	0	0	0	0	0	80	-0
409	42	32	-0	-0	-0	-0	-0	-0	-0
410	55	50	0	0	0	30	-0	-0	-0
411	69	25	42	20	47	30	35	-0	-0
412	171	75	30	56	-0	-0	-0	-0	-0
413	38	92	14	-0	-0	-0	-0	-0	-0
414	23	20	0	0	0	30	35	-0	-0
415	26	41	30	0	25	-0	-0	-0	-0
416	32	10	-0	-0	-0	-0	-0	-0	-0
417	213	99	92	77	72	-0	-0	-0	-0
418	113	71	57	0	0	30	35	-0	-0
419	96	85	0	0	0	0	35	-0	-0
420	47	26	27	20	-0	-0	-0	-0	-0
421	42	13	-0	-0	-0	-0	-0	-0	-0
422	67	76	27	20	0	30	35	-0	-0

G = 3806,1958 FOR TOTAL SET

Table C19 Acid igneous, Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
401	41	48	27	0	25	0	0	80	-0
402	40	28	12	0	25	30	-0	-0	-0
403	62	31	65	17	0	0	35	-0	-0
404	106	62	0	20	25	-0	-0	-0	-0
405	52	13	0	0	0	60	-0	-0	-0
406	84	40	15	20	25	117	-0	-0	-0
407	6	6	0	0	0	0	0	80	-0
408	42	32	-0	-0	-0	-0	-0	-0	-0
409	124	75	42	20	47	60	35	-0	-0
410	209	167	44	56	-0	-0	-0	-0	-0
411	49	61	30	0	25	30	35	-0	-0
412	32	10	-0	-0	-0	-0	-0	-0	-0
413	213	99	92	77	72	-0	-0	-0	-0
414	113	71	57	0	0	30	35	-0	-0
415	96	85	0	0	0	0	35	-0	-0
416	47	26	27	20	-0	-0	-0	-0	-0
417	42	13	-0	-0	-0	-0	-0	-0	-0
418	67	76	27	20	0	30	35	-0	-0

G = 3120,9836 FOR TOTAL SET

Table C21 Total variation, Basic igneous

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
501	45	46	30	0	0	60	0	0	0
502	30	6	0	0	0	0	0	0	0
503	19	0	0	0	0	0	0	0	0
504	17	36	12	0	0	0	0	0	0
505	24	15	0	0	0	0	0	0	0
506	30	13	0	0	0	0	0	0	0
507	23	8	0	0	0	0	0	0	0
508	28	25	0	0	0	0	0	0	0
509	38	18	0	0	0	0	0	40	0
510	32	23	0	0	0	0	0	0	0
511	16	0	0	0	0	0	0	0	0
512	13	0	0	0	0	0	0	0	0
513	20	6	0	0	0	0	0	0	0
514	9	6	0	0	0	0	0	0	0
515	21	6	12	0	0	0	0	0	0
516	35	14	0	0	0	0	0	0	0
517	22	0	0	0	0	0	0	0	0
518	12	0	0	0	0	0	0	0	0
519	30	20	0	0	0	0	0	0	0
520	33	16	14	0	0	0	0	0	0
521	12	0	0	0	0	0	0	0	0
522	7	16	15	0	0	0	0	0	0
523	12	12	0	0	0	0	0	0	0
524	22	13	0	0	0	0	0	0	0
525	22	22	30	0	25	0	0	0	0
526	19	7	0	0	0	0	0	0	0
527	16	20	15	0	0	0	0	0	0
528	19	20	0	0	0	0	0	0	0
529	22	0	12	0	0	0	0	0	0
530	23	6	0	0	0	0	0	0	0
531	10	0	0	0	0	0	0	0	0
532	17	13	0	0	0	0	0	0	0
533	12	19	27	0	0	0	0	0	0
534	34	8	15	0	0	0	0	0	0
535	2	10	0	0	0	0	0	0	0
536	12	24	0	0	25	0	0	0	0
537	20	0	0	0	0	0	0	0	0
538	9	12	12	0	0	0	0	0	0
539	8	14	0	0	0	0	0	0	0
540	0	0	0	0	0	0	0	0	0
541	1	0	0	0	0	0	0	0	0
542	7	0	0	0	0	0	0	0	0
543	35	10	0	0	0	0	0	0	0
544	34	15	0	0	25	0	0	0	0
545	38	6	12	0	0	0	0	0	0
546	28	12	0	0	0	0	0	0	0
547	20	6	0	0	0	0	0	0	0
548	34	20	0	0	0	0	0	0	0
549	36	6	15	0	0	0	0	0	0
550	8	7	39	20	0	0	0	0	0
551	23	7	0	20	0	0	0	0	0
552	19	10	0	0	25	0	0	0	0
553	17	6	0	0	0	0	0	0	0
554	12	28	0	0	0	0	0	0	0
555	24	0	0	0	0	0	0	0	0
556	26	13	0	0	0	0	0	0	0
557	13	23	0	0	0	0	0	0	0
558	12	13	0	0	0	0	0	0	0
559	21	8	15	0	0	0	0	0	0
560	26	18	12	20	0	0	0	0	0
561	30	6	0	0	0	0	0	0	0
562	12	7	0	0	0	0	0	0	0
563	29	30	27	0	0	0	0	0	0
564	13	14	0	0	0	0	0	0	0

