STRATIGRAPHY, SEDIMENTOLOGY, VOLCANOLOGY, AND DEVELOPMENT OF THE ARCHEAN MANITOU GROUP, NORTHWESTERN ONTARIO, CANADA

By

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ABSTRACT

The Archean Manitou Group occurs as a northeast-southwest trending arcuate belt in the central part of the Wabigoon greenstone belt, northwestern Ontario. The Manitou Group is mainly conglomerate, sandstone, tuff, tuff-breccia, and argillite, with minor lavas (somewhat alkaline), and iron formation. Mapping has established four formations: the Cane Lake, Sunshine Lake, Uphill Lake, and Mosher Bay. The Uphill Lake includes two members: the Surprise Lake and Rush Bay.

The Manitou Group lies upon a thick sequence of pillowed and massive basalts with minor volcanogenic sandstones and argillites. They formed a large submarine platform upon which the pyroclastic and sedimentary units of the Manitou Group were constructed.

The Cane Lake Formation is dominated by thick, massive, heterolithic tuff-breccias deposited as lahars and ignimbrites, with minor air-fall tuffs. They form a subaerial volcanic pile built up by explosive volcanic activity and modified by very minor aqueous reworking.

The Sunshine Lake Formation partly intertongues with, and partly overlies the Cane Lake formation. It is composed of intermediate, somewhat alkalic, massive subaerial lava flows.

The Uphill Lake Formation overlies the Sunshine Lake Formation and intertongues with the Cane Lake Formation. Near the Cane Lake Formation, the Uphill Lake Formation consists of massive, coarse pyroclastic breccias identical to the Cane Lake Formation, but away from the contact (northeastward), it grades into more thinly bedded volcanogenic conglomerate and sandstone with rare cross-bedding. This portion of the formation has been interpreted as an alluvial fan composed of reworked material derived from the volcanic cone of the Cane Lake Formation. Further east, the Uphill Lake Formation is not exclusively volcanogenic but also contains granite, iron formation, chert, and quartz clasts, and displays abundant large-scale (up to 1 m) cross-bedding in both conglomerates and sandstones.

This eastern part of the formation represents the deposits of a braided fluvial system.

The Surprise Lake Member occurs near the base of the Uphill Lake Formation and is a small, thin unit of laminated siltstone and argillite considered to represent a lacustrine deposit.

The Rush Bay Member is a highly variable group of siltstones, argillites, volcanogenic and quartzose sandstones, conglomerates, tuffs, and tuff-breccias occupying the top of the Uphill Lake Formation. From its stratigraphic position, the member could be interpreted as a coastal or shallow marine deposit, but, unfortunately, it is entirely without any diagnostic features.

The Mosher Bay Formation is an assemblage of argillites, sandstones, conglomerates, and minor iron formation of the Resedimented Association at the top of the Manitou Group. The sandstones are classical turbidites, and the conglomerates are confined to lenses. The lenses probably represent channels cut into the finer sediments, on a series of submarine fans. The presence of these deep-marine conglomerates and the terrestrial conglomerates of the Uphill Lake Formation at Manitou negates the notion that conglomerates define basin margins.

Paleoflow data for the Cane Lake and Uphill Lake Formations indicate that a single pyroclastic cone to the west shed volcanic debris, whereas in the east a braided stream deposited material from a different source.

There is wide variability among the Archean greenstone belts described to date. However, they commonly have 1) a mafic volcanic base upon which a felsic volcanic pile is built, 2) Non-marine Association sedimentary rocks followed stratigraphically by the Resedimented Association, 3) a lack of identifiable shallow-marine or coastal deposits, 4) terrestrial sedimentary environments indicative of high relief, and 5) sialic debris introduced early. Increased sialic contents stratigraphically upwards appear to be related more to diminishing volcanism than increased exposure of plutons. These suggest that Canadian Archean landmasses were small, had high relief and steep shorelines, were composed of mixed volcanic and plutonic rocks, and were tectonically active. This contrasts sharply with the stable continents of the South African Shield.

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CHAPTER I

ARCHEAN SEDIMENTATION: A REVIEW OF SOME OF THE PROBLEMS IN RELATION TO THE MANITOU LAKE AREA

Although the Archean has been defined as "... the basement complex ....in which ordinary stratigraphic methods are not applicable" (Leith, Lund and Leith, 1935), it has long ago been shown that parts of the Archean will yield to stratigraphic analysis (Pettijohn, 1970). A number of papers amply illustrate the degree of sophistication possible in such analyses (for example: McGlynn and Henderson, 1970; Turner, 1972; Turner and Walker, 1973; Walker and Pettijohn, 1971; Campbell, 1971; Henderson, 1972; Hyde, 1975 and Teal, 1975). Nevertheless, there are many outstanding problems; for example (a) stratigraphy and correlation, (b) sedimentary interpretations, and (c) provenance and basin evolution. Turner (1972) and Turner and Walker (1973) have discussed some of these problems extensively, and much of their discussion remains valid today, in spite of a recent renewal of interest in Archean sedimentation. The following is a review of these problems with particular emphasis upon their application to the sedimentary belt at Manitou Lake, Northwestern Ontario, and the potential contributions towards local and general solutions this area has to offer.

Stratigraphy and Correlation

In order to understand the environments of deposition of sediments and the evolution of a basin, it is necessary to have an accurate, detailed stratigraphy of both the sedimentary and volcanic rocks. However, earlier maps of the Archean were drawn only on a reconnaissance scale, and many recent studies lack a detailed stratigraphy.

No detailed map of the Manitou area existed before this study began in 1972. Early reconnaissance mapping (Thomson, 1933) and recent detailed mapping (Blackburn, 1976a, 1976b, 1976c) did not establish a detailed stratigraphy, and Pettijohn's (1937) map covers only a small portion of the belt.

The area is generally well exposed, particularly along lake shores where waves and fluctuating water levels leave outcrops clear of both lichen and algae. Moreover, exposures inland are frequently good enough for major contacts to be accurately traced and often directly observed in outcrop.

Early mapping in this study established a stratigraphy and determined that the sedimentary belt is essentially monoclinal (Chapter II). Most of the outcrops do not show evidence of strong deformation.

Manitou Lake, then, is a well-exposed area with few structural complications, for which there has been established a stratigraphy that can be used as a basis for determining paleoenvironments and basin evolution.

Sedimentary Interpretations

Before 1940, many of the coarse sediment accumulations in greenstone belts were thought to be continental deposits (Pettijohn, 1943), but this interpretation must be re-examined in the light of the work of Walker and Pettijohn (1971) in the Minnitaki Lake area, which showed that the conglomerates there are resedimented, and associated with proximal turbidites. In fact, most Archean sediments are of the Resedimented Association (Turner and Walker, 1973), mainly turbidites. Studies by Donaldson and Jackson (1965), Campbell (1971), Walker and Pettijohn (1971), McGlynn and Henderson (1970), Ojakangas (1972), Peeling (1974), and particularly Henderson (1972) indicate the prevalence of turbidites in the Archean.

On the other hand, descriptions of shallow, agitated-water or terrestrial sediments are relatively rare.

The only well-documented terrestrial sediments are those of the alluvial fan deposits in the Sioux Lookout area (Turner, 1972; Turner and Walker, 1973), the braided fluvial deposits with minor lacustrine and eolian deposits near Kirkland Lake (Hyde, 1978).

A report (Pettijohn, 1937) of large scale cross-bedding (sets thicker than 10 cm) suggests terrestrial sedimentation at the eastern end of the Manitou Lake area. Shallow-water deposition has also been suggested for some cross-bedded sandstones in the North Spirit Lake area (Donaldson and Jackson, 1965), for cross-stratified graywacke of the Rouyn-Noranda area of Quebec (Holubec, 1972), and for the Kurrawang Beds in Australia (Glikson, 1971). Anhaeusser et al. (1968) list trough cross-bedding, ripple marks, mud cracks, and the presence of calcareous sands and shales as evidence of a shallow-water origin for the Moodies Series (South Africa).

Because of the apparent rarity of occurrences of terrestrial sediments, and the paucity of descriptions of such occurrences, their role in Archean basin development is poorly understood.

A large portion of the Manitou sequence is of terrestrial origin. Following Pettijohn's (1937) report, this study has shown an abundance of cross-bedded sandstone (10 - 20 cm sets) associated with conglomerates showing cross-bedding with sets up to 1 m thick, at the eastern end of the area. Very common large-scale cross-bedding in conglomerate is a strong indication of migrating channels and bars in a braided stream. The thickness of the formation (800 m) and the lack of associated fine-grained sediments argue against a beach origin for these conglomerates. Farther west, cross-bedding is much less abundant, but associated rock types, sedimentary structures, bedding style, and lithology all combine to suggest that the sedimentary rocks there, too, are of terrestrial origin. The well-known stratigraphic relationships of these terrestrial deposits provides an excellent opportunity to assess their role in the development of the basin.

Occurrences of shallow-marine deposits are apparently rare in the Archean. At both Sioux Lookout and Kirkland Lake there are no recognizable shallow marine sediments between the terrestrial and deeper marine deposits (Turner 1972; R.S. Hyde, 1976, personal communication). The only description of possible Archean shallow marine deposits is that of Henderson (1975) in the Slave Province, but that is based mainly on paleontological evidence (stromatolites) rather than sedimentary features.

At Manitou Lake there is a unit composed of argillites, sandstones, conglomerate and tuff, in a stratigraphic position transitional between the underlying terrestrial deposits and the overlying turbidites. It is possible that this transitional unit represents a shallow marine or coastal environment; but, unfortunately, it almost totally lacks any diagnostic sedimentary features. Although its environment may be determined on stratigraphic grounds, without diagnostic features its usefulness in a model of basin development is limited.

Complementary to sedimentary interpretations is the problem of 'volcanic interpretations'; i.e., determining the environments of deposition of Archean pyroclastic and lava-flow rocks. In the Manitou area, both pyroclastic and flow rocks underlie and are in part laterally equivalent to the sedimentary pile. This close association permits an integrated approach to environmental interpretation, using the characteristics of both the volcanic and the sedimentary deposits to arrive at an interpretation compatible with both rock types. It also provides an opportunity to study the relationship between Archean volcanism and sedimentation.

Provenance and Basin Evolution

Recent studies in Greenland the Labrador (Bridgewater and Collerson, 1975; Hurst et al., 1975; Barton, 1975; Bridgewater et al., 1973, and Windley, 1973), and in regions closer to the Manitou area (Morey and Sims, 1976) have established that there are granitic terrains much older than the probable age of most greenstone belts, so the question of whether there was a sialic crust before deposition occurred in greenstone belts is less controversial than it once was.

The problem remains, at the local level, of establishing the sources of the materials in the deposits. It is important to distinguish between (1) the types of debris indigenous to the basin - those which can be accounted for in terms of the immediately underlying stratigraphy, and (2) debris which probably came from outside the basin because a logical source for it cannot be found within the preserved record in the basin. 'Granitic' material is likely to fall into this second category because

Archean granitoid masses almost invariably have intrusive relationships with the greenstone belts. Only a few occurrences of 'granitic' basement to greenstone belts have been documented (McGlynn and Henderson, 1970), and none of these is unequivocal. 'Granitic' (i.e., felsic plutonic), material is useful for determining sources external to the basin because it contrasts sharply with the largely mafic volcanic rocks which dominate greenstone belts.

The importance of paleocurrents in basin analysis is obvious, and the collection of such data essential, even though Archean sediments generally are not well suited to paleocurrent studies due to metamorphism and deformation. However, methods involving cross-laminations (Henderson, 1972), grain orientation (Hyde, 1977; and this study) and clast size (Walker and Pettijohn, 1971; and this study) have yielded some results.

Knowing the timing of the deposition, i.e. the position in the stratigraphy, of the indigenous and external debris, and the direction from which it came, is potentially useful for determining not only the evolution of the basin itself, but also probable tectonic and erosional events in the adjacent hinterland.

Integration of the known sedimentary and tectonic history of the basin and that inferred for the hinterland of several specific basins, of which the Manitou is one, could provide a general model for the development and preservation of Archean sedimentary basins.

CHAPTER II

GENERAL GEOLOGY OF THE MANITOU LAKE AREA

Geological Context

The Manitou Lake area lies about 30 miles (48 km) south of Dryden, Northwestern Ontario (Fig. 1), fully within the Wabigoon volcanic belt. No public roads approach the area at present, although Upper Manitou Lake may be reached, with difficulty, via a logging road from Dryden. A road under construction at present between Highway 11 east of Rainy Lake and Highway 17 at Dryden is scheduled to pass near the area (Blackburn, 1976c), and may provide access to Manitou Lake in the future.

The Manitou Lake-Stormy Lake greenstone belt is arcuate in form, about 19 km wide and 80 km long, tapering at either end (Fig. 2). Volcanic rocks to its north side extend north toward Dryden (Blackburn, 1976a; Davies and Pryslak, 1967). Rocks in the belt are Archean in age (Blackburn, 1976a; Stockwell, 1970; McGlynn, 1970 and D. Birk, 1977, personal communication), and consist of thick volcanic and sedimentary sequences intruded by porphyry dikes, granite stocks, and gabbroic

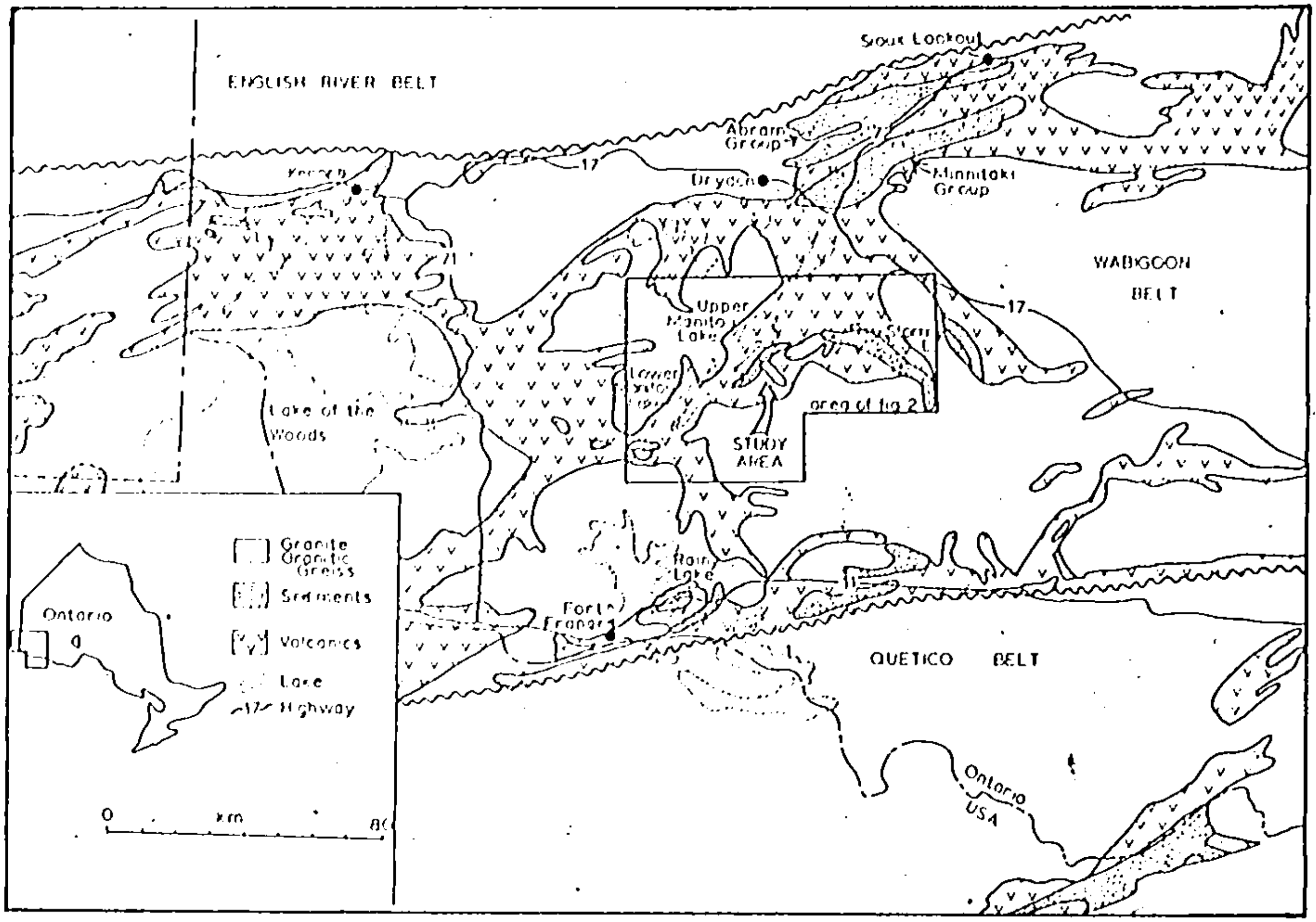
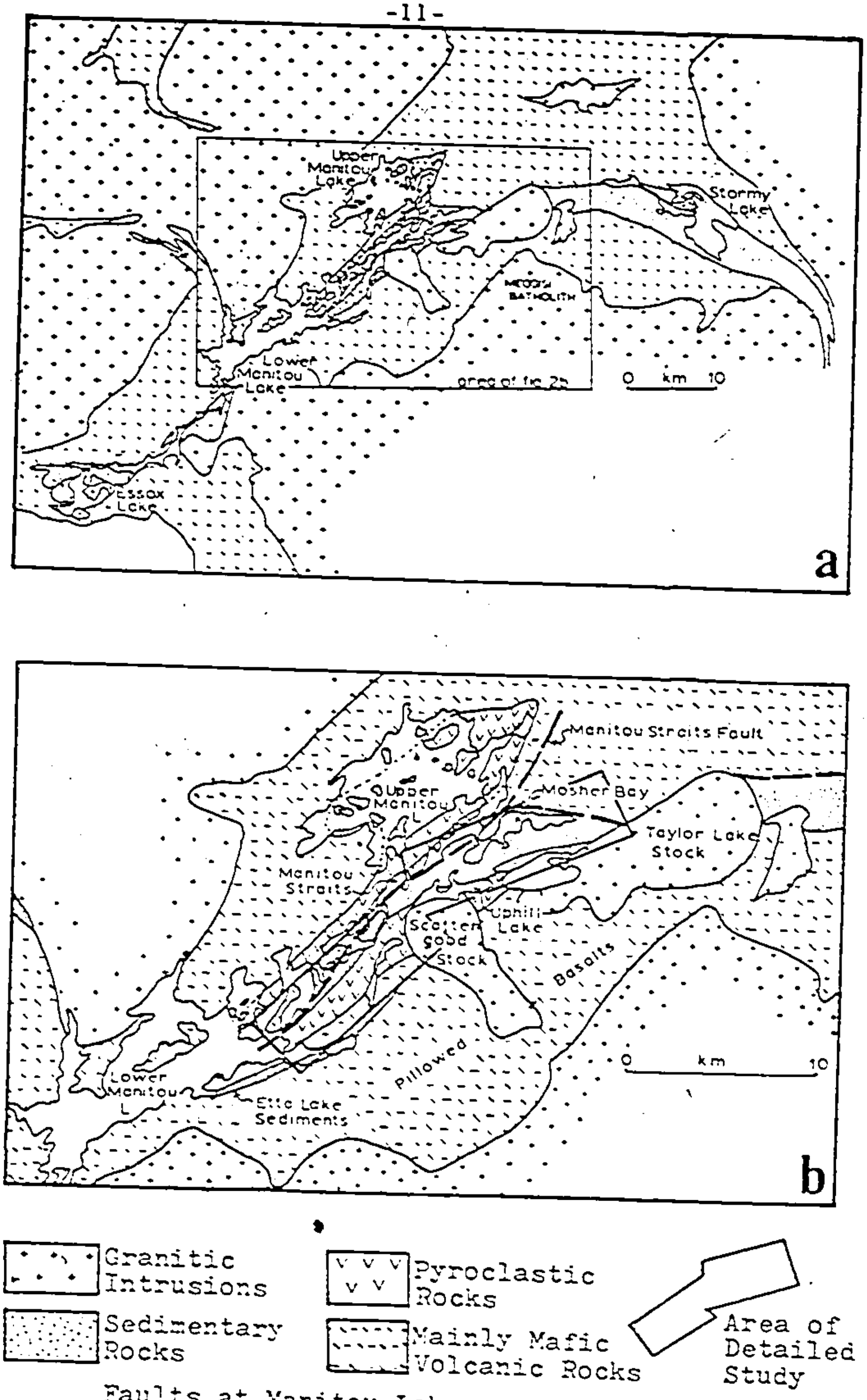


Figure 1. Location of the study area. Geology after Pettijohn, 1943.



Faults at Manitou Lake
Geology simplified from Davies and Pryslak (1967) and Blackburn (1975).

Figure 2. Geologic setting of the Manitou Group.

bodies. The belt is intruded by granitic rocks of batholithic domes (Blackburn, 1976a).

The area available for detailed stratigraphic and sedimentological study is a group of pyroclastic and epiclastic rocks lying along the southern shores of the Manitou Straits and Mosher Bay (Fig. 2).

Previous Work

There has been no comprehensive series of studies on the Manitou Lake Area. Previous work has been only general mapping, or small unrelated studies of a few specific areas.

Thomson (1933) mapped the area at a reconnaissance scale. His report lists the previous works on the area, most of which appear to have been concerned with the gold deposits. Thomson's map delineates very well the belt of clastic rocks which he referred to as the Manitou Series, running along the southeastern side of Manitou Straits (Fig. 2). However, he made little attempt to delineate the different rock types within this belt.

An Ontario Department of Mines Compilation Map (Davies and Pryslak, 1967) largely reflects the older works in the Manitou area.

Goodwin (1965, 1970) conducted limited stratigraphic studies and sample collecting for chemical analyses in the Uphill-Upper Manitou Lakes area as part of a larger study of volcanism and mineralization in the Lake-of-the-Woods - Manitou Lake - Wabigoon region.

In 1972, when this study began in the Mosher Bay area, C.E. Blackburn of the Ontario Division of Mines began a four-year mapping project at a scale of 1 inch to 1/4 mile that would eventually cover the entire Manitou area. After discussions with him, it was decided that a regional study of this nature (approximately 100 sq. miles per field season) could not provide the information necessary for a detailed stratigraphic and sedimentologic interpretation of the sedimentary belt. Furthermore, his mapping would not touch the Mosher Bay area (where most of the sedimentary rocks are located) until two years after this present study began. Therefore, the author mapped independently, and in greater detail, the entire sedimentary belt, using Blackburn's maps only for the distribution of a few intrusive bodies in the southwestern part of the belt, and some details of the pillowed basalts underlying the sedimentary belt. The full co-operation of C.E. Blackburn is deeply appreciated; the exchange of information and ideas has definitely improved this study, and almost certainly has been of use in his project.

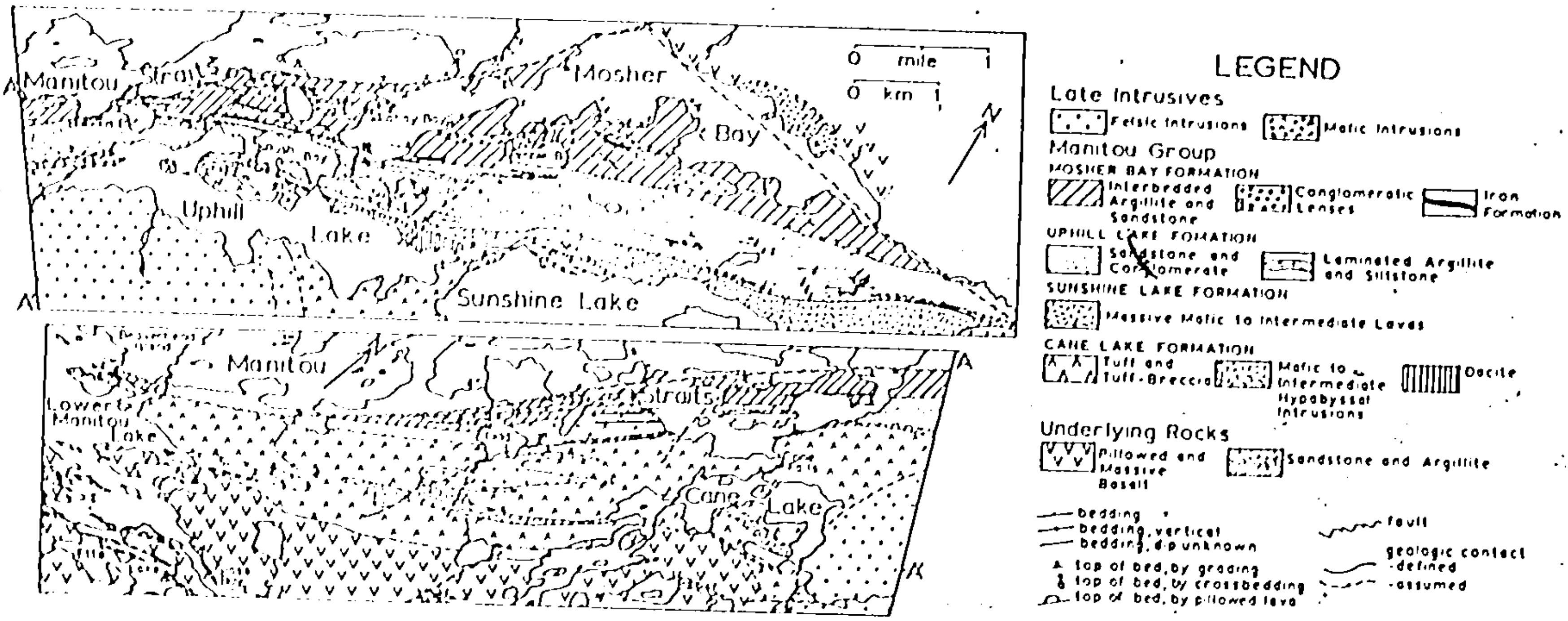
Pettijohn (1937, 1943), in the course of studies on Archean sedimentation, mapped the area south of Mosher Bay, dividing the sediments into six divisions: (a) breccia, containing angular blocks of subjacent lava; (b) arkose with minor conglomerate; (c) conglomerate; (d) graywacke; (e) conglomerate; and (f) slate with graywacke. On the basis of detailed work in this area and the more westerly portions of the sedimentary belt during the present study, it has been found necessary to combine divisions (a), (b), and (c) into one formation: (a) is a local feature developed only on the lavas north of Sunshine Lake and cannot be traced westward, and the distinction between (b) and (c) is essentially compositional, within the same sedimentary environment. This compositional distinction cannot be traced westward, either. Divisions (d), (e), and (f) have also been combined into one formation because division (e) represents only two of many conglomeratic lenses contained within a sequence of turbidites (divisions (d) and (f)).

Within the sedimentary belt, S. Teal (1974) undertook a detailed petrographic study of the pebbles in a conglomerate at Mosher Bay, and Cosgrove and Clifford (in preparation) studied the isoclinal folding in the Mosher Bay area.

The Present Work

In 1972, 1973, and 1974, detailed mapping (Fig. 3) determined that the Manitou Sedimentary Belt is essentially monoclinal and northwest facing (Fig. 8), and established a stratigraphy (Figs. 4,5) which can be used as a framework for study and interpretation of the environments of deposition of the volcanic and sedimentary rocks.

As the mapping was carried out, sections, ranging in length from one to 600 m, were measured to the nearest cm to establish the detailed characteristics of beds and the relationships among beds. The



Geology by P Ree Teal, 1972-1974

Figure 3. General Geology of the Manitou Group, derived from large shoreline exposures and smaller inland outcrops. See Figure 4 for stratigraphic subdivision and Figure 8 for structural geology.

Enlarged map in pocket.

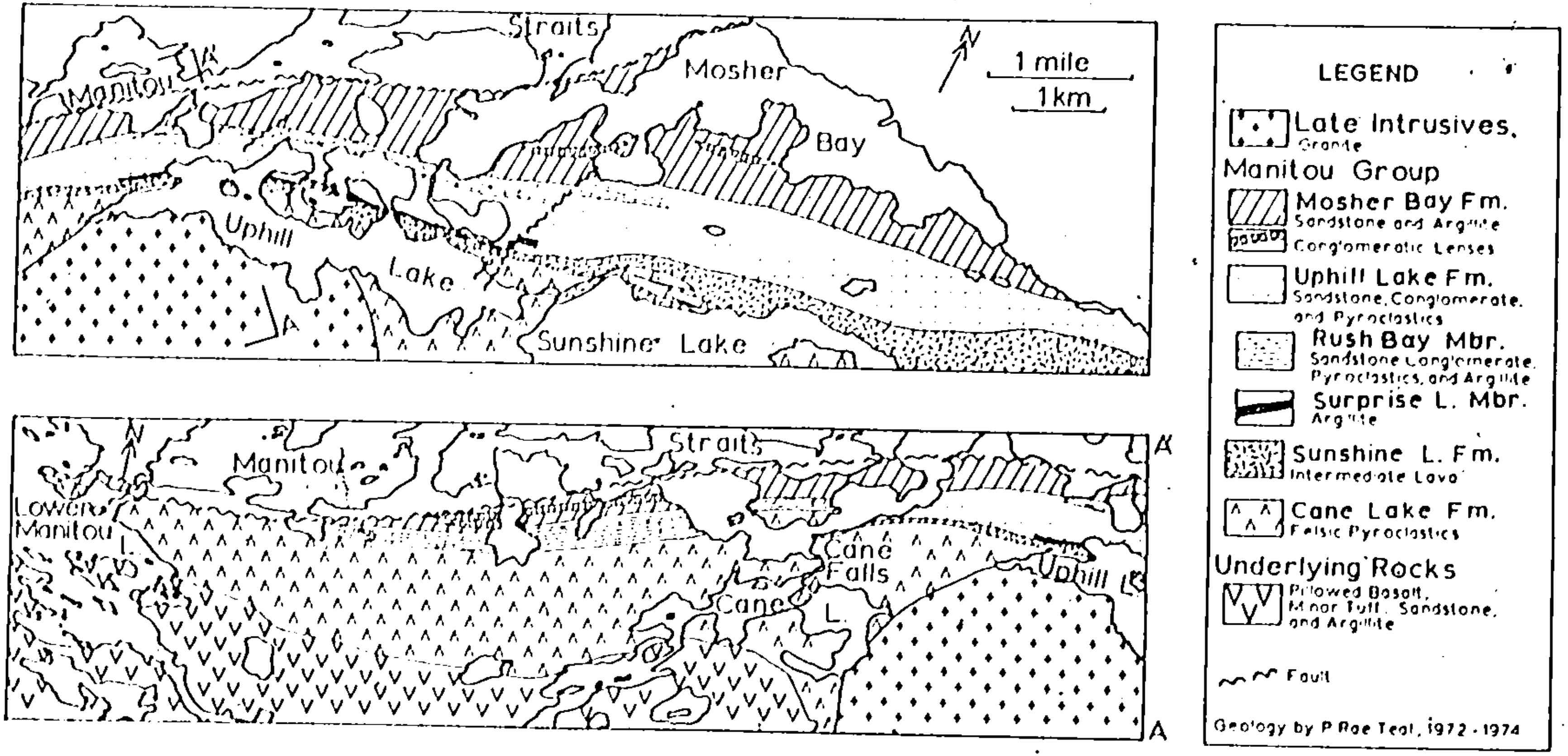


Figure 4. Distribution of the stratigraphic units of the Manitou Group. Note that the right side of the lower map joins the left side of the upper map at A'-A.

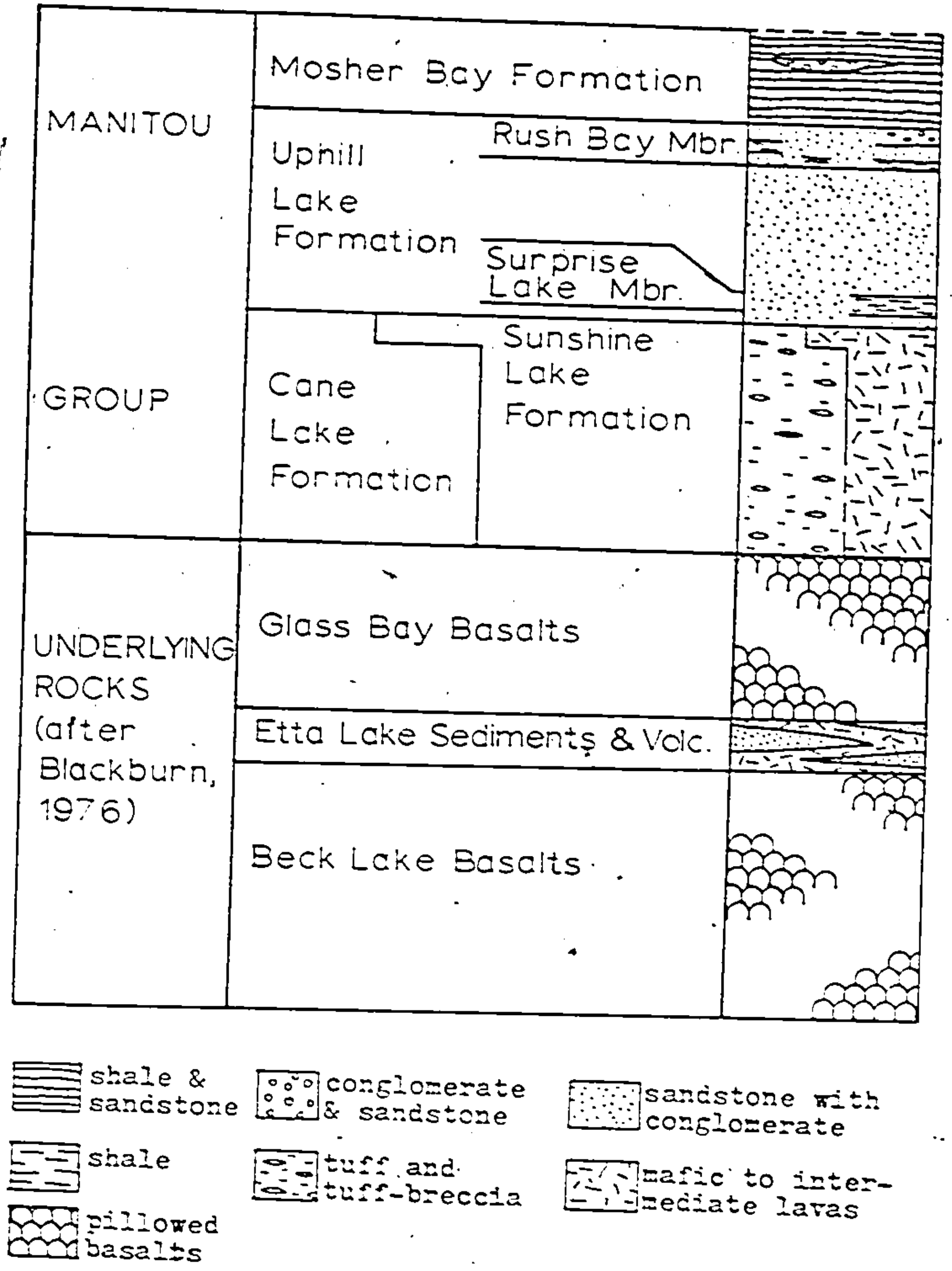


Figure 5. Stratigraphy of the Manitou Group and underlying rocks.

decision to measure many short sections was adopted because there are only a very few localities where longer sections could be measured, and these do not display all of the characteristics of the rocks. The locations of the sections are shown on Figure 6.

A program of sampling was also undertaken to further characterize the rocks in the laboratory through petrographic, chemical, and paleocurrent analyses.

Limits of Study Area

The area available for detailed study, and from which the Manitou Group was defined, is shown in Figure 2. The Manitou Group may extend southwest under Lower Manitou Lake as far as Essox Lake, but the sedimentary rocks there are somewhat different from those at Manitou (Thomson, 1934) and are so far removed (27 km) from the Manitou Group that correlation, at this stage, would be tenuous at best.

Correlation of the northeast end of the Manitou Group with the pyroclastic and sedimentary sequence at Stormy Lake is much more certain, because they are separated by only 8 km and the gross stratigraphy is the same (Fig. 7); also, certain aspects of the detailed stratigraphy appear to be correlative (Bertholf, 1947; Blackburn, 1976b; and Blackburn, personal communication, 1976). Nevertheless, the Taylor Lake Stock forms an effective barrier against very detailed correlation and the exposures and accessibility of much of the Stormy Lake area is

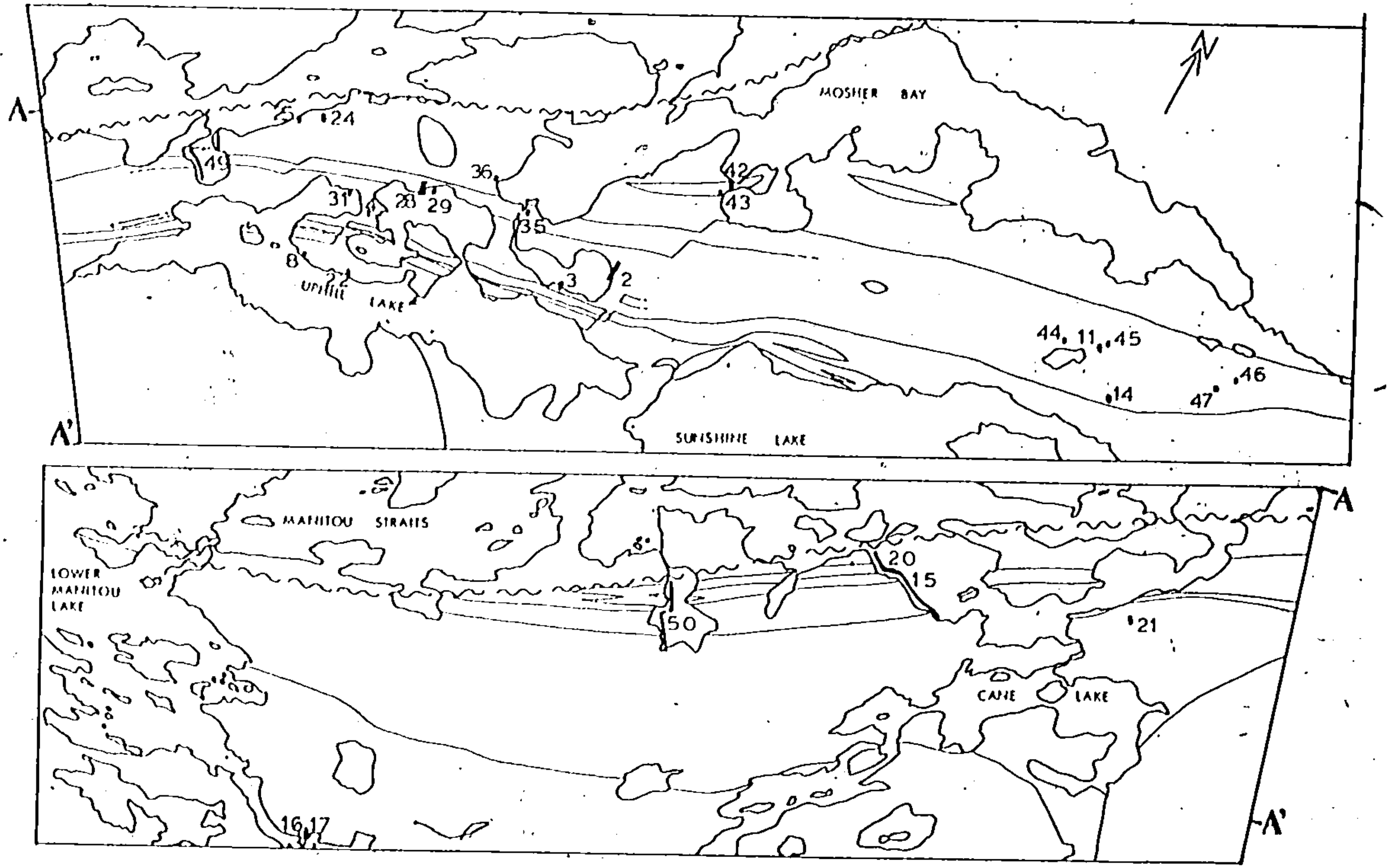


Figure 6. Locations of the measured sections in Figures 9,10,11,12,27,28,29, 31,32,41,43, and 44.

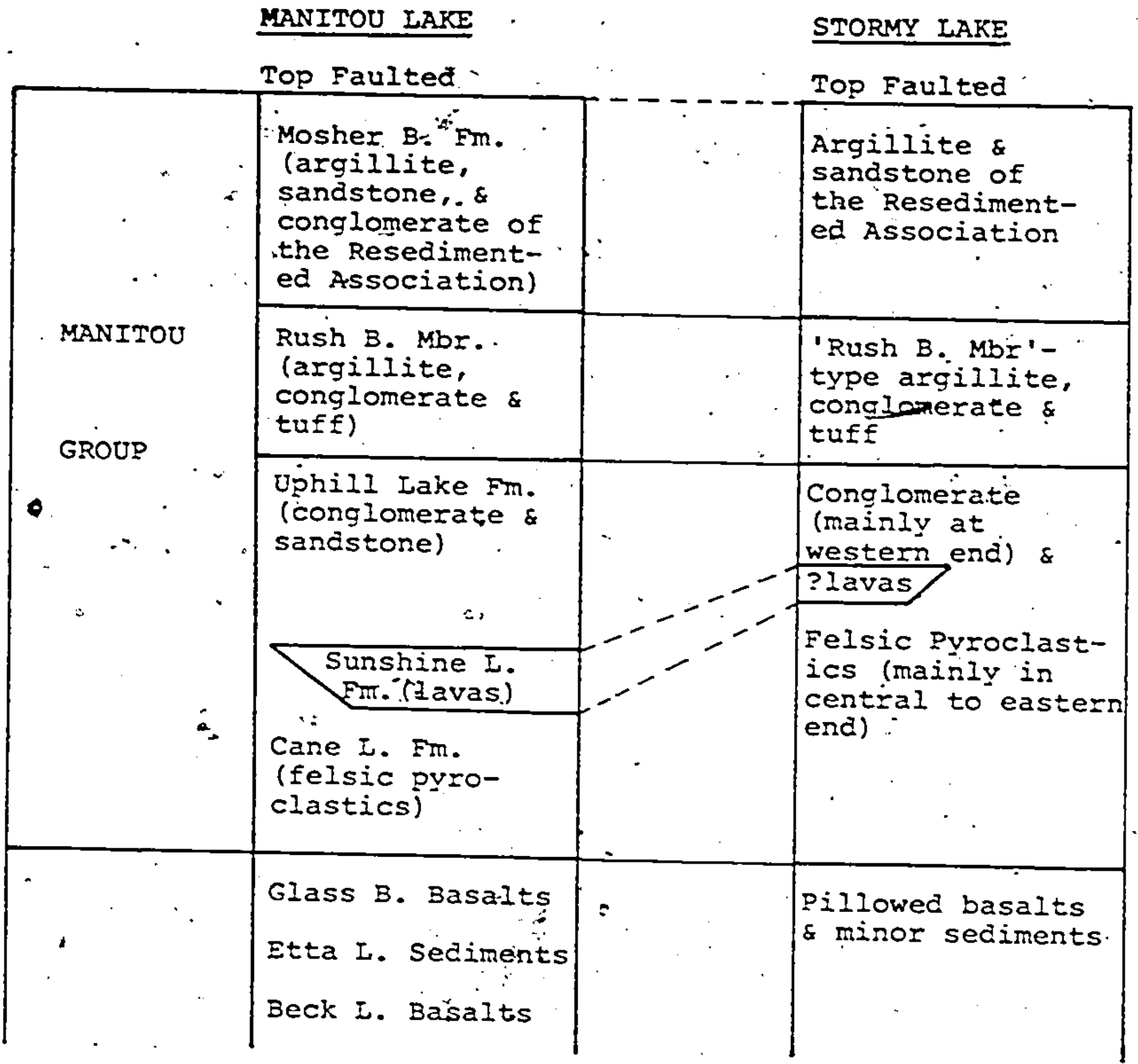


Figure 7. A comparison of the stratigraphic sequences at Manitou and Stormy Lakes. Not to scale.

poor, so detailed work was not extended into that area.

The Manitou Group is underlain by a thick and monotonous series of massive and pillowed basalts with minor intercalated clastic rocks. If there has been no repetition by folding or faulting, this pillowed basalt sequence may be as much as 8 km thick. Its southern limit is at the intrusive contact of the Meggisi batholith (Blackburn, 1976a, c). An examination of the clastic rocks and a few of the basalts was undertaken to establish their position in the framework surrounding the Manitou Group, but they were not intensively studied.