G = 2478.8260 FOR TOTAL SET

Table C22 Basic igneous, HSU's

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
501	75	52	30	0	0	60	-0	-0	-0
502	36	36	12	-0	-0	-0	-0	-0	-0
503	54	28	-0	-0	-0	-0	-0	-0	-0
504	51	33	-0	-0	-0	-0	-0	-0	-0
505	70	41	0	0	0	0	0	40	-0
506	29	-0	-0	-0	-0	-0	-0	-0	-0
507	29	12	-0	-0	-0	-0	-0	-0	-0
508	56	20	12	-0	-0	-0	-0	-0	-0
509	34	-0	-0	-0	-0	-0	-0	-0	-0
510	63	36	14	-0	-0	-0	-0	-0	-0
511	19	16	15	-0	-0	-0	-0	-0	-0
512	34	25	-0	-0	-0	-0	-0	-0	-0
513	41	29	30	0	25	-0	-0	-0	-0
514	35	40	15	-0	-0	-0	-0	-0	-0
515	45	6	12	-0	-0	-0	-0	-0	-0
516	27	13	-0	-0	-0	-0	-0	-0	-0
517	46	27	42	-0	-0	-0	-0	-0	-0
518	14	34	0	0	25	-0	-0	-0	-0
519	29	12	12	-0	-0	-0	-0	-0	-0
520	8	14	-0	-0	-0	-0	-0	-0	-0
521	8	-0	-0	-0	-0	-0	-0	-0	-0
522	69	25	0	0	25	-0	-0	-0	-0
523	66	18	12	-0	-0	-0	-0	-0	-0
524	54	26	-0	-0	-0	-0	-0	-0	-0
525	44	13	54	20	-0	-0	-0	-0	-0
526	42	17	0	20	25	-0	-0	-0	-0
527	29	34	-0	-0	-0	-0	-0	-0	-0
528	50	13	-0	-0	-0	-0	-0	-0	-0
529	25	36	-0	-0	-0	-0	-0	-0	-0
530	47	26	27	20	-0	-0	-0	-0	-0
531	42	13	-0	-0	-0	-0	-0	-0	-0
532	42	44	27	-0	-0	-0	-0	-0	-0