The top of the Manitou Group is cut out, over most of its length, by the Manitou Straits Fault, a major shear zone often in excess of 60 m wide. It brings the Manitou Group into contact with south-facing massive volcanic and pyroclastic material (Fig. 2). C. E. Blackburn (personal communication, 1976) feels that the Manitou Group can be correlated with a series of pyroclastic rocks northwest of the Manitou Straits Fault (Fig. 2). This correlation is not at all evident without Blackburn's recently-completed regional mapping (Blackburn, 1976a, b, c), so an investigation of the pyroclastic rocks northwest of the fault was not undertaken in this study.

In Mosher Bay, the sedimentary sequence is cut out by another fault trending nearly at right angles to the Manitou Straits Fault (Blackburn, 1976b).

Structure

The structure of the Manitou Group is relatively simple in that neither the faulting nor the folding has interferred substantially with thickness estimates, correlation or environmental interpretation within the group.

1. Faults

Apart from the major faults enclosing the Northern parts of the Manitou Group, there are only a few small faults in the area (Fig. 8), generally trending north-south. The fault about 1 km west of Cane Falls is problematic in that thicknesses apparently are not the same across it. This fault may have been active during Manitou Group deposition.

2. Folding

Folding within the Manitou Group has been minimal. Davies and Pryslak (1967), following Thomson's (1933) work, placed a synclinal axis through the Manitou Group. The work of the author and of Blackburn (1976a, b) indicates that this axis does not exist.

The only folding within the Manitou Group is a series of isoclinal folds in the upper part of the Mosher Bay Formation (Fig. 8), indicated by graded bedding. These were the subject of a study by Cosgrove and Clifford (in preparation) who concluded that two phases

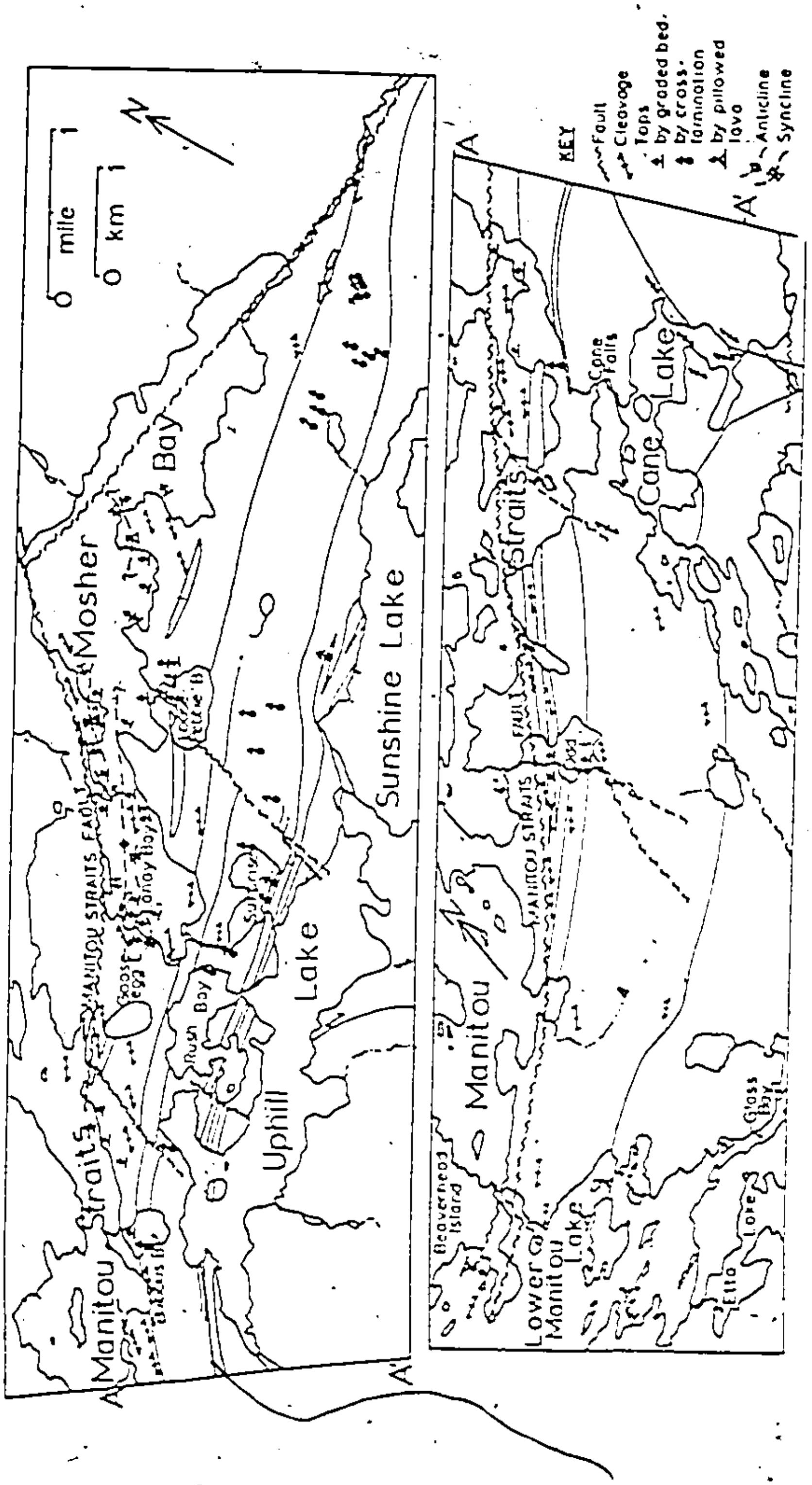


Figure 8. Structural geology of the Manitou Group.

of folding affected these fine-grained sedimentary rocks, but not the conglomerates below them. Because this folding is developed only within the Mosher Bay area and is restricted to the upper 800 m or so of the Mosher Bay Formation, at the very top of the Manitou Group, it does not affect correlation or thickness calculations for the bulk of the group.

Contemporary with or subsequent to the formation of the isoclinal folds, there was a major deformational episode which placed the Manitou Group on edge (dips are rarely less than 80°) and bent it into a concave-southward arc.

3. Deformation and Cleavage

The folding and faulting has resulted in the development of a cleavage and deformation of the clasts over some portions of the map area (Fig. 8). Near the Manitou Straits Fault there is commonly a strong cleavage parallel to the fault visible in the outcrops, and many of the volcanic clasts exhibit tectonic extension in a sub-vertical direction. The Mosher Bay Formation has a much stronger cleavage than the other formations, probably due to ~~its~~ finer grain size and the development of isoclinal folding. Near the Scattergood stock and the other granitic intrusions, clasts have been rotated and a foliation developed parallel to the intrusive contact. In most other areas of the Manitou Group the cleavage is weak or absent.

CHAPTER III

STRATIGRAPHY OF THE MANITOU GROUP

From the mapping, it has been possible to divide the volcanic and sedimentary rocks along the southwestern edge of the Manitou Straits and Mosher Bay into four formations (Figs. 4,5). It is here proposed that these formations be referred to as the Manitou Group because they are essentially the same rocks Thomson (1933) called the Manitou Series, and also because they lie adjacent to the large Upper Manitou Lake - Manitou Straits - Lower Manitou Lake system.

On the following pages, the stratigraphy of the Manitou Group forms the framework for the systematic descriptions of the various lithologic types, their distribution, and their sedimentary and volcanic features. Environmental interpretations based on these descriptions are given in Chapter IV.

In the course of the descriptions, it is necessary in places to refer to localities that have no official name. These places have been given names by the author, but where they are used, they appear in quotation marks to denote their unofficial status.

Underlying Pillowed Basalts

The massive and pillowed basalts and their associated sediments below the Manitou Group (Fig. 2) are not assigned formal names in this work. C.E. Blackburn of the Ontario Division of Mines is currently attempting to assign formal names to them. Although they are not actually part of the Manitou Group, but form a base upon which the group rests, they are described here as part of the stratigraphic setting of the Manitou Group.

The basalts extend southwest well beyond the most south-westerly exposure of the Manitou Group (Thomson, 1933; Blackburn, 1976a) and eastward at least as far as Stormy Lake, probably farther. The southern limit of the sequence is at the intrusive contact of the Meggisi Batholith (Blackburn, 1976c). At its upper contact the basalt sequence appears to be generally conformable with the overlying Manitou Group.

Blackburn (1976a) has informally divided the mafic volcanic rocks into three conformable units - the Beck Lake Basalts, Etta Lake Basalts, and the Glass Bay Basalts. Blackburn's partial chemical analyses indicate that they are, indeed, basalts, and his few complete analyses indicate that they are probably all tholeiitic (Chapter VII).

In the Beck Lake Basalts, pillows are ubiquitous in the medium to fine-grained lavas and also occur sporadically within the coarser flows. The Etta Lake Basalts are interbedded with clastic sediments and minor pyroclastics (described later). They are dominantly porphyritic basalts, some very coarse grained, but no pillowed basalts were found interbedded with the sediments (Blackburn, 1976a).

~~In the~~ Glass Bay Basalts, pillows are again ubiquitous, as amply displayed on the islands and shoreline at the entrance to Glass Bay. Towards the top of the sequence, brecciated lavas of probable aquagene origin (Blackburn, 1976a) are associated with the pillowed lavas.

Etta Lake Sediments

Clastic sediments and pyroclastics occur interbedded with massive basalts over a strike length of at least 10 km, from beyond the map area to the southwest, through Glass Bay to Cane Lake. Minor volcanogenic sandstones and argillite intercalated with pillowed basalts southwest of Stormy Lake are possible lateral equivalents of these rocks. Individual clastic units are mostly discontinuous along strike (Blackburn, 1976a). The sediments are well exposed along the shores of numerous small lakes, especially at Etta Lake; hence Blackburn (1976a) termed them informally the Etta Lake Sediments.

The Etta Lake Sediments are of two types: thickly bedded and thinly bedded. The thicker beds range in thickness from a half metre to full outcrop widths of several metres. They tend to be massive except for rare grading at their very tops. Contacts between beds are sharp. Both in the field and in thin-section the rocks show a very high matrix content and a dominance of dispersed, angular volcanic rock fragments and plagioclase of coarse sand size. These thicker beds are considered to be tuff deposits. Some of these beds are shown in sections 16 and 17 (Fig. 9). The thinly bedded sediments are parallel-sided, sharp-based, medium grained, green sandstone beds 5 to 20 cm thick, grading to green or white siltstone and argillite, with some thinly laminated siltstone and argillite. There is no cross-bedding or other tractional structures. The repetition of sharp based graded sandstones, grading into argillites, suggests that they are probably turbidites. The centre portion of section 16 (Fig. 9) contains a small number of these beds. The sandstones are composed mainly of volcanic rock fragments and it is probable that the siltstone and argillite is green, weathering to white, due to a high ash content. These rocks are clearly part of the volcanic regime that dominated the area at that time.

At the northeast end of Glass Bay, on the peninsula jutting northward into the bay, there are peculiar 'nodules' in the finer-grained portion of a series of graded beds. They are oblate to spherical bodies

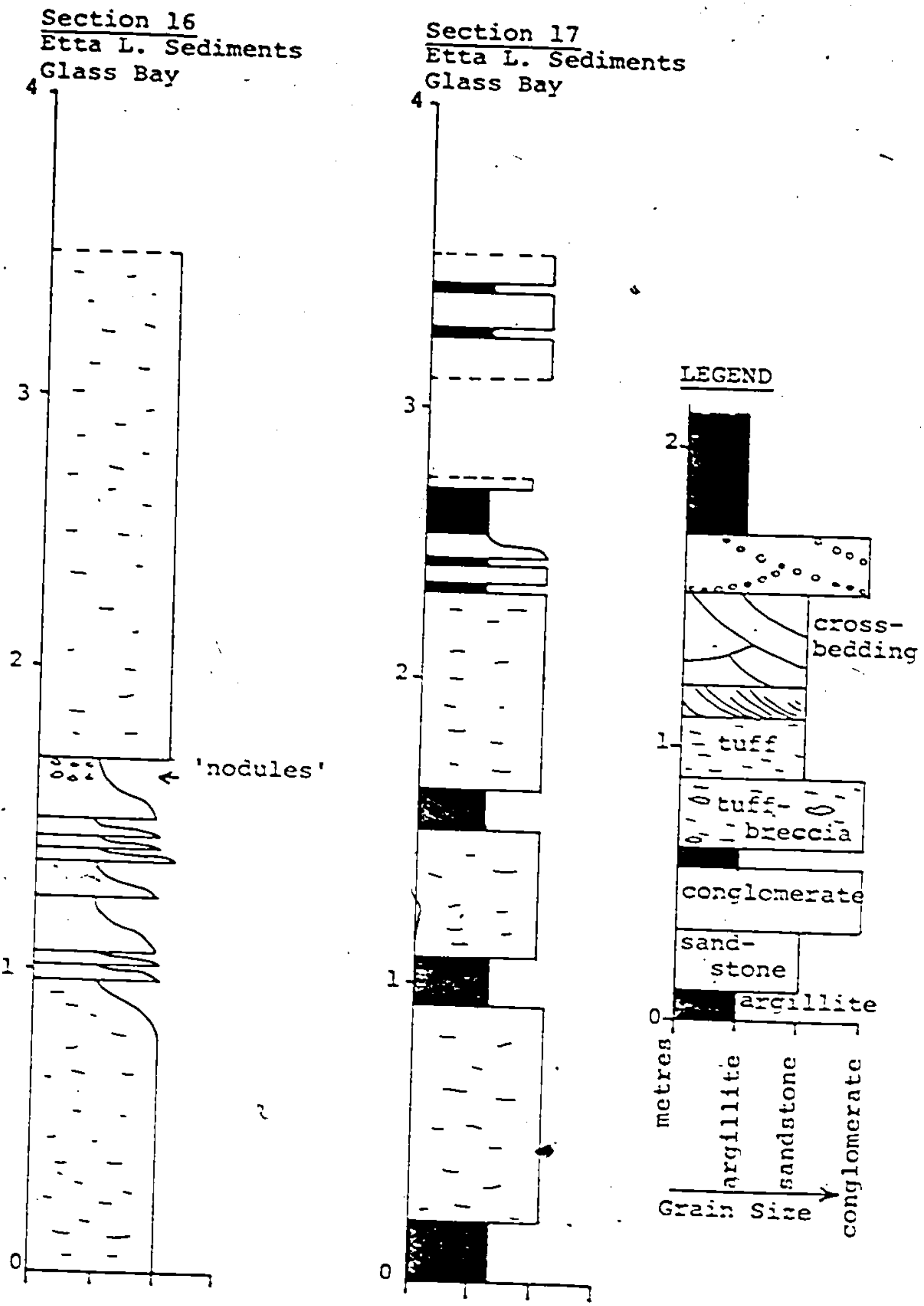


Figure 9. Measured sections of Etta Lake Sediments, Glass Bay. Locations on Figure 6.

with diffuse edges, in places coalescing, about 1 cm in diameter. Their internal grain size does not appear to be very different from the rest of the argillite. Blackburn (1976a) also reports these 'nodules' and from his thin-section studies, in which he found them to be dominantly a very fine-grained or amorphous mineral, he concluded that they were of a concretionary or replacement origin. This is the most reasonable explanation, in view of the fact that they cross-cut laminations, and show no evidence of having been porphyroblasts.

Cane Lake Formation

The lowermost formation of the Manitou Group is the felsic pyroclastic Cane Lake Formation. It extends from the western end of the field area at Lower Manitou Lake, eastward as far as Sunshine Lake (Fig. 4). It ranges in thickness from 800 to 1600 m, being thickest at Cane Lake. It has been called the Cane Lake Formation because it is best developed near that lake. Unfortunately, exposures are rather small and poor in that area. The best exposures of the formation are along the shores of Uphill Lake, but the name "Uphill Lake" has been reserved for another formation. Small exposures make the choice of a type section difficult, and a number of areas have been used to establish the characteristics of the formation. However, the lowermost 65 m of section 50 (Fig. 12) is the longest measured section of the Cane Lake

Formation, and in many ways it is typical of the formation, so it has been chosen as the type section. Other shorter sections, such as 8, 21, and 22 (Fig. 11), and especially section 15 (Fig. 10), provide detail.

The base of the Cane Lake Formation appears to be generally conformable upon the underlying pillowed basalts. No angular discordance has been observed. At Glass Bay the contact is sharp and smooth with no fragments of the pillowed basalts in the overlying material.

However, at Cane Lake, some large blocks (1 m diameter) of basalt lie on and just above the base of the Cane Lake Formation. These blocks could have been torn from the underlying basalts when the explosive volcanism began, but they are rounded, and confined to the first 2 m of the formation. The blocks probably indicate a local erosional surface, and because of the eroded material is pillowed basalt, the area must have been tectonically uplifted above sea level, rather than built up to sea level by lava deposition.

Therefore, at least one area of the mafic platform underlying the Manitou Group was subjected to tectonic uplift prior to the Cane Lake Formation pyroclastic volcanism, but most of the platform remained submerged. However, the Cane Lake pyroclastics rapidly built up to and above sea level throughout the study area.

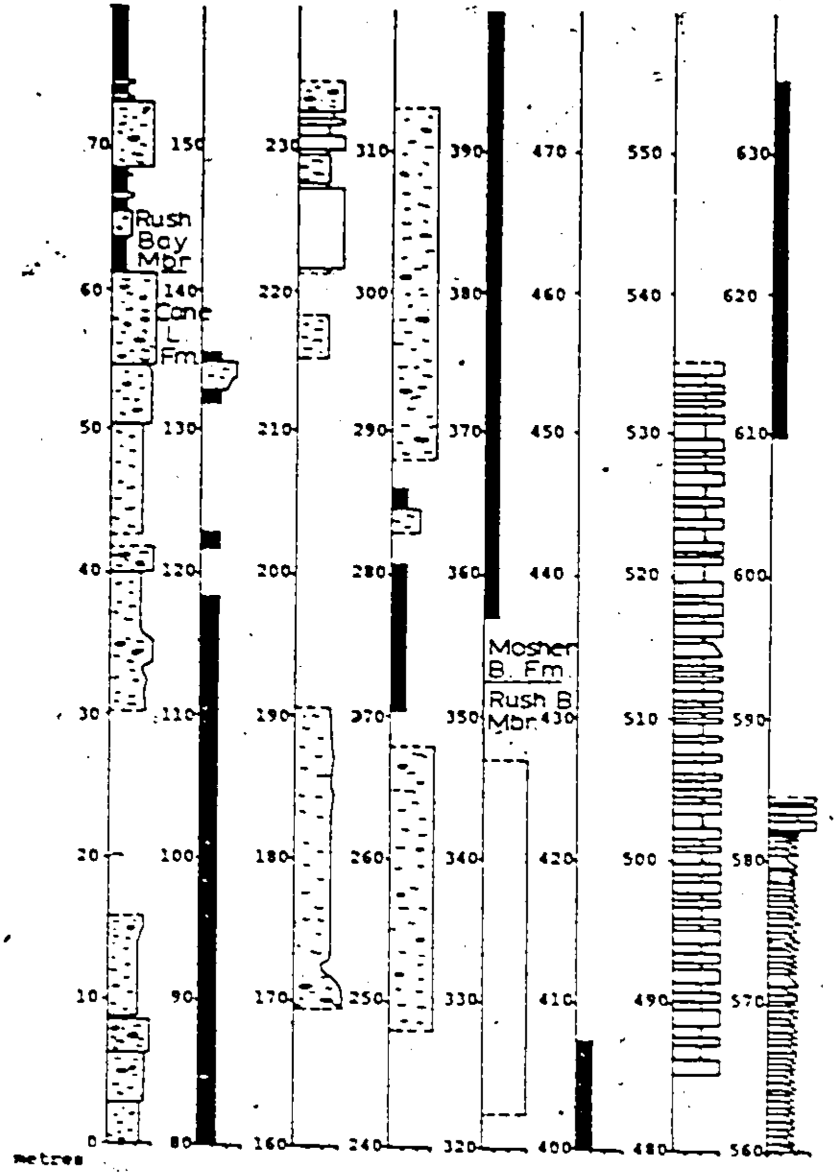


Figure 10. Measured section 15, Cane Lake Formation, Rush Bay Member of the Uphill Lake Formation, and Mosher Bay Formation, 1 mile (1.6 km) southwest of Cane Falls, including section 20. Location on Figure 6. Legend as for Figure 9.

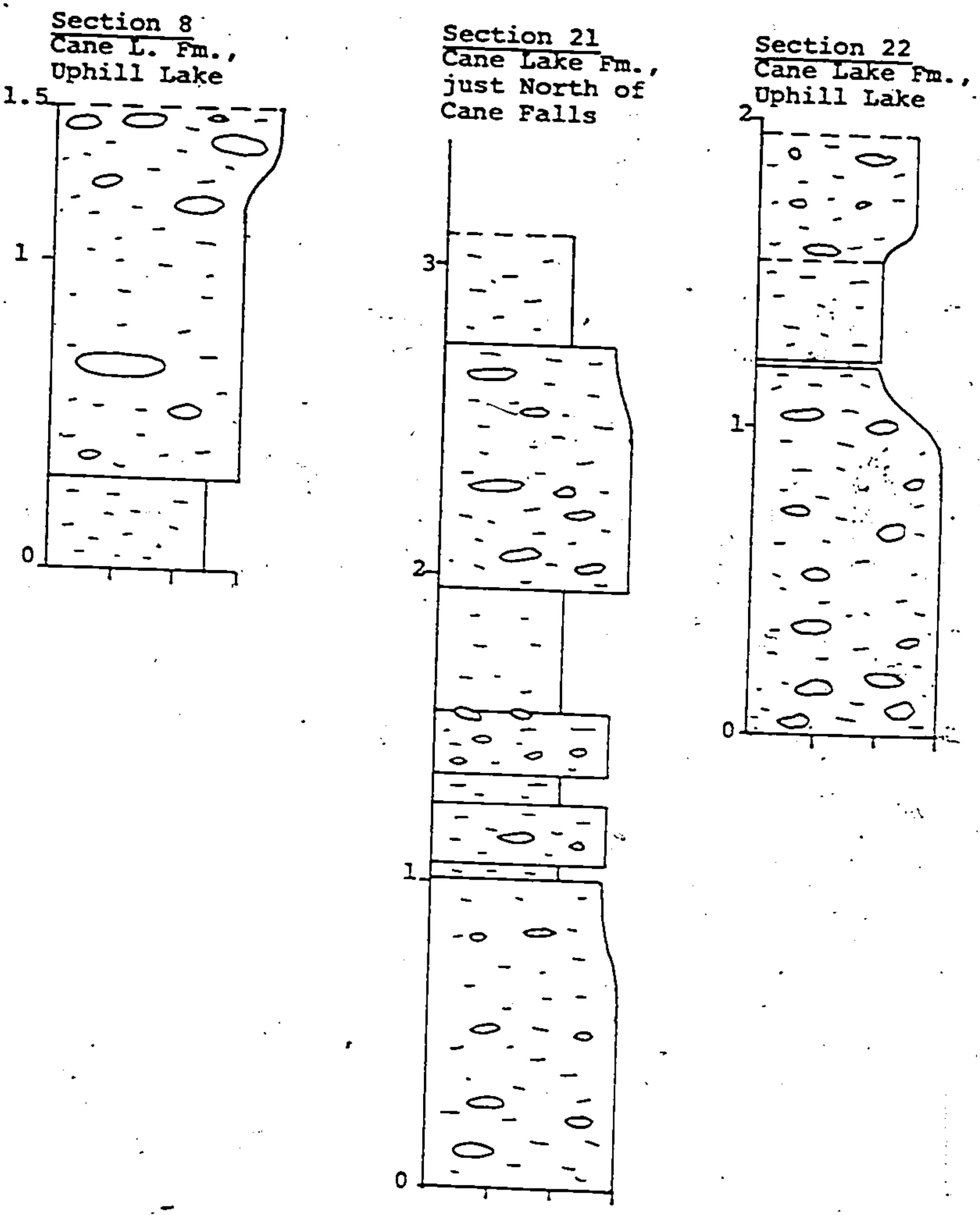


Figure 11. Measured sections of the Cane Lake Fm.
Locations on Figure 6. Legend as for Figure 9.

At the extreme eastern end of the Cane Lake Formation its top is obscured by Sunshine Lake. At the western end of Sunshine Lake, the Cane Lake Formation is intercalated with lavas of the Sunshine Lake Formation (Fig. 4). All contacts in this area of intercalation appear to be conformable. From the eastern end of Uphill Lake westward as far as Cane Falls, the Cane Lake Formation is overlain by a thin tongue of Sunshine Lake Formation (Fig. 4). This contact, as well, is conformable. At Cane Falls, this thin unit of Sunshine Lake lava stops, and the Cane Lake Formation and main part of the Uphill Lake Formation cannot be distinguished. Southwest of this point the entire section up to the base of the Rush Bay Member is referred to the Cane Lake Formation (Fig. 4). The contact of the Cane Lake Formation with the Rush Bay Member is generally sharp: in all exposures northwest of Cane Falls, coarse pyroclastic rocks are followed abruptly by a 70 m unit of laminated argillite (e.g. section 15, Fig. 10). However, at "Odd Lake" (section 50; Fig. 12) the contact is somewhat gradational. In the upper 10 m of the Cane Lake Formation there are 10 thin (2 to 40 cm) argillite beds intercalated with the pyroclastics (section 50; Fig. 12). Some of the thinner, sand-sized pyroclastic beds show evidence of reworking in the form of planar and trough cross-lamination (2 - 10 cm sets) (Figs. 13,14). They appear to remain poorly sorted and angular. Above the 9 m laminated argillite unit which marks the base of the Rush Bay Member, the lower half of the

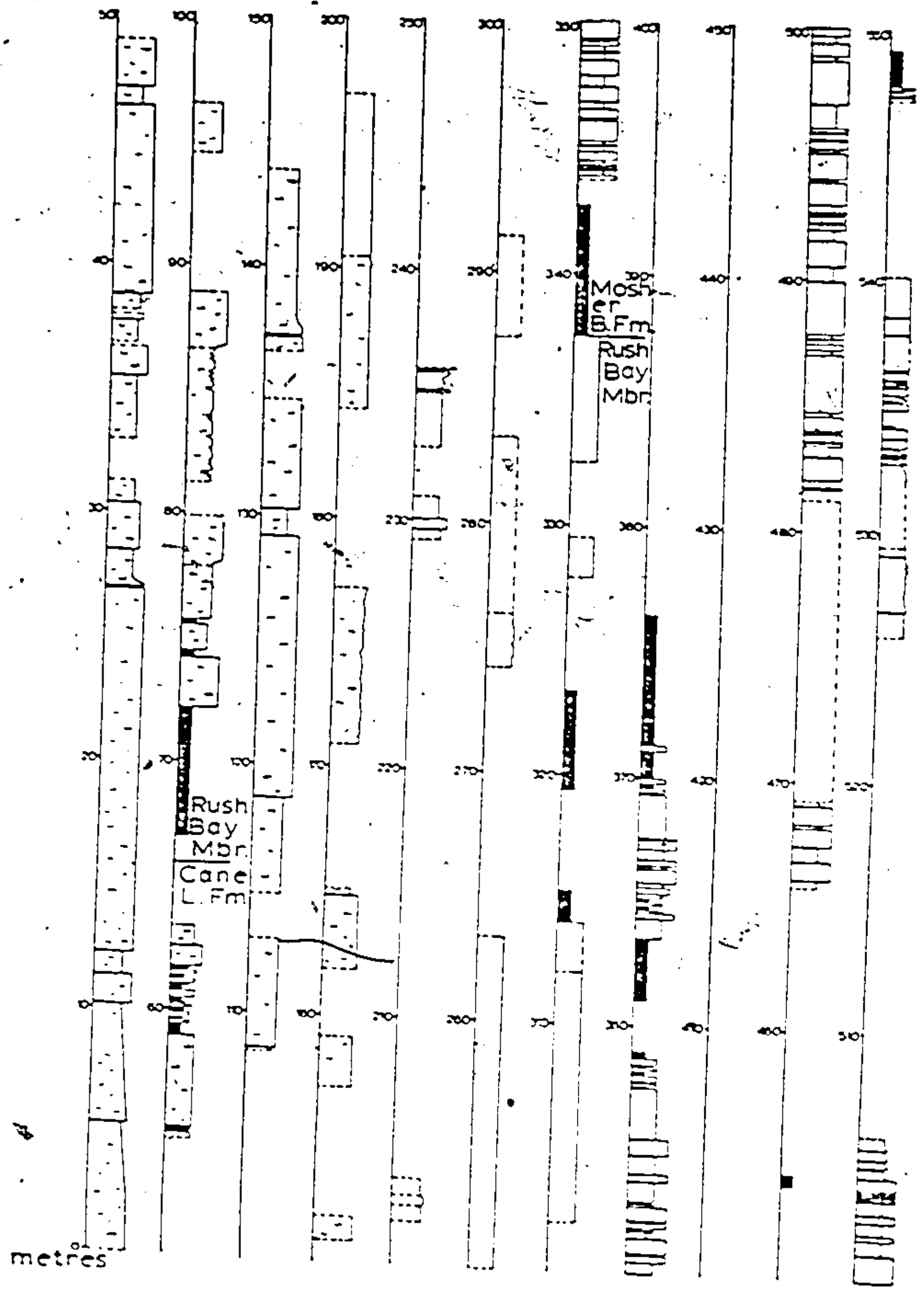


Figure 12. Measured section 50 at "Odd Lake": Cane Lake Fm., Rush Bay Mbr., and Mosher Bay Fm. Dashed: tuff, tuff-breccia, and volcanógenic sediments; unpatterned: quartzose sediments; black: argillite.

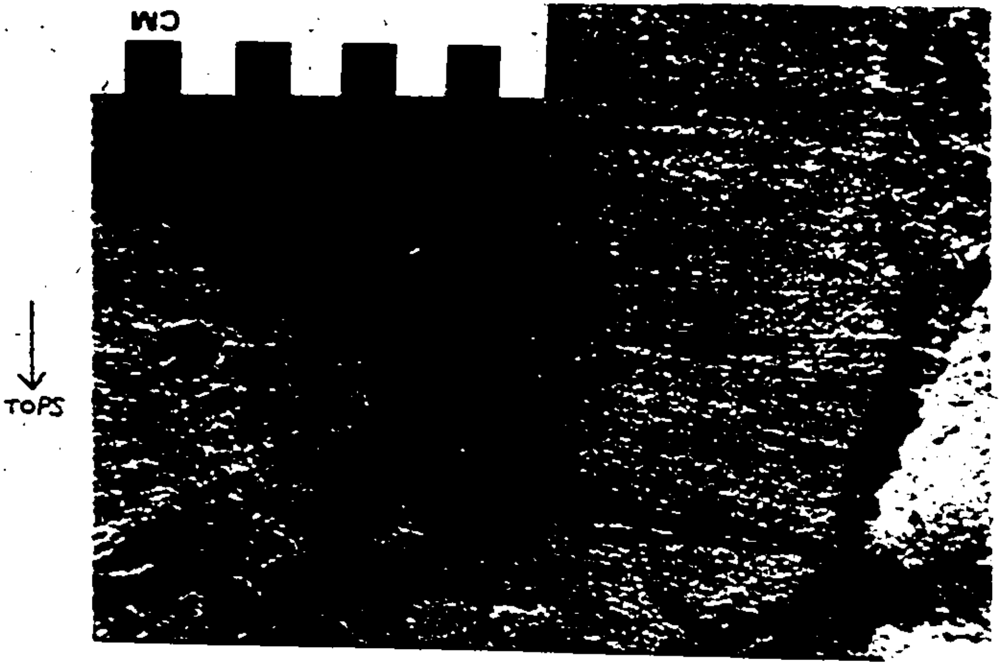


Figure 13. Planar cross-lamination in Cane Lake Formation at "Odd Lake".

Figure 14. Trough cross-lamination in the Cane Lake Formation at "Odd Lake".

Rush Bay Member is composed of pyroclastic rocks very similar to the Cane Lake Formation (section 50; Fig. 12).

At its eastern end, the Cane Lake Formation is intercalated with the Sunshine Lake Formation. At its southwestern end, the formation is covered by the waters of Lower Manitou Lake. The Scattergood Stock, a late granitic body, intrudes the Manitou Group just east of Cane Lake (Fig. 2) and almost completely divides the Cane Lake Formation into two parts (Fig. 4).

The Cane Lake Formation is dominated by thick, massive heterolithic tuff-breccias, with minor tuffs (Figs. 15,16). In a very few places, the tuff-breccias have only one or two clast types (Chapter VI, Fig. 17), but the bulk of the formation is composed of pyroclastics with a wide assortment of volcanic clast types (Fig. 15). The only tuffs showing any evidence of reworking are at the very top of the formation at "Odd Lake". This is also the only place where even very thin siltstone and argillite (probably tuffaceous) appear. At the southwestern end of the area, a small percentage of granitoid, quartz, iron formation and chert clasts appear among the otherwise volcanogenic clasts (Chapter VI). A few thin, laminated, tuffaceous sandstone beds also occur, indicating input of non-volcanic debris by non-volcanic depositional agents, but a lack of diagnostic sedimentary features prevents clear-cut identification of the sedimentary environment.

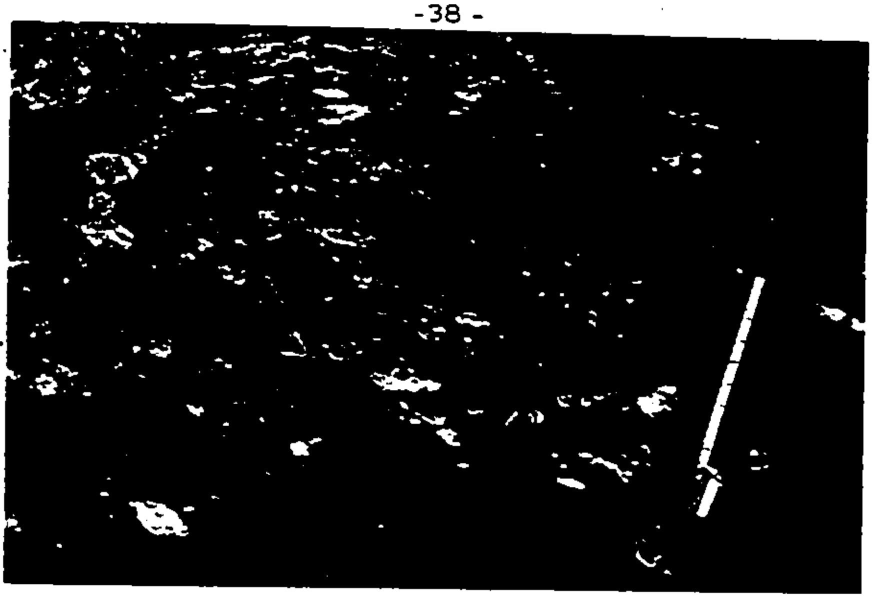


Figure 15. Heterolithologic tuff-breccia of the Cane Lake Formation at Uphill Lake. Tape is 20 cm long.

Figure 16. Tuff of the Cane Lake Formation, just north of Cane Falls. Tape is 20 cm long.

Clasts in the Cane Lake Formation range in size from less than 1 cm to a maximum of 60 cm. The maximum clast size is not uniform throughout the formation, being coarsest near Cane Lake and decreasing in size both east and west from there (Chapter V). Sorting is poor. The tuff-breccias are composed of large, rounded to subangular clasts generally dispersed in a coarse tuff matrix. Tuff-breccias composed of a few clast types more commonly have angular to subangular clasts of low sphericity. In at least one locality there are only two clast types. One is felsic, very vesicular, irregular in shape with re-entrants, and has a thin "skin" with smaller vesicles (Fig. 18). This is pumice. The other clasts are lithic fragments: more mafic, dense, and of higher sphericity and roundness than the pumice (Fig. 17). Both are enclosed in a coarse tuff composed of these same clast types.

The tuffs and tuff-breccias are very thickly bedded (2 to 10 m). The beds are most commonly massive and sharp-based, although fairly abrupt changes in grain size can occur within beds (both coarse to fine (sec. 15; Fig. 10) and fine to coarse (sec. 8; Fig. 11)). Some of the thick beds are graded (section 50; Fig. 12): at the base the bed is composed of tuff-breccia, with clasts up to 20 cm, which grades into coarse-grained tuff with scattered 1 cm clasts by a gradual and somewhat irregular decrease in the size and concentration of the larger clasts. The sand-sized

Figure 17. Tuff breccia with two clast types: lithic fragments (green) and pumice (pale yellow), Cane Lake Fm., South Manitou Straits.

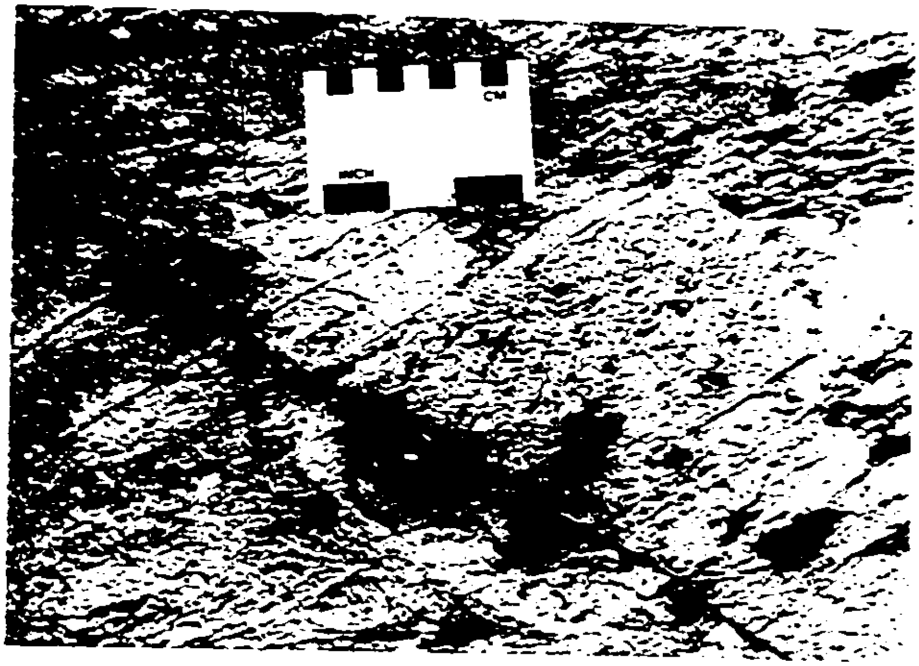


Figure 18. Pumice in tuff-breccia, Cane Lake Formation, South Manitou Straits

material, which forms the matrix of the tuff-breccia at the base and represents the bulk of the bed at the top, does not appear to change in size. A number of the 1 to 1-1/2 m thick tuff-breccia beds are graded only in their top 20 to 30 cm (sections 21, 22; Fig. 11). In two of these cases, they grade to an only slightly finer-grained tuff-breccia (section 21; Fig. 11). In another case, the bed grades to tuff by a diminishing concentration of larger clasts (section 22; Fig. 11). At about 35 m above the base of measured section 15 (Fig. 12), a 2 m thick bed of tuff-breccia exhibits inverse grading. From a fairly sharp base, the grain size increases slowly to about 25 cm, but there are a few very large (60 cm) clasts near the top. The grain size then falls very rapidly, making gradational contact with the overlying tuff bed. Many of the tuff beds are as thick as the tuff-breccias and equally massive (Fig. 19). The thinner tuff beds (10 to 50 cm) are not graded and many are faintly to distinctly laminated (Fig. 20).

No cross-bedding was observed. However, at "Odd Lake" (section 50; Fig. 12), in the top 40 m of the formation, volcanogenic sandstone beds are intercalated with massive tuffs and tuff-breccias. The sandstone beds are trough and planar cross-laminated (2 to 10 cm sets) and plane laminated, medium to coarse-grained, and 1 to 3 m thick (average about 1-1/2 m). Associated with these are thin (1 to 20 cm) laminated siltstone-argillite beds. This portion of the formation has clearly been reworked.

Figure 19. Massive tuff, Cane Lake Formation at "Odd Lake". For scale, the spider is about 10 cm from toe to toe.

Figure 20. Faintly bedded tuff, Cane Lake Formation at "Odd L."

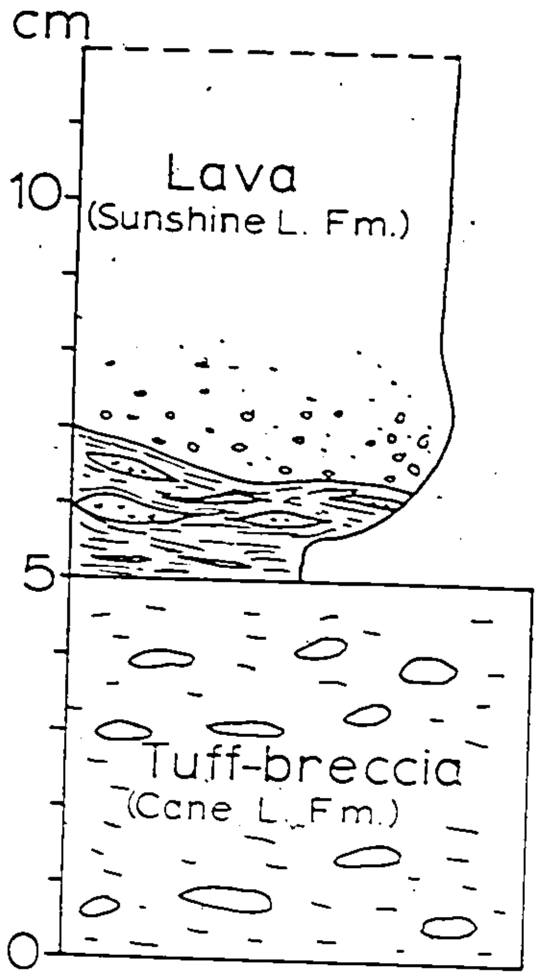


Figure 21. Lower contact of the Sunshine Lake Formation at Uphill Lake, just west of Rush Bay Narrows.

Sunshine Lake Formation

The Sunshine Lake Formation is a group of intermediate, somewhat alkalic (Chapter VII) lava flows. The bulk of the formation lies directly north of Sunshine Lake (Fig. 4) where the formation is at least 550 m thick. The eastern end is cut out by the Taylor Lake Stock, a late granitic intrusion. At the western end of Sunshine Lake, the Sunshine Lake Formation is intercalated with the Cane Lake Formation, but a thin tongue made up of the uppermost few flows of the formation extends westward as far as Cane Falls (Fig. 3). This tongue tapers from about 60 m thick at Surprise Lake to only a few metres at Cane Falls. It serves as a marker horizon separating the Cane Lake Formation from the Uphill Lake Formation. Where it is observed, the base of the Sunshine Lake Formation is marked by a dark green, brecciated zone about 20 cm thick which passes upward into amygdaloidal, then massive lava over about 1 m (Fig. 21). This can be interpreted as a flow bottom breccia developed as the first lava flow moved over the underlying pyroclastic rocks. The top of the formation shows no angular unconformity with the Uphill Lake Formation, but the base of the Uphill Lake Formation is crowded with clasts derived from the Sunshine Lake Formation, indicating, at least, reworking of loose debris from the Sunshine Lake Formation during initial Uphill Lake Formation deposition. At one point a possible regolith is developed. This is discussed more fully in the section on the Uphill Lake Formation. At the eastern end of the area, one or two lava flows are intercalated with the Uphill Lake Formation sediments, indicating a gradational contact as volcanism waned and sedimentation began.

Most of the Sunshine Lake Formation lies in the bush, well away from good shoreline exposures. Where it is near the shore, outcrops are small and scattered. For this reason, no measured sections were obtained. Photographs (Figs. 22, 23, 24) from north of Sunshine Lake and along Uphill Lake must serve as 'type sections'. The formation is composed of generally massive, porphyritic, amygdaloidal lava. The phenocrysts, of feldspar and amphibole, are 2 to 5 mm in length (Fig. 22). Amygdules are generally also about 2 to 5 mm in diameter, but can range up to 1 cm in diameter (Fig. 24). They are filled with either quartz or calcite. In many places this porphyritic and amygdaloidal lava is broken up into angular to subangular blocks ranging from 10 cm to several metres in diameter (Figs. 23, 24). The material between the blocks is a very fine-grained massive lava apparently of similar composition to that of the blocks, but without amygdules or phenocrysts. Faint laminations within the fine-grained material appear to be flow-banding (Fig. 24). Outcrops of this sort are flow breccias, developed at both the base and the top of the flow as it moves (Macdonald, 1972, p. 96). No pillows are present. Between some of the flows there are a few beds of volcanogenic sandstone and conglomerate composed of clasts identical to the Sunshine Lake lavas. They are clearly derived from the flows by interflow weathering and sedimentation. Well-bedded medium to coarse grained sandstones, fine-

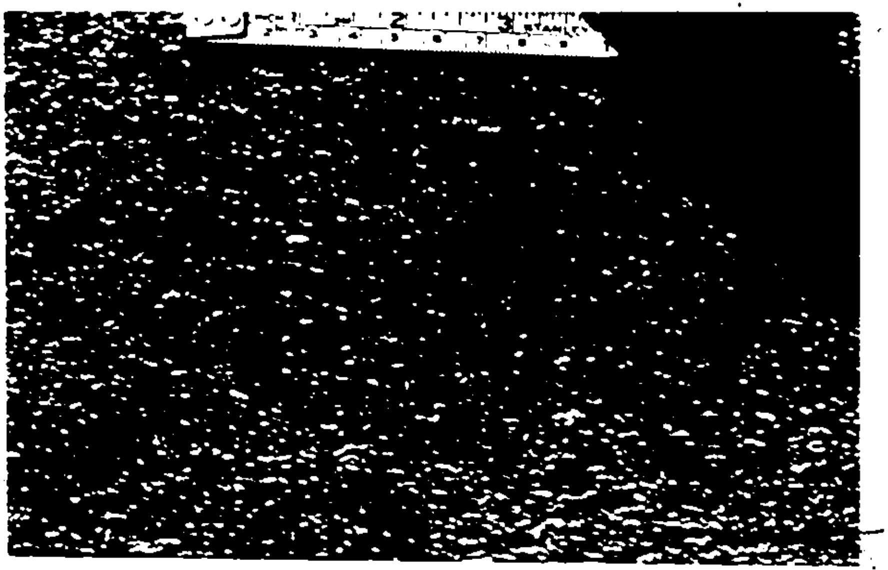


Figure 22. Massive portion of the Sunshine Lake Formation, NW Uphill Lake. Note the feldspar (white) and hornblende (black) phenocrysts.

Figure 23. Brecciated lava, Sunshine Lake Formation, north of Sunshine Lake.

Figure 24. Flow breccia in lava, Sunshine Lake Formation, north of Sunshine Lake. Lamination in fine material at left apparently is flow-banding. Blocks are porphyritic and amygdaloidal. Amygdules weather out (inset).

grained clast-supported conglomerate, rounded clasts, and a few occurrences of cross-bedding (>10 cm sets) indicate deposition by tractional currents.

Uphill Lake Formation

The Uphill Lake Formation is well developed in the northern Uphill Lake area, from which it derives its name. The formation is somewhat variable, ranging from thickly-bedded pyroclastics in the west, to reworked pyroclastics in the central portion, to cross-bedded conglomerate and sandstones in the east. Most of its characteristics, however, can be observed in outcrops on or near Uphill Lake, from its southwest end through Rush Bay to Surprise Lake.

The Uphill Lake Formation extends virtually the entire length of the sedimentary belt (Fig. 4), although southwest of Cane Falls it is represented only by the Rush Bay Member (Fig. 4). The formation varies in thickness from 500 m to 1200 m, the thickest portion being east of Surprise Lake.

It has been possible to recognize two distinct members within the Uphill Lake Formation: the Surprise Lake Member, entirely enclosed within the formation, and the Rush Bay Member, which forms the top of the formation over most of its length (Fig. 4). These two members are discussed separately in later sections. Hence, the following discussion refers only to the main mass of the formation, exclusive of these members.

There is no evidence of an angular unconformity between the Sunshine Lake Formation and the overlying Uphill Lake Formation, but clasts of Sunshine Lake volcanic material are frequently incorporated into the lower beds of the Uphill Lake Formation, indicating local erosion or reworking of loose flow-top debris. At one locality north of Sunshine Lake the contact appears to be gradational in that the lava rocks gradually lose their "igneous" appearance, looking more like breccias, over a few metres stratigraphically, until finally clear, unequivocal clasts and bedding are evident. This could represent a regolith formed on the lavas, but there is no apparent discoloration. Herd et al. (1976) report an Archean non-oxidized regolith, but it is marked by an altered micaceous rind in one instance, and in another place, by a thick altered and fractured zone. Neither of these features is present at the locality north of Sunshine Lake. At the eastern end of the area, a few thin flows of the Sunshine Lake Formation are intercalated with equally thin Uphill Lake-type sediments, indicating a transition from one to the other by decreasing volcanism and eventual establishment of the sedimentary regime.

Because the sandstones and conglomerates of the main part of the Uphill Lake Formation and of the overlying Rush Bay Member are similar, the contact between them is gradational via the introduction of more and thicker fine-grained units. This contact, therefore, has been arbitrarily set at the base of the lowest siltstone-argillite unit that can be traced a reasonable distance (which generally means the first one 10 m thick or more).

With the exception of the Rush Bay Member, the Uphill Lake Formation cannot be traced as a separate entity beyond Cane Falls (Fig. 4). The western portion of the Uphill Lake Formation is pyroclastic material identical in all respects to the Cane Lake Formation. The distinction between these two formations from "Bulbous Bay" to Cane Falls depends solely upon the presence of the tongue of Sunshine Lake Formation lying between them. West of where this tongue ends, there is no longer any justification for two formations. Since it is all pyroclastic material, it is referred to the Cane Lake Formation. In effect, the Cane Lake Formation is completely transitional into the western end of the Uphill Lake Formation at Cane Falls. The eastern end of the Uphill Lake Formation is cut out by a fault.

The Uphill Lake Formation shows considerable lateral variation, making it impossible to select one type locality. On the basis of bedding style, sedimentary structures and composition, the formation can be divided into three parts, each laterally equivalent to and transitional into those beside it: the western, central, and eastern areas. The western area runs from Cane Falls to a line approximately equidistant between 'Bulbous Bay' and Rush Bay (Fig. 25). The central area is divided from the eastern area by a diagonal line running through Surprise Lake then rising through the section to a point southeast of 'Loose-Pebble Bay' (Fig. 25).

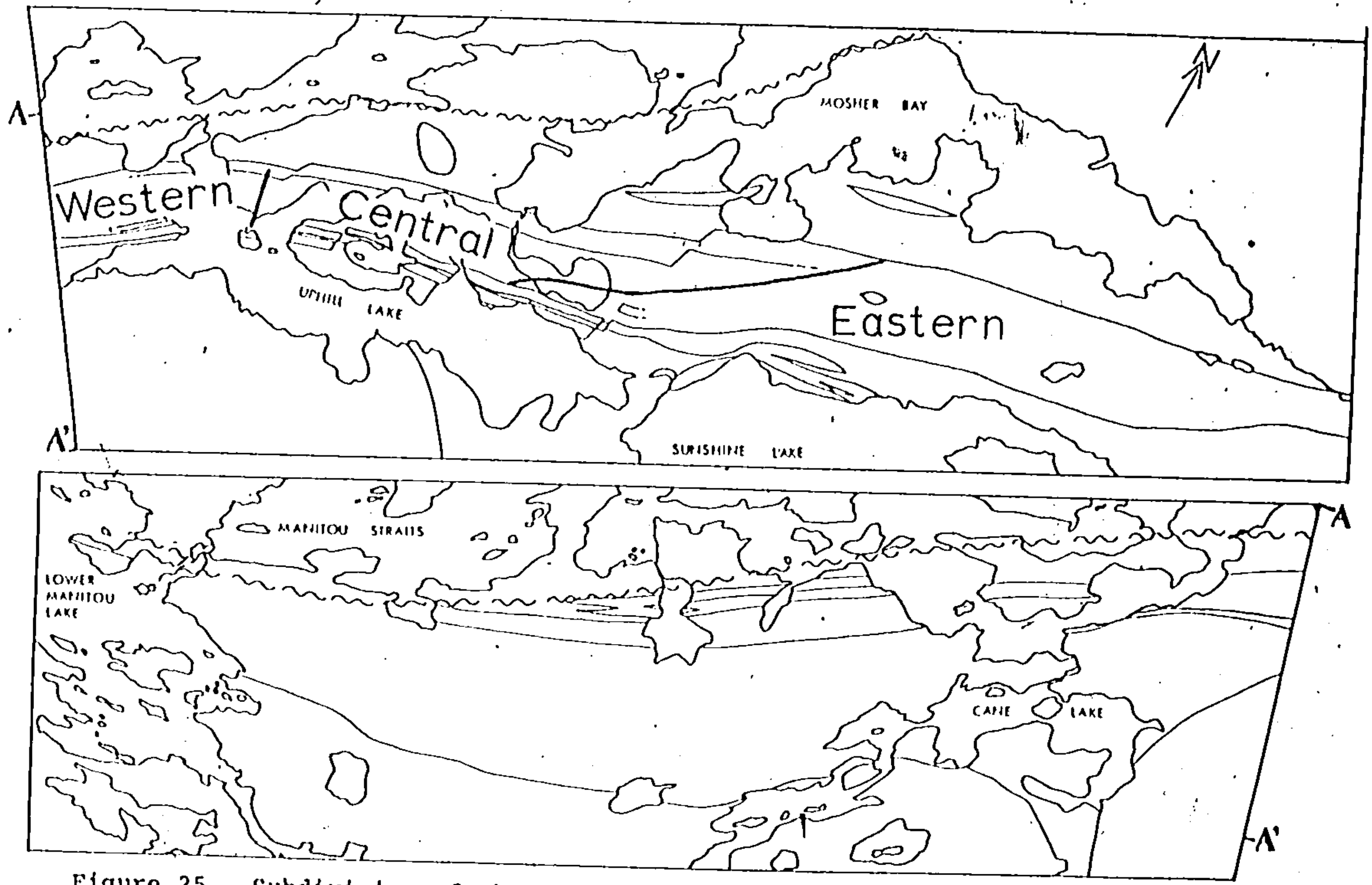


Figure 25. Subdivision of the Uphill Lake Formation into western, central, and eastern areas.

1. The Western Area

The type area for this portion of the formation is about 200 m northwest of Cane Falls, just above the Sunshine Lake Formation on the southeast shore, and the large outcrops opposite, along the northwest shore, up to the first argillite unit of the Rush Bay Member.

Thin bedding (10 cm) and one occurrence of cross-lamination (3 to 10 cm sets) immediately above the Sunshine Lake Formation indicate reworking at the base of the formation, but the entire exposed remainder of the section is very thickly-bedded, massive tuffs and tuff-breccias (Fig. 26). Bedding thicknesses range from 1 to 20 m. The clasts (2 to 25 cm) are all volcanic, mainly felsic, but with an important mafic component as well. They are dispersed in a buff-weathering matrix of similar volcanic debris. No fine-grained, thinly-bedded, sorted sandstones or argillites were found interbedded with these tuffs. These rocks are in no way distinguishable from the pyroclastic rocks of the Cane Lake Formation along strike to the southwest or to the southeast, below the tongue of Sunshine Lake Formation (Figs. 16, 26).

Further to the east, at "Bulbous Bay", a measured section (section 49, Fig. 27) which includes the top several metres of the Uphill Lake Formation shows the massive and thickly-bedded nature of these pyroclastics, although the beds are commonly even thicker than these.

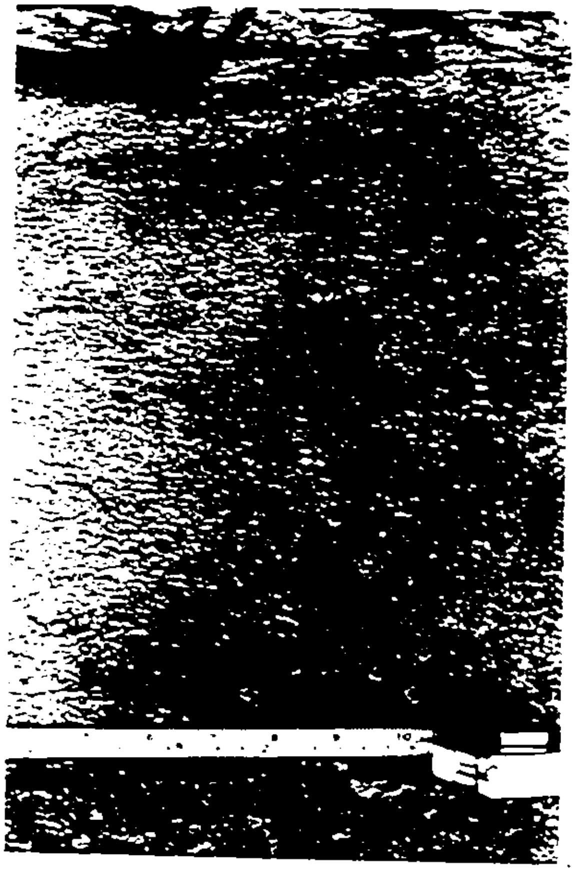


Figure 26. Massive tuff of the Uphill Lake Formation on northwest shore of the Manitou Straits, about 200 m northwest of Cane Falls.

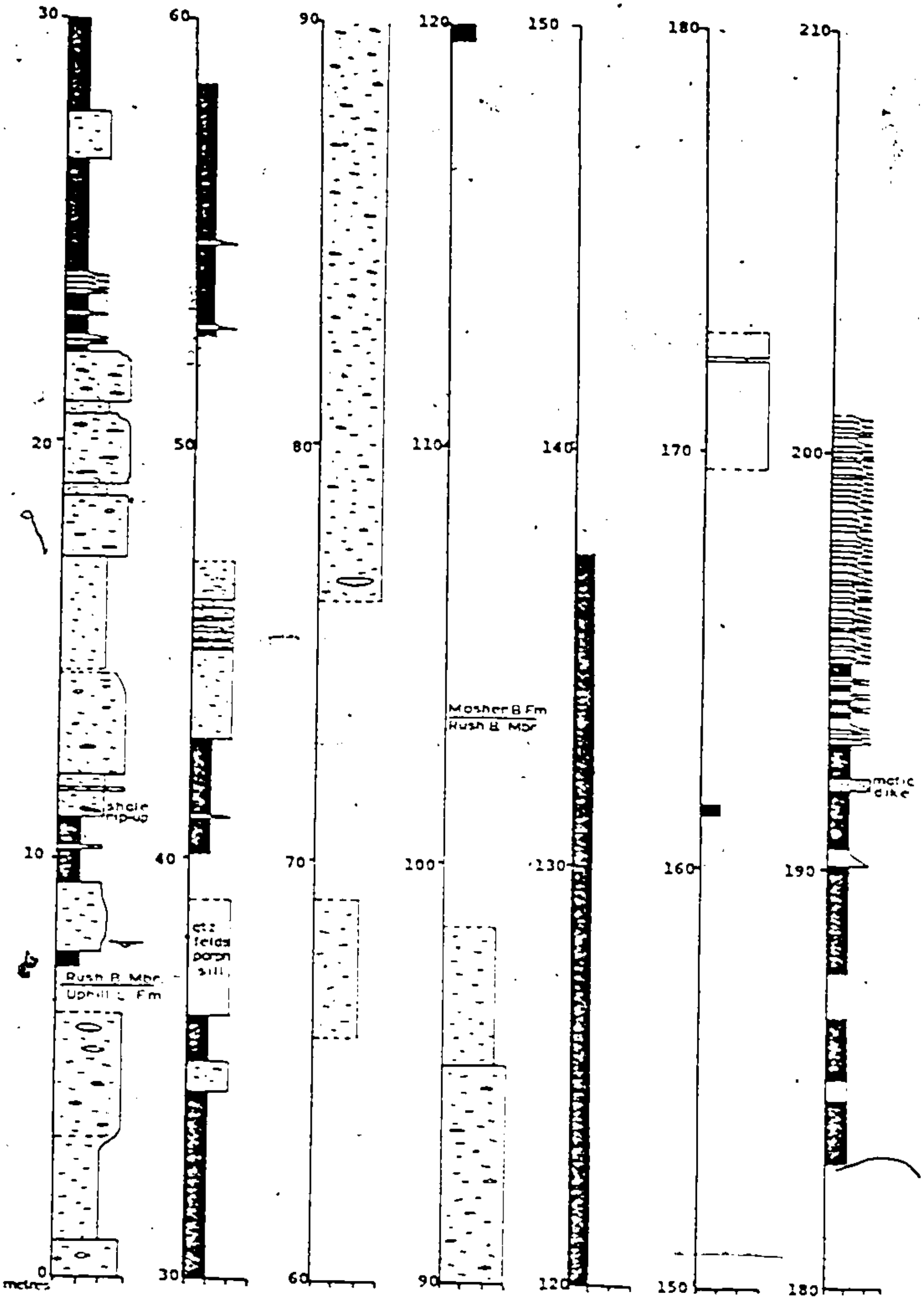


Figure 27. Measured section 49 at "Bulbous Bay" of the western area of the Uphill Lake Formation, the Rush Bay Member of the Uphill Lake Formation, and the Mosher Bay Formation. Location on Figure 6. Legend as for Fig. 9.

2. The Central Area

It is more difficult to select a specific type outcrop for the central area, because of the dispersed nature of the exposure. However, a number of short measured sections (sections 2 (Fig. 28), 4 and 31 (Fig. 29)) illustrate the features. The longest (section 2, Fig. 28), at the northeast corner of Surprise Lake, fairly well typifies the proportions of different rock types and their relationships with one another, except that the thin argillite beds seem more common here than in the rest (especially western part) of this area. It is more typical of the eastern portion of the area, whereas sections 4 and 31 (Fig. 29) are more typical of the western end.

The rocks in this area are composed entirely of volcanogenic sandstone and conglomerate, with some direct volcanic input in the form of tuff beds. The clasts are generally rounded, poorly sorted, and close-packed or dispersed in the conglomerate beds. Most of the sandstone beds have at least a few pebbles dispersed in them. In fact, over large parts of the area, the only lithology appears to be medium to coarse-grained sandstone with dispersed rounded clasts, about 1 to 15 cm in diameter, with very rare ones to 40 cm.

Bedding thickness ranges from a few cm to about 30 cm, rarely to 100 cm. Bedding contacts are distinctly visible, but are commonly not sharp (section 31; Fig. 29). Over several metres, the section

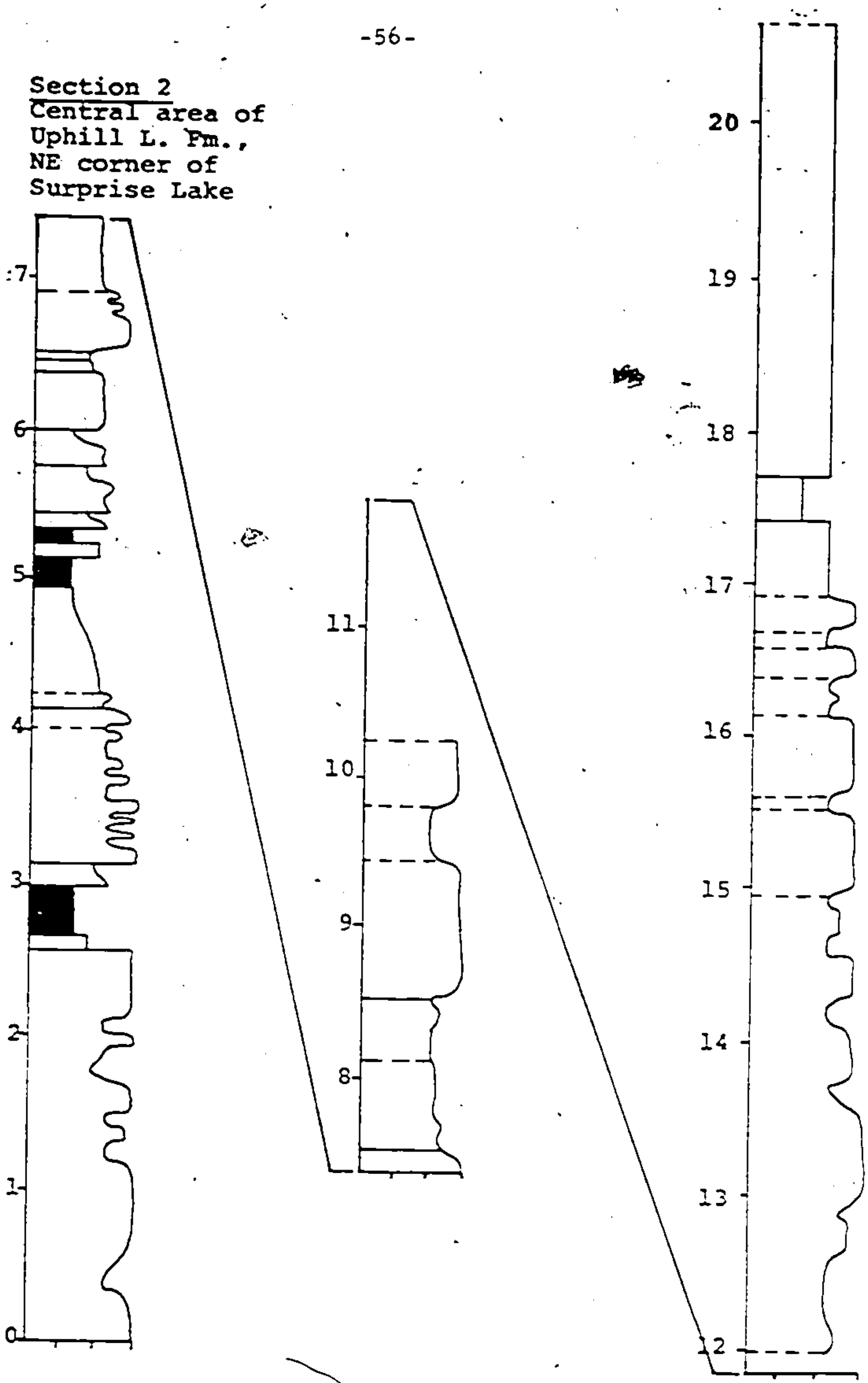
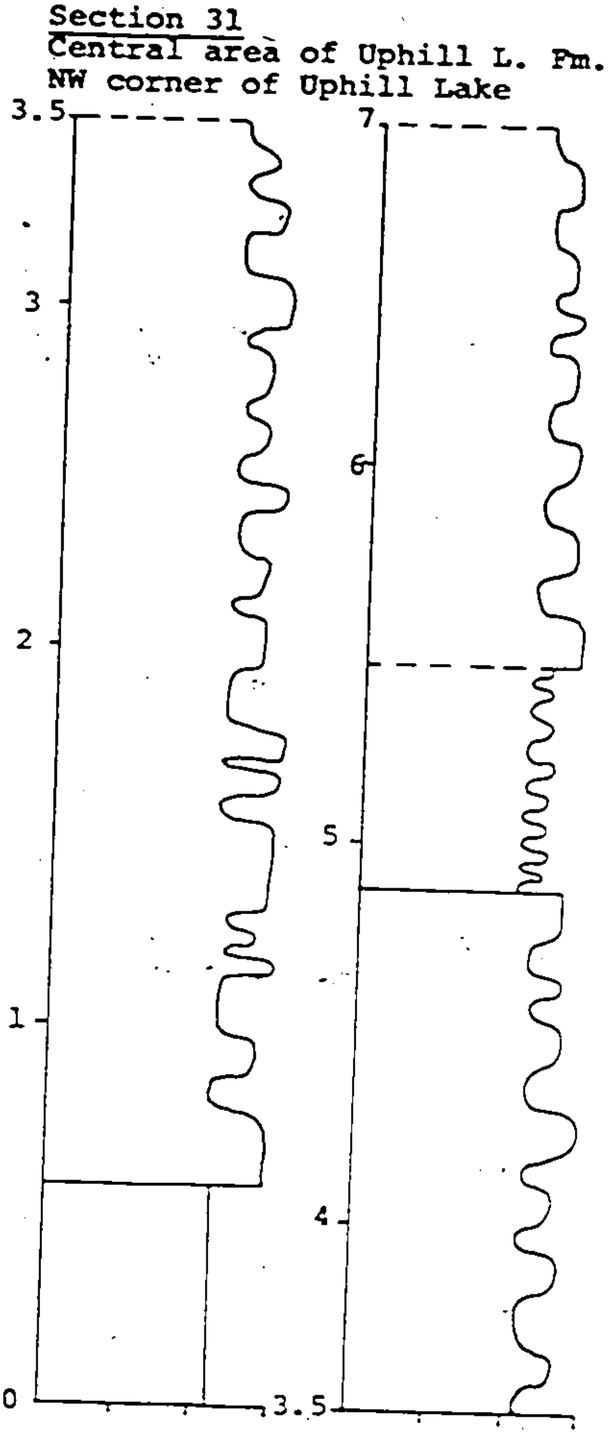


Figure 28. Measured section 2 of the central area of the Uphill Lake Fm., northeast corner of Surprise L.



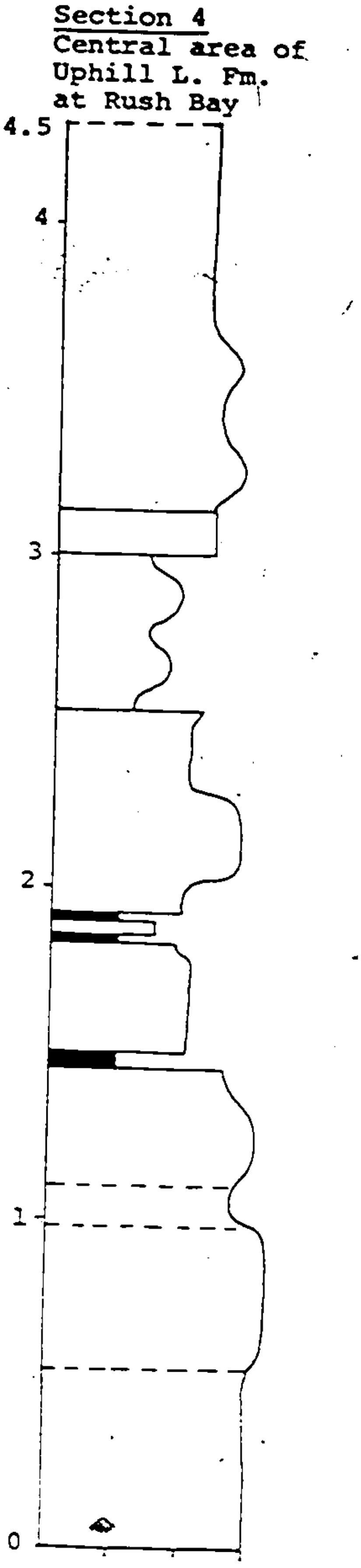


Figure 29. Measured sections of the central area of the Uphill Lake Fm. Locations on Fig. 6. Legend as for Fig. 9.

consists only of alternating conglomerate and sandstone with indistinct contacts between them (Fig. 30). Trough cross-bedding (15 cm sets) is present, but not common (Fig. 8), although it is more common toward the eastern part of the area. It is confined to sand-sized material. The rocks underlying the Surprise Lake Member are very similar to those above, except perhaps for a tendency towards more clasts of the immediately underlying Sunshine Lake Formation.

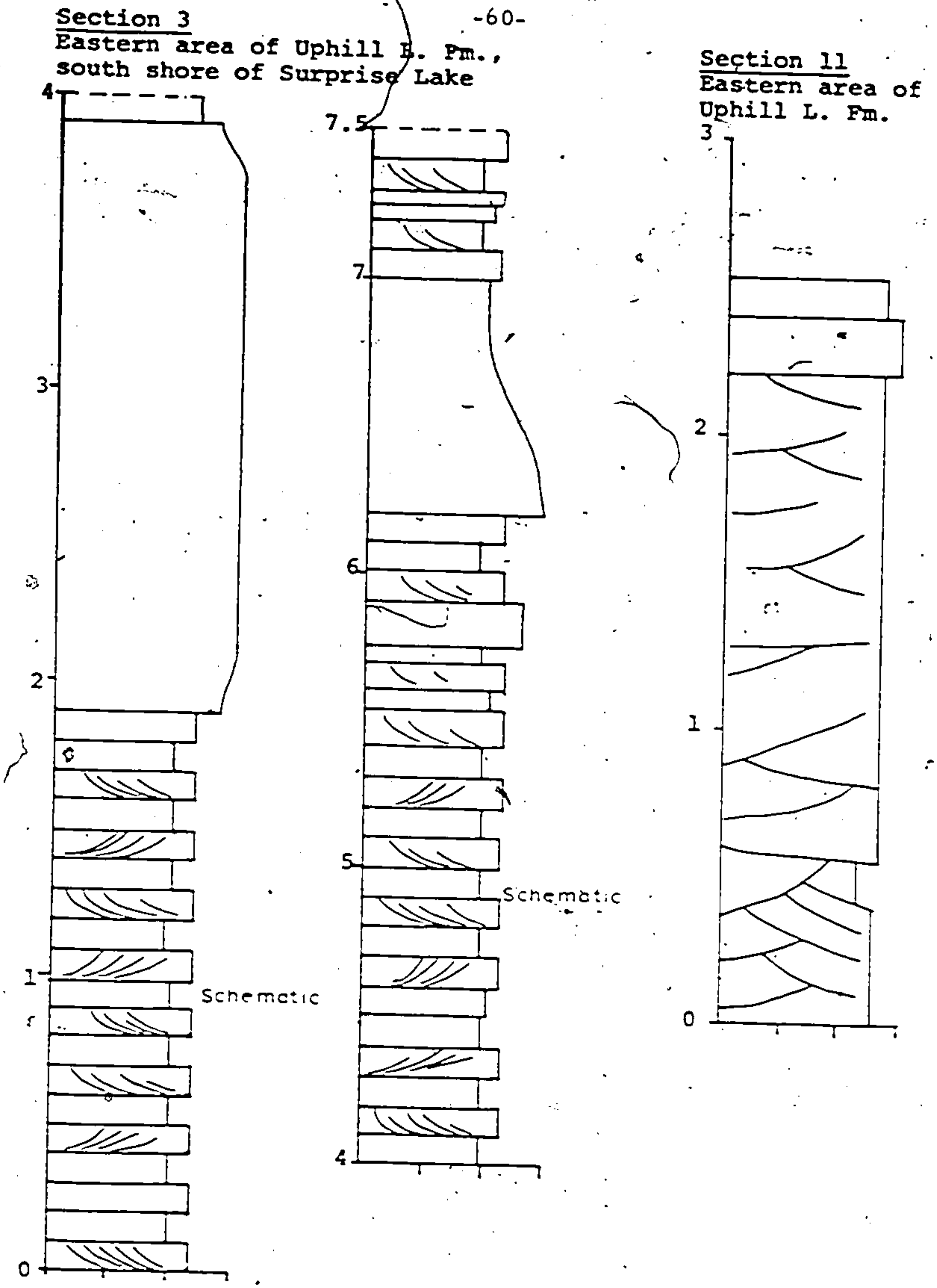
3. The Eastern Area

No measured section of any great length was possible for the eastern area because it is entirely inland, where outcrops are only a few metres across. Measured sections 11 (Fig. 31), 45, 46 and 47 (Fig. 32) are generally typical, although cross-bedding is less evident in the lower part of the formation (section 14, Fig. 32).

The eastern area is very different from the other two areas. It is not composed exclusively of volcanogenic material, but rather has a component of granite, iron formation, chert and quartz clasts in both the conglomerate and sandstones (Chapter VI).

The rocks in the area are mainly conglomerate with some interbedded sandstone. Conglomerate beds range in thickness from 1/2 to 2 m. sandstone beds are generally somewhat thinner at about 5 to 25 cm. Conglomerate makes up at least 75% of this part of the formation.

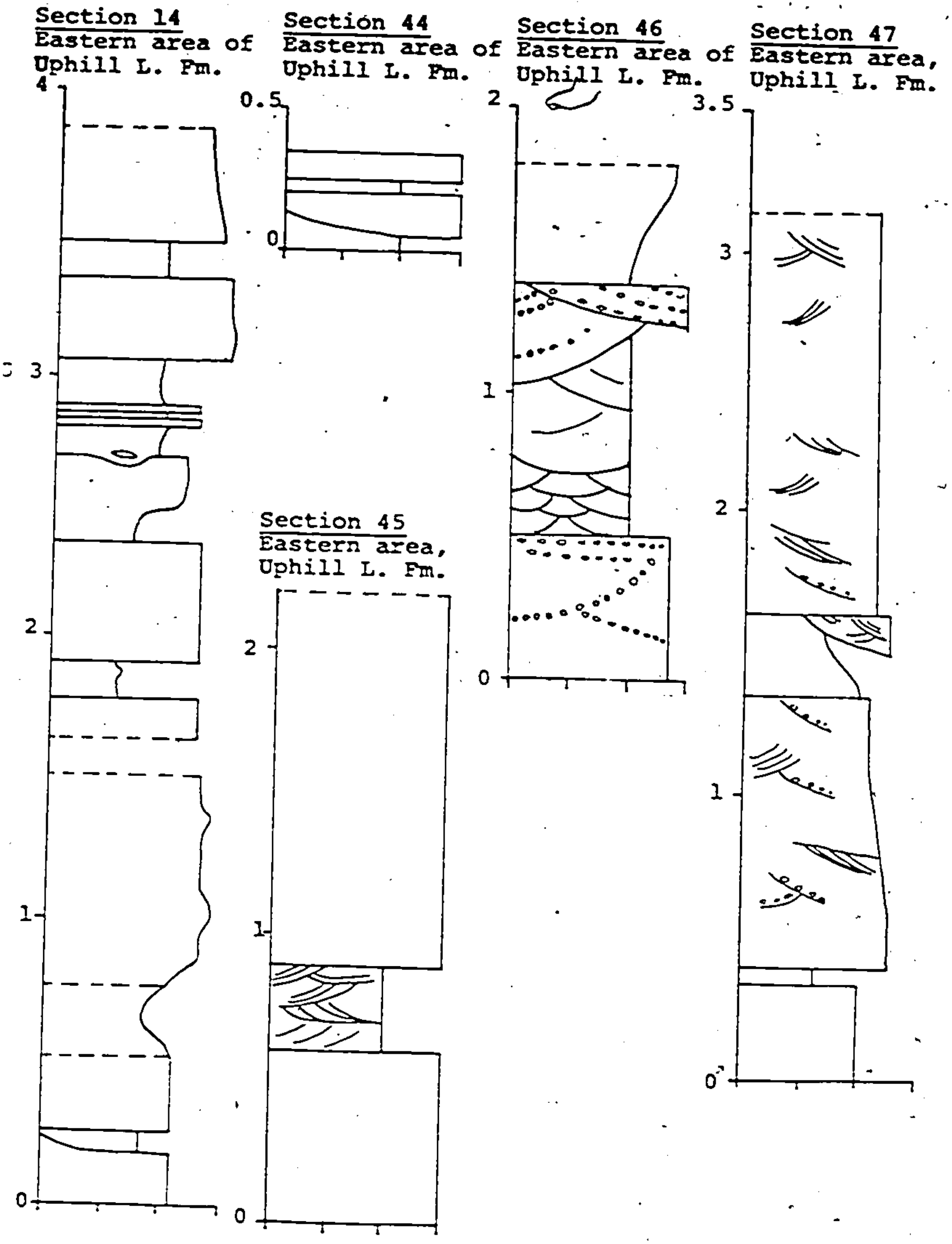
Figure 30. Alternating sandstone and conglomerate with indistinct contacts between them, central area of the Uphill Lake Formation, northwestern Uphill Lake.



Section 3
Eastern area of Uphill L. Fm.,
south shore of Surprise Lake

Section 11
Eastern area of
Uphill L. Fm.

Figure 31. Measured sections of the eastern area of the Uphill L. Fm. Locations on Fig. 6; legend as for Fig. 9.



Section 14
Eastern area of Uphill L. Fm.

Section 44
Eastern area of Uphill L. Fm.

Section 46
Eastern area of Uphill L. Fm.

Section 47
Eastern area, Uphill L. Fm.

Section 45
Eastern area, Uphill L. Fm.

Figure 32. Measured sections of the eastern area of the Uphill Lake Fm. Locations on Fig. 6; legend as for Fig. 9.

The conglomerates in this area are commonly finer-grained than those to the west: clast sizes rarely exceed 10 cm, and many of the conglomerates are composed only of 1 - 2 cm clasts. Many of the sandstones, as well, are in the fine to medium sand range as opposed to the coarse to very coarse grained sandstones to the west. The sandstones appear sorted and the conglomerates are clast-supported, except towards the west, along the south shore of Surprise Lake (section 3, Fig. 31) where pebbly sandstones are abundant.

In one measured section (14, Fig. 32) there are three 10 cm thick siltstone beds. There is also a 2 m thick, apparently discontinuous, argillite unit which could be an extension of the Surprise Lake Member. Other than these, no argillite beds were observed.

Large scale cross-bedding, with sets from 10 cm to 1 m thick, is very abundant in both the sandstones and the conglomerate. Some outcrops are entirely cross-bedded (sections 11 (Fig. 31), 46 and 47 (Fig. 32)). There are two types of cross-bedding:

1) thinner sets, in sandstones, and apparently most common near Surprise Lake; and

2) thicker sets, in both sandstones and conglomerates, and more common towards the east.

In the first type, each sandstone bed is a cross-bed set. Beds are 8-10 cm thick, with a few only 2-3 cm thick. Cross-bedding shows most clearly in the lowest 3 cm of the bed and is defined by dark streaks that are finer-grained, apparently a heavy mineral concentration. Rarely a 1 to 2 cm pebble lies between beds or along the inclined part of the cross-bed. The cross-beds are asymptotic at the base and truncated at the top (Fig. 33). In places, the cross-beds appear to form tabular sets (Fig. 33; section 3, Fig. 31) but other, otherwise identical, cross-bed sets in the same outcrop are trough-crossbeds (Fig. 34). Equally common, and closely associated with these cross-beds are 2 m thick or more sections of trough cross-bedding with cross-bed sets 10 to 20 cm, rarely to 30 cm. There are no bedding planes, just troughs. This cross-bedding is also defined by heavy minerals. One outcrop has been eroded to expose the original bedding plane, clearly showing the traces of a trough (Fig. 35). This trough gives a flow direction of 055°.

The second type of cross-bedding is found in the conglomerates that dominate the central and eastern parts of the eastern area. Conglomerate beds are about 1 to 1-1/2 m thick, composed entirely of trough cross-beds in 20 to 50 cm sets (section 11; Fig. 31). Sets occasionally reach 1 m in thickness (Fig. 36). In sandstones, the trough cross-bedding is much the same, except beds are a little thinner (generally less than 1 m) and the cross-bed sets are 10 to 30 cm thick (Fig. 37). Commonly the beds filling one trough are conglomerate at the base changing upward to pebbly sandstone or sandstone, or sandstone at the base and changing upwards to conglomerate, or even alternate between grain sizes (section 46; Fig. 32). In these cases the maximum clast size is 5 cm.

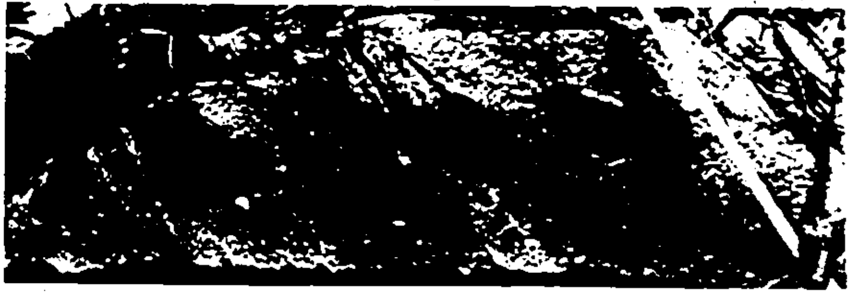


Figure 33. Cross-bedding in coarse, slightly pebbly sandstone, eastern area of the Uphill Lake Formation, south shore of Surprise Lake.

Figure 34. Trough cross-bedded sandstone, eastern area of the Uphill Lake Formation, south shore of Surprise Lake.

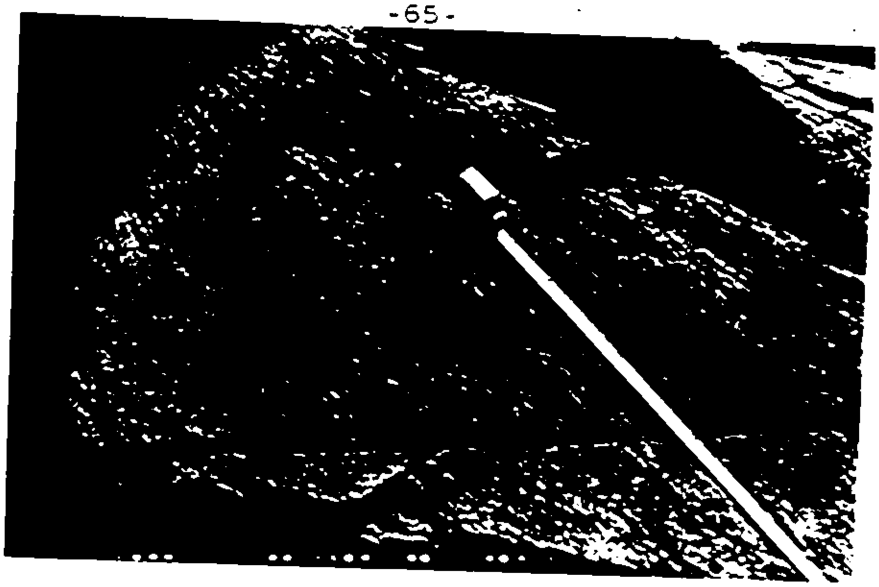


Figure 35. Plan view of trough exposed in trough cross-bedded sandstones, eastern area of the Uphill Lake Formation, south shore of Surprise Lake.

Figure 36. Very large scale cross-bedding in conglomerate of the eastern area, Uphill Lake Formation. Top edge of photograph parallels regional bedding, the pebbles running from the upper left to lower right define a cross-bed set about 1 m thick.

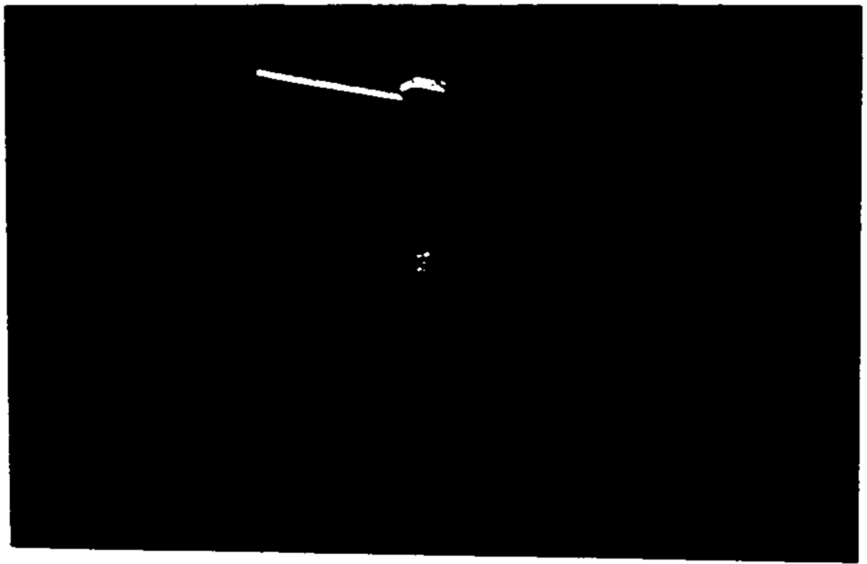


Figure 37. Large-scale cross-bedded sandstone and conglomerate in the eastern area of the Uphill Lake Formation.

Figure 38. Laminated argillite and siltstone of the Surprise Lake Member, Uphill Lake.

There appears to be no consistent vertical sequence in grain size or sedimentary structures. In one section (47; Fig. 32) the sequence goes from trough cross-bedded conglomerate and sandstone, which decreases upwards in grain size and size of cross-bedding sets, into parallel laminated coarse-grained sandstone which decreases in size, passing in turn into parallel laminated fine sandstone or siltstone. This is partially cut out by an erosional trough filled with cross-bedded sandstone and conglomerate and the cycle repeats at least once more, perhaps twice.

On the other hand, in another section (46; Fig. 32), nearby, the sequence begins at a sharp base with medium to coarse grained sandstone, trough cross-bedded in 10 to 20 cm sets which passes gradationally upwards into trough cross-bedded conglomerate via increasing grain size and thickness of cross-bed sets. This is truncated by a sharp base and the cycle is apparently repeated at least once.