G = 1862.8740 FOR TOTAL SET

Table C23 Basic igneous, Pits

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
501	75	52	30	0	0	60	-0	-0	-0
502	36	36	12	-0	-0	-0	-0	-0	-0
503	105	61	-0	-0	-0	-0	-0	-0	-0
504	99	41	0	0	0	-0	0	40	-0
505	29	12	-0	-0	-0	-0	-0	-0	-0
506	56	20	12	-0	-0	-0	-0	-0	-0
507	34	-0	-0	-0	-0	-0	-0	-0	-0
508	63	36	14	-0	-0	-0	-0	-0	-0
509	19	16	15	-0	-0	-0	-0	-0	-0
510	34	25	-0	-0	-0	-0	-0	-0	-0
511	76	69	45	0	25	-0	-0	-0	-0
512	72	19	12	-0	-0	-0	-0	-0	-0
513	60	61	42	0	25	-0	-0	-0	-0
514	29	12	12	-0	-0	-0	-0	-0	-0
515	8	14	-0	-0	-0	-0	-0	-0	-0
516	8	-0	-0	-0	-0	-0	-0	-0	-0
517	189	69	12	0	25	-0	-0	-0	-0
518	86	30	54	40	25	-0	-0	-0	-0
519	104	83	-0	-0	-0	-0	-0	-0	-0
520	47	26	27	20	-0	-0	-0	-0	-0
521	42	13	-0	-0	-0	-0	-0	-0	-0
522	42	44	27	-0	-0	-0	-0	-0	-0

G = 1458,5819 FOR TOTAL SET

Table C24 Basic igneous, Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
501	75	52	30	0	0	60	-0	-0	-0
502	36	36	12	-0	-0	-0	-0	-0	-0
503	105	61	-0	-0	-0	-0	-0	-0	-0
504	99	41	0	0	0	-0	0	40	-0
505	29	12	-0	-0	-0	-0	-0	-0	-0
506	90	20	12	-0	-0	-0	-0	-0	-0
507	63	36	14	-0	-0	-0	-0	-0	-0
508	19	16	15	-0	-0	-0	-0	-0	-0
509	110	94	45	0	25	-0	-0	-0	-0
510	132	80	54	0	25	-0	-0	-0	-0
511	37	26	12	-0	-0	-0	-0	-0	-0
512	8	-0	-0	-0	-0	-0	-0	-0	-0
513	189	69	12	0	25	-0	-0	-0	-0
514	86	30	54	40	25	-0	-0	-0	-0
515	104	83	-0	-0	-0	-0	-0	-0	-0
516	47	26	27	20	-0	-0	-0	-0	-0
517	42	13	-0	-0	-0	-0	-0	-0	-0
518	42	44	27	-0	-0	-0	-0	-0	-0

G = 1325,3534 FOR TOTAL SET

Table C26 Total variation, Foliated metamorphic

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
601	2	0	0	0	0	0	0	0	0
604	3	0	0	0	0	0	0	0	0
605	5	0	0	0	0	0	0	0	0
606	3	0	0	0	0	0	0	0	0
607	3	0	0	0	0	0	0	0	0
609	1	0	12	0	0	0	0	0	0
610	3	0	15	0	0	0	0	0	0
611	0	8	0	0	0	0	0	0	0
612	2	0	0	0	0	0	0	0	0
613	1	10	0	0	0	0	0	0	0
614	3	0	0	0	0	0	0	0	0
617	5	0	0	0	0	0	0	0	0
619	0	12	0	0	0	0	0	0	0
620	0	6	0	0	0	0	0	0	0
623	1	0	0	0	0	0	0	0	0
624	0	0	0	20	0	0	0	0	0
625	2	0	0	0	0	0	0	0	0
626	3	0	0	0	0	0	0	0	0
629	5	8	0	0	24	0	0	0	0
631	2	0	0	0	0	0	0	0	0
632	5	0	0	0	0	0	0	0	0
633	3	0	0	0	0	0	0	0	0
635	1	0	0	20	0	0	0	0	0
641	5	0	0	0	0	0	0	0	0
644	5	0	0	0	0	0	0	0	0
646	9	0	15	0	0	0	0	0	0
647	15	0	0	0	0	0	0	0	0
649	5	0	0	0	0	0	0	0	0
650	3	0	0	0	0	0	0	0	0
658	4	0	0	0	0	0	0	0	0
659	1	0	0	0	0	0	0	0	0
661	2	0	0	0	0	0	0	0	0
662	6	7	0	0	0	0	0	0	0
663	5	28	0	0	0	0	0	0	0
664	0	10	0	0	0	0	0	0	0

G = 719,6722 FOR TOTAL SET

Table C27 Foliated metamorphic, HSU's

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
601	2	-0	-0	-0	-0	-0	-0	-0	-0
602	3	-0	-0	-0	-0	-0	-0	-0	-0
603	8	-0	-0	-0	-0	-0	-0	-0	-0
604	3	0	0	0	0	0	0	0	0
605	4	0	27	-0	-0	-0	-0	-0	-0
606	2	8	-0	-0	-0	-0	-0	-0	-0
607	4	10	-0	-0	-0	-0	-0	-0	-0
609	5	0	0	0	0	0	0	0	0
610	0	18	-0	-0	-0	-0	-0	-0	-0
612	1	0	0	20	-0	-0	-0	-0	-0
613	5	-0	-0	-0	-0	-0	-0	-0	-0
615	5	8	0	0	24	-0	-0	-0	-0
616	7	-0	-0	-0	-0	-0	-0	-0	-0
617	3	0	0	0	0	0	0	0	0
618	1	0	0	20	0	0	0	0	0
621	5	0	0	0	0	0	0	0	0
622	5	0	0	0	0	0	0	0	0
623	9	0	15	0	0	0	0	0	0
624	15	0	0	0	0	0	0	0	0
625	8	-0	-0	-0	-0	-0	-0	-0	-0
629	4	0	0	0	0	0	0	0	0
630	1	0	0	0	0	0	0	0	0
631	8	7	-0	-0	-0	-0	-0	-0	-0
632	5	38	-0	-0	-0	-0	-0	-0	-0

G = 685,3799 FOR TOTAL SET

Table C28 Foliated metamorphic, Pits

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
601	2	-0	-0	-0	-0	-0	-0	-0	-0
602	3	-0	-0	-0	-0	-0	-0	-0	-0
603	11	-0	-0	-0	-0	-0	-0	-0	-0
604	6	8	27	-0	-0	-0	-0	-0	-0
605	4	10	-0	-0	-0	-0	-0	-0	-0
607	5	0	0	0	0	0	0	0	0
608	0	18	-0	-0	-0	-0	-0	-0	-0
610	1	0	0	20	-0	-0	-0	-0	-0
611	5	0	0	0	0	0	0	0	0
612	12	8	0	0	24	-0	-0	-0	-0
613	4	0	0	20	-0	-0	-0	-0	-0
616	5	-0	-0	-0	-0	-0	-0	-0	-0
617	29	0	15	-0	-0	-0	-0	-0	-0
618	8	-0	-0	-0	-0	-0	-0	-0	-0
619	4	-0	-0	-0	-0	-0	-0	-0	-0
620	1	0	0	0	0	0	0	0	0
621	8	7	-0	-0	-0	-0	-0	-0	-0
622	5	38	-0	-0	-0	-0	-0	-0	-0

G = 556,9114 FOR TOTAL SET

Table C29 Foliated metamorphic, Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
601	2	-0	-0	-0	-0	-0	-0	-0	-0
602	3	-0	-0	-0	-0	-0	-0	-0	-0
603	11	-0	-0	-0	-0	-0	-0	-0	-0
604	6	8	27	-0	-0	-0	-0	-0	-0
605	4	10	-0	-0	-0	-0	-0	-0	-0
606	5	0	0	0	0	0	0	0	0
607	0	18	-0	-0	-0	-0	-0	-0	-0
609	1	0	0	20	-0	-0	-0	-0	-0
610	16	8	0	20	24	-0	-0	-0	-0
612	5	-0	-0	-0	-0	-0	-0	-0	-0
613	29	0	15	-0	-0	-0	-0	-0	-0
614	8	-0	-0	-0	-0	-0	-0	-0	-0
615	4	-0	-0	-0	-0	-0	-0	-0	-0
616	1	0	0	0	0	0	0	0	0
617	8	7	-0	-0	-0	-0	-0	-0	-0
618	5	38	-0	-0	-0	-0	-0	-0	-0

G = 506,4383 FOR TOTAL SET

Table C30 Foliated metamorphic, Super Clusters

ID	Volume Class 1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
616	1	0	0	0	0	0	0	0	0
620	53	26	15	40	24	-0	-0	-0	-0
617	8	7	-0	-0	-0	-0	-0	-0	-0
640	29	18	27	-0	-0	-0	-0	-0	-0
618	5	38	-0	-0	-0	-0	-0	-0	-0
614	8	-0	-0	-0	-0	-0	-0	-0	-0
615	4	-0	-0	-0	-0	-0	-0	-0	-0