Yet again, many of the sections (for example, 3 (Fig. 31), 45, 44 and 14; Fig. 32) show no stratigraphic organization whatever.

This lack of clear-cut vertical sequences could be in part due to the limited exposure and relatively small outcrops, but the general impression from the field and examination of measured sections is that there is no consistent pattern to vertical sequences in the eastern area.

4. The Surprise Lake Member of the Uphill Lake Formation

The Surprise Lake Member is a fine grained unit lying entirely within the Uphill Lake Formation. It is 60 m thick, lies about 30 m above the base of the formation, and extends from the western to the eastern end of Uphill Lake (Fig. 4). It has been named the Surprise Lake Member because a large outcrop south of Surprise Lake, just west of the stream connecting Uphill Lake to Surprise Lake, displays well the general aspects of the member, including a sandstone bed.

The base of the member is sharp and even, with laminated argillite overlying coarse sandstones of the underlying portion of the Uphill Lake Formation. The top of the member dies out in a small coarsening-upwards sequence only about 1 m thick in which siltstone replaces argillite in the laminated fine grained sediments, then a few fine grained sandstone beds appear and increase upwards until all fines are gone, and coarse sandstones, grit, and conglomerate appear.

The Surprise Lake Member is composed dominantly of thinly-bedded to laminated siltstone and argillite (Fig. 38). Bed thicknesses range from 1/2 to 10 cm, but are nearly all about 1 cm. Bedding contacts are sharp, parallel, and continuous along strike. In a few places, there is convolute lamination involving 10 to 20 laminae and confined between parallel beds (Fig. 39). There are several occurrences of syndepositional slumping which disrupts and occasionally obliterates laminations and

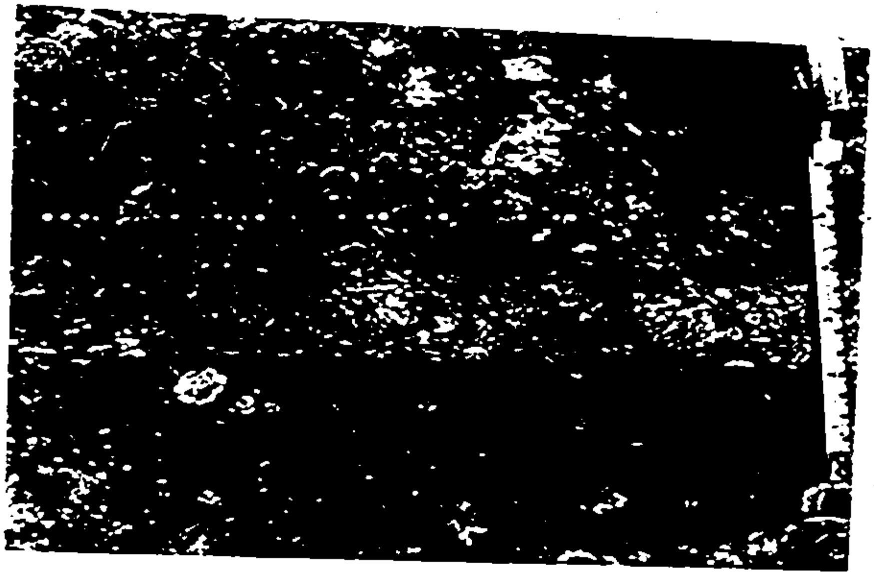


Figure 39. Convolute lamination in the Surprise Lake Member, Uphill Lake.

bedding (Fig. 40). In a few beds, the grain size increases to that of fine sand. These sandstone beds are from 5 to 20 cm thick and trough cross-bedded (10 cm sets) in places. Graded bedding was not observed.

5. The Rush Bay Member of the Uphill Lake Formation

The Rush Bay Member is a highly variable assemblage of siltstone, argillite, volcanogenic and quartzose sandstone, conglomerate, tuff and tuff-breccia occupying the top of the Uphill Lake Formation over most of its length (Fig. 4). At its western end, the member is cut out by the Manitou Straits fault. At its eastern end, the member merges with the rest of the Uphill Lake Formation because the argillite units which serve to separate out the member cannot be traced beyond "Loose-Pebble Bay". It cannot be reliably traced between "Bulbous Bay" and a point north of Cane Falls (Fig. 3), but this is almost certainly due to a lack of outcrop rather than a lack of the unit. The member ranges in thickness from about 200 m northwest of Cane Falls to a maximum of 400 m at "Odd Lake".

The coarse clastic rocks of the Rush Bay Member are generally similar to those of the rest of the Uphill Lake Formation. The lower boundary of the member has therefore been arbitrarily set at the lowest siltstone-argillite unit that can be traced a reasonable distance, which generally means the first one 10 m thick or more. In the field, at most localities, it has been possible to separate the Rush Bay Member

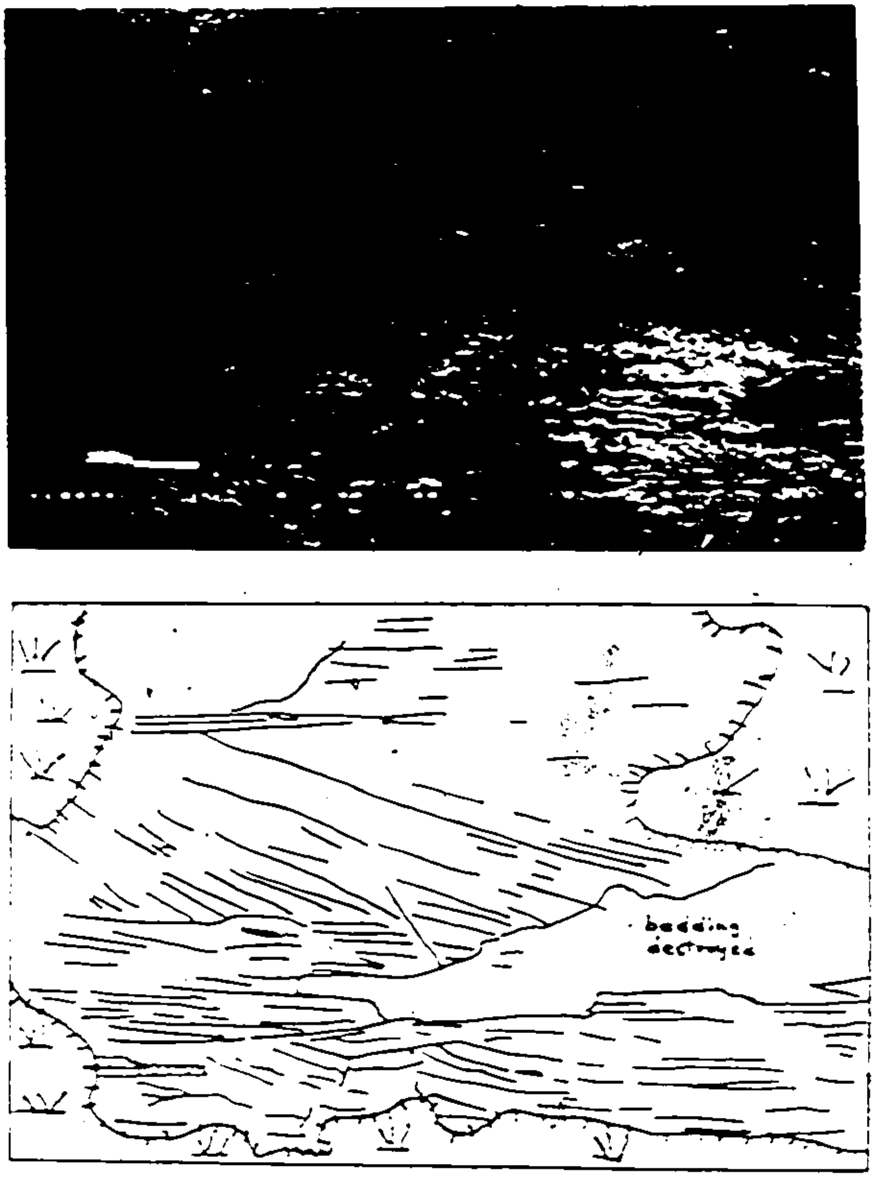


Figure 40. a. Syndepositional slumping in the Surprise Lake Member, at Rush Bay. b. Tracing from the photograph in (a), showing disrupted bedding.

from the overlying Mosher Bay Formation on the basis of the colour of the argillites: the Rush Bay argillites are green-gray whereas the Mos Bay argillites are blue-gray. Where this distinction is less evident, t contact is placed above the last sandstone or conglomerate similar to others in the Rush Bay Member and below the first appearance of interbedded sandstone and argillite of the Resedimented Association (Turner Walker, 1973) which constitute the Mosher Bay Formation. The actual contact was only rarely observed, in small outcrops, but there is no angular discordance of bedding and the contact appears to be conformabl

The Rush Bay Member was first encountered along the northern shore of Rush Bay, from which it derives its name. Two measured sections (28, 29; Fig. 41) from this area display fairly well the characteristics of the member, although the quartzose sandstone and granite-pebble-bearing conglomerates are not well represented. Laminated argillite and siltstone units about 15 m thick alternate with tuff-breccia beds from 2 m to at least 25 m thick. The maximum clast size is about 15 cm. Some of the coarse clastic beds contain a small percentage of plutonic, quartz, and iron-formation clasts (measured section 29; Fig. 41). In an outcrop a little to the east, single argillite beds have apparently broken up into slabs that lie in or near their origina bedding plane, between beds of siltstone and fine sandstone (Fig. 42). Close investigation of the fine-grained beds in this area revealed no

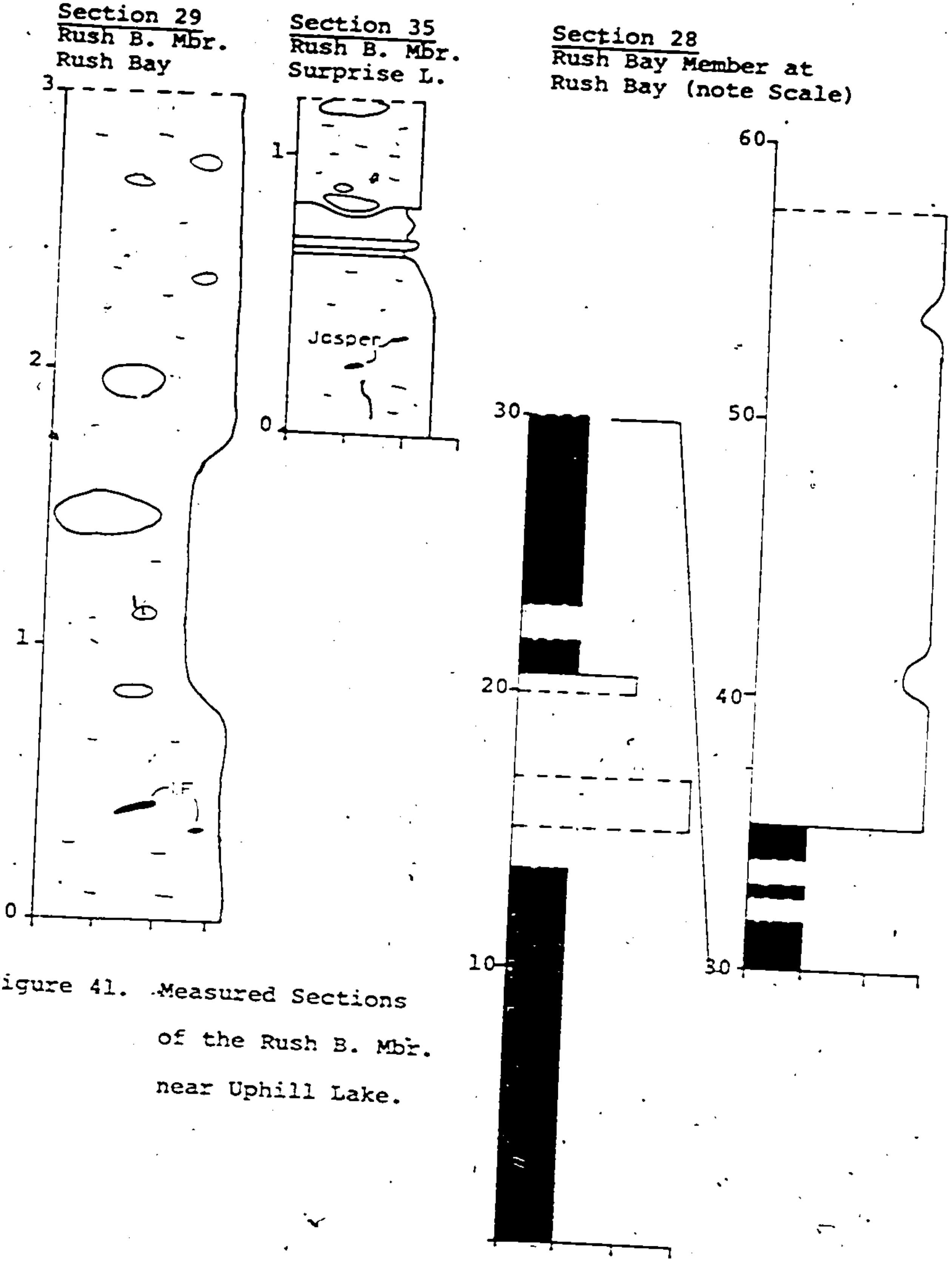


Figure 41. Measured Sections of the Rush B. Mbr. near Uphill Lake.

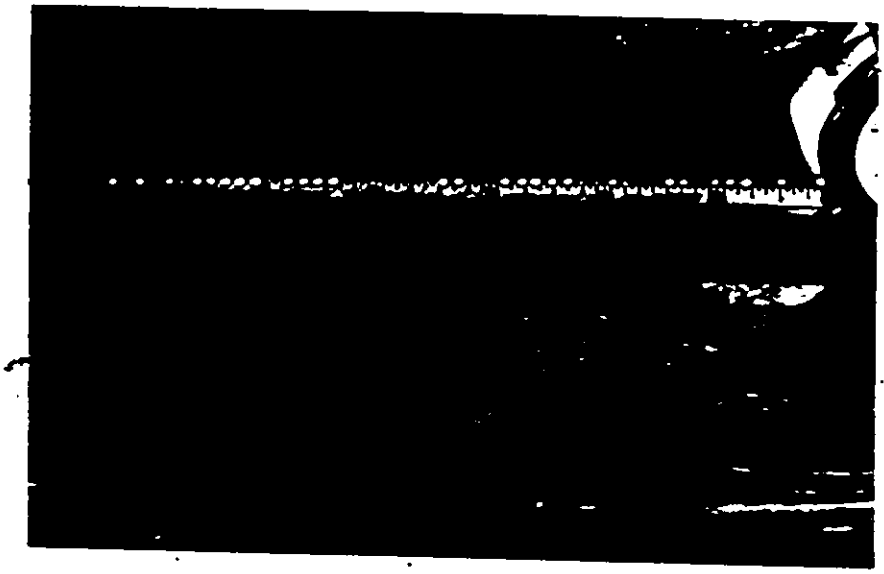


Figure 42. Intraformational conglomerate composed of argillite fragments, Rush Bay Member, Rush Bay.

graded bedding or cross-lamination. There are a few occurrences of convolute lamination.

About 1-1/2 km to the west; at "Bulbous Bay", a measured section (49; Fig. 27) passes completely through the Rush Bay Member. Here, the member is similar to that at Rush Bay in that it is composed of alternating laminated fine-grained sediments and tuff-breccias, but it differs in some details.

A number of the argillite-siltstone units contain thin (2 to 15 cm) fine sandstone beds, some of which are graded (e.g., between 22 and 25 m of section 49; Fig. 27). There are two occurrences of apparent syndepositional deformation in the fine sediments. The siltstone-argillite units range in thickness from 1 m to 7 m, somewhat thinner than at Rush Bay.

The coarse units are not all tuff-breccias, but also include many coarse tuffs. The lowermost of these is parallel laminated, with some indistinct cross-lamination. It is finer grained at both the base and the top. A number of the others are faintly to distinctly laminated in the top 20 cm or so. None of these is appreciably graded. They range in thickness from 30 cm to 3.5 m, and have sharp contacts with either the argillites or the tuff-breccias. In one tuff bed, slabs of laminated argillite 10 cm by 60 cm have been torn up and included in the base of the tuff-bed, together with a 20 cm porphyry clast. Neither this section nor those at Rush Bay illustrate a feature otherwise common in the Rush Bay Member and perhaps best developed north of Surprise Lake (section 35; Fig. 41): beds with all the characteristics of tuffs except that they contain small (1/2 to 1 cm) very angular chips of jasper.

The tuff-breccias range in thickness from 10 cm to 5 m, but most are around 1.5 m. Three of the beds are ungraded, and three show normal grading in the top 20 cm of the bed. One of the latter is inversely graded over 20 cm at its base. The tuff-breccias are poorly sorted, the clast size ranging from 2 to 20 cm, with rare clasts to 30 or even 60 cm. Throughout the Rush Bay Member, felsic clasts appear to be more abundant than in the pyroclastics of the Cane Lake Formation.

The Rush Bay Member at section 15 (Fig. 10), 1-1/2 km northwest of Cane Falls, and section 50 (Fig. 12) at "Odd Lake", contains laminated argillite and siltstone, and tuffs and tuff-breccias similar to those already described. In addition, these sections display well a feature present, but not well developed, in the uphill Lake area; namely, quartzose sandstone and polymictic conglomerate.

One occurrence of a 1 m thick polymictic conglomerate in section 15 (Fig. 10) is composed largely ~~of~~ felsite, porphyry, and greenstone clasts, ranging from 1 to 30 cm in diameter (mainly about 12 cm), but it has a notable number of chert, quartz, jasper, and granitoid clasts generally less than 10 cm in diameter. The clasts are close-packed and poorly sorted. The bed rests with a sharp base upon tuff. At its top it grades into a volcanic-clast bed very similar to the conglomerate except that there are no non-volcanic clasts and the clasts are somewhat dispersed. A second occurrence of polymictic conglomerate is similar to the first, but is isolated from the rest of the section by late basalt dikes.

At "Odd Lake" (section 50; Fig. 12) the upper half of the Rush Bay Member is dominated by quartz-rich sandstone, pebbly sandstone, and polymictic conglomerate. The transition from tuffaceous rocks in the lower part of the member to the quartz-rich rocks occurs over an 80-cm transition zone. The massive coarse-grained tuff with scattered 1 to 4 cm felsite clasts does not change in overall appearance at all, but in the sand-sized portion the quartz content rises from zero to about 25%, and about 10% of quartz clasts appear among the felsite clasts. In the lower, tuffaceous, part there are zones of higher concentration of clasts, and in the upper, quartz-rich part there are streaks or lenses (about 2 cm by 20 cm) of siltstone, but over a stratigraphic thickness of 21 m there is no good bedding plane. The transition zone is in the middle of this part of the section. Most of the section above the transition consists of massive, coarse-grained, quartz-bearing sandstone with scattered felsite, quartz, and rare mafic volcanic and slate clasts. There is one 50 cm thick bed of close-packed conglomerate containing quartz, chert, felsic volcanic and rare mafic volcanic pebbles, 1/2 to 8 cm in diameter.

A number of thinner (10 cm) beds are similar, possibly containing some granitoid clasts. These sandstone and conglomerate beds are essentially ungraded, contain no parallel lamination, cross-lamination, or cross-bedding, and lack any associated fine-grained rocks. There are similar rocks within the Rush Bay Member to the east of "Odd Lake", among pyroclastic rocks, and to the west of the lake to the end of exposure. A 30 m unit of similar rocks was traced via scattered small outcrops along the very top of the Rush Bay Member, from "Bulbous Bay" to Rush Bay. They are totally unlike the sandstone and conglomerate of the rest of the Uphill Lake Formation, and equally unlike those of the Mosher Bay Formation.

The Mosher Bay Formation

The Mosher Bay Formation is a group of argillites, sandstones and conglomerate of the Resedimented Association (Turner and Walker, 1973) at the top of the Manitou Group. It is named after Mosher Bay, where nearly continuous outcrops along the irregular south shore clearly display all aspects of the formation. The formation extends almost the full length of the study area, from Beaverhead Island to eastern Mosher Bay, with the exception of a small gap just east of Beaverhead Island, and at the extreme eastern end, where faults cut down through the stratigraphy (Fig. 4). It is a minimum of 500 m thick, but estimates of its true thickness are impossible due to the Manitou Straits Fault (Fig. 3) and isoclinal folding in the upper part of the formation (Fig. 8). The base of the formation, as previously described, is based on the colour of argillite (green-gray of the Rush Bay Member vs. blue-gray of the Mosher Bay Formation) and the first appearance of the rocks of the Resedimented Association. Although sparsely exposed, the contact appears to be conformable. The top of the formation, and ~~thus~~ the top of the Manitou Group, is cut out by the Manitou Straits Fault, and by another fault through Mosher Bay (Fig. 3).

For purposes of description, the Mosher Bay Formation can be separated into two parts: 1) the argillites and sandstones that form the bulk of the formation; and 2) large lenses of interbedded conglomerate and coarse sandstone.

Extensive small-scale faulting and a strong cleavage make it difficult to obtain measured sections of the finer grained materials. Section 36 (Fig. 43) at Mosher Bay, covers a few beds, and some are included in the upper parts of section 49 (Fig. 27) at "Bulbous Bay" and section 50 (Fig. 12)at "Odd Lake".

The coarsest of the graded sandstones are represented in section 36 (Fig. 43). There are several amalgamated beds, and some of the beds show complete Bouma sequences (Fig. 45). Argillite at the top of the sandstone beds is relatively thin (<10 cm) compared to the sandstone, and there are no large thicknesses of only argillite.

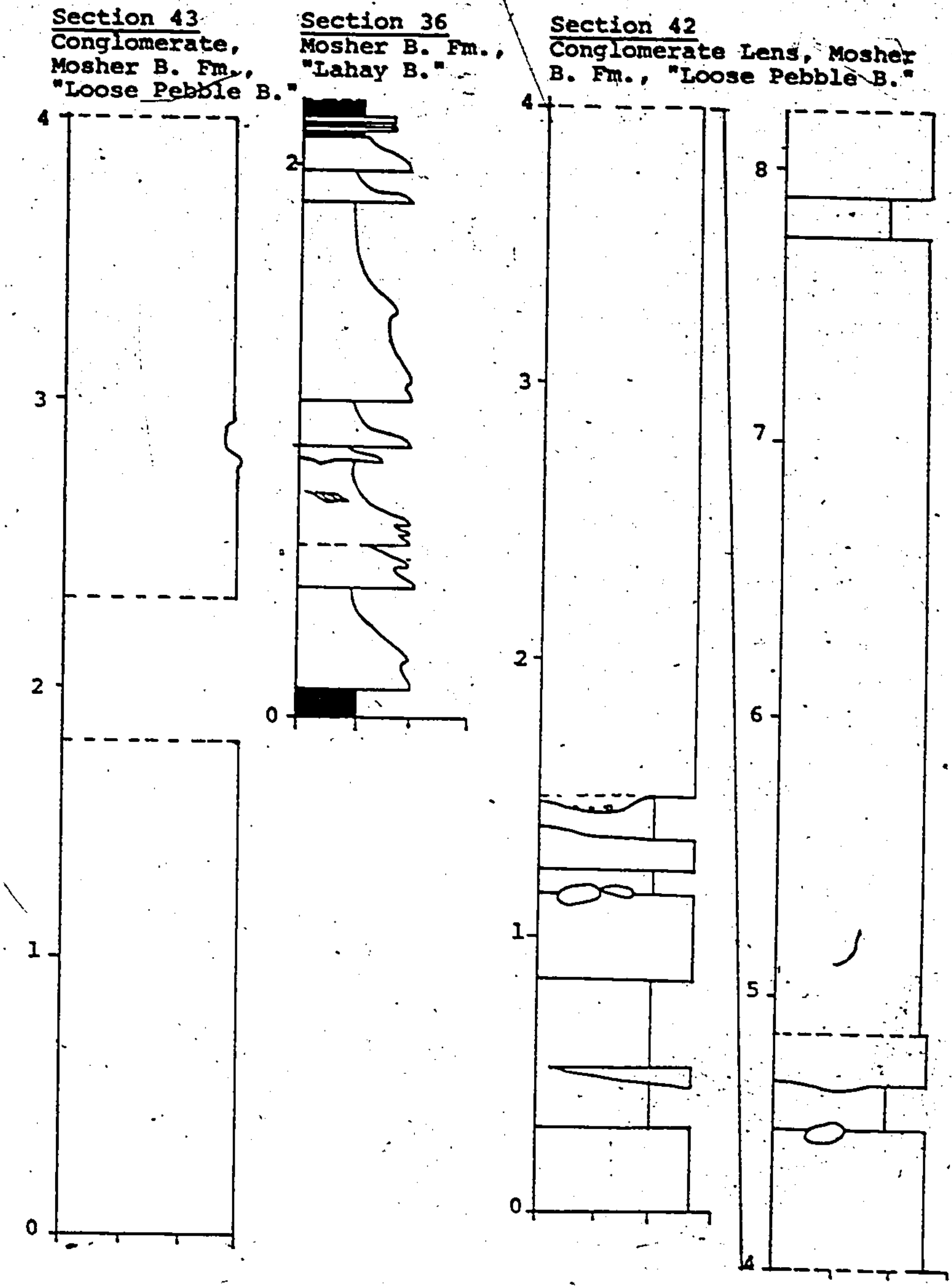
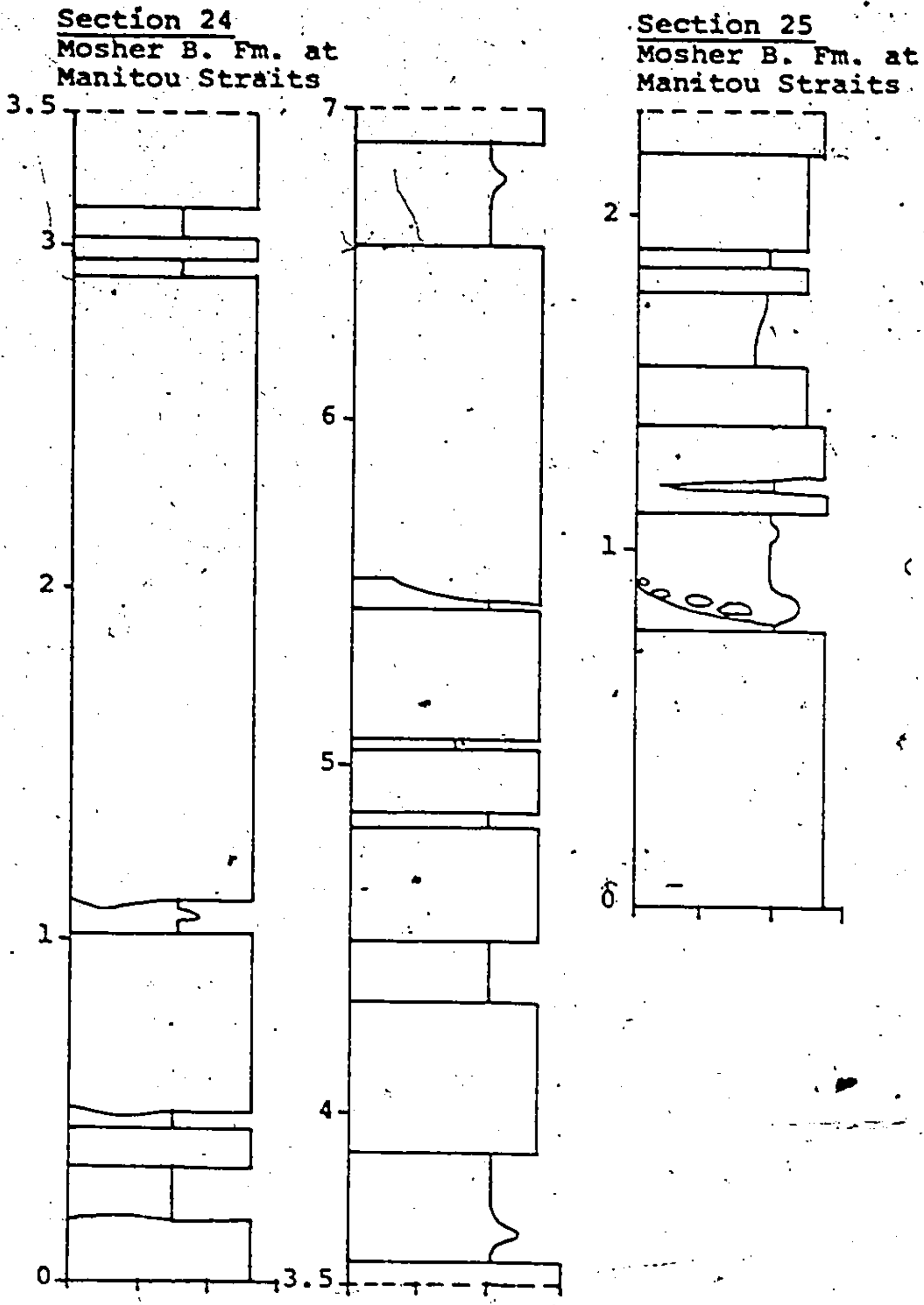


Figure 43. Measured sections of the Mosher Bay Fm. Locations on Figure 6. Legend as for Figure 9.



Section 24
Mosher B. Fm. at
Manitou Straits

Section 25
Mosher B. Fm. at
Manitou Straits

Figure 44. Measured sections of the Mosher B. Fm. at Manitou Straits. Locations on Figure 6. Legend as for Figure 9.

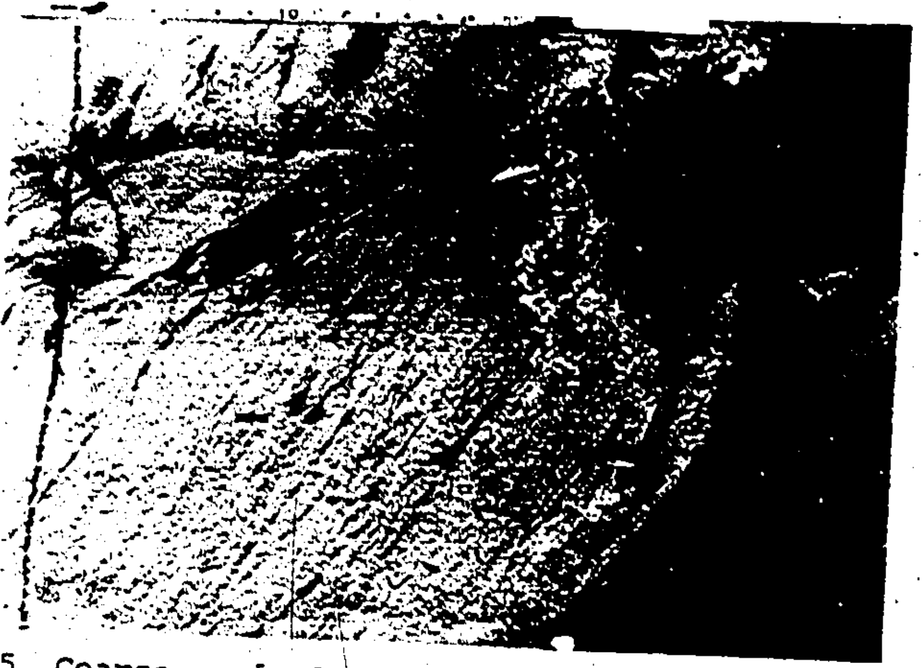


Figure 45. Coarse grained sandstone showing a complete Bouma sequence, Mosher Bay Formation at "Lahay Bay".

Figure 46. Graded beds (A - E) of the Mosher Bay Formation at "Bulbous Bay". A distinct cleavage runs from the lower left to the upper right.

Most of the other graded sandstone beds in the formation are finer grained. The section at "Bulbous Bay" (section 49 (Fig. 28) between 193 and 201 m) is typical: there are about 32 graded beds, each one grading from medium- to coarse-grained quartzose sandstone up into argillite (Fig. 46). No internal structures were seen in any of the graded beds (all A→E). There are about 3 or 4 laminated argillite units, 20 to 30 cm thick, interbedded with the sandstones. The graded beds range from 8 to 40 cm thick, but are nearly all between 18 and 24 cm. The argillite at the top of the beds ranges from 1/2 cm to about 10 cm, but it is almost always near 4 cm. The bases of the graded beds are sharp. There is no observable systematic variation in bed thickness or other properties. This group of graded beds is preceded by a 10 m thick unit of laminated argillite containing a few graded beds. From other areas, it is probable that there is also argillite above the sandstones.

Large thicknesses of the Mosher Bay Formation consist of nothing but laminated siltstone and argillite containing some convolute lamination. Many of these 1/2 to 3 cm beds are graded. North-northeast of "Loose-Pebble Bay", on the shore of Mosher Bay, there is a section at least 160 m thick composed only of such argillites. Similar units occur further to the east, along the northwest shore of Mosher Bay, and throughout the formation in the bush.

Associated with the argillite are minor amounts of magnetite iron formation. It is exposed on Beaverhead Island, just north of Surprise Lake, and in small, scattered outcrops south of the east end of Mosher Bay. The iron formation looks like laminated argillite except that it is a deep purple colour and magnetic. It occurs in units a few cm to a few metres thick, interbedded with the argillites, and apparently laterally discontinuous.

Within this general background of argillites and graded sandstones, there are a number of lenses of interbedded polymictic conglomerate and coarse sandstone (Fig. 3). The largest lens is about 2.8 km long and 200 m thick. They range all the way down to lenses a few metres thick and probably only a few tens of metres long.. The conglomerate - sandstone lenses tend to be resistant, and therefore well-exposed, so a number of measured sections were possible (sections 24, 25 (Fig. 44), 42 and 43 (Fig. 43)). The lenses also appear in the upper parts of sections 15 (Fig. 10), 49 (Fig. 27), and 50 (Fig. 12).

Where the bases of the conglomerate lenses are seen, they are sharp and rest with apparent conformity upon laminated argillite. Over the short outcrop widths available, no scouring was observed. At the top of the lower segment of the lens in section 50 (Fig. 12), the sandstone and conglomerate dies out upwards via a fining-upwards sequence in which there are fewer and slightly thinner conglomerate beds in favour of more and thicker sandstone beds which in turn give way to laminated argillite units of increasing thickness (Fig. 47), until only laminated argillite is present. This occurs over about 4 metres. At the top of the upper segment, the transition is similar, but goes rather abruptly into 30 cm graded sandstone beds. Although exposure is much poorer at other localities, there is some evidence that these fining-upwards sequences are typical for the tops of most of the conglomerate-sandstone lenses. For example, a number of the conglomerate lenses north of Rush Bay (Fig. 3) appear to have this feature, but the bush outcrops are too sparse and too poor to establish it with certainty.

The conglomerates contain quartz, ~~chert,~~ magnetic iron formation, granitoid, and mafic and felsic volcanic clasts (Chapter VI). The sandstones are quartzose, and essentially finer-grained equivalents of the conglomerates in terms of composition.

The large lens at "Loose Pebble Bay" is dominated by conglomerate (sections 42 and 43, Fig. 43). Massive, 15 to 30 cm, coarse-grained sandstone beds make up only 10% of the sections. They are ungraded and make sharp contact with the conglomerate at both their bases and their tops. The conglomerates are close-packed, not graded, and show little internal structure except in rare finer zones (section 43; Fig. 43). The thinner conglomerate beds (and perhaps the thicker ones as well) are not all uniform in thickness. Some of them taper in places, a few finally ending in sandstone (section 42; Fig. 43).

Figure 47. Fining upwards sequence at the top of a large conglomerate lens, Mosher Bay Formation at "Odd Lake". Right to left, sandstone beds decrease in number and thickness and argillites (dark) increase stratigraphically upwards.

Figure 48. Interbedded conglomerate and sandstone beds of the conglomeratic lens at "OddLake", Mosher Bay Fm.

Two measured sections (24 and 25; Fig. 44) of the same conglomerate on Manitou Straits are quite different from each other. Section 24 is 80% massive conglomerate. Contacts with the sandstones are somewhat irregular but sharp. One distinct scour of conglomerate into sandstone was observed. The sandstones are also massive. A few have one or two-layer pebble trains in them. One 6 cm sandstone bed is laminated. None is graded. Section 25 is an intimate mixture of sandstone and conglomerate of various grain sizes. Conglomerate beds contain sandstone lenses; and sandstone beds contain pebble trains. Both contain slate rafts in places. In one bed a pebble train defines the base of a trough cut into sandstone. The remainder of the trough is filled with sandstone. Another bed is a highly contorted mixture of sandstone and argillite in which bedding is disrupted by synsedimentary deformation. This bed is only 30 cm thick and probably represents a small slump. This short section apparently represents a disruption of the usual sedimentation in the lens because the outcrop below and above it, though not well exposed, appears to be similar to section 24.

The sandstone - conglomerate lens in section 50 (Fig. 12) is exposed in two segments with some argillite between (Fig. 3). It is composed of about equal parts sandstone and conglomerate in beds 5 to 80 cm thick (Fig. 48) with the conglomerate beds averaging slightly thicker than the sandstone beds. The sandstone beds are occasionally pebbly.

Sandstone lenses and slate rafts appear in some of the conglomerate beds. All bedding contacts are sharp; no beds are graded. Most of the pebbles in these conglomerates are 1 to 10 cm in size, averaging about 3 cm. The sandstones are medium to coarse grained. There are a few argillite units about 10 cm thick, and one at least 2.5 m thick.

CHAPTER IV

DEPOSITIONAL ENVIRONMENTS

On the basis of the descriptions in the preceding chapter, it is possible to assign each of the stratigraphic units of the Manitou Group to a specific sedimentary environment. Due to the general lack of continuous stratigraphic sections and sparse exposures in some wooded areas, these interpretations have depended more on stratigraphic relationships at the member and formation level, and specific sedimentary structures in short measured sections, and less on detailed facies relationships over large areas or vertical sequence in lengthy sections.

Each of the stratigraphic units is discussed in the same order as they were described in Chapter III and the reader is referred to that chapter for the detailed information supporting the summary descriptions and interpretations in this chapter.

Underlying Pillowed Basalts

The very common occurrence of pillows in the basalts and the presence of turbidites in the clastic rocks indicate a submarine environment for the basalts and sediments underlying the Manitou Group.

The pillowed basalts can be generated directly on the sea floor, but the turbidites require an elevated source area. The volcanogenic nature of the turbidites and the presence of associated pyroclastics indicate that this source area was a pyroclastic pile that was developed adjacent to the map area at the time the Etta Lake Sediments and Basalts were deposited.

The pillowed and massive tholeiitic basalts and their associated sediments and minor pyroclastics represent a large submarine platform, possibly 8 km thick, and at least 55 km long, which forms a base upon which the Manitou Group was deposited.

The Cane Lake Formation

The Cane Lake Formation overlies the marine pillowed basalts, and it is intercalated with the subaerial lavas of the Sunshine Lake Formation and the terrestrial sediments of the Uphill Lake Formation. Thus, its stratigraphic position does not necessarily limit its possible environments, so the characteristics of the formation itself are important in its interpretation. The Cane Lake Formation is believed to be subaerial mainly on the basis of negative evidence: there are no fine-grained 'background' marine sediments such as Francis and Howells (1973) report for some Ordovician marine tuffs, or like those associated with the Archean submarine pyroclastic pile at Sturgeon Lake (Shegelski, 1976). There is no evidence of turbidites.

There is a number of different bed types in the Cane Lake Formation, ranging from thick, massive to somewhat graded, coarse tuff-breccias to relatively thin, faintly bedded tuffs. This reflects the variety of processes, such as air-falls, ash-flows, lahars, and aqueous reworking, to be expected on a complex volcanic cone.

The tuffs have originated in two ways. The relatively thin, faintly to distinctly laminated tuffs are probably of air-fall origin. In contrast, the thick, massive tuffs are ignimbrites (ash flows) based on Parsons' (1969) criteria: nonstratified, unsorted, monolithologic, subangular to subrounded clasts, with some pumice clasts. Tectonic deformation has imparted a flattening and vertical extension to the clasts in many of the best-exposed areas, thus obscuring any syndepositional flattening or welding.

On the other hand, again using Parsons' (1969) key for the recognition of volcanic breccias, it appears that many of the coarse pyroclastics (i.e., the tuff-breccias) were deposited by lahars: heterolithologic and with some crude grading. They are like the tuffs in being nonstratified, unsorted, and having subangular to subrounded clasts. The essentially mono- or dilithologic tuff-breccia beds with much pumice are ignimbrites.

Rare occurrences of cross-laminated volcanogenic sandstone indicate minor aqueous reworking.

In summary, the Cane Lake Formation is a subaerial pyroclastic pile built up by explosive volcanic activity, as shown by the ignimbrites and air-fall tuffs, modified by lahars and minor aqueous reworking.

At the eastern end of Uphill Lake, there is a small felsic body (Fig. 3). Although its position in the geological history of the area is not certain, it appears to be closely associated with the Cane Lake Formation. It is mainly enclosed by, and seems to be rooted in, the Cane Lake Formation. Clastic deposits in the Cane Lake Formation immediately to the east of the body are probably derived from it, and in places are difficult to distinguish from it. Chemically, the body is a dacite (Chapter VII). In the field this rock appears to be flow-banded, and is totally brecciated (Fig. 49). Its composition, brecciation, and shape on the map (Fig. 3) suggests that it could be a lava dome formed late in the development of the Cane Lake Formation, perhaps as a flank eruption to the main volcanic vent.

The Sunshine Lake Formation

The Sunshine Lake Formation is interpreted to be a series of subaerial lava flows. This interpretation is ~~based as much~~ on negative evidence as on positive. None of the lavas is pillowed, and there are no pillow breccias. None of the intercalated sediments could be construed as deep marine. There are certainly no fine-grained 'background'

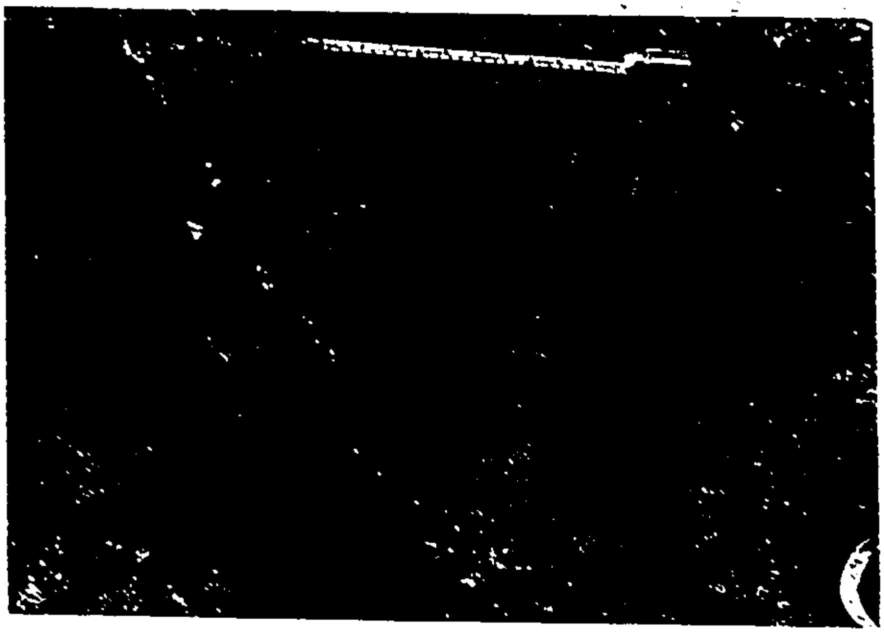


Figure 49. Dacite at the eastern end of Uphill Lake, showing original laminated aspect of the rock and subsequent brecciation.

sediments. On the positive side, the lavas are intercalated with the subaerial pyroclastics of the Cane Lake Formation and are conformably overlain by the terrestrial Uphill Lake Formation. Some of the intercalated sediments are cross-bedded. Flow breccias which are 'cemented' by the solidification of lava squeezed between the blocks are more likely to have formed on land. Such flow breccias are common in the Sunshine Lake Formation.

The Uphill Lake Formation

The bulk of the Uphill Lake Formation can be divided into three parts - western, central, and eastern areas - on the basis of bedding style, sedimentary structures, and composition.