G = 198,6638 FOR TOTAL SET

GSTAT/DEGREES OF FREEDOM 4,1388

APPENDIX D, DETAILED DISCUSSION AT PIT LEVEL

APPENDIX D

Between Pit 12 and Pit 13

The limestone and weak sediments categories both show significant differences between pit 13 and pit 12 (cluster 10). Both of these compositional categories are probably from within the lower peninsula and are not very durable. Thus, they are very likely not far traveled. They probably do not lie very far from their subcrop, thereby strengthening the idea of mixing rather than long distance transport for individual clasts. The difference in skewness values (Table 9) shows that both categories indicate a more mature state in the pit 13 position (Figure 4). This is in agreement with their relative positions on opposite sides of a subcrop contact which provides for the contribution of additional material to the more southerly pit 12 position.

The foliated metamorphic compositions are even less durable than the above discussed compositional categories and, as they are not of local derivation, they are indicators of the later or last episode of energy flux to effect these positions. As might have been expected, the skewness values (Table 9) for the more southerly pit 12 position indicate greater maturity for the foliated metamorphic material. This emphasizes the reason for the differences shown by the previous two categories: 1) the addition of new material of probably local source and 2) the mixing and remixing which would have surely decreased the amount of less durable material if an additional influx was not available, in this case the foliated metamorphic compositions. Field observations tend to support this conclusion of very poor relative durability of the foliated metamorphic compositions, as the individual clasts were in almost every instance in an advanced state of deterioration.

The quartzose category provides the only other compositional category for which significant differences were found for the pit 12 and pit 13 comparison. The skewness values (Table 9) for the quartzose category show the pit 13 position having greater maturity. This is the same result as for the limestone and weak sediments and, in this case, is most likely not due to the additional incorporation of quartzose material between pit 13 and pit 12. The tremendous durability of the quartzose compositions, relative to the limestone and weak sediments, suggest long time preservation in this environment rather than addition from a nearby subcrop.

Between Pit 14 and Pit 15

Pit 14 is northwest of pit 15 and both are located in the central portion of the major spillway (super cluster 2, cluster 11, Figure 4). The limestone and acid igneous categories are the only compositional categories which show significance. This provides a comparison of a local, not very durable derivative and a non local, very durable compositional category.

The skewness values (Table 9) for both categories suggest the pit 14 position having greater maturity. It should be noted here that the skewness values for the more durable acid igneous compositions are negative, whereas they are positive for the less durable limestone compositions. This does not say that this negative versus positive skewness could serve as an additional measure of durability. However, as can be observed for the compositions showing significant differences between pits 12 and 13, there does seem to be a relationship to the relative durability. The negative skewness indicates the drawing out of the left tail. In this case, the smaller size by volume clasts are fewer volumetrically. Thus, lithologic species which are not durable would decrease in size when destructively acted upon, thereby increasing the volume of smaller size clasts. Conversely, the more durable species would provide a lesser volume of smaller size clasts under similar destructive circumstances.

In both cases, the skewness values suggest that influx of additional material, resulting in mixing of older with newer material, is responsible for the indicated pattern.

Between Pit 6 and Pit 7

The acid igneous category is the only significant compositional category for this comparison. Pit 6 and pit 7 are in cluster 6, which is the easternmost cluster in the minor spillway (Figure 4). Pit 6 is slightly north and east of Pit 7. The skewness values (Table 9) show a change from negative skewness to positive skewness going from pit 6 to pit 7 or in the direction of the considered flow for this minor spillway. This increase in volume of smaller size clasts of acid igneous material suggests attrition with little addition of newer material. However, it is felt that, due to the small proportion of acid igneous materials in these samples and the lack of significant results for any of the other compositions, this result should not be relied upon too heavily.