The western end of the Uphill Lake Formation is gradational into the subaerial pyroclastics of the Cane Lake Formation. The eastern end of the Uphill Lake Formation is characterized by very abundant trough cross-bedding, commonly up to one metre thick in both sandstones and conglomerates. This cross-bedding, together with the thickness of the formation and the lack of any fine-grained material, strongly suggests a braided fluvial environment for the eastern part of the formation. The central area of the Uphill Lake Formation shares some of the features of both the western and eastern parts. The entire formation, then, is subaerial and can be interpreted in terms of a pyroclastic pile (the Cane

Lake Formation and western Uphill Lake Formation) which developed an alluvial fan on its flank (the central Uphill Lake Formation). The alluvial fan intertongues with a braided fluvial system (the eastern Uphill Lake Formation). Detailed interpretations of each of these environments are given below. Environmental interpretations of the surprise Lake and Rush Bay Members of the Uphill Lake Formation follow the discussion of the western, central, and eastern areas.

1. Western Area of the Uphill Lake Formation

From the very close similarity between the western area of the Uphill Lake Formation and the Cane Lake Formation, and the fact that the one is laterally gradational into the other, it is clear that the western area represents an extension of the subaerial pyroclastic activity responsible for the deposition of the Cane Lake Formation. All of the volcanic features and interpretations for the Cane Lake Formation apply equally well to the western Uphill Lake Formation.

2. Central Area of the Uphill Lake Formation

The central area of the Uphill Lake Formation was deposited on an alluvial fan. This interpretation is based on a comparison of the features of the central area with those of alluvial fans as outlined by Bull (1972).

The central area is laterally equivalent to and transitional into the subaerial pyroclastics of the western area. The Cane Lake volcanic cone, which continued to grow during Uphill Lake Formation deposition, and which is the source of the material in the central area, provided the high adjacent interland which is a prerequisite for alluvial fan development.

On alluvial fans, sediment is either water-laid, or deposited from debris flows (Bull, 1972; Hooke, 1967; Johnson, 1970). Water-laid sediments are sheetflood, stream-channel, or sieve deposits. Sheetflood sediments are deposited by surges of sediment-laden water that spread out over the fan as shallow distributary channels rapidly fill and shift, forming a sheetlike deposit of sand or gravel. These deposits may be cross-bedded, laminated, or massive. Depths of water generally are less than 30 cm, so bedforms, such as cross-bedding, will not have high relief, and the deposits will be thin (perhaps 5 to 20 cm, estimating from Bull's (1972) figure 3B). The alternating sandstone-conglomerate beds common in the central area are most likely sheetflood deposits. They are thin, massive or parallel laminated, and associated with rare small cross-bedded sandstones (10 - 15 cm sets).

There is no direct evidence of incised channels, such as exposed channel walls or channel cross-sections, in the central area. The fining-upwards interbedded conglomerate and sandstone unit in the lower part of section 2 (Fig. 28) could represent channel backfilling.

Sieve deposits require that there be little sand, silt, or clay in the source area. The abundant sandstone in the central area, and the high matrix content of these sandstones (Chapter VI) indicate that these grain sizes were available, so the sieve mechanism described by Hooke (1967) probably did not operate. Massive, well sorted, clast-supported conglomerates that could be interpreted as sieve deposits were not observed in the central area of the Uphill Lake Formation.

Debris flows are high density, high viscosity flows with sufficient matrix strength to carry large boulders. Their deposits tend to be very poorly sorted, dispersed-pebble conglomerates with much mud in the matrix. The bedding of debris-flow sequences commonly is not well-defined: close examination is required to find bedding planes between debris flows. Debris flows appear to have been responsible for much of the central area of the Uphill Lake Formation. Large areas are underlain by dispersed-pebble conglomerate with few bedding planes visible, associated with only rare water-laid sediments. The ready availability of loose debris of all sizes from the Cane Lake pyroclastic cone probably contributed to the abundance of debris flows. In this sense the debris flows responsible for the dispersed-pebble conglomerates of the central Uphill Lake Formation can be considered lahars, in that they are composed of pyroclastic material from the flank of a volcanic cone (AGI Dictionary, 1962, p. 276).

In summary, the elevated volcanic source area, stratigraphic thickness (about 1000 m), bedding style (interbedded thin, massive conglomerates and sandstones, thicker dispersed-pebble conglomerates), and sedimentary structures (parallel lamination, rare cross-bedded sandstones in 10-15 cm sets, no cross-bedded conglomerate, very rare graded bedding) of the central area all indicate an alluvial fan origin for this part of the Uphill Lake Formation. Sheetflood (interbedded thin sandstones and conglomerates) and debris flow (massive, dispersed-pebble conglomerates) were the predominant depositional mechanisms operating on the fan.

3. Eastern Area of the Uphill Lake Formation

The eastern area of the Uphill Lake Formation was deposited by a braided fluvial system. This interpretation is based principally on the very common large-scale cross-bedding in both sandstones and conglomerates and the lack of fine-grained sediments. Due to the generally poor exposure and small outcrops, it is not possible to discern complete bars within the area. However, in comparisons with recent studies of more modern braided streams (e.g., Smith, 1970; Boothroyd, 1970; Church, 1972; Rust, 1972; Eynon and Walker, 1974; Boothroyd and Ashley, 1975; Cant and Walker, 1976; Walker, 1976; and Hein and Walker, 1977) individual small measured sections can be explained best if they are assigned to the various bar or channel facies of a braided fluvial system.

Most of the coarsest-grained conglomerate in the area occurs as massive or crudely stratified beds. The stratification shows up as minor changes in grain size of the conglomerate in layers a few pebble diameters thick, or as discrete, thin, parallel laminated or trough cross-bedded sandstone beds. These conglomerate beds are analogous to the bar core facies and bar top facies of Eynon and Walker (1974) and the lag deposits of Hein and Walker (1977). Both of these papers suggest the origin of massive to crudely stratified coarse gravel beds by the movement of diffuse gravel sheets without foreset slopes during the flood stages of braided systems. Crude horizontal stratification is also a prominent feature in the Donjek River bars (Rust, 1972), the longitudinal bars of the Platte River (Smith, 1970), the braided sandurs of Baffin Island (Church, 1972), and Alaskan outwash fans (Boothroyd, 1970; Boothroyd and Ashley, 1975).

The finer-grained conglomerates and the sandstones are nearly all trough cross-bedded. The coarser-grained, larger cross-bed sets probably formed in the channels where they would have the best chance of preservation, together with the bar core, in the deepest part of the system. Rare coarsening and fining upwards sequences represent, respectively, the increasing or decreasing importance (and competence) of individual channels within the system. Sequences of relatively uniform grain-size and cross-bed size represent persistent channels, or are too short to record changes in the channel. There is no sense of a consistent pattern to vertical sequences in the eastern area. Specifically, there is no pattern of repeated fining-upwards sequences expected in a meandering fluvial system (Allen, 1970; Walker, 1976).

The smaller cross-bed sets in sandstones tend to form tabular sheets one cross-bed set thick, interbedded with laminated sandstones. They appear to be analogous to the sands deposited by shallow water on the tops of transverse bars in the Platte River (Smith, 1970, p. 2999), and to the uppermost sands of the shallow braided stream facies of Eynon and Walker (1974). They are much less common than the thicker cross-bedded conglomerate and sandstone beds, which is in keeping with their inferred position high in the system where preservation is less likely.

By measuring the stratigraphic thickness represented by trough cross-bedding in measured sections of the eastern area, it is estimated that 60% of the eastern area is trough cross-bedded. This is in agreement with Smith's (1970) estimate for a Lower Silurian braided system.

In summary, comparisons with studies of more modern braided rivers indicates that the features of the eastern area of the Uphill Lake Formation, particularly the large-scale cross-bedding in conglomerates, were developed in a braided fluvial system. The crudely stratified conglomerates in bar cores and the large-scale cross-bedded conglomerates and sandstones of adjacent channels were the most commonly preserved deposits. Smaller-scale cross-bedded sandstones on bar tops were much less commonly preserved.

4. Rejection of Other Environments for the Uphill Lake Formation

i) Glacial (tillites)

Tillites are characteristically composed of dispersed, poorly-sorted pebbles and boulders in a matrix of clay, silt, and sand (Harland *et al.*, 1966). Some of the dispersed-pebble conglomerates in the central area of the Uphill Lake Formation have these characteristics, and the cross-bedded conglomerates of the eastern area might be construed as glacial outwash deposits. However, the thickness of the formation (about 1000 m), the lack of associated varved clays with dropstones (and the other glacial features listed by Harland *et al.* (1966)), and the very large number of individual dispersed-pebble conglomerates make a glacial origin for the Uphill Lake Formation very unlikely.

ii) Coastal (beach)

A beach environment for the Uphill Lake Formation can also be ruled out. The stratigraphic thickness of the formation, and the repeated occurrence of many conglomerate and sandstone beds in the sequence would imply alternating beach, offshore, and non-marine environments due to repeated transgressions and regressions. However, offshore or lagoonal fine-grained sediments are absent. The excellent sorting and mature sediments expected in a beach environment are certainly not a characteristic of the lithic wackes and dispersed-pebble conglomerates that constitute much of the Uphill Lake Formation.

iii) Deep Basinal

A deep basinal environment for the Uphill Lake Formation can be readily rejected. It has already been mentioned that the formation is laterally gradational into a subaerial pyroclastic pile. Furthermore, it is totally unlike the conglomerate-sandstone lenses of the Resedimented Association in the Mosher Bay Formation (discussed later). The comparison given by Turner and Walker (1973, their Table 2) outlining the differences between the Ament Bay alluvial fan and the Minnitaki Group Resedimented Association applies in nearly every detail to the differences between the Uphill Lake Formation and the Mosher Bay Formation (Table 1). In the Mosher Bay Formation, the background sedimentation was mud (items 7,8,9; Table 1), implying a normally quiet basin, periodically interrupted

Table I. A comparison of the conglomerate - sandstone units of the Manitou Group.

	A. Central area of the Uphill Lake Formation	B. Eastern area of the Uphill Lake Formation	C. Rush Bay Member of the Uphill Lake Formation	D. Mosher Bay Formation, especially conglomeratic lenses
1.	graded beds rare.	graded beds rare.	grded beds rare	graded beds common
2.	parallel lamination present in sandstone.	parallel lamination present in sandstone.	parallel lamination rare.	parallel lamination rare
3.	sandstone only rarely cross-bedded (15 cm sets).	sandstones very commonly cross-bedded (10 - 30 cm sets).	sandstones never cross-bedded.	sandstones never cross-bedded in sets greater than 10 cm.
4.	conglomerates never cross-bedded.	conglomerates very commonly cross-bedded in sets up to 1 m thick.	conglomerates never cross-bedded.	conglomerates never cross-bedded.
5.	beds normally massive.	sandstones cross-bedded or parallel laminated; conglomerates cross-bedded or massive.	beds normally massive.	sandstones occur in 5-25 cm graded beds outside lenses, or in massive 15-30 cm beds in lenses. Conglomerates usually massive.
6.	dispersed pebble conglomerate common.	conglomerates clast-supported.	conglomerates mainly clast-supported.	conglomerates mainly clast-supported.
7.	argillite interbeds rare.	argillite interbeds absent.	argillite interbeds absent.	argillite interbeds present.
8.	argillite clasts rare.	argillite clasts absent.	argillite clasts rare.	argillite clasts present.
9.	never associated with argillite units.	never associated with argillite units.	argillite in distinct units about 60 m thick.	commonly associated with argillite units.
10.	never associated with repeated graded graywacke-argillite beds showing the Bouma sequence (i.e., turbidites).	never associated with turbidites.	never associated with turbidites.	conglomerate lenses enclosed by turbidites.
11.	features characteristic of the Non-marine Association.	features characteristic of the Non-marine Association.	? transitional	features characteristic of the Resedimented Association.

by turbidity currents (1,5,10), but no other strong currents (2,3,4). In contrast, there is no background mud sedimentation in the Uphill Lake Formation (7,8,9) and no sign of turbidity currents (1,5,10). However, there is evidence of strong shallow-water currents (2,3,4,5,6). Because of these differences, a deep-basin turbidite origin for the Uphill Lake Formation can be ruled out.

5. The Surprise Lake Member

The Surprise Lake Member is a small, thin (60 m) unit of thinly-bedded to laminated argillite and siltstone with minor cross-bedded fine-grained sandstone. It is completely enclosed in coarser sediments which can be ascribed to terrestrial environments (alluvial fan and braided fluvial). On this basis, the Surprise Lake Member has been interpreted as a lacustine deposit.

6. The Rush Bay Member

The sedimentary environment of the Rush Bay Member cannot be precisely determined. It is distinctly different from the central Uphill Lake Formation alluvial fan (Table 1; columns A and C; 2,3,6,7,9), eastern Uphill Lake Formation braided river (columns B and C; 2,3,4,5,8,9), and the Mosher Bay Formation Resedimented Association (columns C and D; 1,5,7,8,10). A glacial origin is also very unlikely: there are a few dispersed-pebble conglomerates that might be interpreted as tillites, but none of the other sediments could be construed as outwash deposits, and none of the argillites contains dropstones.

The Rush Bay Member occupies a stratigraphic position transitional between underlying terrestrial deposits and overlying turbidites. It is possible, therefore, that this transitional unit represents a coastal or shallow marine environment. If so, a much more detailed environmental interpretation would be desirable, because shallow marine deposits apparently are rare in the Archean. However, the Rush Bay Member presents difficulties to environmental interpretation. Paleontology and paleoecology, which have been so useful in interpreting Phanerozoic shallow marine environments, are not available to Archean workers. The fine-grained sediments are simply laminated argillite with a few graded beds and rare convolute lamination. Such sediments are common in lacustrine, fluvial, lagoonal, offshore, and deep marine environments. The tuffs and tuff-breccias are virtually identical to those lower in the stratigraphy and merely indicate that explosive volcanic activity is continuing. Massive, unsorted, ungraded pyroclastics are commonly considered terrestrial (Williams and McBirney, 1969), but they can be deposited in subaqueous environments (Francis and Howells, 1973). The pyroclastic and sedimentary rocks are almost totally lacking any diagnostic sedimentary structures: there is no cross-bedding; and parallel lamination and graded beds are rare. The conglomerate beds containing quartz, chert, iron formation and granitoid clasts are in the upper half of the member. Other than this, there is no apparent consistent stratigraphic organization.

Interpretations of shallow marine environments have depended heavily upon paleontology, and (like other environments) stratigraphic succession and sedimentary structures. Without these, it is difficult indeed to closely establish an environment for the Rush Bay Member. Its stratigraphic position indicates that it is probably coastal or shallow marine, but without diagnostic features, the precise nature of the environment(s) cannot be determined, and the member is of little use in developing any model of Archean shorelines.

The Mosher Bay Formation

The Mosher Bay Formation was deposited in a deep marine environment. The monotonous sequences of graded sandstone-argillite forming the bulk of the formation are clearly turbidites deposited in relatively quiet waters, below storm wave base. Associated with these turbidites are fairly thick accumulations of 'background' laminated argillite, again indicating a deep, quiet marine environment. The conglomerate lenses are enclosed within the argillite and turbidite sequences, so they must have formed in the same environment. Their lens shape (Fig. 3) indicates that they are very likely channels cut into the finer sediments (although cross-cutting relationships were not actually observed).

Channelled conglomerates associated with classical turbidites and laminated argillites immediately suggests a submarine fan (Nelson and Kulm, 1973; Walker and Mutti, 1973; Normark and Piper, 1972; Walker, 1975). However, in many parts of the formation it has not been possible to establish clearly the lateral and stratigraphic relationships of the various resedimented facies due to isoclinal folding, small-scale faults, and areas of poor exposure. Attempts at paleocurrent determinations were frustrated by a strong cleavage. This cleavage also obscured conglomerate pebble fabrics which are important in distinguishing certain facies, such as the disorganized versus organized conglomerates (Walker and Mutti, 1973; Walker, 1975).

Nevertheless, from the information available, it seems that the Mosher Bay Formation cannot be adequately explained by a simple model based on the growth of a single submarine fan. Channellized units of massive conglomerates and sandstones are confined to the upper, inner fan (Walker and Mutti, 1973; Nelson and Kulm, 1973; Walker, 1975) and should appear only after deposition of the outer and mid-fan muds and sandstones in a prograding fan (Walker and Mutti, 1973). In the Mosher Bay Formation, massive conglomerate and sandstone lenses appear throughout the formation, even within a few meters of the base.

At 'Odd Lake', where the stratigraphy is uniformly northwest facing, 5 m of argillite at the base of the formation is followed by one of the largest and thickest conglomerate-sandstone lenses in the formation. This lens is followed by a series of graded (A → E) medium grained sandstones of the type which occur on the mid-fan (Walker, 1975; Walker and Mutti, 1973; Nelson and Kulm, 1973). This is the reverse of the sequence expected from a single prograding submarine fan.

Immediately north of Surprise Lake there is a general stratigraphic progression from argillites and siltstones to graded sandstones up to the large conglomerate lens at 'Loose-pebble Bay', but 'mid and outer fan type' turbidites occupy the isoclinally-folded area above the lens. Conglomerate lenses of all sizes occur throughout the formation in the Goose-egg Lake area (Fig. 3).

Although a complete understanding of the Mosher Bay Formation is difficult due to structural complications and a complete lack of paleocurrent information, it seems most likely that the formation was formed by a number of small, laterally coalescing, and stratigraphically overlapping submarine fans. Feeder channels cut through older fan deposits, and new fan depositional lobes were deposited over older channels, leading to very complex facies relationships.

Summary

The stratigraphic relationships of the various sedimentary environments comprising the Manitou Group are shown schematically in Figure 50. Initially, a large platform of pillowed basalts formed a base upon which the Manitou Group developed. A subaerial felsic pyroclastic pile (the Cane Lake Formation) covered the entire study area at first, but was later restricted to the western part, while a series of subaerial, intermediate, somewhat alkaline, lavas (the Sunshine Lake Formation) were extruded in the east. As the pyroclastic pile grew, it was subjected to erosion and developed an alluvial fan (the central Uphill Lake Formation) on its flank. The alluvial fan intertongued at its eastern end with braided fluvial deposits (the eastern Uphill Lake Formation). Deposits of a small lake (the Surprise Lake Member) accumulated near the base of the alluvial fan. These non-marine Association rocks were covered by a series of pyroclastics, conglomerates, sandstones, and argillites (the Rush Bay Member) which may represent a coastal or shallow marine environment. During or immediately following deposition of the Rush Bay Member, the entire area submerged and was covered by one, or more likely, several, small submarine fans (the Mosher Bay Formation).

The implications of this stratigraphic development are discussed in the last chapter (VIII), integrated with the paleocurrent, petrographic, and geochemical information presented in the following chapters (V - VII).

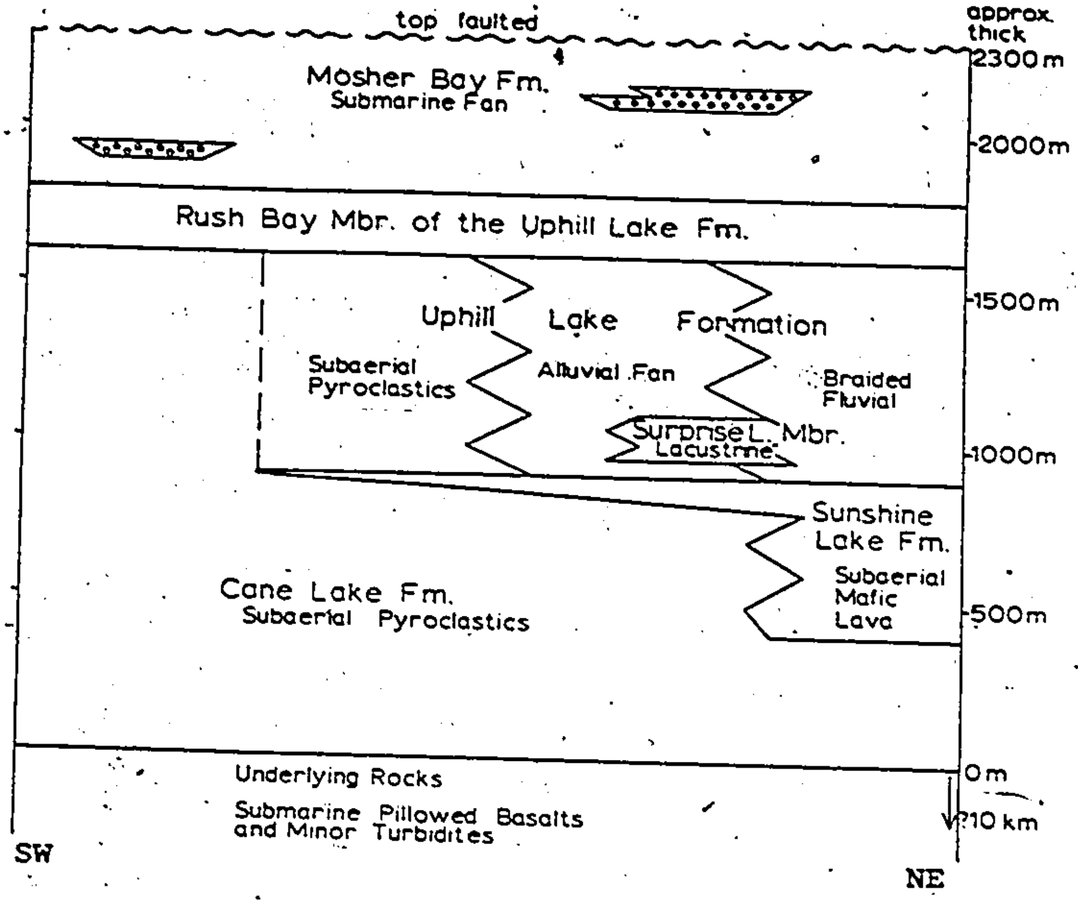


Figure 50. A schematic representation of the relationship between stratigraphic units of the Manitou Group. Section runs parallel with strike of units in Figure 4, from SW to NE.

CHAPTER V

PALEOCURRENTS

Paleocurrents are important not only for determining source areas and the dispersal patterns in a basin (Potter and Pettijohn, 1963), but also for their potential usefulness in environmental interpretation (Blatt et al., 1972, p. 188). The paleocurrent information collected in this study is useful for outlining source areas and dispersal patterns for some formations of the Manitou Group. However, because of the difficulty of collecting large numbers of samples and the consequent lack of detailed information at individual outcrops, the paleocurrent data available cannot make a large contribution to the environmental interpretation of the Manitou Group. Therefore, the conclusions reached in this chapter deal primarily with paleogeographic, rather than paleoenvironmental, interpretations.

Unfortunately, the Manitou Group, like many Archean sedimentary rocks, is not well suited to paleocurrent studies. Tectonic deformation has placed the group on end (dips are rarely less than 80°), thus exposing only a single cross-section, the former areal distribution of a unit being obscured. This same tectonism generally imparts a cleavage to finer-grained rocks and can 'stretch', and thus effectively rotate larger clasts until their orientation may be quite different from that imparted by sedimentary processes. Induration effectively seals bedding planes, so that sole marks, ripples, cross-bed troughs, and parting lineations are very rarely seen.

One exception to this lack of exposed bedding - plane features in the Archean is the Kirkland Lake area where R.S. Hyde (1977) has been able to measure sole marks, oriented argillite clasts, and ripple marks. In that area, conglomerate beds 'weather-out' sufficiently that Hyde can measure the three-dimensional orientation of conglomerate clasts in place. Ross (1962) and Henderson (1972) measured ripple foresets in the Bouma C division of Archean turbidites at Yellowknife, N.W.T., and were able to use them in basin analysis. In general, however, methods that do not rely on three-dimensional exposures are necessary for Archean paleocurrent work. Two approaches which have been used in the Archean are clast size measurements (Walker and Pettijohn, 1971; Smith et al., 1973) and grain orientation in thin section (Hyde, 1977). Both were used on the Manitou Group in this study.

Clast Size

Pyroclastic fragments decrease in both their maximum size and median diameter away from their source (Fisher, 1964). There is a general decrease in size downstream in fluvial systems, at least for gravel-sized material (Pettijohn, 1975, p. 45; Potter and Pettijohn, 1963, p. 202). Particle size decreases downfan on alluvial fans (Bull, 1972). With these facts in mind, clast size measurements were used in an attempt to find the component of the regional paleocurrent direction in the exposed section through the Manitou basin, and thus possibly assign a directional sense to the line-of-motion data obtained from the grain-orientation study.

1. Methods

During the mapping, routine observations at outcrops included the smallest, largest and "average" clast size of conglomerates and tuff-breccias. One centimeter was the practical limit of the smallest size. For some outcrops the single largest size was recorded, but in most cases, the D/10 (average diameter of 10 largest clasts) was recorded. D/10 measurements are used in lieu of largest clast size to minimize the effect of a few very large clasts.

Exotic clasts of large diameter, far outside the normal size range at their outcrop, are apparently very rare in the Manitou Group, so "largest clast size" and "D/10" values can be used approximately interchangeably in this study and have been grouped together. The "average" clast size is a visual estimate made at the outcrop. The 'middle-sized' clast was picked out by eye and its diameter recorded, so it is probably a reasonable approximation to the median diameter, by number frequency.

These observations are plotted on Figs. 51, 52, 53 and 54, using different diameters of circles to represent different particle diameters.

2. Results

In the Cane Lake Formation, the clast size distribution is not uniform. Both the largest and the 'average' clast size are larger at Cane Lake and decrease both east and west from there (Figs. 51 and 52), suggesting that the centre of volcanic activity responsible for the Cane Lake Formation pyroclastic pile is near Cane Lake. However, no recognizable pipe breccia, dikes, or other evidence of a vent were observed, so the actual vent is not at the present erosional level. This is dealt with in more detail in the Discussion.

In the western and central parts of the Uphill Lake Formation, there is a general decrease in the largest clast diameter from Cane Falls to Surprise Lake (Fig. 53), suggesting that there is an easterly component to the paleocurrents in that area. Transport would be off the Cane Lake volcanic pile, down the alluvial fan, towards the eastern fluvial area.

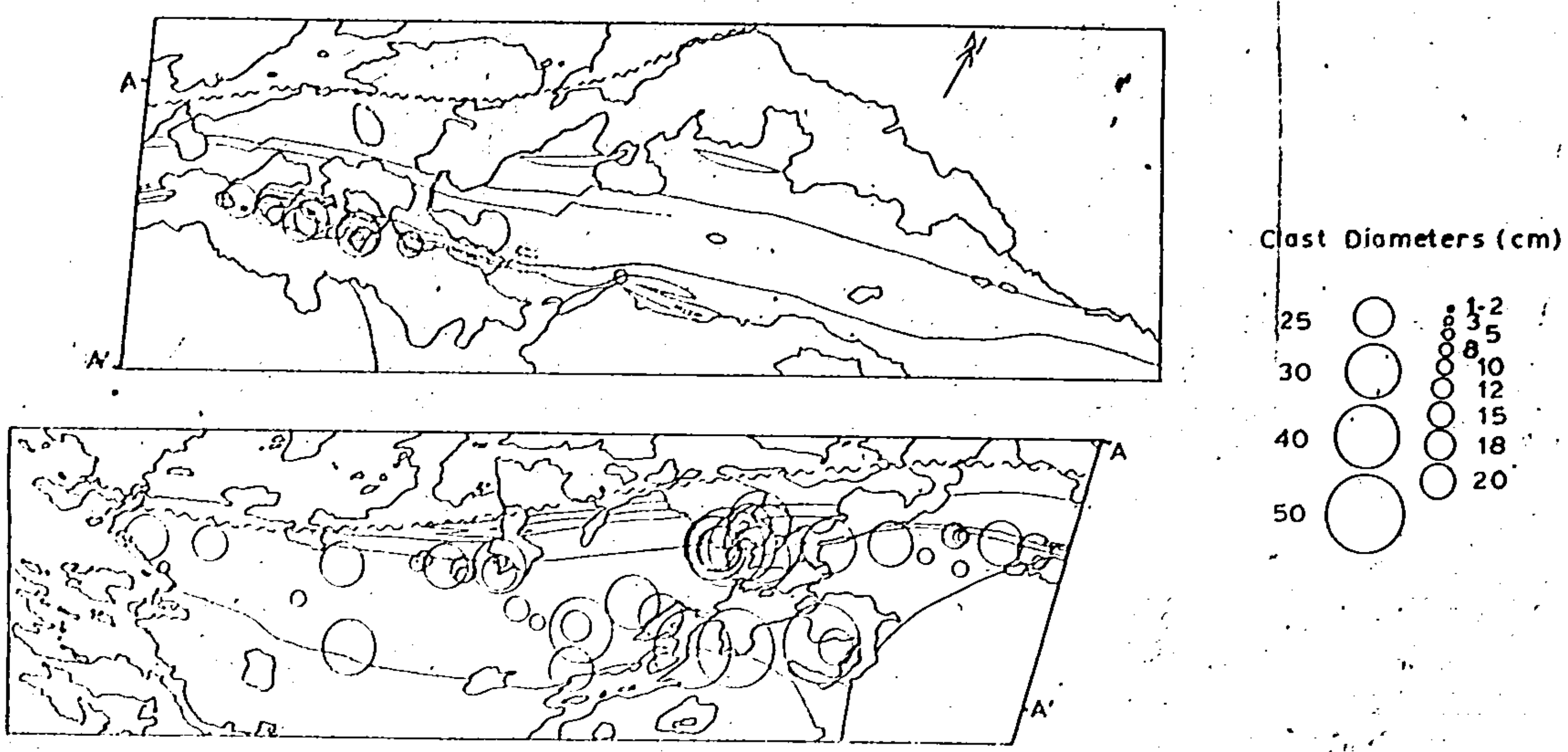


Figure 51. Largest clast diameters for the Cane Lake Formation.

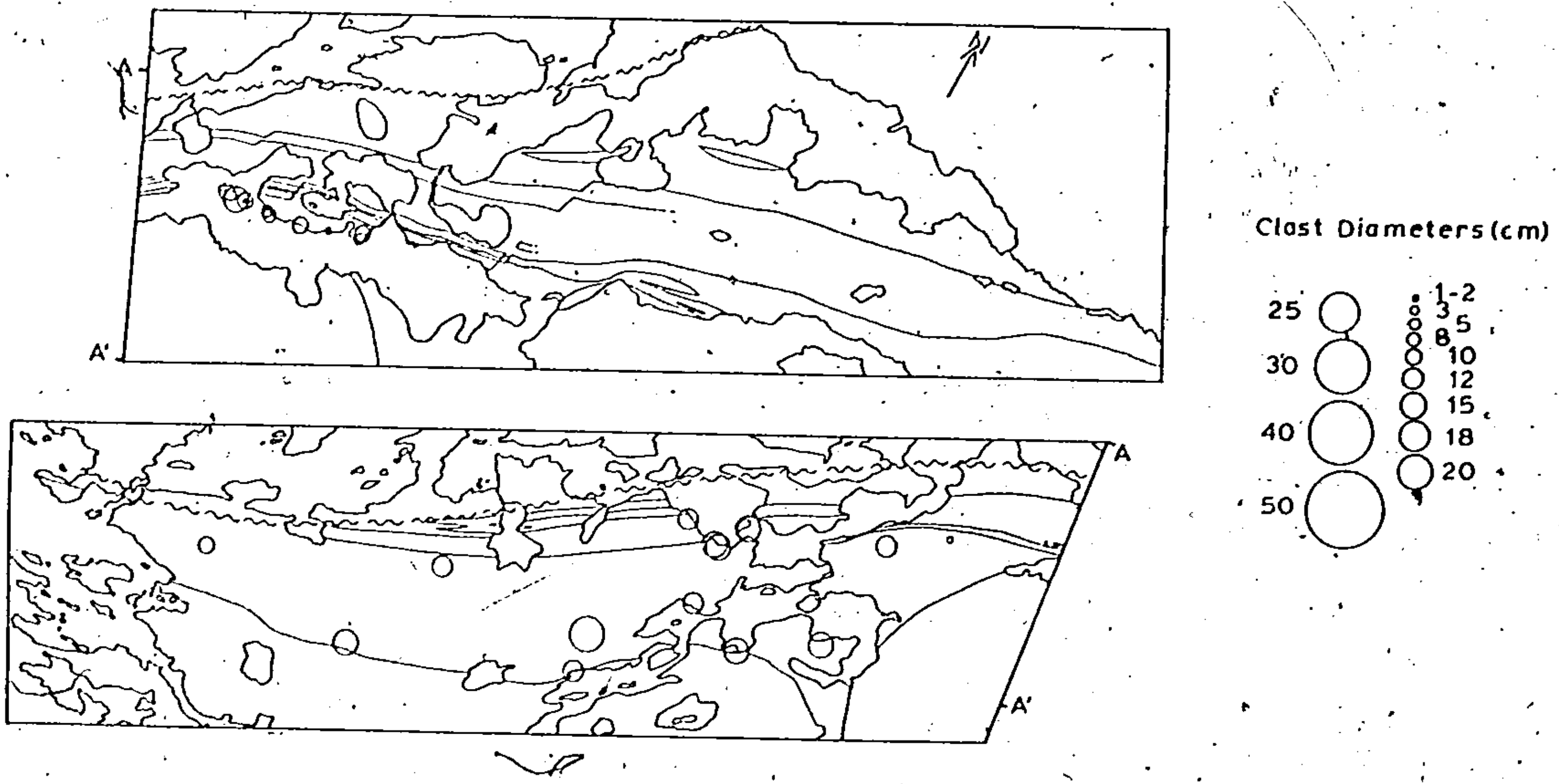


Figure 52. "Average" clast diameters for the Cano Lake Formation.

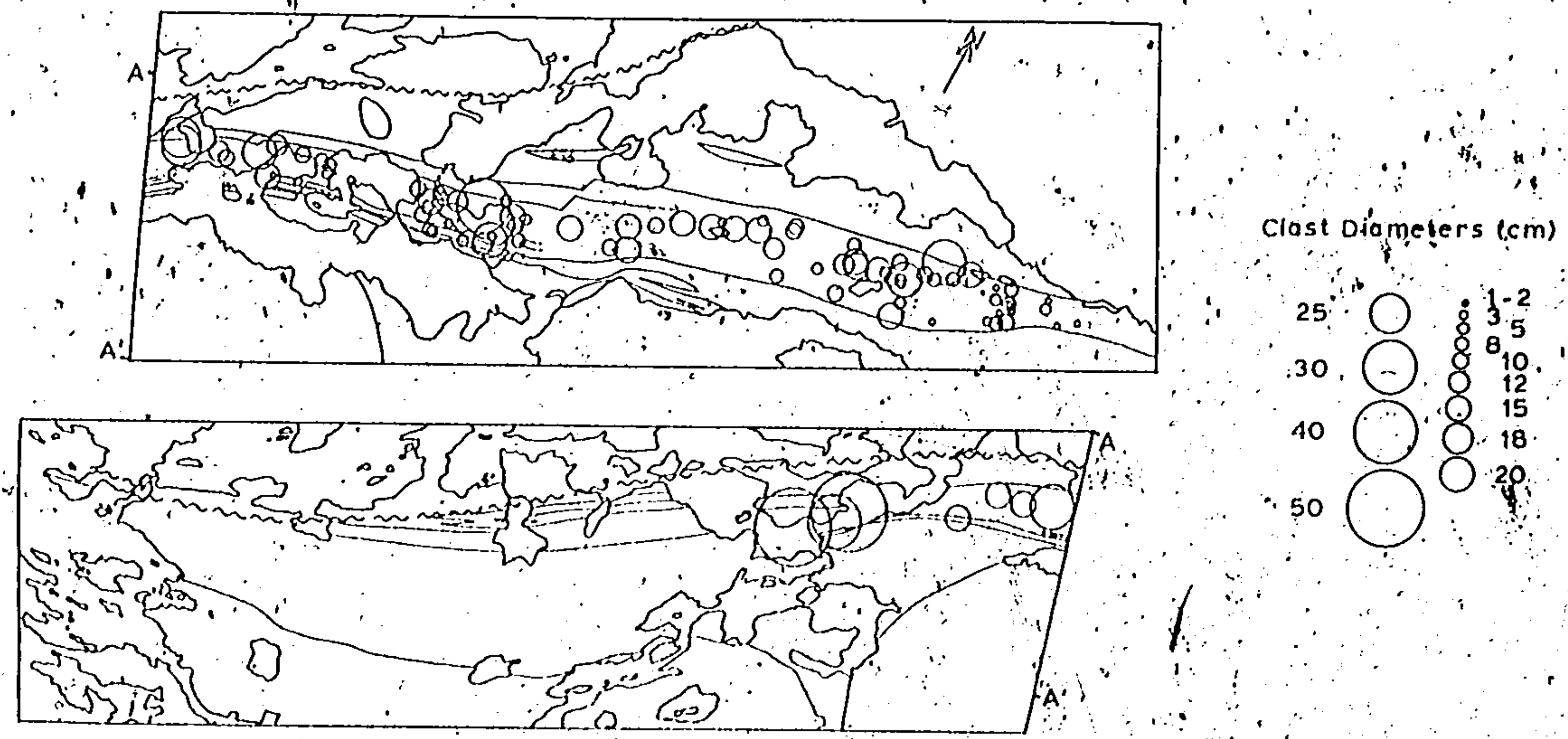


Figure 53. Largest clast diameter for the Uphill Lake Formation, excluding the Rush Bay Member.

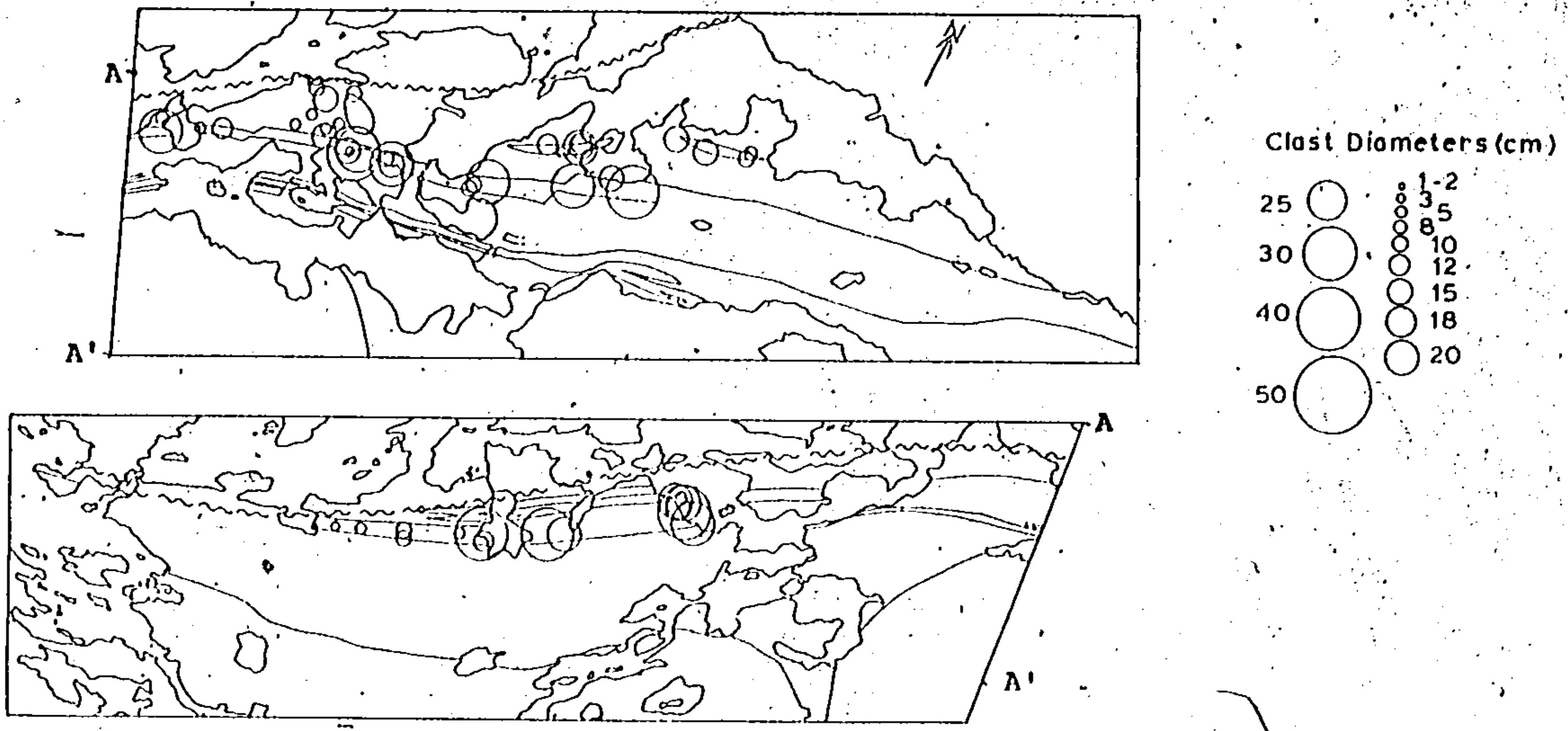


Figure 54. Largest clast diameters for the Rush Bay Member and Mosher Bay Formation.

Clast diameters in the eastern part of the Uphill Lake Formation are fairly uniform, not revealing an east or west component in the paleoflow (Fig. 53).

For the Rush Bay Member and Mosher Bay Formation, measurements are too sparse to show trends, if any exist (Fig. 54).

Grain Orientation

It has been demonstrated that the statistically preferred orientation of the long axes of grains in a sandstone indicates the direction of the paleocurrent depositing that sandstone (Blatt et al., 1972, p. 12). If there has been no tectonic deformation, obtaining grain orientations is a possible, although laborious, means of obtaining Archean paleocurrent data, because it is virtually independent of exposed bedding planes.

1. Methods

In the Manitou Lake Area, like much of the Archean, outcrops suitable for obtaining oriented samples are relatively rare because of induration and the smoothness of many of the glacially-rounded exposures. It is necessary to find an outcrop in which the bedding plane is clear (both strike and dip), in which there is no evident cleavage or other signs of tectonic deformation, and from which it is possible to extract the sample once it is marked. When collecting with a rock hammer, the sample was removed first, then replaced and marked with a sample number, the bedding plane, the stratigraphic top of the sample, and an arrow of known orientation in the bedding plane. Thirteen of the samples were collected from smooth outcrops using a GSC sampler drill. In these cases, a 'T' mark was chiseled on the outcrop first. The top of the 'T' was parallel to strike and the base pointed stratigraphically downwards. The axis of the drill was hel[illegible]arallel to bedding during drilling. The chiseled 'T' on one end of the tubular sample allowed reorientation so the sample could be clearly labeled with a felt marker. Other features which might influence the grain orientation, such as weak cleavages (areas of prominent cleavage were not sampled), joints, or sedimentary structures, were also recorded. If an oriented sample from an area was especially desirable, but no outcrop with clear bedding could be found, an oriented sample was taken and the regional bedding used for that sample. The error in the recorded bedding attitude is probably not greater than 10°.

The computations on the data have the effect of rotating the grain orientations about the strike line; i.e., removing the effects of a simple, single fold. There is no evidence of more complex deformation, such as two phases of folding, over most of the area. Cleavages seem to be closely related to the Manitou Straits Fault, isoclinal folding in the Mosher Bay Formation, and late granitic intrusions.

None of these areas was sampled. The very lack of any cleavage throughout most of the group might be taken as evidence of a simple structural history.

Oriented thin-sections were prepared from 41 of the samples, while acetate peels were taken from the remaining 34, using the methods of Hiscott (1977). Where textural, rather than compositional, characteristics of a sample are required, acetate peels are a quick, inexpensive, and yet very effective means of preparing samples for study. Both the thin-sections and the peels were analyzed on a standard petrographic microscope with a mechanical stage.

Special care was taken during thin-section and peel preparation to ensure that the section was in the bedding plane, that the top of the section was stratigraphically upwards, and that one (marked) edge of the section was parallel to the arrow of known orientation on the sample. It is all too easy to lose or confuse the orientation during thin section preparation (Bonham and Spotts, 1971).

Many of the Manitou Group sandstones are volcanogenic and thus are composed mainly of rock fragments (Chapter VI), which cannot always be reliably distinguished from the matrix. However, grains generally show clearly due to differences in mineralogy, internal grain size, color, and the degree to which they accept the amaranth stain, compared to the matrix (Fig. 55).

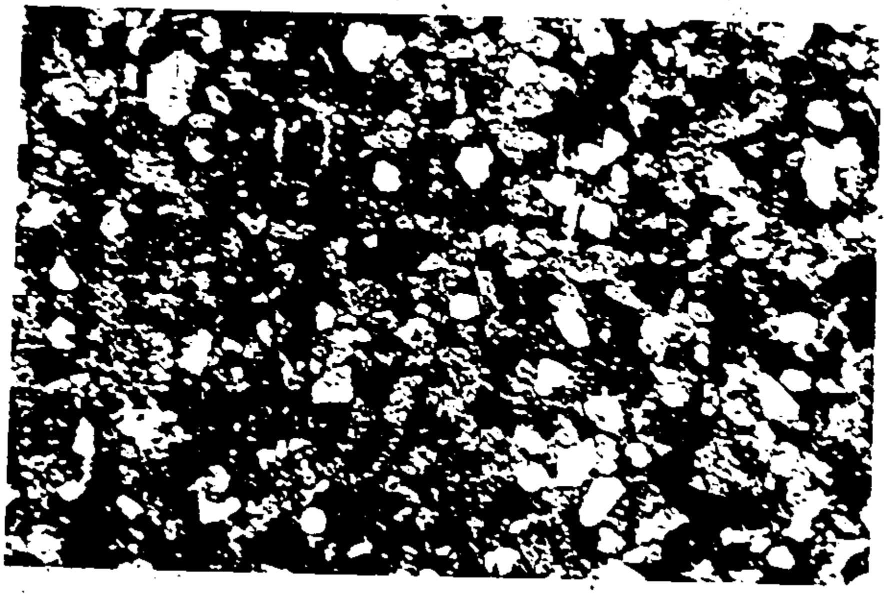


Figure 55. Photomicrograph of volcanogenic sandstone showing the distinction between clasts and matrix. Approximately 10x magnification.

Because of the abundance of rock fragments and the typically low quartz contents (Chapter VI), in counting the samples it was necessary to use all those grains intersected, regardless of mineralogy or lithology, which had clear and complete grain boundaries, a diameter larger than 0.1 mm, and a width to length ratio of 0.7 or less (Onions, 1965). Most of the grains are at least twice as long as they are wide so few were rejected due to shape. The grains are generally ellipsoidal, except the feldspars which are lathe-like. Grains intersected more than once were only recorded once.

The vector mean and other statistics of the raw orientation data were obtained using a computer program devised by I. P. Martini (1965). Briefly, this program (as used here) converts the raw data to real "line-of-movement" directions using the direction of the known orientation arrow on the thin section, then computes a histogram, the vector mean, and the vector length, and performs a Chi-square test of significance on the results. The output from this program for the Manitou Group appears in Appendix I. In addition, the vector length was used to obtain the standard deviation using Curray's (1965) Figure 3, and the Rayleigh test of significance using Curray's Figure 4. For all specimens with a preferred orientation, the Chi-square and Rayleigh tests both gave the same level of significance. A summary of the data appears in Table II and the results are plotted in Figures 56 and 57.

Table II. Summary of dimensional grain orientation data for the Manitou Group.

Sample Number	Strike	Vector Mean	Vector Mean minus Strike	95% Confidence	Vector Length
Eastern Uphill L. Fm. (East)					
OT-74- 1	060	116	56	±6.9	24.8
OT-74- 2	060	177	117	±8.0	29.6
OT-74- 6	050	69	19	±7.1	42.2
OT-74- 8	055	56	1	±5.9	58.0
OT-74- 9	060	170	110	±7.8	31.4
Grand Vector Mean		57	14		7.0
Eastern Uphill L. Fm. (Central)					
OT-73-25	090	1	91	±8.2	38.5
Eastern Uphill L. Fm. (West)					
OT-73-18	075	146	71	±6.7	48.3
OT-73-26	070	139	69	±7.5	25.6
OT-74-11	075	177	102	±6.9	24.4
OT-74-12	080	156	76	±7.1	42.5
Grand Vector Mean		154	79		30.3
Uphill Lake Area					
OT-73-12	075	10	115	±7.4	18.2
OT-73-14	070	71	1	±7.2	28.1
OT-73-15	070	40	150	±5.3	64.1
OT-73-16	075	61	166	±6.5	50.5
OT-73-24	085	119	34	±7.6	35.8
OT-73-28	070	60	170	±7.2	18.9
OT-74- 4	075	28	133	±7.6	33.5
Grand Vector Mean		51	160		19.6

(CONT.)

Table II. Summary of dimensional grain orientation data for the Manitou Group (Cont.)

Sample Number	Strike	Vector Mean	Vector Mean minus Strike	95% Confidence	Vector Length
"Bulbous Bay" Area					
OT-73- 2	060	82	22	±7.4	14.4
OT-73-21	065	21	— 136	±6.9	45.8
T-12	045	159	114	±6.6	45.8
T-13	045	173	128	±8.6	21.6
T-16	050	23	153	±6.6	49.3
T-17	040	146	106	±5.6	61.3
Grand Vector Mean		175	127		20.1
Cane Falls Area					
T- 7A	030	101	71	±4.4	74.8
T- 7B	030	118	88	±7.0	46.2
T- 8A	030	93	63	±6.2	55.5
T- 8B	030	93	63	±9.0	20.6
T- 8C	030	101	71	±4.6	71.0
T- 9	035	93	58	±4.4	76.4
T-19	035	175	140	±7.8	35.5
T-20	035	105	70	±8.2	31.1
Grand Vector Mean		101	70		41.4
Western Cane Falls Area					
T- 1A	020	71	51	±7.0	45.6
T- 1B	020	74	54	±8.0	32.2
T- 2A	035	107	72	±6.4	49.6
T- 2B	035	96	61	±6.4	52.1
T- 3A	035	60	25	±9.2	18.3
T- 3B	035	95	60	±4.4	74.6
T- 3C	035	99	64	±8.0	32.2
T- 3D	035	98	63	±6.8	47.0
T- 3E	035	99	64	±4.8	69.9
T- 5A	025	92	67	±7.8	35.2
T- 5B	025	86	61	±8.4	26.6

(CONT.)

Table II. Summary of dimensional grain orientation data for the Manitou Group (Cont.)

Sample Number	Strike	Vector Mean	Vector Mean minus Strike	95% Confidence Interval	Vector Length
Western Cane Falls Area (Cont.)					
T- 6	030	136	106	±7.0	46.4
T-10	035	100	65	±7.0	45.9
T-18A	035	86	51	±6.4	51.4
T-18B	035	104	69	±5.6	62.9
T-18C	035	111	76	±4.0	79.8
Grand Vector Mean		97	65		43.2
Rush Bay Member					
OT-73-11		39		±4.9	67.5
Mosher Bay Fm.					
OT-73-13		19		±7.4	16.0
OT-73-20		159		±4.9	66.5
No Preferred Orientation (at 95% significance level for 150 points)					
Eastern Uphill L. Fm.					
OT-74- 7					12.4
OT-74-10					13.4
Western Uphill L. Fm.					
T-15					15.2
Cane L. Fm					
OT-73-17					12.4
Mosher Bay Fm.					
OT-73- 5					5.3

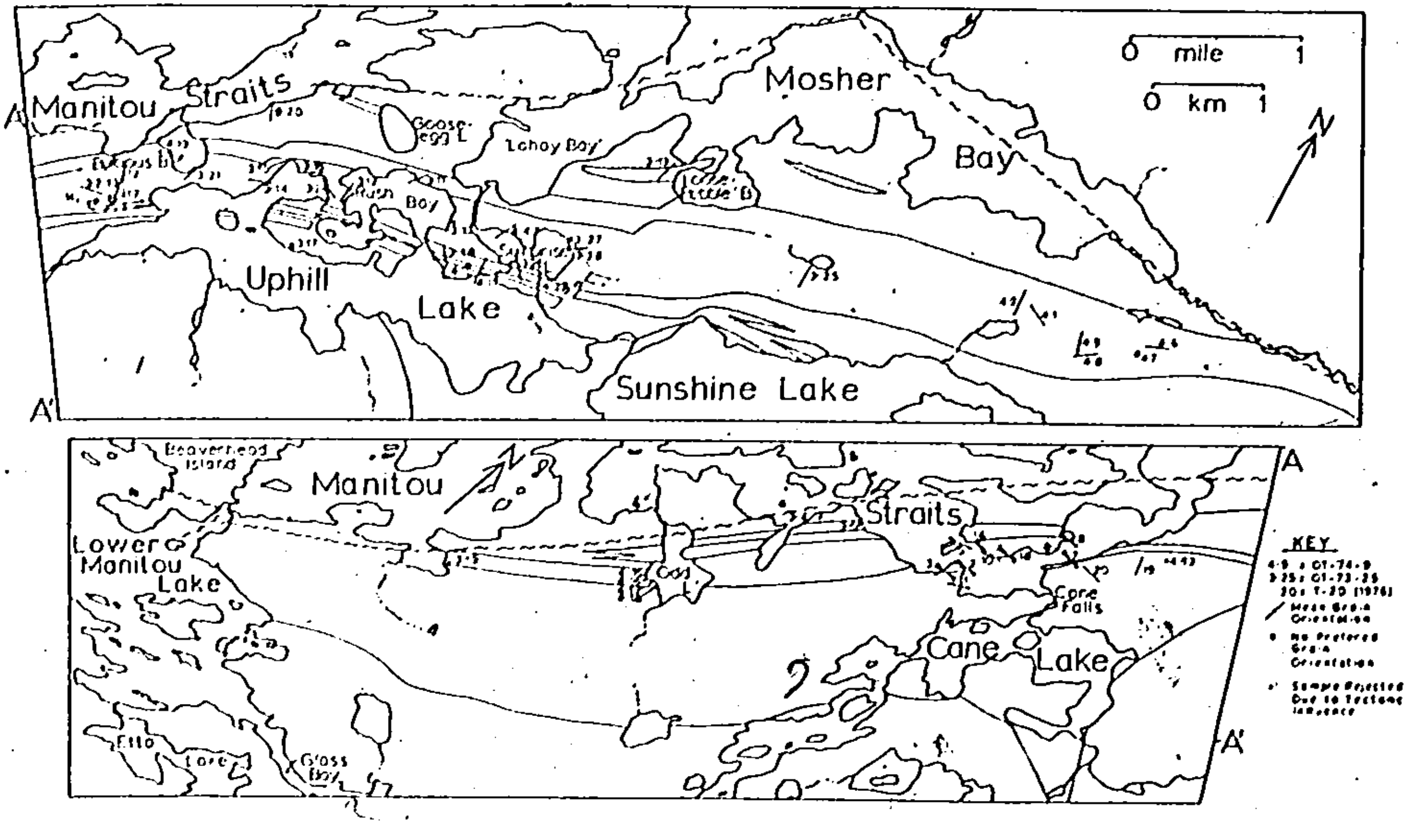


Figure 56. Location of samples for grain otientation study, with mean grain orientation shown for each.

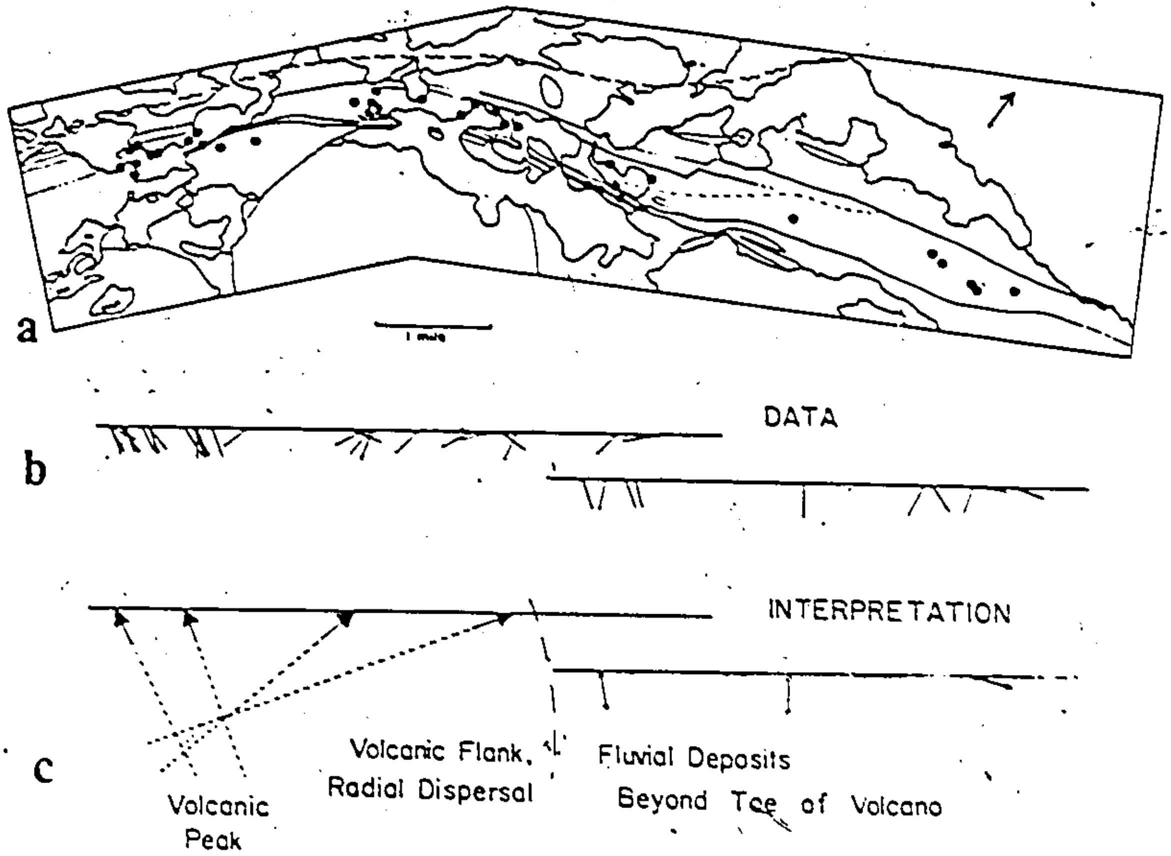


Figure 57. Simplified paleogeographic reconstruction of the Manitou area based on paleocurrent data. a. Location of samples. Several samples were taken from some locations. b. Representation of data as angles with respect to strike. c. Orientation of grand vector means of grouped data (see text), and paleogeographic interpretation.

In order to test the reproducibility of the grain orientation measurements, three operators did two replicates on each of two specimens (one thin section and one peel). The results are shown in Table III. Operator R was experienced; operator H was experienced with grain orientation, but using a somewhat different method; operator S had no experience. The time between replicates ranged from two weeks to over a year.

An analysis of variance for two variables with replication (Dixon and Massey, 1957) performed on these results showed that there is no significant difference between the results of each operator on replicates of each specimen, nor between the results obtained by different operators on the same specimen (Table IV). A similar analysis of the vector magnitudes obtained by the different operators gives similar results (Tables V, VI).

One of the problems of grain orientation studies is determining whether the preferred orientation is due to sedimentation or to subsequent tectonic deformation. For the Manitou Group sandstones, tectonic influences were tested in two ways. First, the vector mean of each sample was plotted on a stereonet together with all known fabrics pertinent to that sample (for example, cleavage in the sandstone or adjacent argillite, joints, and clast elongation directions in adjacent conglomerates or tuff-breccias). If the grain orientation fell within about

Table III. Results of experiment for operator error in vector means.

Specimens	Operators R	 S	 H	
Thin Section OT73-16	61	68	52	replicates
	61	69	64	
Peel T3-B	100	102	100	replicates
	95	104	100	

Table IV. Two-way analysis of variance for operator error in in vector means

Source of Variation	d.f.	Sum of Squares	Mean Square	F	$F_{0.95}$
Specimen	1	4256.3	4256.3	290.6	5.32
Operators	2	117.2	58.6	4.0	4.46
Interaction	2	30.2	15.1	1.0	5.14
Subtotal	5	4403.7			
Unassigned error	6	87.0	14.5		
Total	11	4490.7			

Table V. Results of experiment for operator error in vector length.

Specimens	R	S	H	
Thin Section OT73-16	28.5 50.5	46.4 42.7	42.8 42.2	replicates
Peel T3-B	76.2 74.6	63.5 65.6	59.5 70.4	replicates

Table VI. Two-way analysis of variance for operator error in vector length.

Source of Variation	d.f.	Sum of Squares	Mean Square	F	$F_{0.95}$
Specimen	1	2046.24	2046.24	356.76	5.32
Operators	2	30.62	15.31	0.27	4.46
Interaction	2	146.58	73.29	1.41	5.14
Subtotal	5	2223.44	444.69		
Unassigned Error	6	311.91	51.99		
Total	11	2535.35			

5^{o} of the orientation of a tectonic fabric, the sample was rejected as an unreliable paleocurrent indicator. Secondly, the thin sections were examined for evidence of tectonism. The presence of a distinct alignment of matrix grains indicates a tectonic fabric because the matrix is re-crystallized to micas and chlorite and should have a random pattern if not subjected to strain during re-crystallization. In most cases a suspected tectonic influence indicated by the stereonet was confirmed by the presence of a strongly oriented matrix.

If there had been a penetrative deformation which had imparted a tectonic preferred orientation to the sandstone grains in an area, then all of the samples from that area should have a preferred orientation. However, some of the samples in the Uphill Lake area show no preferred orientation (Fig. 56). It follows that the orientations of the other, adjacent, samples are not tectonic, but sedimentary in origin.

2. Results

Of the 75 samples collected, seven were unsuitable for analysis, 13 apparently owe their grain orientation to tectonic deformation, and five did not give significant orientations for 150 points counted, thus leaving 50 samples with significant results (Table II; Fig. 56).

Nearly all of the samples showing significant grain orientations are in the Uphill Lake and Cane Lake Formations. It is clear from the sample distribution (Fig. 56) and the division of the Uphill Lake Formation into several environments (discussed in Chapters III and IV) that a grand vector mean of all the samples is not very useful. Therefore, the samples were divided into 7 geographic groups. The eastern area of the Uphill Lake Formation was divided into east (5 samples), central (1 sample), and west (4 samples). The remainder of the Uphill Lake Formation was divided into the Uphill Lake (7 samples), the 'Bulbous Bay' (6 samples), and the Cane Falls (8 samples) groups. The Cane Falls group of samples contains T-19 and T-20 which are from the Cane Lake Formation immediately below the Uphill Lake Formation (fig. 56). The western Cane Falls samples are the remaining samples (16) in the Cane Lake Formation.

Grand vector means were then calculated for each of these groups (Table II), removing much of the variation among individual samples, but retaining a measure of the regional variation across the map area.

However, the strike direction is not uniform throughout the map area, varying from a minimum of about 030° near Cane Falls to a maximum of about 075° at Uphill Lake, then returning to about 060° at the eastern end of the belt. Because the paleocurrent directions were obtained essentially by rotating the samples back to the horizontal about the strike line, the effects of this, presumably late, gentle bending of the sedimentary belt has to be removed in order to reconstruct the paleogeography. Therefore, Martini's (1965) orientation program was modified to subtract the strike of each sample from the orientation of each grain measured and to use these values in calculating the vector means. In effect, this restores the strike line to a straight line and records the orientation directions as departures from this line in a clockwise sense (Table II). These results were plotted along a line at scale distances from each other in Figure 57b. The group grand vector means are plotted in Figure 57c.

Discussion

1. The Cane Lake Pyroclastic Cone

The four western groups of samples in Figure 57 are chemically and petrographically very similar volcanic rocks which can be traced into one another. The clast-size data indicate that they were derived from a source in the vicinity of Cane Lake. Transport distances were short. It is therefore a reasonable assumption that the paleocurrents shown by the grain orientation study result from direct flow down a volcanic cone. It can readily be seen from Figure 57c that if the mean paleocurrent directions from these 4 western groups of samples are extrapolated, they converge upon a fairly small area approximately 1.6 km from the strike line. This area very likely represents the location of the volcano from which the pyroclastic pile of the Cane Lake Formation and western Uphill Lake Formation erupted.

Figure 57c, in effect, is a paleogeographic map showing the location of the Cane Lake cone. The strike line runs approximately northeast, and the beds face to the northwest, so restoration of the structure to the present configuration rotates this vent out of the page of Figure 57c; i.e., 'in the air', above the present level of erosion, which accounts for the lack of evidence of a vent in the currently exposed outcrops.

It is worthwhile to emphasize that the western Cane Falls and Cane Falls groups of samples nearly all came from the centre parts of thick, massive tuffs which have been interpreted as ignimbrites. Elston and Smith (1970) describe a method for the study of grain orientation in pyroclastics that is essentially the same as that used in this study. Their method was used in a number of studies by Smith and Rhodes (Rhodes and Smith, 1972; Smith and Rhodes, 1972; and Smith and Rhodes, 1974), but it does not appear that any other workers have used grain orientation in the study of pyroclastics.

The present study is the first attempt to apply this technique to Archean pyroclastics. It indicates that the method is as useful for Archean rocks as it is for the Tertiary volcaniclastics studied by Elston and Smith (1970). They state that the strong preferred orientations obtained and their consistent relationship to the inferred paleogeography indicate that fabric studies of pyroclastic rocks for purposes of paleogeographic reconstruction is a useful volcanological tool, especially for locating centres of volcanic activity from which ignimbrites emanate. The technique of obtaining grain orientation from small oriented specimens is particularly applicable to those terrains in which erosion or structural complications have obscured the original areal distribution of the pyroclastic rocks and their source vents. In the Archean, where extensive erosion, folding, faulting, and dips approaching 90° are the rule, grain orientation studies of sedimentary and volcanic rocks are invaluable in paleogeographic reconstruction. In this particular case, the understanding of the paleogeography of the Manitou Group has been greatly enhanced by studying the paleoflow of the pyroclastic rocks in the group.

2. Regional Paleoflow

At the time of Uphill Lake Formation deposition, the western part of the map area was dominated by the Cane Lake volcano (Figs. 50, 57c). A radial dispersal pattern developed around the volcanic peak in both the direct volcanic accumulations (ignimbrites and lahars) nearer the peak and the reworked materials of the flanking alluvial fan further from the peak.

Beyond the distal end of the alluvial fan, the braided fluvial system of the eastern Uphill Lake Formation was transporting material past the volcano in a direction tangential to the radial pattern of the volcanic peak. This direction is almost exactly perpendicular to the outcrops, so the abundant cross-bedding gives ambiguous current directions in the two-dimensional outcrop, about half of them indicating a component of flow to the west, the others indicating a component to the east. However, two exposed cross-bed troughs in the eastern area provide meagre evidence that transport may have been northward.

This paleogeographic interpretation derived from the paleoflow information, together with the stratigraphic development discussed in Chapter IV, permits the reconstruction of a three-dimensional view of the Manitou Group. This reconstruction is discussed in Chapter VIII.

CHAPTER VI

PETROGRAPHY

The purpose of petrographic studies on the sandstones and conglomerates of the Manitou Group is threefold: 1) to quantify the compositional differences between the various stratigraphic units, 2) to establish the nature of the source rocks, and 3) to establish the extent and nature of metamorphism and fabric reorganization as a prelude to fabric studies for paleocurrent determinations.

Textures

On the basis of general characteristics, the sandstones and tuffs of the Manitou Group can be divided into three lithologic groups: 1) the tuffs of the Cane Lake Formation and western Uphill Lake Formation, 2) the volcanogenic sandstones of the western and central Uphill Lake Formation, and 3) the quartz-bearing sandstones of the eastern Uphill Lake Formation, Rush Bay Member, and Mosher Bay Formation.

The tuffs of the Cane Lake and western Uphill Lake Formations are predominantly lithic tuffs composed of a wide variety of volcanic rock fragments dispersed in a fine-grained sericitic matrix. The average grain size is perhaps 1/2 to 1 mm, but sorting is very poor, clasts ranging from very fine up to pebble size. Roundness also varies widely, from angular to rounded, even within a single thin-section. The more angular grains are generally crystals or broken lithic fragments; the better rounded grains are nearly all lithic fragments. Due to the mineralogical and textural similarity of the matrix of these tuffs and the lithic fragments within them (which themselves are derived from tuffs), the edges of some lithic fragments grade into the matrix. These grains had to be avoided in the grain orientation studies. However, in most cases, grains are easy to see (Fig. 58).

The volcanogenic sandstones of the western and central Uphill Lake Formation are, overall, very similar to the tuffs. Like the tuffs, they are composed of a wide variety of volcanic rock fragments, so they are lithic sandstones, predominantly lithic graywacke (Pettijohn, 1975, p. 211). Many of these sandstones are nearly identical to the tuffs in having angular to rounded grains, a high matrix content, and very poor sorting. However, the average roundness and sorting are better than for the tuffs because some of the sandstones have more-rounded grains (rounded to subangular) and good sorting. The average grain size in those samples examined is about 1/2 mm.

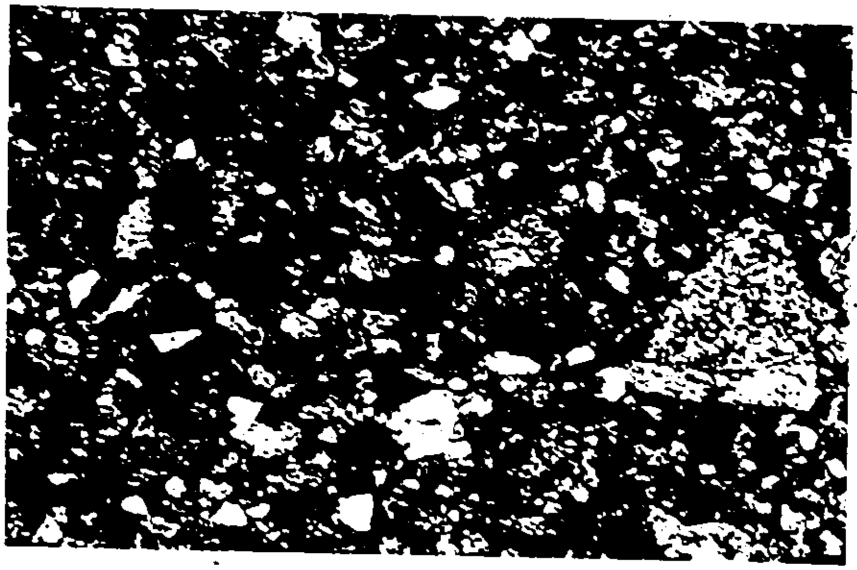


Figure 58. Photomicrograph of lithic tuff or volcanogenic sandstone, western Uphill Lake area. Approximately 10x magnification.

The sandstones of the eastern Uphill Lake Formation, Mosher Bay Formation, and parts of the Rush Bay Member, differ from the western and central Uphill Lake Formation in that their framework grains are not exclusively volcanic rock fragments and feldspar, but include also quartz, iron formation, chert, and plutonic rock fragments. The sandstones of the eastern Uphill Lake Formation are similar to the rest of the formation in being composed of poorly rounded and poorly sorted grains. However, the eastern area sandstones are generally clast-supported, as opposed to the matrix-supported sandstones of the rest of the formation. The sandstones of the Mosher Bay Formation are typical graywackes: grains are poorly rounded, very poorly sorted, and matrix-supported. The matrix consists of finer grains similar to the framework grains and very fine-grained chlorite and sericite.

Overall, the sandstones of the Manitou Group are very immature, containing a high proportion of labile grains which are generally poorly rounded, poorly sorted, and matrix supported.

The conglomerates and tuff-breccias of the Manitou Group can be considered essentially as coarser-grained versions of the sandstones and tuffs, although rounding in the conglomerates is somewhat better, and the conglomerates of the eastern Uphill Lake Formation and Mosher Bay Formation tend to be clast-supported.

Metamorphism and Deformation

The metamorphic grade of the Manitou Group is predominantly greenschist facies, rising to amphibolite facies near late granitic intrusions (Blackburn, 1976). The regional greenschist metamorphism has had little effect on the texture and composition of the group, resulting only in the recrystallization of the matrix (which is mainly chlorite), alteration of feldspars to sericite to varying degrees, and devitrification of any glass in the volcanics. Near the Manitou Straits Fault and granitic intrusions, there is a distinct foliation in outcrops, which is reflected in thin-section by a pronounced alignment of matrix minerals, and in most cases the framework grains as well. These samples, of course, could not be used for grain orientation studies, and in some cases were not reliable for composition studies either due to loss of definition of rock fragment grain boundaries. However, over most of the study area, metamorphism and deformation do not significantly affect fabric and composition determinations.

Composition of the Sandstones and Tuffs

1. Methods

The samples for thin-section study were collected during the mapping, and are well distributed throughout the various stratigraphic units (Fig. 59). The lack of sand-sized material in the very coarse

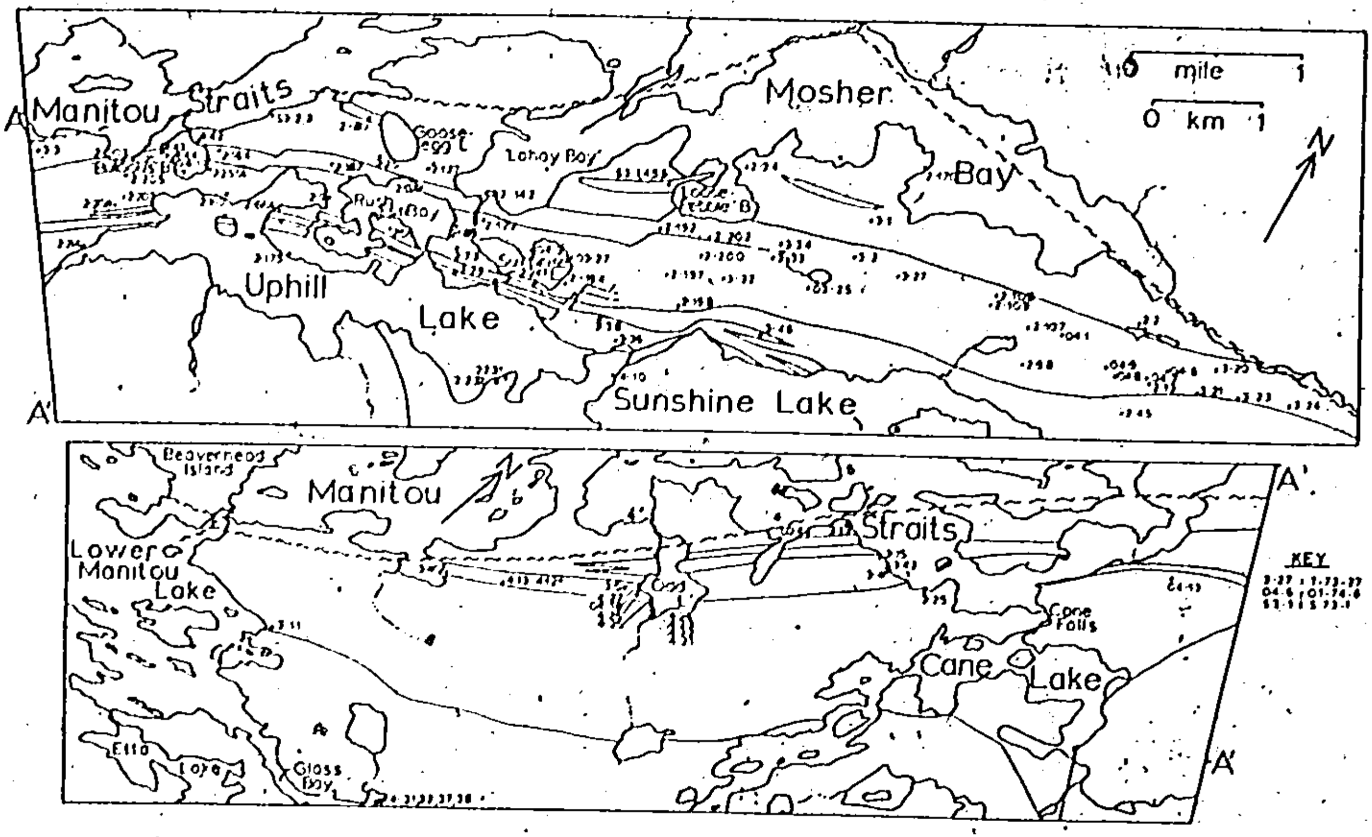


Figure 59. Location of samples for petrographic study.

lower parts of the Cane Lake Formation southwest of Cane Lake, together with a pronounced tectonic foliation in both the clasts and the matrix, precluded extensive sampling in that area.

To establish the mineralogical composition of the Manitou Group sandstones and tuffs, 500 points were counted on each of 101 thin-sections. Traverse lines were 5 mm apart and the spacing between points was 0.3 mm, which gave nearly complete coverage of the thin-section.

Seventy-two of the thin-sections were stained with sodium cobaltinitrite and amaranth using the method of Laniz et al. (1964). The quality of the staining varied, but was sufficiently good to indicate that potassium feldspar contents are generally very low, and much of the plagioclase is not twinned.

The thin-sections were analyzed for four different kinds of quartz, potassium feldspar, twinned and untwinned plagioclase, several varieties of volcanic rock fragments, plutonic rock fragments, chert, and matrix.

The quartz grains were separated on the basis of extinction and crystallinity into 4 classes: 1) monocrystalline, plain extinction; 2) monocrystalline, strained extinction; 3) polycrystalline, plain extinction; and 4) polycrystalline, strained extinction. However, over much of the Manitou Group, quartz contents are very low, commonly less than 3%, so the amount of any one quartz type cannot be considered a reliable indicator of the source area. In those rocks with higher quartz contents (the Mosher Bay Formation), virtually all quartz has an undulose extinction. The matrix of these rocks is commonly foliated and the outcrops show tectonic deformation, so it is suspected that the deformation in the quartz grains occurred after their deposition. For these reasons, only total quartz has been reported.

Feldspar grains were divided into potassium feldspars, plagioclase, and untwinned feldspars. Potassium feldspars and plagioclase were separated on the basis of twinning and staining. Untwinned feldspar is reported with the plagioclase because all untwinned feldspar grains in all stained sections became pink when treated with the amaranth stain.

Several types of volcanic rock fragments were recognized on the basis of groundmass and phenocryst types, but the number and types tend to vary from section to section, and none could be reliably related to magma type (mafic, intermediate, or felsic), partly due to their small size, and partly due to alteration. Therefore, they are all reported together under "volcanic rock fragments". The plutonic rock fragments are composed of a few feldspar and quartz grains, with or without minor mafic constituents, that are attached together.

Chert is often difficult to distinguish reliably from felsic rock fragments. However, in most sections the chert could be distinguished by a lack of staining (felsic volcanic rock fragments stained pink), a slightly coarser grain size, and a general lack of the small platy or lathe-like (? mica) minerals common in the very fine-grained volcanic rock fragments.

The matrix is all material finer than 0.03 mm. It is composed predominantly of sericite and chlorite, with some very fine quartz, feldspar and rock fragments similar to the sand-sized constituents.

2. Results

The results are tabulated in Table VII and Appendix II, and illustrated in Figure 60. The end-members used in Figure 60 are: F:total feldspar plus plutonic rock fragments; Q:quartz; and L:volcanic rock fragments.

Matrix contents are generally high for all stratigraphic units, ranging from 11 to 92% (Appendix II). Only 6 samples would be arenites in the classification of Pettijohn (1975, p. 211). Thirteen would be classed as mudstones; twenty-one are tuffs; and the rest (sixty-one) are wackes.

Five samples from the Etta Lake sediments indicate that they are volcanogenic in origin, being composed dominantly of volcanic rock fragments.

Table VII. Average modal composition of the sandstones and tuffs of the Manitou Group.

Stratigraphic Unit	No. of Samples	Quartz	K-Feld.	Plag.	Volcanic Rock Frag.	Plutonic Rock Frag.	Chert	Matrix
Etta L. Sediments	5	1.2		15.8	28.2			54.8
Cane L. Fm.	14	0.3		7.0	41.4		0.1	51.2
western Uphill Lake Fm.	5	1.3		23.3	42.1			33.2
central Uphill Lake Fm.	18	1.1	0.7	12.3	52.2		0.1	32.9
eastern Uphill Lake Fm.	18	7.0	0.03	8.6	34.3	0.8	0.9	48.8
Rush Bay Member	22	8.0	0.2	6.1	26.2	0.1	0.4	59.1
Mosher Bay Fm.	18	14.9	1.4	10.1	11.5	2.0	0.1	60.1

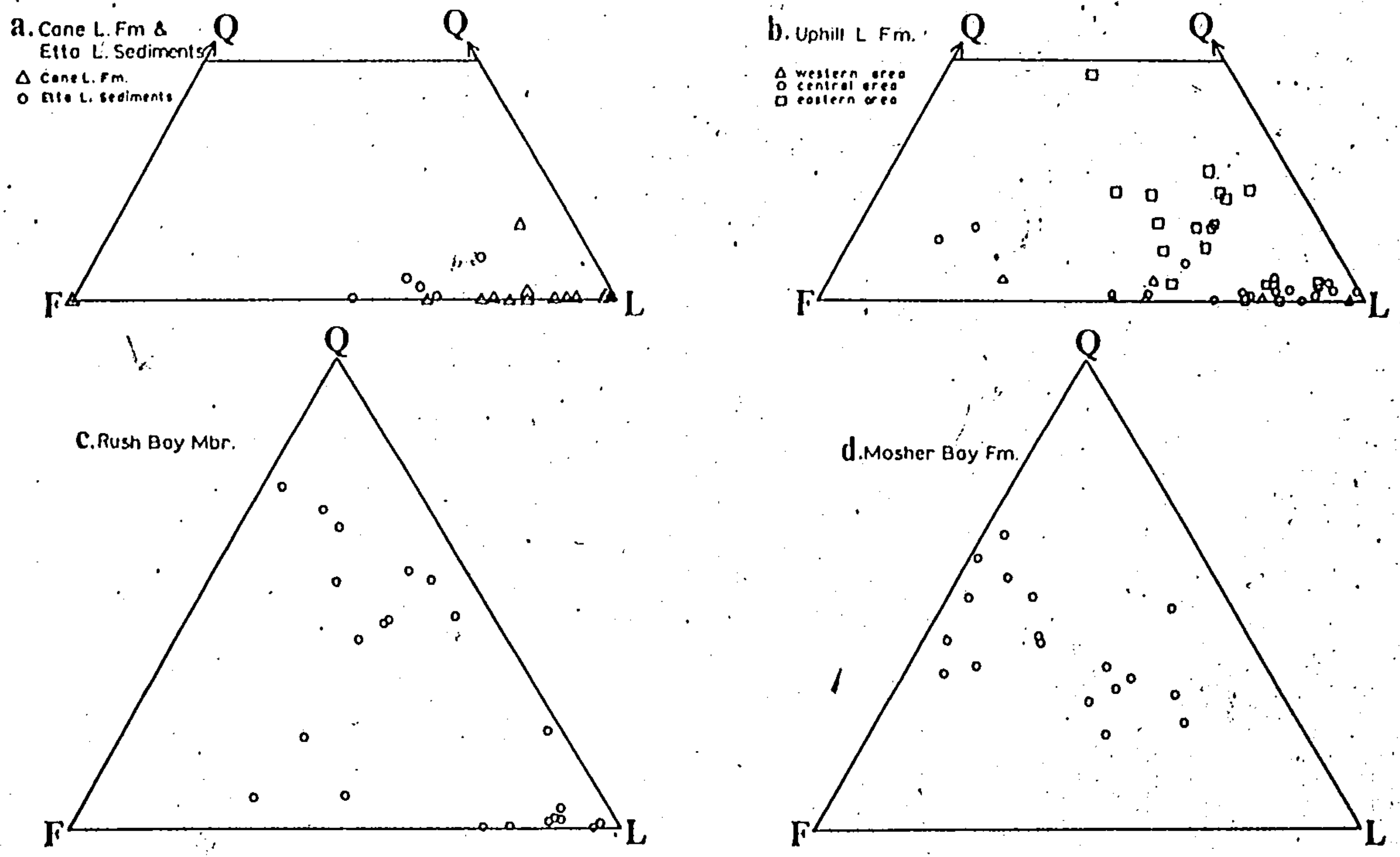


Figure 60. Modal composition of sandstones and tuffs of the Manitou Group. Q = quartz and chert; F = feldspars and plutonic rock fragments; L = volcanic and sedimentary rock fragments. Most rock fragments are volcanic.

All of the Cane Lake Formation samples are clustered near the volcanic rock fragment apex on Fig. 60a. On the basis of composition, texture, and field occurrence, most of these (11) can be considered tuffs. Classifying these on the basis of their crystal vs. lithic fragment content (Pettijohn, 1975, p. 306) indicates that 9 are lithic tuffs, one is a lithic-crystal tuff, and one is a crystal tuff. The crystals are essentially all plagioclase (Table VII). Of the 3 remaining samples, which probably are not tuffs, 2 are volcanic mudstones, and the other is a volcanic arenite.

The samples of the western and central areas of the Uphill Lake Formation lie near the volcanic rock fragments apex and spread along the rock fragment-feldspar line, occupying the same field as the Cane Lake Formation (Fig. 60b). In contrast, the majority of the eastern area samples are well above the feldspar-rock fragment line, reflecting the less volcanic nature of that area. A few plutonic rock fragments occur in the eastern area (Table VII).

In the field, the Rush Bay Member of the Uphill Lake Formation appears to be inhomogeneous, and this is confirmed by the composition data (Fig. 60c). Most of the samples fall roughly into two groups. The concentration at the volcanic rock fragment apex is similar to the western and central areas of the Uphill Lake Formation, whereas the more quartz-rich samples have quartz contents similar to the Mosher Bay Formation, but with somewhat more rock fragments than feldspar compared to that formation. The four samples towards the feldspar apex have high matrix contents (Appendix II); feldspar and some rock fragments were almost the only recognizable grains in these four samples.

In contrast to all the underlying units, the Mosher Bay Formation samples lie well away from the volcanic rock fragment apex (Fig. 60d). Plutonic rock fragments are a small, but important, component of these rocks (Table VII). The samples from the conglomeratic lenses have a higher percentage of rock fragments, probably because they are coarser grained, so rock fragments are better preserved and more easily identified.

Composition of the Conglomerates

Conglomerate-sized material forms an important part of all stratigraphic units of the Manitou Group. In order to quantify their composition, 16 stations were measured for clast composition at the outcrop (Fig. 61). A further seven were taken from the work of S. Teal (1974).

1. Methods

The clast composition measurements of conglomerates in outcrop were done using a traverse-line method. A series of 5 traverse

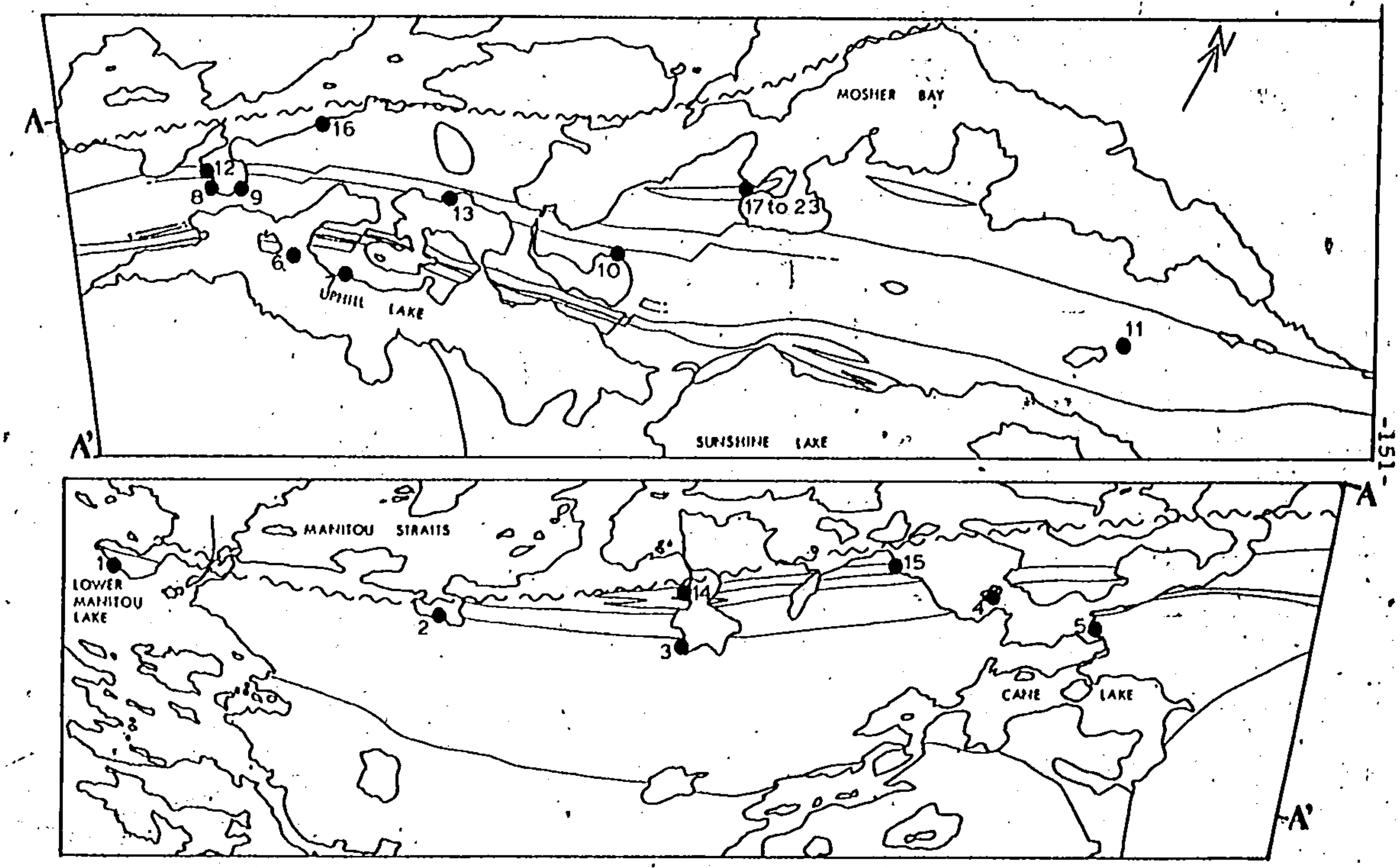


Figure 61. Locations of measurements of clast composition in conglomerates and tuff-breccias of the Manitou Group.

lines, preferably 1 m in length, were drawn on the outcrop 20 cm apart, approximately perpendicular to strike. A tape measure was then laid along the line. Volume percentages of the various clast types, and matrix, were estimated by measuring the intercept of each clast along the traverse line.