APPENDIX E, DETAILED DISCUSSION AT HSU LEVEL

APPENDIX E

Between HSU 5 and HSU 6

HSU 5 and HSU 6 are located in pit 4, which is the most western pit in the minor spillway (Figure 4). HSU 6 is the stratigraphically lower unit (older). The skewness values (Table 10) indicate an increase in the volume of larger size material from HSU 6 time (older) to HSU 5 time for two (weak sediments and foliated metamorphic categories) of the three compositional categories showing significant differences. The proportion of basic igneous material in HSU 6 precluded the computation of a valid skewness value. This result points to the vagaries of local scale transport and, in the case of foliated metamorphic compositions, hints at the effect of local scale process intensity on these nondurable lithologic species.

Between HSU 13 and HSU 14

HSU 13 and HSU 14 are located in pit 11, which is in the eastern part of the central portion of the major spillway (Figure 4). HSU 13 is the older unit. The weak sediments (local and nondurable) and acid igneous (non-local and durable) are the compositional categories showing significant results. As in the above comparison, the skewness values (Table 10) indicate an increase in the volume of large size material from older (HSU 13) to younger (HSU 14) for both categories. It should be pointed out

Table 10. Skewness Values at the HSU Level

Compositional Category	HSU												
	5	6	13	14	15	16	17	18	22	23	24	25	26
Weak Sediments	-0.91	1.23	1.0	-0.61	0.73		-0.93	-0.99	1.75		0.18	-1.38	-0.53
Quartzose		-0.13	0.30	-0.26	0.50	2.44	-0.22	-0.83	0.82	0.88	0.01	-0.54	0.58
Acid Igneous	1.02	1.06	-0.02	-0.27	0.28	1.58	0.06	-1.43	0.53	0.24	0.53	1.09	0.81
Basic Igneous	1.01		0.64	0.35	1.24	0.77	0.07	-0.49	1.23	1.31	0.76	-0.11	0.27
Foliated Metamorphic	-2.32	-1.77			-0.75			-4.58		-0.55			

that this is not actually an increase from one HSU to the next. It is merely a shift in the size frequency distributions.

Between HSU 15 and HSU 16

HSU 15 and HSU 16 (pit 12) are located in the eastern part of the central portion of the major spillway, slightly west and north of HSU's 13 and 14 (Figure 4). HSU 16 is the older unit. These compositional categories provided significant results. Of these, it was not possible to compute valid skewness values for both HSU's for the foliated metamorphic and weak sediments categories. The skewness values for the acid igneous category (Table 10) indicate greater maturity for the younger (HSU 15). This may be a reflection of the mixing and remixing with each successive pulsation of glaciofluvial energy.

Between HSU 17 and HSU 18

HSU 17 and HSU 18 (pit 13) are located to the north and east of the previous HSU's compared (Figure 4). HSU 17 is the older unit. Four compositions show significant differences. It was not possible to compute a valid skewness value for both HSU's for the foliated metamorphic category. The skewness values (Table 10) for the remaining three compositional categories, weak sediments, quartzose and basic igneous indicate greater maturity for HSU 17 (older) for all three categories. Considering the difference in durability and the local and nonlocal derivation for these compositional categories, it is apparent that at this local level a balance of the effects of depositional and transport process intensity is obtained.

Between HSU's 22, 23 and 24

HSU's 22, 23 and 24 (pit 17) are located in the northwestern part of the central portion of the major spillway (Figure 4). HSU 22 is the oldest unit and HSU 24 is the youngest unit. The quartzose, basic igneous and foliated metamorphic categories yield significant results.

It was not possible to compute a valid skewness value for the foliated metamorphic category for two of the three HSU's. The skewness values (Table 10) for the remaining two categories indicate an overall increase in maturity from the oldest to youngest. The similar results with the disparity here in relative durability is again evidence of the addition of newer material (the presence of the very weak basic igneous) and reworking.

Between HSU 25 and HSU 26

HSU 25 and HSU 26 (pit 18) are located southwest of the minor spillway in an upland area (Figure 4). HSU 26 is the older unit. The weak sediments, quartzose, acid igneous and basic igneous categories show significance. The skewness values (Table 10) for all four categories indicate greater maturity for the older unit (HSU 26). Again, the disparity in source and durability demonstrate by similar results the continued addition and reworking of the glaciofluvial sediments.