The clast types were identified by weathering colour, texture, and visible mineralogy. Dark coloured aphanitic clasts were considered basalts, whereas pale pink- or white-weathering aphanitic rocks were called felsite. Clasts of medium grey or grey-green colour that could not be readily assigned to the basalt or felsite classes were considered intermediate. Porphyries were those felsic clasts containing feldspar and/or quartz grains generally greater than 2 mm in diameter and noticeably larger than the background material. "Granite" clasts were those with an equigranular plutonic texture and commonly containing visible quartz. Of eleven "granite" clasts, S. Teal (1974), using the IUGS classification (Streckeisen, 1967, IUGS Subcommission on the Systematic of Igneous Rocks, 1973) found four to be granite and seven, granodiorite. Five of the eleven are foliated. Iron formation is readily recognized by a deep purple colour, banding, and attraction to a magnet. Sandstone and argillite were recognized by sedimentary textures and bedding, and chert by colour, hardness, and banding. "Matrix" is all grains less than about 1 cm in diameter.

Detailed descriptions of the clast types (especially the 'granite' clasts) are given by S. Teal (1974).

2. Results

Clast composition measurements require exceptionally clean outcrops, which, unfortunately, are not very abundant in the area. In fact, they are restricted almost entirely to shoreline exposures, giving a somewhat non-uniform distribution of stations (Fig. 61). Nevertheless, each formation is represented by at least 6 stations, for a total of 23 stations, the traverses averaging 4.7 m per station.

The results are shown in Table VIII. A more complete tabulation is given in Appendix III. The data of Table VIII are summarized pictorially in Fig. 62. The porphyries are plotted with the volcanics because microscopic (S. Teal, 1974) and field examination indicate that these are more closely associated with the felsic volcanic clasts than with the plutonic rocks.

It can be seen from Fig. 62 that most of the Manitou Group is volcanogenic in origin. Only the Mosher Bay Formation analyses depart very far from the volcanic-clast apex. Sample 11 is in the eastern area of the Uphill Lake Formation and shows the small amount (5.7%) of non-volcanic clasts that help separate that area from the rest of the Uphill Lake Formation. Sample 1 is from the extreme southwest end

Table VIII. Clast composition of conglomerates and tuff-breccias of the Manitou Group. CL=Cane L. Fm., WUL,CUL,EUL=western, central, and eastern areas of Uphill L. Fm, RBM=Rush B. Mbr., MB=Mosher B. Fm.

Location (see Fig.61)	Unit	Basalt	Intermediate	Felsite	Porphyry	Granite	Iron Fm.	Sedimentary	Matrix
1	CL	12.7	7.7	34.4	5.6	2.3			30.5
2	CL	30.2		35.0					43.8
3	CL	19.6		19.4	27.8				33.2
4	CL	30.8	1.0	12.7	25.4				30.2
5	CL	19.7	5.5	46.6	1.9				26.4
6	CL	44.1	2.6	32.2					21.1
7	CL	44.0		23.9	7.1				25.0
8	WUL	20.5		29.4	33.1				17.0
9	WUL	37.2	3.5	22.4	5.6			0.8	30.6
10	CUL	6.7		27.3	33.2			0.2	32.6
11	EUL	53.1		19.4	3.4	5.7	2.0	3.3	13.1
12	RBM	26.5		17.5	41.5				14.5
13	RBM	18.4	10.6	15.4	23.3		1.0	5.2	26.3
14	MB	12.3		14.5	3.3	5.3	3.1	9.5	52.0
15	MB	4.8	0.5	23.9	9.7	8.9	0.3	13.5	38.5
16	MB	4.5	2.9	14.8	1.1	5.1	0.2	12.7	58.7
*17	MB	0.4	2.6	13.0	3.9	32.4	7.3	6.7	33.7
18	MB	0.2	3.4	14.3	0.8	19.2	4.1	10.3	47.7
19	MB	3.2	0.7	34.2	7.0	4.4	3.5	10.0	37.0
20	MB	0.6	1.0	14.9	6.4	14.7	4.4	6.9	51.1
21	MB	3.1	0.8	14.4	6.4	10.8	9.9	9.5	45.1
22	MB	4.3	4.3	19.3	13.9	4.0	4.1	7.4	42.8
23	MB	1.1	2.3	15.8	5.5	11.7	10.5	8.4	44.8

*17 to 23 from S. Teal, 1974. Sedimentary clasts are mainly chert.

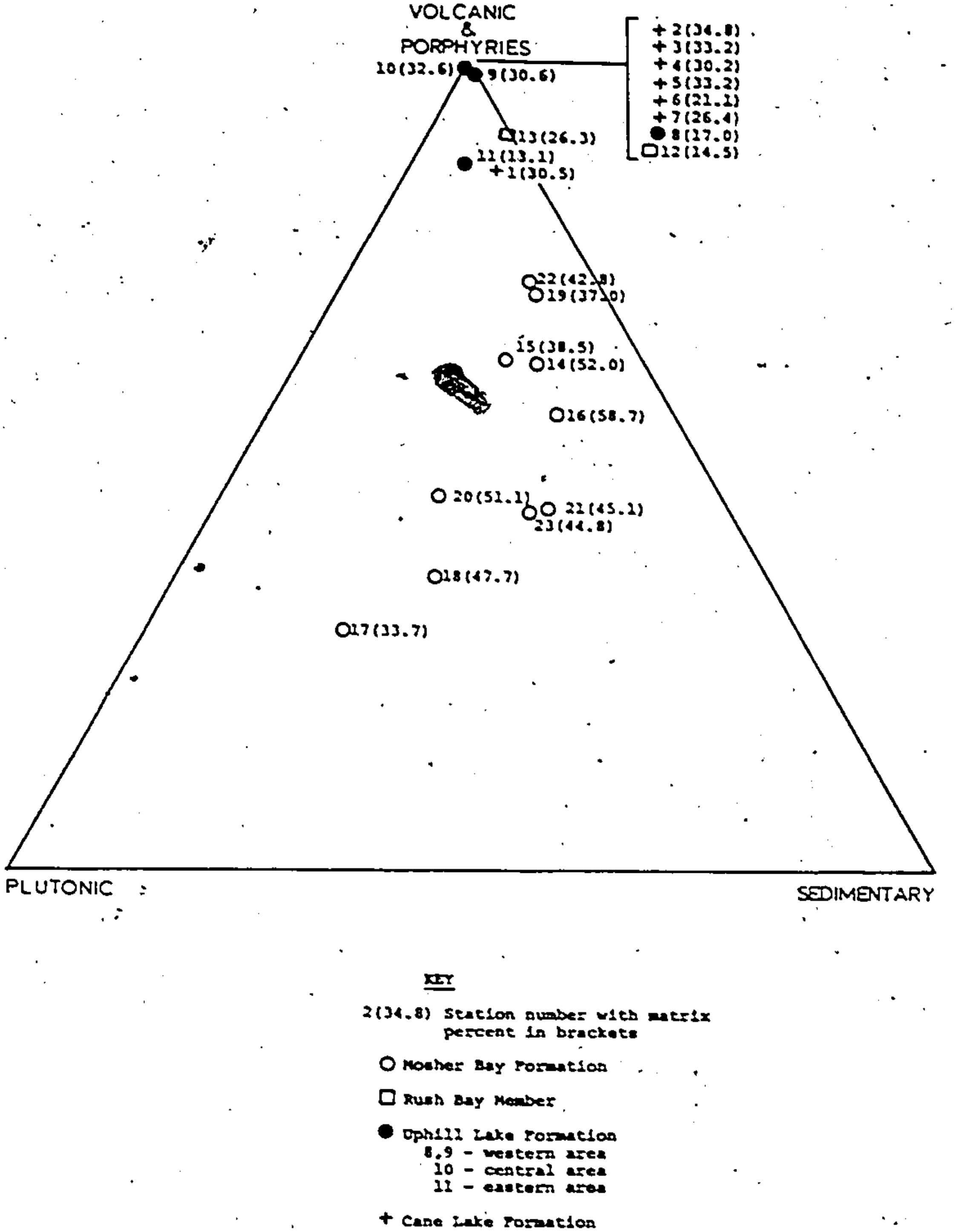


Figure 62. Clast composition of conglomerates and tuff-breccias of the Manitou Group. For sample locations, see Figure 61.

of the Cane Lake Formation and reflects the presence in that area of a few chert and plutonic clasts among the predominantly volcanic debris. Sample 13 illustrates that some beds of the Rush Bay Member contain non-volcanic clasts, but not all (compare stations 12 and 13). These results generally agree with the results from the thin section studies and support the provenance, environmental, and paleogeographic interpretations given elsewhere (Chapters IV, VIII).

Provenance

The Etta Lake sediments are turbidites from a volcanic source and are most probably related to the volcanic activity that built the platform underlying the Manitou Group.

Many of the Cane Lake Formation samples can be considered tuffs; i.e., direct volcanic accumulations, and the Cane Lake Formation has been interpreted as a subaerial pyroclastic pile (Chapter IV). Because 1) the western Uphill Lake Formation is laterally equivalent to and grades into the Cane Lake Formation, 2) paleocurrent data (Chapter V) indicates flow from the Cane Lake Formation into the western Uphill Lake Formation, and 3) they have an almost identical volcanic composition both in sandstones and conglomerates, it is almost inescapable that the western and central portions of the Uphill Lake Formation were derived from the erosion of the Cane Lake pyroclastic pile, probably while that pile was still actively being built.

The sandstones of the eastern area of the Uphill Lake Formation contain an average of 8% quartz and some plutonic and chert grains, and the conglomerates contain "granite", iron formation, and chert clasts, so they are not derived from a strictly volcanic source. The volcanic rock fragments, chert and iron formation can be accounted for by uplift and erosion of an area similar to the Manitou Group, although chert and iron formation occur only above the Uphill Lake Formation in the Manitou Group. No source for the "granite" clasts can be found among the local rocks. Their occurrence in the Uphill Lake Formation implies that a hinterland containing granitic plutons was exposed to erosion at the same time as the Cane Lake pyroclastic pile was building. This granite-bearing hinterland was probably not too far distant and had to be attached to the Manitou area, with no intervening sea, because the eastern Uphill Lake Formation was deposited by a fluvial system. The area now occupied by the Meggisi Batholith (south of the area) is a possible location of this hinterland, but it is not possible to prove this with the data available at present.

Compositionally, the Rush Bay Member of the Uphill Lake Formation is a transitional unit in that some of the beds are like those of the underlying formation, whereas other beds are more like the overlying Mosher Bay Formation. In terms of provenance, it seems reasonable that the source areas are similarly divided: the volcanic beds being derived from the last of the volcanic activity; while the first quartz and "granite"-bearing material was being deposited, perhaps from the same sources as the eastern Uphill Lake area.

The composition of the Mosher Bay Formation can be accounted for almost entirely in terms of the underlying stratigraphy. Lithologies equivalent to mafic and felsic volcanics, and porphyry, clasts are all present in the underlying stratigraphy. Iron formation, chert, and sedimentary clasts in the conglomerate lenses can be explained by channels down-cutting through previously deposited Mosher Bay Formation. Again, however, no source for the granitoid clasts or the quartz and K-feldspar grains can be found among the local rocks.

S. Teal (1974) suggests the intrusion of a small granitic body into the volcanic-sedimentary sequence, followed by uplift and erosion, would account for the presence of both the granitic clasts and the clasts with lithologies similar to those of the underlying stratigraphic sequence. No evidence of such an intrusive body has been found at Manitou Lake, however, and the presence of some granitic clasts noticeably different in composition from the others (S. Teal, 1974) suggests that a single small source might not be adequate to account for the clast types observed. As in the case of the eastern Uphill Lake Formation, possible source areas of large, exposed granitic plutons are the Meggisi Batholith and

Atikwa Batholith, but these cannot be directly connected with the Mosher Bay Formation debris using the currently available data.

In summary, the Cane Lake Formation is a primary, pyroclastic accumulation, and the western and central areas of the Uphill Lake Formation were derived directly from those pyroclastics. The eastern part of the Uphill Lake Formation was derived from an area dominated by volcanic rocks, but composed in part of a granitic pluton which was exposed at the same time as the Cane Lake pyroclastics were accumulating. The Mosher Bay Formation consists of debris from a source area similar to that of the eastern Uphill Lake Formation, but in which a higher proportion of "granite" was available.

CHAPTER VII

GEOCHEMISTRY

Introduction

Chemical analysis of selected rocks of the Manitou Group was undertaken for three principal reasons: 1) to provide a chemical basis for the classification of the Sunshine Lake Formation lavas; 2) to classify the Cane Lake Formation and western Uphill Lake Formation pyroclastics and compare them to the volcanogenic sedimentary rocks of the central Uphill Lake Formation; and 3) to investigate the chemical composition of the sedimentary rocks, particularly the argillites.

Twenty-two analyses for this study were completed by the Mineral Research Branch of the Ontario Division of Mines through arrangements with C. E. Blackburn, using atomic absorption spectrometry. Eighteen others were done using X-ray fluorescence by Fred Longstaffe of McMaster University, who is using these results as part of his Ph. D. thesis on oxygen isotopes in the Archean. These 40 analyses are listed in Table IX. The published sources of the remaining analyses are given with the table. All the analyses of Table IX have been recalculated to 100% volatile-free. The original analyses, and

Table IX. Chemical analyses of selected rocks of the Manitou Group.

MANITOU LAKE FORMATION / MAFIC SILLS

	1	2	3	4	5	6	7	8	AVG.	9	10	11	AVG.
SiO_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al_2O_3	14.9	15.3	15.7	14.9	18.2	15.1	13.8	15.9	15.2	14.0	17.3	14.3	15.2
Fe_2O_3	2.14	2.32	2.36	2.31	2.29	2.38	2.43	2.01	2.28	2.38	2.34	2.31	2.34
FeO	3.31	3.33	3.96	3.12	4.22	3.73	6.04	3.28	3.86	6.15	4.82	3.35	4.77
MgO	3.98	4.33	3.64	4.10	3.02	3.33	9.21	3.08	4.60	8.15	4.40	3.70	6.08
CaO	6.13	3.36	7.17	4.32	3.84	3.70	6.27	2.64	5.43	3.89	4.44	3.84	5.46
Na_2O	4.03	3.44	3.86	3.40	4.21	3.63	3.14	4.73	3.81	4.17	4.38	3.48	4.14
K_2O	3.32	2.47	3.36	4.44	4.27	4.17	3.44	2.02	3.36	2.49	2.79	3.87	3.05
TiO_2	.61	.31	.82	.74	.73	.83	.92	.30	.73	.83	.81	.80	.81
MnO	.08	.10	.10	.06	.09	.00	.00	.00	.07	.00	.00	.00	.00

PYROCLASTIC AND VOLCANOGENIC SEDIMENTARY ROCKS

CANE LAKE FORMATION

	12	13	14	15	16	17	18	19	AVG.
SiO_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al_2O_3	16.8	15.5	16.0	15.27	16.1	15.96	15.95	16.43	16.00
Fe_2O_3	2.17	2.23	2.07	7.03	2.10	1.91	3.33	3.83	4.81
FeO	.76	4.39	1.96		1.61	1.81			
MgO	1.43	4.19	3.00	2.36	3.04	2.88	3.22	1.38	2.62
CaO	2.79	3.27	3.42	3.24	4.09	3.90	3.16	2.06	3.26
Na_2O	4.46	4.03	4.44	3.88	3.86	4.46	3.36	4.44	4.23
K_2O	2.49	2.30	2.41	2.44	2.78	2.76	2.60	2.49	2.73
TiO_2	.62	.71	.32	.36	.32	.41	.38	.34	.73
MnO	.06	.08	.09	.30	.17	.07	.06	.06	.18
P_2O_5						.09	.22	.23	.18

WESTERN UPSILL LAKE FM. / CENTRAL UPSILL LAKE FM.

	20	21	22	23	AVG.	24	25	26	27	28	AVG.
SiO_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al_2O_3	17.4	16.6	16.4	16.75	16.74	15.5	15.6	14.05	15.76	16.12	15.40
Fe_2O_3	1.94	2.06	2.26	4.03	4.20	2.05	2.13	2.25	4.33	3.25	4.79
FeO	1.73	1.57	2.39			1.57	1.44	5.80			
MgO	1.44	2.16	2.67	2.49	2.44	2.88	2.76	4.10	2.50	1.80	2.80
CaO	4.40	3.91	3.70	3.88	3.97	3.29	3.04	3.95	3.25	3.19	3.76
Na_2O	4.41	3.88	3.42	4.27	4.00	4.36	4.00	2.98	4.28	4.76	4.07
K_2O	1.39	2.07	2.23	2.30	2.10	2.15	2.12	1.73	2.51	1.64	2.05
TiO_2	.41	.51	.72	.49	.73	.51	.61	.73	.63	.42	.38
MnO	.06	.05	.07	.05	.06	.06	.05	.15	.06	.05	.07
P_2O_5				.19	.19			.32	.21	.13	.22

EASTERN UPSILL LAKE FM.

	29	30
SiO_2	63.73	71.17
Al_2O_3	13.73	14.30
Fe_2O_3	2.13	1.86
FeO	3.44	1.11
MgO	3.96	2.88
CaO	3.13	2.08
Na_2O	3.09	2.80
K_2O	1.36	3.39
TiO_2	.63	.36
MnO	.15	.06
P_2O_5	.09	.15

ARGILLITES

STUPOLER L. MBR. / BURR BAY MEMBER / HOOKER BAY FM. ARGILLITES / "AVERAGE SHALES"(PETTIJOHN,1957)

	31	32	AVG.	33	34	35	36	37	AVG.	38	39	40	41	AVG.	42	43	44
SiO_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al_2O_3	18.0	16.6	17.3	17.7	18.4	16.3	17.48	16.85	17.05	17.2	18.4	17.86	23.09	19.14	16.90	18.43	18.63
Fe_2O_3	7.04	5.96	6.50	7.16	7.92	5.37	6.35	4.13	6.23	7.09	7.49	2.11	2.42	7.40	7.37	6.48	10.19
FeO												4.13	5.42				
MgO	3.48	3.39	3.36	3.37	3.44	3.30	3.11	2.31	3.09	3.02	2.93	2.46	1.86	2.61	2.48	2.77	2.74
CaO	3.57	1.44	2.61	2.32	.94	1.24	1.90	2.07	1.69	1.98	1.56	1.43	.46	1.41	3.41	1.44	1.08
Na_2O	2.93	3.97	3.45	2.94	2.91	3.06	2.87	2.67	2.89	3.38	3.25	3.72	3.04	3.37	1.43	1.27	1.33
K_2O	4.47	3.33	4.01	2.70	2.48	2.40	2.42	2.53	2.40	1.48	2.91	2.97	3.83	2.73	3.36	3.93	4.10
TiO_2	.84	.72	.78	.63	.73	.62	.72	.68	.66	.83	.62	.41	.32	.73	.73	.78	.83
MnO	.07	.06	.06	.09	.07	.08	.07	.05	.07	.08	.07	.09	.07	.08			.11
P_2O_5							.36	.14	.20			.07	.09	.08	.19		.15

SANDSTONES

HOOKER BAY FM. SANDSTONES / "AVERAGE" GREYWACKES(PETTIJOHN,1957)

	45	46	47	48	AVG.	49	50	51	52
SiO_2	[illegible]	67.99	67.31	[illegible]	[illegible]	[illegible]	[illegible]	63.71	[illegible]
Al_2O_3	13.92	13.48	12.96	14.36	13.68	13.73	16.19	16.12	15.4
Fe_2O_3	1.96	1.93	1.96	3.27	3.82	.39	1.42	.79	1.6
FeO	3.49	3.73	3.42			4.78	4.71	8.04	4.1
MgO	3.74	2.94	3.13	2.19	3.00	3.44	3.38	3.36	2.3
CaO	2.47	2.46	3.04	.90	2.27	4.73	3.76	2.23	3.2
Na_2O	4.76	4.17	4.38	4.23	4.39	2.77	3.94	2.62	3.2
K_2O	1.42	2.05	.92	1.72	1.33	2.66	2.29	1.77	2.0
TiO_2	.46	.43	.46	.44	.46	.32	.46	.91	.5
MnO	.10	.10	.10	.05	.09			.17	.1
P_2O_5	.07	.06	.12	.09	.09			.28	.2

FELSIC BODY, NE OF UPSILL LAKE

	53
SiO_2	[illegible]
Al_2O_3	16.3
Fe_2O_3	2.04
FeO	.27
MgO	1.02
CaO	2.04
Na_2O	4.39
K_2O	1.88
TiO_2	.31
MnO	.05
P_2O_5	

Samples 1,2,3,4,5,6,12,13,14,16,20,21,22,24,25,31,32,33,34,35,38,and 39 analysed by the Mineral Research Branch, Ontario Division of Mines.

Samples 15,17,18,19,23,26,27,28,29,30,36,37,40,41,45,46,47, and 48, analysed by Fred Longstaffe, McMaster University.

Published sources of the other analyses are given below.

1. T-72- 10 , andesite
2. T-73- 45 , andesite
3. T-73- 65 , andesite
4. T-72- 87 , andesite
5. T-72-113 , trachybasalt
6. T-73-122 , andesite
7. 72B-240 , basalt (Blackburn, 1976 and written communication)
8. 72B-270 , dacite (Blackburn, 1976 and written communication)
9. 72B-166 , andesite (Blackburn, 1976 and written communication)
10. 72B-176 , andesite (Blackburn, 1976 and written communication)
11. 72B-236 , andesite (Blackburn, 1976 and written communication)
12. T-72-232 , dacitic lithic tuff
13. T-72-118 , andesitic tuff
14. T-73- 12 , andesitic tuff
15. OT-73- 17 , andesitic tuff
16. OT-74- 13 , andesitic tuff
17. T-73- 25 , dacitic lithic-crystal tuff
18. T-72-119 , andesitic tuff
19. T-72-214 , dacitic crystal tuff
20. T-72-208 , arkosic greywacke
21. T-72-231A, volcanic lithic greywacke
22. OT-73- 21 , volcanic lithic greywacke
23. OT-73- 2 , volcanic lithic greywacke
24. T-72- 9 , volcanic lithicgreywacke
25. T-72- 322, volcanic lithic greywacke
26. T-72-109 , volcanic lithic greywacke
27. T-73- 32 , volcanic lithic greywacke
28. OT-74- 4 , volcanic lithic greywacke
29. OT-74- 6 , volcanic lithic greywacke
30. OT-73- 25 , mudstone
31. T-72- 49 , argillite
32. T-72- 78 , argillite
33. T-72- 16 , argillite
34. T-72-143 , argillite
35. T-74- 44 , argillite
36. T-72-270 , argillite
37. T-72-222 , argillite
38. T-72-104 , argillite
39. T-73- 16 , argillite
40. T-72- 38 , argillite
41. T-72-132 , argillite
42. Average shale(Clarke,1924,p. 24; taken from Pettijohn, 1957)
43. Unweighted average of 36 analyses of slate (Pettijohn, 1957, p. 344)
44. Unweighted average of 33 analyses of Precambrian slates(Pettijohn,1957,p.344)
45. A-73- 2 , volcanic lithic greywacke
46. A-73- 3 , volcanic lithic greywacke
47. OT-73- 3 , volcanic lithic greywacke
48. T-74- 42 , arkosic greywacke
49. Average of 3 Archean greywackes, Minnesota (Pettijohn, 1957, p. 306)
50. Average of 3 Archean greywackes, Kirkland Lake (Pettijohn, 1957, p. 306)
51. Archean greywacke, Hamilton Lake (Pettijohn, 1957, p. 306)
52. Average of 23 greywackes (Pettijohn, 1957, p. 306)

norms for the volcanic rocks, are given in Appendix IV. Sample locations are on Fig. 63.

The Sunshine Lake Formation

In thin-section, the Sunshine Lake Formation lavas are typically composed of a felted mass of very fine-grained, green, fibrous minerals and a large amount of completely unresolvable groundmass. Mafic and feldspar phenocrysts, when present, are moderately to severely altered. Therefore, the chemical classification scheme of Irvine and Baragar (1971) was used to determine the nature of these lavas. Where Fe_2O_3 and FeO have been subdivided in the analyses, it was done using the method suggested by Irvine and Baragar (1971).

There is a tendency for the samples to cluster near the alkaline-subalkaline dividing line of Irvine and Baragar (Fig. 64a), but the formation has a fairly wide range of composition. Most samples classify as tholeiitic andesites (Fig. 64c) and all fall into the calc-alkaline field on the AFM diagram (Fig. 64b). One sample (5) falls in the alkaline field on Fig. 64a.

The somewhat alkalic nature of the Sunshine Lake Formation is mainly due to high K_2O values, particularly in samples 4, 5, 6 and 7. In this regard, these lavas are similar to the trachytes of the Kirkland Lake area (Cooke and Moorehouse, 1969) which are also intercalated

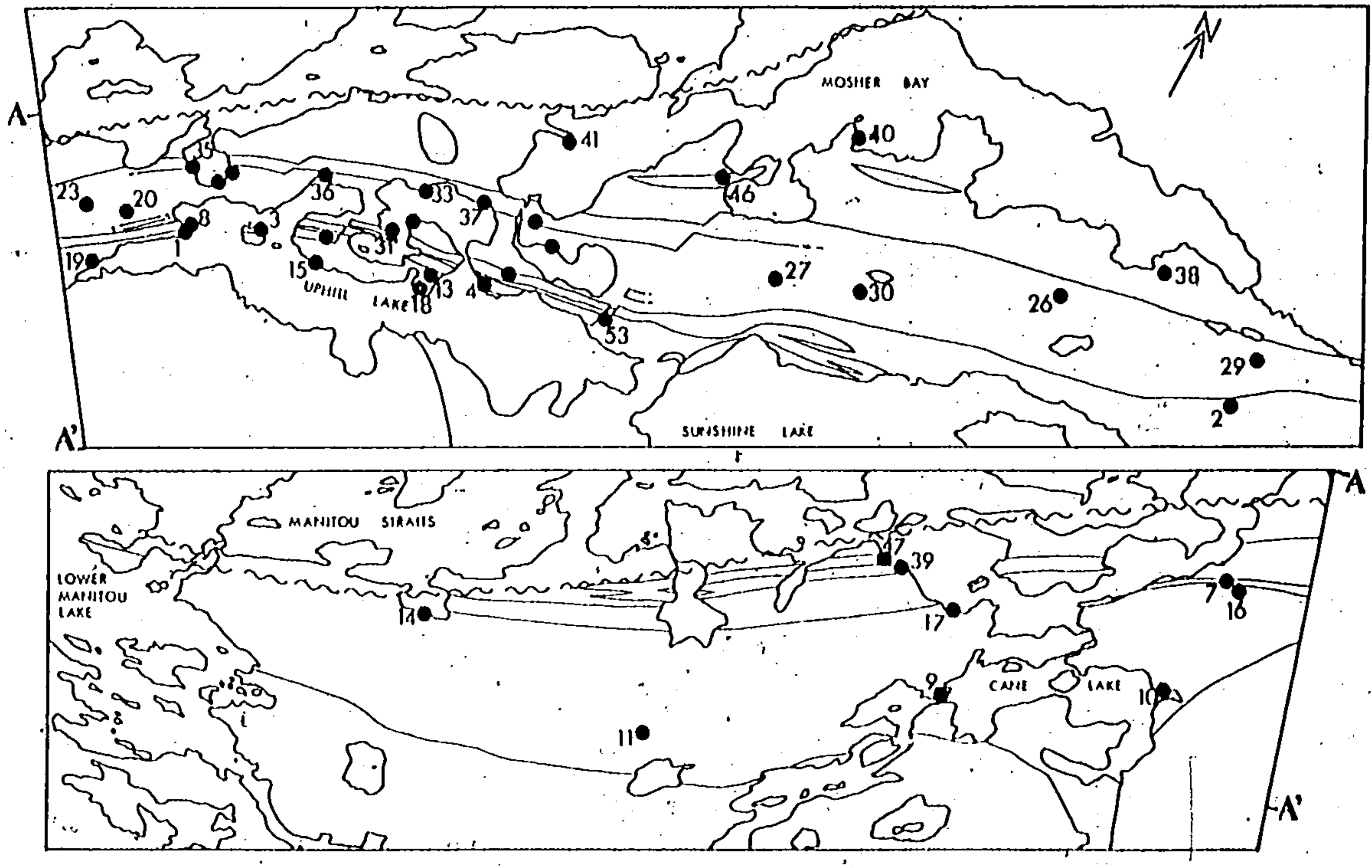


Figure 63. Location of samples selected for chemical analysis.

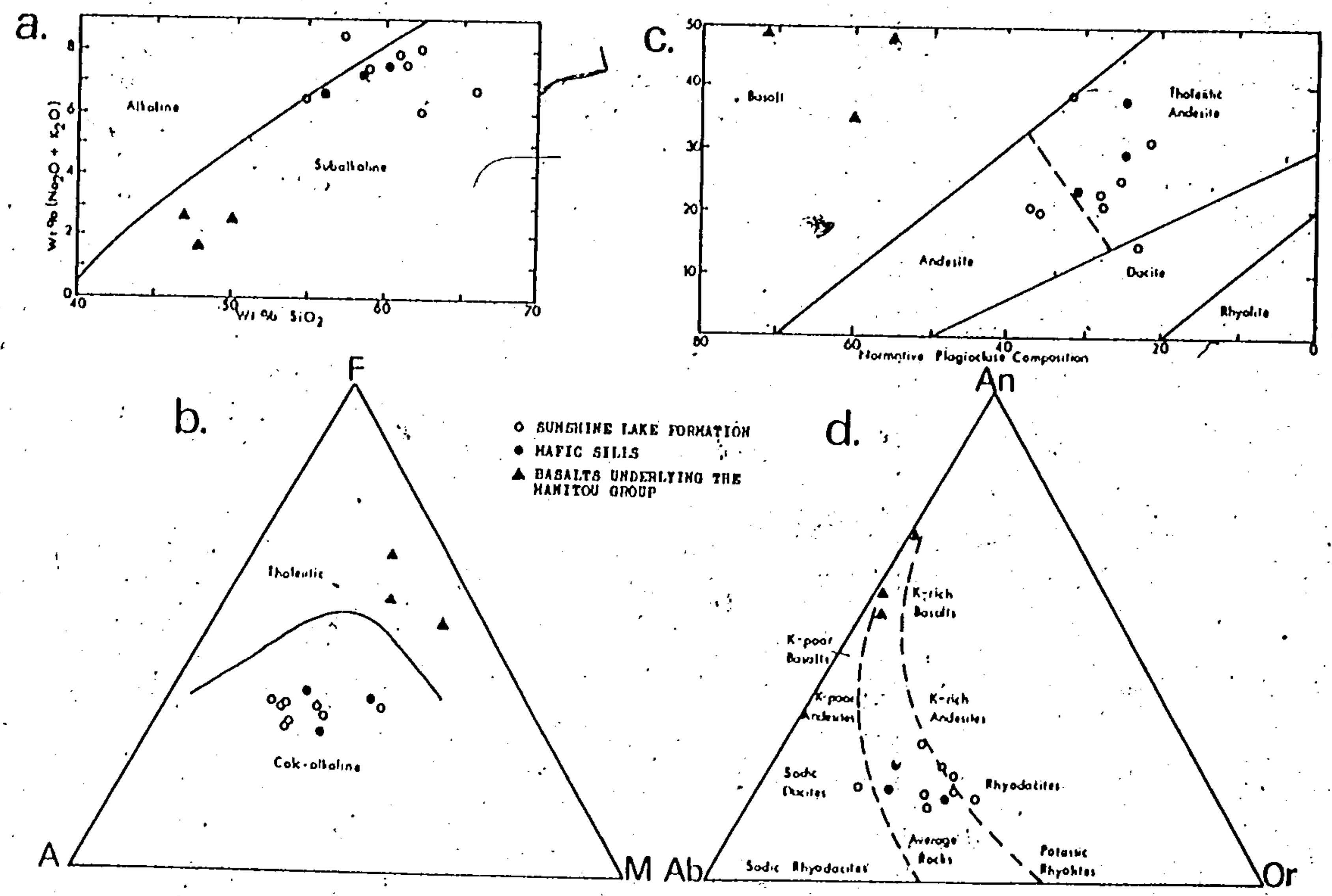


Figure 64. Chemical classification (after Irvine and Baragar, 1971) of lavas of the Manitou Group.

with nonmarine sediments and overlie mafic lavas (Hyde and Walker, 1977). However, the Kirkland Lake alkalic lavas have a much lower SiO_2 content than the Sunshine Lake Formation and a rather different appearance, so further comparison seems unwarranted.

Three analyses of the basalts underlying the Manitou Group from Blackburn (1976; p. 8; A, D, and E) are shown as triangles on Fig. 64. They are tholeiitic basalts and plot well away from the Sunshine Lake Formation on all the diagrams. This suggests that the Sunshine Lake Formation is not a differentiation product from the basalts, so the submarine tholeiites and the subaerial, slightly alkaline Sunshine Lake Formation probably came from different sources.

There are several extensive, thick sills within the Cane Lake Formation (Fig. 3). In the field, these appear almost identical to the Sunshine Lake Formation. This is confirmed by their chemistry, which is also very similar to the Sunshine Lake Formation. They occupy the same fields in the Irvine and Baragar classification diagrams. It is probable that the sills and the Sunshine Lake Formation flows represent the same event, the magma being more or less simultaneously injected into the Cane Lake pyroclastic pile in the Cane Lake area, and erupted on the surface in the Sunshine Lake area.

Pyroclastics

The coarse-grained pyroclastic rocks of the Cane Lake Formation and western Uphill Lake Formation are composed of a wide variety of volcanic clasts, from mafic to felsic, intimately intermixed (Chapter VI). The finer-grained tuffs appear to have a variety of clasts similar to those of the tuff-breccias, based on thin-section analysis (Chapter VI). However, there is a large amount of unresolvable matrix surrounding the grains, and groundmass material within many of the rock-fragment grains. Phenocrysts are moderately to severely altered. These factors prevent classification of the pyroclastics from thin-section analysis, so the Irvine and Baragar chemical classification was again used, even though a chemical classification of heterogeneous clastic material might be difficult to interpret.

In spite of the many varieties of clast types in thin-section and hand specimen, most of the samples from the Cane Lake Formation and western and central Uphill Lake Formation are very similar in chemical composition, in the calc-alkaline andesite to dacite range (Fig. 65). Even those samples showing evidence of reworking (24, 25, 26, 27, 28) in the alluvial fan environment of the central Uphill Lake Formation have a chemical composition very similar to the Cane Lake pyroclastics. This is in agreement with the stratigraphic, paleocurrent, and petrographic data, all of which indicate that the alluvial fan material

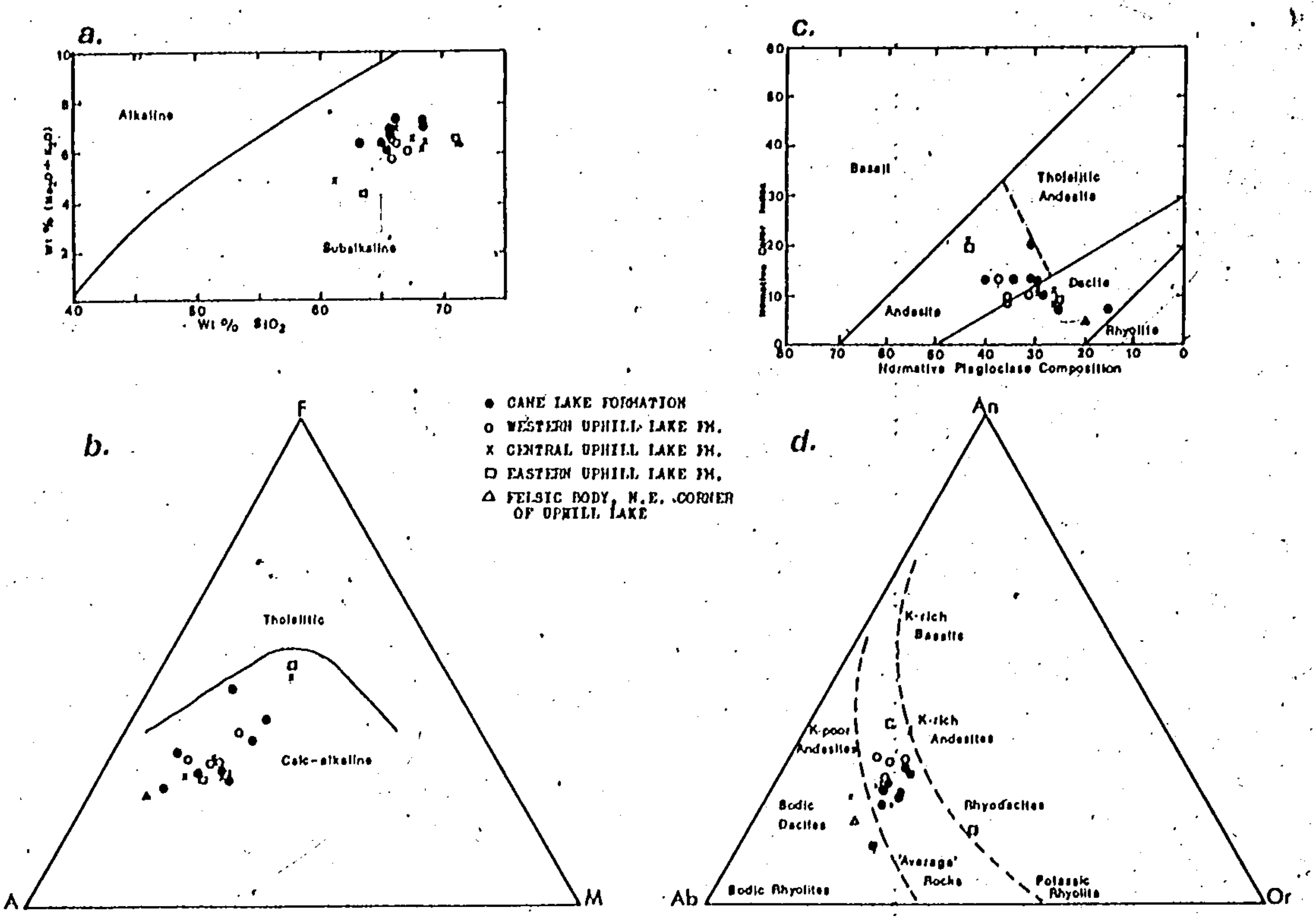


Figure 65. Chemical classification (after Irvine and Baragar, 1971) of pyroclastic and volcanogenic sedimentary rocks of the Manitou Group.

was derived from the Cane Lake volcanic pile, probably by the rapid transport of loose, or at least easily-eroded, volcanic material.

The two analyses of the eastern Uphill Lake Formation (29, 30, Table IX) are rather dissimilar (Fig. 65). This appears to support the petrographic data, which indicates a greater heterogeneity for this part of the formation. This is perhaps a reflection of the more extensive reworking and mixing of several source rocks, not all of which are volcanic.

The one analysis of the felsic body at the northeast corner of Uphill Lake described in Chapter III is chemically a dacite (Table IX (53); Fig. 64). On this very limited basis, the felsic body appears to differ from the Cane Lake Formation in having a slightly higher SiO_2 content, and lower $FeO+Fe_2O_3$ and MgO varies, i.e. more differentiated.

Argillites

There is some variation in chemical composition between argillite samples within stratigraphic units (Table IX). However, on average, the different units are fairly similar. The Rush Bay Member has a higher SiO_2 value due to a high content of quartz silt. The Mosher Bay Formation argillite average Al_2O_3 value is high mainly due to sample 41, which has a very high Al_2O_3 value. All the analyses are generally similar to average shale and slate analyses given by Pettijohn (1957), with the exception that the Manitou Group argillites have about twice as much Na_2O as Pettijohn's averages. This is probably due to their derivation from predominantly volcanic material (Pettijohn, 1957, p. 345), as evidenced by the associated coarser sediments.

The important mineralogical differences among the Uphill Lake Formation, the Rush Bay Member, and the Mosher Bay Formation, as shown by the conglomerates and sandstones (namely, an increase in quartz and 'granite' clasts stratigraphically upwards) are not reflected in the bulk chemistry of the associated argillites. This is because these mineralogical differences are quite small: quartz contents are generally low, and would be even lower in the fine-grained sediments; and plutonic rock fragments are even less abundant than quartz (Chapter VI).

Mosher Bay Formation Sandstones

The chemical analyses of graywackes compiled by Pettijohn from various sources (1957, p. 306; see Table IX) give an indication of the variations in composition of Archean graywackes, and how they differ from 'average' graywackes. The Mosher Bay Formation graywackes are higher in SiO_2 and Na_2O, and lower in Al_2O_3 and MgO than all the average Archean graywacke compositions compiled by Pettijohn (Table IX).

The higher SiO_2 values cannot be related to a higher quartz content because the Mosher Bay Formation sandstones have only about one-third the quartz of average graywackes (compare Table VII with Pettijohn, 1957, p. 304). However, the bulk of the rock fragments are volcanic, and by comparison with the associated conglomerates (Table VIII), these rock fragments are mainly felsite. The remaining rock fragments in the sandstones are felsic plutonic clasts. This high felsic component, together with the free quartz, probably accounts for the high SiO_2 values in the chemical analyses. The predominantly felsic (as opposed to mafic) nature of the rock fragments would also explain the slightly low MgO value.

The high Na_2O value is probably also related to the high volcanic rock fragment content of these graywackes, as Pettijohn (1957) suggests for argillites.

Summary

The Sunshine Lake Formation is mainly composed of rocks chemically classified as calc-alkaline andesites which are high in alkalis, particularly K_2O. One sample classifies as a dacite, and one as a trachy-basalt, in the chemical classification scheme of Irvine and Baragar (1971).

The pyroclastics of the Cane Lake Formation are fairly uniform in chemical composition, straddling the calc-alkaline andesite-dacite boundary. The volcanogenic sedimentary rocks of the central Uphill Lake Formation, derived directly from the Cane Lake Formation, have a chemical composition very similar to the Cane Lake Formation.

The chemical composition of the sandstones and argillites of the Manitou Group are generally similar to published average compositions of rocks of this type. Higher SiO_2 values in some argillite analyses can be related to higher quartz contents due to silt (e.g., the Rush Bay Member). The generally higher Na_2O values of Manitou Group argillites are probably related to their derivation from predominantly volcanic material.

Higher SiO_2 and Na_2O values, and lower Al_2O_3 and MgO, in Mosher Bay sandstones can be related to the high volcanic rock fragment content of these sandstones.

The increase in quartz and plutonic clasts stratigraphically upwards in the Manitou Group is not reflected in the bulk chemistry of the associated argillites.

CHAPTER VIII

ARCHEAN SEDIMENTATION

The information presented in the preceding seven chapters is summarized below in a geological history of the Manitou Group. The role of the sedimentary rocks within this evolution is then compared to other Archean belts in an effort to isolate similarities and differences among the belts.

The following areas have been chosen for comparisons because they are the only areas of the Canadian Shield for which detailed modern descriptions and interpretations of the Archean sedimentary rocks have been published: Kirkland Lake (Temiskaming Group; Hyde and Walker, 1977; Dimroth et al., 1975), Sioux Lookout (Abram Group; Turner and Walker, 1973; and Minnitaki Group; Walker and Pettijohn, 1971), Sturgeon and Savant Lakes (Shegelski, 1975, 1976), Rice Lake (Rice Lake Group; Campbell, 1971), Yellowknife (Yellowknife Supergroup; Henderson, 1972).

Detailed comparisons with the well described examples from South Africa have been specifically avoided in this discussion because it is now becoming clear that shallow-water shelf, tidal, and nearshore sediments are common in the Archean of South Africa at 3300 Ma ago (von Bruun and Hobday, 1976, Ericksson, 1977), whereas coastal and shallow shelf environments have yet to be identified in the Canadian Archean, despite the younger age (2700 Ma) and the presence of favorable stratigraphic intervals (see later). This suggests a higher degree of tectonic stability for the South African Shield compared to the Canadian Shield, which in turn implies that the South African deposits were formed in a fundamentally different tectonic regime from those in Canada, and thus are not directly comparable to Canadian examples.

The information from the geological history of the Manitou Group and the comparison of it to other Archean belts is used to reappraise the problems discussed in Chapter I.

Geological History of the Manitou Group

The initial deposit in the study area was an extensive series of massive and pillowed tholeiitic basalts. These lavas are at least 8 km thick and extend well beyond the study area (Blackburn, 1976b). They form a base upon which the Manitou Group was deposited. Intercalated with these submarine basalts are minor volcanic turbidites.

Prior to the deposition of the Manitou Group there was local tectonic uplift of this base. Part of it became exposed and was eroded, developing a local disconformity at Cane Lake (Chapter III). Elsewhere the base remained submerged.

A volcano formed, erupting felsic to intermediate pyroclastics which rapidly built up above sealevel in those areas not already exposed, and developed as a subaerial pyroclastic pile (the Cane Lake Formation) covering the entire area (Chapters III, IV). The tuffs and tuff-breccias were deposited as ignimbrites, lahars, and air-fall tuffs (Chapter IV) which were distributed in a radial pattern about a vent near Cane Lake (Chapter VI). Penecontemporaneous intrusions within the pile are felsic quartz-feldspar porphyry and mafic to intermediate feldspar porphyry sills.

At about the same time as the felsic pyroclastic pile was developing in the western part of the study area, a series of subaerial lava flows (the Sunshine Lake Formation) was deposited at the eastern end (Chapters III, IV). They are intermediate in chemical composition and tend to be somewhat alkaline (Chapter VII). These lavas are chemically very similar to the mafic-to-intermediate sills within the pyroclastic pile and very likely represent the same event, the magma being more or less simultaneously injected into the pyroclastic pile to the west and erupted on the surface to the east.

Eruption of the lavas in the east ceased, but the pyroclastic pile to the west continued to grow. As it did so, it was subjected to erosion and an alluvial fan (the central Uphill Lake Formation), composed of debris from the cone (Chapter VI) developed on the flanks of the volcano (Chapter IV) in a radial pattern the same as the pyroclastics, ~~But~~ further from the vent (Chapter V).

Early in the development of the alluvial fan a small lake formed at the toe of the fan, and 60 m of laminated argillite and siltstone (the Surprise Lake Member) was deposited in the lake (Chapters III, IV).

The alluvial fan intertongues at its toe with deposits of a braided fluvial system (the eastern Uphill Lake Formation; Chapters III, IV) which was bringing material from an area which was not exclusively volcanic, but in which some 'granite' was also exposed (Chapter VI). Transport in the braided river was approximately at right angles to that on the adjacent part of the alluvial fan (Chapter V).

The alluvial fan and braided fluvial system grew together, the fan slowly encroaching upon the river through time (Chapter III).

The non-marine phase of the Manitou Group closed with the introduction of units of laminated argillite intercalated with tuffs, tuff-breccia, conglomerate, and sandstone (the Rush Bay Member; Chapter III). The argillite and the coarse-grained units are both about 60 m thick. The entire member is generally about 200 m thick, but thickens to 400 m west of Cane Lake because of continued deposition of pyroclastic material representing the last activity of the Cane Lake volcano. The depositional environment of the Rush Bay Member has not been clearly established (Chapter IV). This problem is discussed later in this Chapter.

The Rush Bay Member is followed abruptly by turbidites as the entire area foundered and was covered by submarine fans (the Mosher Bay Formation; Chapter IV) composed of argillites, turbidites and channelized conglomerates. Without paleoflow data (Chapter V), it is not possible to determine for certain if the source of the Mosher Bay Formation is the same as that of the eastern Uphill Lake Formation.

At some later time, folding placed the entire group on edge, facing northwest, and faulting cut out the uppermost parts of the group.

Stratigraphy and Correlation

The Manitou Group is underlain by a large base, possibly over 10 km thick, and extending more than 50 km laterally, composed of submarine pillowed and massive tholeiitic basalts (Blackburn, 1976 a) with minor volcanogenic turbidites and pyroclastic rocks. Submarine mafic volcanic bases of similar size and composition underlie the felsic to intermediate pyroclastic and/or sedimentary rocks of all the areas being compared here (Temiskaming Group, Abram Group, Sturgeon Lake area, Rice Lake Group and Yellowknife Supergroup) and also those of Lake St. Joseph (Clifford and McNutt, 1971), Kakagi Lake (Smith, McNutt and Clifford, 1973), and the Vermillion District (Minnesota, Ojakangas, 1972). The South African, Rhodesian, and western Australian belts also have a large mafic lava sequence as the lowest element in their stratigraphic sequence (Windley, 1977). Therefore, it appears that one of the most common aspects of greenstone belt development is that deposition begins with a submarine mafic volcanic platform composed predominantly of lava flow rocks, followed sharply by a sequence composed predominantly of pyroclastic and/or clastic sedimentary rocks.

It is an oversimplification to state that the mafic volcanism is followed by felsic volcanism, which in turn is followed by sediments, as suggested by Langford and Morin (1976), Moorbath (1977), and Windley (1977). In the Abram Group, Minnitaki Group, and Yellowknife Supergroup, no substantial felsic volcanics appear before the sediments; and in the Manitou Group, Temiskaming Group, and Sturgeon Lake area felsic pyroclastics and sediments are laterally equivalent. In the Rice Lake Group, formations of predominantly mafic lavas, felsic pyroclastics, and assorted sedimentary rocks alternate upwards through the group.

The presence of a dominating felsic pyroclastic pile in the clastic sequence has a profound effect on lateral facies changes in the Manitou Group and Sturgeon Lake area, and apparently to a lesser extent in the Temiskaming Group. Over a distance of less than 5 km, deposits change from volcanic, to volcanogenic sedimentary rocks, to at least partly non-volcanic sedimentary rocks, the origin and mode of deposition of which are not directly related to the volcano. This is particularly well illustrated by the Uphill Lake Formation of the Manitou Group. In those areas where no pyroclastic pile developed, lateral facies changes appear to be much less rapid.

In contrast, lateral facies changes apparently are not common in the mafic platform, so units within it can be traced greater distances than in the overlying volcanic-sedimentary rocks. For example, C.E. Blackburn (personal communication, 1977) has been able to trace certain identifiable units of the mafic lavas underlying the Manitou Group from Lower Manitou Lake eastward to Stormy Lake, a distance of about 40 km. Contrast this to "less than 5 km" stated above for the pyroclastics and associated sediments.

Similarly, the rocks of the Resedimented Association (Turner and Walker, 1973) such as the Burwash Formation (Yellowknife Supergroup) and Little Vermillion Formation (Abram Group) tend to be monotonous both vertically and laterally. The Mosher Bay Formation of the Manitou Group is an exception to this tendency in that it contains channelized conglomerates, a facies readily distinguished from the enclosing fine-grained facies, and the Minnitaki Group (Walker and Pettijohn, 1971) contains resedimented conglomerates which display a lateral decrease in quartz-porphyry clast size.

This study, together with many other recent works, has amply illustrated that determining accurate, detailed stratigraphy is possible for most of the less-deformed Archean sedimentary belts. Stratigraphy has performed an essential role in establishing sedimentary facies relationships in this and other studies and is a prerequisite to the understanding of other areas that may be studied.

However, the correlation of sedimentary stratigraphy between belts will be much more difficult, if not impossible, due to several factors. At the small scale, rapid facies changes make it difficult to walk out stratigraphic units even within one belt. For example, the western Uphill Lake Formation (massive pyroclastics) is so different from the eastern Uphill Lake Formation (large-scale cross-bedded sandstone and conglomerate) that without good exposure, and the Sunshine Lake Formation and Rush Bay Member as markers, it would be difficult to ascertain that the ends of the Uphill Lake Formation are indeed at the same stratigraphic level and therefore correlate. As another example, on a slightly larger scale, correlation of the fluvial deposits are Kirkland Lake with the turbidites to the east in the Temiskaming Group would not be possible without the alkaline volcanic marker (Hyde and Walker, 1977). At this scale, perhaps the task of correlation is best pursued in the mafic volcanic base of the belts, because these portions seem less subject to sudden lateral facies changes.

At a somewhat larger scale, structural complexities, granitic intrusions, and a lack of detailed information on basin geometry prevents lithologic correlation of sedimentary belts even reasonably close to one another. Furthermore, the biostratigraphic methods of the Phanerozoic are not available to Archean workers, so no time framework can be erected. For example, the gross stratigraphy of the Manitou Group and the Stormy Lake belt is the same (Fig. 6), but a series of faults and the Taylor Lake Stock separate the belts, so that it cannot be firmly concluded that they correlate, but might represent adjacent basins which underwent similar development.

In this regard, attempts have been made to formulate criteria for the recognition of basin margins and therefore delineate basin geometry (Goodwin, 1973, 1976, 1977). The weaknesses of these criteria have been fully discussed by Walker (1978) and need not be discussed in detail here except with respect to the "local interior conglomerate zone" (Goodwin, 1977) at Manitou Lake, near the centre of Goodwin's Wabigoon 'Basin'. The conglomerates at Manitou Lake are of two kinds, a stratigraphically lower portion (Uphill Lake Formation) deposited in alluvial fan and braided fluvial environments, and an upper portion (Mosher Bay Formation) deposited in deep water. The alluvial fan conglomerates are volcanogenic in origin, but the braided fluvial deposits contain a sialic component, indicating that sialic rocks were exposed in at least part of the hinterland. Because the deposits are fluvial, no sea could have intervened between these deposits and their sialic source, which is not compatible with interpretation of the Manitou Group as a volcanic pile constructed on tholeiitic crust in the centre of a basin.

Goodwin (1973, 1977) has used conglomerates as an indicator of basin margins. Alluvial fan and braided fluvial deposits do tend to form nearer the margins of the area of sediment accumulation, both marine and non-marine, so in this sense they do mark the basin margins, although their presence at Manitou Lake is not consistent with the margins of the Wabigoon 'Basin' as defined by Goodwin (1973, 1977). However, the conglomerates of the Mosher Bay Formation, which Goodwin presumably includes in the "local interior conglomerate zone" are deep-water conglomerates that could occur many tens or hundreds of kilometres from the margin (Griggs <u>et al</u>., 1970). The Mosher Bay Formation overlies the alluvial fan and fluvial conglomerates without a stratigraphic break, suggesting a major foundering of the area, with consequent major shifts in position of the basin margin. With rapid vertical changes in one area from non-marine to deep-marine environments and without lateral correlation, conglomerates, or other sedimentary facies, cannot be used for large-scale basin reconstruction.

Several general summaries of Archean greenstone belts (for example, Anhaeusser, 1973; Windley, 1977) have stated that the general stratigraphic sequence of the sedimentary part of the belt is from the Resedimented Association upwards to the Non-marine Association. This sequence has figured in some models of Archean evolution (for example, Glikson, 1972, 1976; Anhaeusser, 1973; Windley, 1973; Tarney et al., 1976) and is implied in others (Hargraves, 1976; Moorbath, 1977). The sequence of Resedimented Association followed by Non-marine Association does occur in South African belts, particularly the Barberton Mountain greenstone belt (Visser, 1956; Anhaeusser, 1976; Eriksson, 1977), upon which many of the models seem to be based. However, in all Canadian greenstone belts for which detailed stratigraphy and modern sedimentary interpretations are available, the general stratigraphic sequence is: a thick and extensive submarine mafic lava platform, followed by pyroclastic and/or Non-marine Association sedimentary rock, followed in turn by Resedimented Association sedimentary rocks (Fig. 67). Some areas are submarine throughout. The important point is that the Resedimented Association is at the top of the stratigraphic sequence.

It appears that South Africa, which shows good evidence of stabilized cratons in the Archean, had a tectonic behavior similar to younger regions, resulting in ~~a~~ stratigraphic sequence similar to the

Phanerozoic flysch-molasse sequence, whereas the Canadian Shield, which lacks evidence of extensive stabilization, had a fundamentally different tectonic behavior in the Archean, specifically, foundering of the basin after non-marine deposition and/or felsic pyroclastic volcanism.

Sedimentary Interpretations

Turner and Walker (1973) proposed two distinct associations of Archean sedimentary rocks - the Resedimented Association and the Non-marine Association (their Continental Association). This division is used in the following discussion. However, it also includes comments on rocks in between the Resedimented and the Non-marine Associations described from the Manitou Group.

1. Resedimented Association

Most Archean sediments are of the Resedimented Association. The association is common in all the areas being compared here, and in other belts as well (for example, North Spirit Lake, Donaldson and Jackson, 1965; Vermilion District of Minnesota, Ojakangas, 1972; and the Beardmore-Geraldton area). In some areas, such as Yellowknife and Minnitaki, the sedimentary pile is entirely of the Resedimented Association. In most cases, the association is represented by classical turbidites and argillites. However, conglomerates are present in the

Minnitaki Group, Temiskaming Group, and the Mosher Bay Formation of the Manitou Group. In the Mosher Bay Formation, it has been established that the conglomerates are confined to channels within the turbidites and argillites, and that the channel fill consists of a fining-upwards sequence in some cases.

Sedimentary rocks of the Resedimented Association are commonly interpreted to have formed on submarine fans (for example, this study, Hyde and Walker, 1977; Henderson, 1971). Yet the question remains as to how well these deposits conform to models of submarine fans. The Mosher Bay Formation of the Manitou Group is composed of the appropriate sedimentary facies: classical turbidites, laminated argillites, and especially conglomerates confined to channels. In some cases the channel fill forms a fining-upwards sequence. However, isoclinal folding, faulting, and poor exposure (much of the formation is under Mosher Bay) preclude the identification of detailed facies relationships such as fining-upwards or coarsening-upwards sequences, or lateral facies changes. Attempts at paleocurrent analysis were frustrated by a strong cleavage which also obscured conglomerate pebble fabrics. Nevertheless, on the strength of the channelized conglomerates and the presence of the other facies, submarine fan deposition is the most likely origin of the Resedimented Association rocks of the Mosher Bay Formation, and probably other similar Archean rocks as well.

2. Non-marine Association

At the time the Non-marine Association of Archean sedimentary rocks was defined by Turner and Walker (1973), their alluvial fan was the only sedimentary environment known to belong to this association. From the present study, the volcanogenic alluvial fan, braided fluvial and lacustrine environments can be added. More or less simultaneously with this work, braided fluvial, lacustrine, and minor eolian deposits were also described from the Kirkland Lake area (Hyde, 1978).

The Manitou Group and Abram Group both include an alluvial fan environment. However, the alluvial fan of the Abram Group is indirectly tied to a volcanic-plutonic source through petrography, and is presumed to have formed along a fault scarp (Turner and Walker, 1973). On the other hand, the alluvial fan of the Manitou Group is tied directly to its source, a pyroclastic pile with which it intertongues. The relief required for alluvial fan development is assumed to be related to faulting for the Abram Group whereas that of the Manitou Group formed from the growth of a volcano. Because these are the only two occurrences of Archean alluvial fans of the Superior province described to date, it is impossible to say which, if either, is the more common mode of origin.

The Manitou Group and Temiskaming Group both include braided fluvial deposits. In this case, Hyde and Walker (1977) relate the fluvial deposits of the Temiskaming Group to volcanic activity, referring to them as "a remnant of a volcanic island". However, the fluvial deposits of the Manitou Group are not related to the volcano responsible for the alluvial fan, as indicated by paleocurrent trends and petrography. Unfortunately, again, these are about the only carefully studied occurrences of Canadian Archean fluvial deposits, so no generalizations can be made.

Alluvial fan and braided fluvial deposits tend to form near their source, in areas which have steep slopes and are tectonically active. Non-marine deposits formed far from their source, in areas of tectonic stability and low gradients, such as distal floodplain (meandering stream) and deltaic deposits have yet to be identified in the Canadian Archean. The lack of such deposits may have a bearing on the size of drainage basins and thus on the size of Archean continental masses. The size of a delta is related to the size of its drainage basin, although there is much variation due to varying water and sediment discharges, shoreline geometry, and rates of delta destruction (Fig. 66 and Smith, 1966). Generally, the smaller the drainage basin, the smaller the delta. Similarly, large distal flood plain deposits would not be expected in small drainage basins. However, at least some small distal flood-

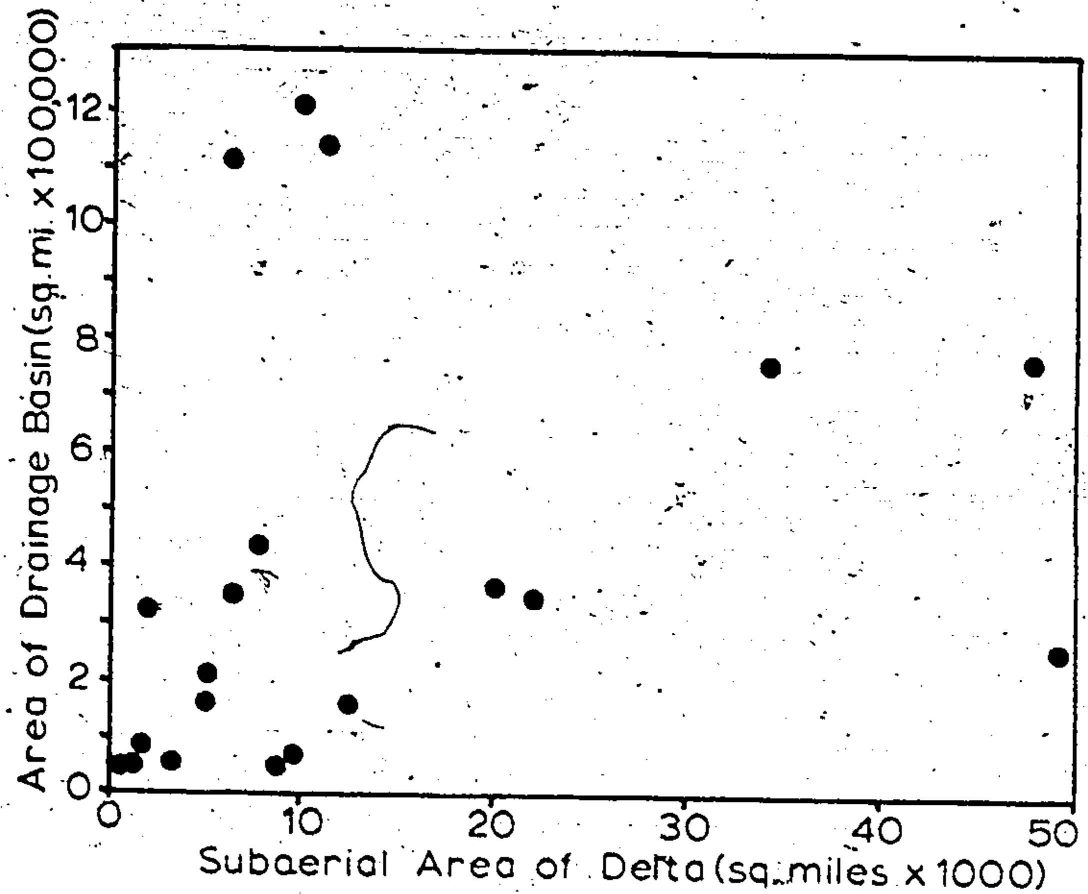


Figure 66. Delta size versus the size of the drainage basin associated with the delta. Data from Smith, 1966.

plain and deltaic deposits should be preserved, unless the basin has uniformly steep gradients, and terminates at a steep, open coast, where wave and longshore drift action would redistribute sediments before any substantial delta could form, as happens with the Yana outwash fan in Alaska (Boothroyd and Ashley, 1975) and the Rio Samala in Guatemala (Kuenzi et al., 1975, and David Kuenzi, personal communication, 1978), in spite of high sediment discharges. Therefore, the absence of distal floodplain and deltaic environments, together with the occurrence of alluvial fan and braided fluvial environments, suggests that Archean drainage basins were relatively small, had steep gradients, and were tectonically active.

This lends support to the idea that during the Archean, continents were much smaller than they are today, an old idea that has been suggested or implied by numerous authors (Goodwin, 1968, 1974; Glikson, 1972, 1976; Engel and Kelm, 1972; Burke and Dewey, 1973; Engel et al., 1974; Hargraves, 1976).

3. Rocks between the Resedimented and Non-marine Associations

It is possible that the Rush Bay Member of the Manitou Group represents a shallow marine or coastal environment, based on its stratigraphic position (see discussion in Chapter IV), but the member contains no features diagnostic of its environment. Furthermore, sediments like the Rush Bay Member, located stratigraphically between non-marine and marine deposits, have not been described from other greenstone belts. The non-marine - marine transition is marked by ash flows in the Abram Group, and trachytic volcanism in the Temiskaming Group. Canadian Archean coastal and shallow marine deposits remain elusive. As pointed out earlier, Archean coastal deposits *do* occur in South Africa (Eriksson, 1977), indicating the presence of stabilized cratons, and therefore, a tectonic regime apparently very different from that of the Canadian Shield.

Based on the sedimentary environments of the Non-marine Association, it has already been suggested that Canadian Archean land masses were small, had high relief, and were tectonically active. Their high relief would in turn suggest steep shorelines, and thus a narrow shoreline with little sedimentation. If the landmasses were small, with steep shorelines, they presumably would not develop large coastal and shallow marine deposits, based on the idea that the volume of sediment delivered to the oceans is a linear function of continental area (Davies *et al.*, 1977~~, p. 54~~). Finally, small size would more readily permit rapid tectonic activity, such as the vertical movements responsible for the sudden subsidence of the Manitou Group, Abram Group, and Temiskaming Group. Turner and Walker (1973) attribute the subsidence of the Abram Group to faulting; Hyde and Walker (1977) consider volcanism a possibility for the Temiskaming Group; there is no evidence for either mechanism at Manitou Lake. Even though the mechanism causing subsidence is not yet understood, if indeed it is the same mechanism in all cases, it can be said that rapid subsidence of a tectonically active small landmass with high relief and steep shorelines would account for the poor development of nearshore and coastal sedimentary deposits in the Canadian Archean.

Volcanic Interpretations

Complementary to sedimentary interpretations are volcanic interpretations; i.e., determining the environments of deposition of Archean pyroclastic and lava flow rocks.

The Cane Lake Formation of the Manitou Group is a subaerial pyroclastic pile built up entirely of ignimbrites and air-fall tuffs erupted from a single central vent, with modification by lahars and water reworking. This interpretation is based on bed thickness and style, composition, and texture, as compared to Parson's (1969) criteria for recognition of volcanic breccias. Indeed, because of low metamorphic grade and a lack of deformation in some parts of the Cane Lake Formation, many outcrops are identical in all respects to the outcrops of Tertiary and Quaternary ignimbrites and air-fall tuffs the author has observed in Oregon. Massive rocks within the pile are high-level intrusions; there are no flow rocks. In spite of the lack of lava flows, the volcano would best be considered a composite cone because it had a single central vent, a radial dispersal pattern, and very common ignimbrite and lahar deposits (Macdonald, 1972). It was, in effect, a volcano at the pure ash end of the range in proportions of tephra and lava flows possible in composite cones.

The Sturgeon Lake volcanic pile, on the other hand, is composed of four cycles (Franklin, 1975) which typically start with flow rocks and pass upwards into pyroclastics, forming a composite volcano with subequal proportions of pyroclastics and flow rocks. The felsic portions of the pile apparently have an appearance similar to that of the Cane Lake Formation, based on descriptions by Shegelski and Bell (1976).

However, the Cane Lake pyroclastic pile is deposited upon a disconformity, contains no background marine sediments, and intertongues with subaerial lava flows and alluvial fan deposits. Clearly it was developed in a terrestrial environment. On the other hand, the Sturgeon Lake pyroclastic pile is intercalated with shale, turbidites, and submarine lava flows, and is clearly submarine. A number of other descriptions of pyroclastic piles, such as Kakagi Lake (Smith, McNutt and Clifford, 1973) and Lake St. Joseph (Clifford and McNutt, 1971) indicate that most Archean pyroclastic piles are generally similar to one another, whether submarine or subaerial. Analysis of the associated sedimentary and lava rocks is necessary to distinguish major environments.

There is one other important distinction between the Cane Lake and Sturgeon Lake volcanic piles: the Cane Lake Formation is barren; the Sturgeon Lake pile is host to economic massive sulfide deposits. Franklin (1976) attributes the sulfide deposits to the interaction of felsic pyroclastics and seawater. Therefore, a submarine pyroclastic pile appears to be necessary for this kind of ore concentration. If ore bodies are, in fact, restricted to submarine felsic volcanoes, sedimentological criteria applied to the sedimentary rocks associated with a given felsic pile can be used to determine its environment and thus more closely define its economic potential.

Furthermore, pyroclastic rocks themselves are amenable to criteria and techniques more commonly applied to sedimentary rocks. Fabric analysis for paleoflow determination was successfully applied to both the sandstones and the tuffs of the Manitou Group. This appears to be the first time this technique has been used on Archean pyroclastic rocks. The dispersal pattern discovered by this analysis pin-pointed a volcanic vent located 1.6 km south-southeast of Cane Lake. This permits an understanding of the third dimension, not available from the map, in reconstruction of the paleogeography and geological history. For example, it indicates that the Cane Lake Formation represents a roughly circular volcano of limited size with a single vent, not part of a large ignimbrite plain. In addition, felsic volcanic vents are commonly the locations of sulfide mineralization (Franklin, 1976; Fox, 1977). Therefore, the general application of the essentially sedimentological techniques of fabric analysis and clast size measurements to pyroclastic rocks can be of economic importance.

Provenance.

A comparison of the provenance of the various greenstone belts can be made using the data in Table X. In addition to this information, in the Rice Lake Group, quartz content increases stratigraphically upwards (Campbell, 1971); the Minnitaki Group contains granite-bearing conglomerates (Walker and Pettijohn, 1971); the clasts in the conglomerates of the Sturgeon Lake area are mainly volcanic with no 'granite' (Shegelski, 1976); and the conglomerates of the Temiskaming Group are predominantly volcanic, but with some 'granite' clasts (Hyde and Walker, 1977).

Two principal source types are of interest in the Archean, volcanic and 'granitic'. Volcanic debris can usually be easily related to volcanic materials laterally equivalent to or immediately underlying the sediments, and from which the sediments could be readily derived. 'Granitic' debris, on the other hand, usually cannot be related to identifiable local sources.

Table X. Major constituents of sandstones and conglomerates from Non-marine and Resedimented Associations of some Archean greenstone belts.

A. Sandstones

	Manitou Gp.[1]		Abram Gp.[2]		Minnitaki[3]	Yellowknike[4]	Temiskaming[5]	
	Non-marine	Resedimented	Non-marine	Resedimented	Resedimented	Resedimented	Non-marine	Resedimented
Average of:	41	18	14	10	6	9	?	
Quartz	3.1	14.9	35	23	29.5	24.9	9.9	
Feldspar	15.0	11.5	28	16	16.5	12.6	12.8	
Volc. R.F.	42.9	11.5	16	14	14.2	11.8	56.8	
Other R.F	0.3	2.0				9.9		
Matrix and Others	38.6	60.2	20	48	38.5	39.4	20.5	

B. Conglomerates

	Manitou Gp.[1]		Abram Gp.[2]
	Non-marine	Resedimented	Non-marine
Average of:	4	10	6
Mafic Volcanic	30.3	5.3	35
Felsic Volcanic	24.6	17.9	8
Porphyry	18.8	5.8	6
"Granite"	1.4	11.6	23
Matrix and Others	24.4	59.4	27

[1] This Study

[2] Turner and Walker, 1973

[3] Walker and Pettijohn, 1971

[4] Henderson, 1972

[5] Hyde and Walker, 1977

In those areas where a felsic volcanic pile developed (Manitou and Sturgeon Lakes), the readily available loose or easily-eroded volcanic debris from the volcano tends to overwhelm material from any other source, so the sediments are predominantly volcanogenic, whether marine or non-marine. However, in areas away from felsic volcanoes, 'granite' debris appears early in the sedimentary history of the basin. A small, but noticeable, per cent of 'granite' clasts and quartz appears in the eastern Uphill Lake Formation after only about one-third of the presently preserved thickness of the laterally equivalent pyroclastic pile was deposited. At the extreme southwest end of the Manitou Group, 'granite' debris appears just above the pillowed basalts. In the Abram Group and Yellowknife Supergroup, 'granite' debris was available from the beginning of sedimentation.

In the Manitou Group, 'granitic' debris becomes more abundant stratigraphically upwards, based on clast composition measurements of conglomerates and quartz content of sandstones. The major change in composition is at the Non-marine to Resedimented Association boundary. This is also the point at which volcanism ceased. This increase in abundance of 'granitic' material stratigraphically upwards has not been clearly documented for other areas, although the quartz content increases upwards in the Rice Lake Group.

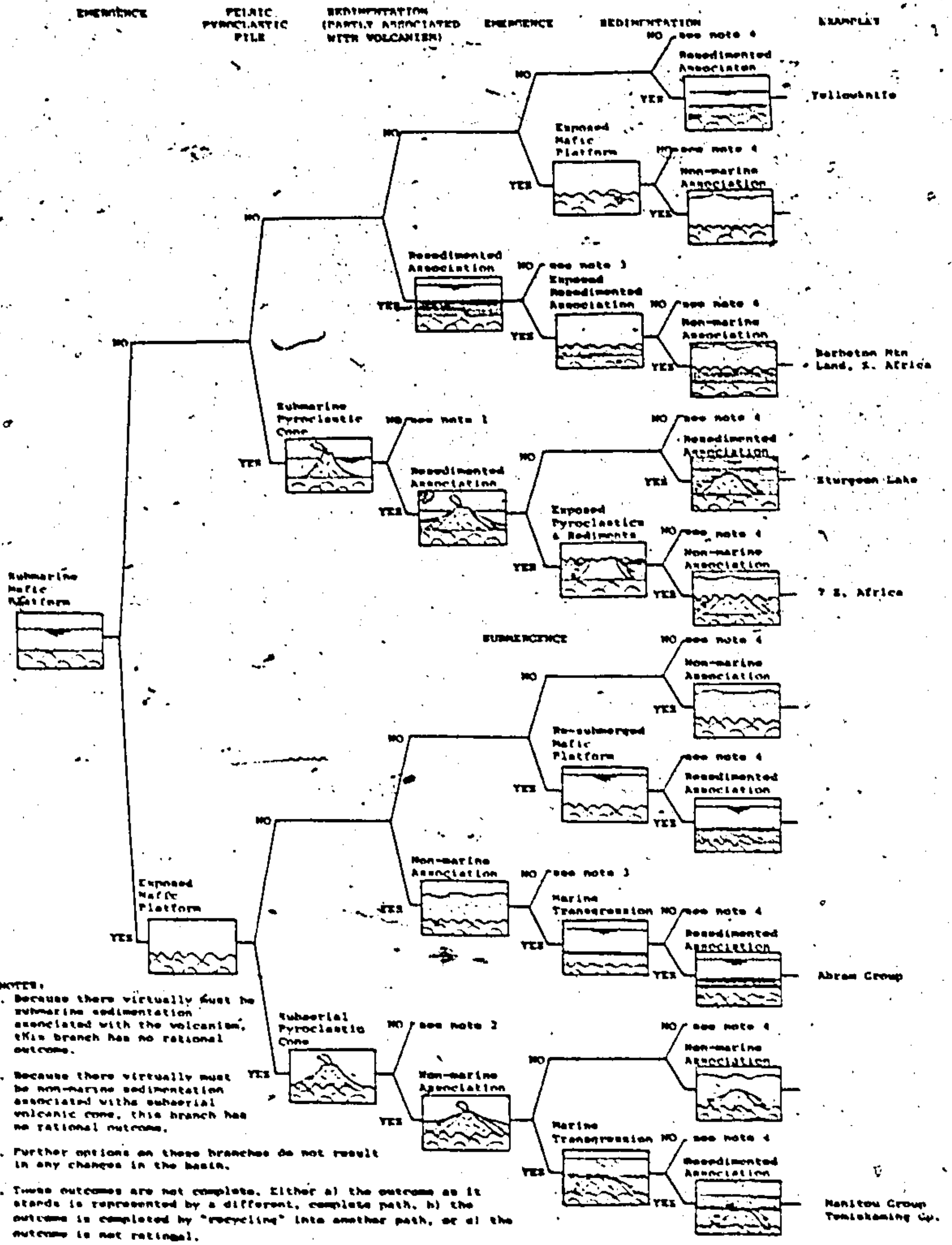
An increase in granitic component stratigraphically upwards could result from three causes: 1) a shift to a different source area, 2) an increase in the amount of exposed 'granite' in the hinterland, or 3) reduction in the dilution factor of volcanic input. The first cause cannot be evaluated without paleocurrent data from the marine sediments, so it remains a possibility. A gradual increase in the amount of exposed granite in the hinterland (cause 2) is not reflected in the composition of samples from the eastern Uphill Lake Formation, or the Mosher Bay Formation. There is no trend towards higher quartz contents or more 'granite' pebbles with higher stratigraphic position within each formation. Therefore, the third cause, namely, a reduction in the volcanic contribution when felsic volcanism ceases, seems the most probable explanation for an increased sialic component stratigraphically upwards in the sedimentary rocks of the Manitou Group.

Support for this comes from the Abram Group, where there is no extensive volcanism, and where the quartz content of the sediments is the same (44% of framework grains) in both the Non-marine Association and overlying Resedimented Association. The increase in quartz content stratigraphically upwards in the Rice Lake Group is apparently also related to decreasing volcanism. Therefore, in the absence of adequate paleocurrent information, and on the basis of present data, admittedly meagre, it appears that, whatever the evolution of greenstone belts, 'granite' (sialic plutonic or phaneritic igneous) rocks must have been already extensively exposed in the source area, or unroofed very early.

Studies of paleoflow have been undertaken in detail only upon the Manitou Group (this study), the Temiskaming Group (Hyde & Walker, 1978), and the Burwash Formation of the Yellowknife Supergroup (Henderson, 1972) so few generalizations can be made, except that paleoflow information can be obtained, if somewhat tediously, from Archean rocks. The radial-dispersal pattern obtained for the Cane Lake and Uphill Lake Formations determined that the volcano at Manitou Lake was an isolated, approximately circular peak that served as a point source for volcanic debris. No paleoflow data could be obtained from the rocks of the Resedimented Association. Paleoflow data for the Temiskaming Group show no regionally consistent paleocurrent directions (Hyde, 1978). Paleoflow in the Burwash Formation is eastward, away from a large granitic mass that Henderson (1972) suggests is the source of the formation.

Basin Evolution

Figure 67 is a flow chart which illustrates the ways in which Archean greenstone belts may develop. The sequence of events across the top of the chart is based primarily upon the history of the Manitou Group. However, a generalized depositional history of 1) mafic



NOTES:

1. Because there virtually must be submarine sedimentation associated with the volcanism, this branch has no rational outcome.
2. Because there virtually must be non-marine sedimentation associated with a subaerial volcanic cone, this branch has no rational outcome.
3. Further options on these branches do not result in any changes in the basin.
4. These outcomes are not complete. Either a) the outcome as it stands is represented by a different, complete path, b) the outcome is completed by "recycling" into another path, or c) the outcome is not rational.

Figure 67. Flow chart of possible different Archean basin evolutions, based on generalizations from this and other studies.

platform, 2) felsic pyroclastic volcanism and/or sedimentation and 3) renewed or continued sedimentation without felsic volcanism applies to all the well-studied examples of greenstone belts, so the sequence has general applicability, especially when the variation made possible by the yes/no options are considered. The tectonic events (emergence of the mafic platform and emergence/submergence following felsic volcanism) placed between the major depositional episodes are also based on the Manitou Group, and other greenstone belts.

A submarine platform composed predominantly of mafic lavas appears to be the initial deposit of all greenstone belts, so that serves as a starting point. This mafic platform may become emergent (Manitou Group, Abram Group, Temiskaming Group) or it may not (Yellowknife Supergroup, Sturgeon Lake area, and South African examples). The initial emergence of the platform could occur in two ways: 1) build-up of lava flows to sealevel and above, or 2) tectonic uplift. In the first case, pillow breccias, hyaloclastites, and other evidence of shallow-water volcanism should occur. Although the author has observed pillow breccias near Savant Lake, and they have been reported by others in other areas (for example, Blackburn, 1976b), their stratigraphic position near the top of the mafic platform has not been documented. On the other hand, evidence for tectonic uplift, in the form of unconformities on the mafic platform, has been documented for the base of the Manitou Group (this study), Abram Group (Turner and Walker, 1973), Temiskaming Group (Thomson, 1946; Hyde and Walker, 1977), and at Savant Lake (Shegelski, 1976). Therefore, it appears from current evidence that emergence of the mafic platform is common, and is by tectonic uplift.

Sedimentation follows felsic volcanism on the flow diagram, but in fact they occur at the same time (Manitou Group, Temiskaming Group, Sturgeon Lake area). It would not be possible for a volcanic pile, submarine or subaerial, to form without some associated sediments, so these options have been eliminated (Fig. 67, Notes 1 and 2). It is possible, however, for sedimentation to take place without felsic volcanism (Yellowknife Supergroup, Abram Group, Barberton Mountain Land), so felsic volcanism and sedimentation must be treated as separate events in the development of the belt. Sedimentation is placed after volcanism because the volcano, if it forms, is the source of much of the sediment.

After felsic volcanism and/or initial sedimentation, the basin may undergo a tectonic revolution, i.e., the submarine basins emerge, or those that are exposed, submerge. Interestingly, all Canadian examples which were submerged remain submerged, and all those that were exposed, submerge. In other words, for Canadian Archean greenstone belts, the last preserved depositional event is marine sedimentation. In contrast, South African areasemerge at this time, and the top of their stratigraphic sequence is represented by Non-marine Association sedimentary rocks.

The options of the flow chart of basin evolution (Fig. 67) led to 10 different outcomes. Of these, only 4 are represented by Canadian examples: outcome 10 by two examples, and outcomes 1, 4, and 8 by one each. Two more (3 and 5) may be represented in South Africa. There is no *a priori* reason why the outcomes without examples should not be represented, and the two examples for outcome 10 probably only reflect an interest in recent years in Archean non-marine sedimentation, which led to the study of these areas instead of others. This illustrates the difficulty of making any generalizations about Archean basin evolution based on our present knowledge. However, from the flow chart of Archean greenstone belt development, and the few well-described areas available, it appears that 1) the sedimentary and/or pyroclastic deposits are built upon a submarine mafic volcanic base, 2) this base commonly emerges, and this emergence is by tectonic uplift rather than volcanic build-up, 3) the initial sedimentation is commonly closely associated with intermediate to felsic volcanism, either subaerial or submarine, and 4) Non-marine Association sedimentary and subaerial (or submarine) pyroclastic rocks are followed stratigraphically by the Resedimented Association.

The Manitou Group and Archean Plate Tectonics

There has been much discussion concerning whether or not plate tectonics operated during the Archean (Talbot, 1973; Burke and Dewey, 1973; Windley, 1973, 1976; White et al., 1971; Burke et al., 1976; Kröner, 1977; Condie and Hunter, 1976). It has become clear that there are many similarities between lithological, structural, volcanological, and geochemical aspects of Archean greenstone belts and those of more modern rocks formed at continental margins and island arcs, so the question of Archean plate tectonics must be seriously considered.

If it is assumed that plate tectonics did exist in the Archean, the question is which kind of environment(s) within the plate tectonic scheme the greenstone belts represent. The possibilities are: island arc, mid-ocean ridge, 'hot spot' island, passive (Atlantic-type) or active (Andean-type) continental margins, or marginal basins. For Archean greenstone belts in general, the passive continental margin is ruled out by the extensive volcanism and a lack of shallow-marine deposition. For the Manitou Group and Abram Group, island arc, mid-ocean ridge, and 'hot-spot' islands are also unlikely because of the presence of non-marine, non-volcanogenic sedimentary rocks. This contrasts sharply with the opinions of many authors who, based on volcanic rock types and major element geochemistry, favour an island arc model (Wilson et al., 1965; Goodwin, 1968; Baragar and Goodwin, 1969; Hart et al., 1970; White et al., 1971; Anhaeusser, 1973; Langford and Morin, 1976, and others) or an oceanic ridge setting (Glikson, 1970; Windley and Bridgewater, 1971; Windley, 1973). Jolly (1975), Halberg et al. (1976) and Hawksworth and O'nions (1977) indicate problems with an island arc model, based on anomaloously high nickel abundances in volcanic rocks.

Windley (1976) and Windley and Smith (1976) have suggested that Archean gneissic belts are analogous to the large belt-like batholiths of the Cordillera and Andes (Roddick and Hutchinson, 1976; Dalziel et al., 1974; Gastil, 1975) which typify Andean-type continental margins. However, Andean margins presently contain the classic eu- and miogeosynclinal pair (Dickinson, 1976), but the miogeosynclinal belt, or retroarc basin (Dickinson, 1974), has yet to be recognized in the Canadian Archean. Undeformed cratonic sequences are also absent. On the other hand, if Archean continental masses were much smaller than today, as suggested earlier, stable cratonic masses and shallow marine, 'miogeosynclinal' deposition may not have been very extensive. Thus, strict analogies between Canadian Archean greenstone belts and Andean-type continental margins are not possible.

In recent years there have been several attempts to explain Archean greenstone belts as fossil back-arc or marginal basins (Burke et al., 1976; Tarney et al., 1976; Condie and Harrison, 1976; Windley, 1977; Moorbath, 1977). Marginal basins are spreading centres (Karig, 1971), so volcanic rock types and their geochemistry should reflect rifting. However, complications ensue if the dip of the subducting plate changes or lateral migration of the subduction zone occurs (Burke et al., 1976). These led to a change in the position and type of volcanic rocks and tectonic environments, and can lead to a confusing geochemical picture. This may allow greenstone belts to have chemical and tectonic features characteristic of both spreading marginal basins and subduction in front of island arcs. With so few restraints on speculation, almost any chemical or tectonic picture could be accommodated, but this does little to define the actual tectonic regime of Archean greenstone belts.

Furthermore, the stratigraphic sequence used by Windley (1977) and others in the marginal basin model is based on examples from South Africa, namely mafic volcanics followed by Resedimented Association rocks which are in turn followed by the Non-marine Association. In contrast, the sedimentary sequence of the Manitou Group, and several other Canadian Archean Greenstone Belts, consists of the Non-marine Association overlain by the Resedimented Association. Such a fundamental difference in development suggests that the marginal basin models, as proposed, are not directly applicable to the Canadian Archean.

Hawksworth and O'nions (1977) and Wilson et al. (1978) present a fourth proposal, based on stratigraphic setting and geochemistry of volcanic rocks, in which they suggest that Rhodesian greenstone belts represent volcanism associated with rifting of continental blocks.

Clearly, there is little agreement on the origin of Archean greenstone belts. In general, there are many similarities between lithological, volcanological, and geochemical aspects of Archean greenstone belts and those of several tectonic settings within a plate tectonic regime. However, in many arguments, too much reliance is placed on one aspect or another, particularly geochemistry, and not enough on other features, such as paleogeography. The Manitou Group does not fit well into any of the plate tectonic models proposed to date because of specific sedimentary difficulties such as the Non-marine - to - marine stratigraphic sequence, rapid subsidence with poor development of near-shore and shoreline facies, and the close association of subaerial volcanism and non-marine sedimentation from non-volcanic sources. The same may be said of several other Canadian greenstone belts such as the Abram

Group, Savant-Sturgeon Lakes area, and the Temiskaming Group, which have similar problems to those of the Manitou Group.

However, in view of the wide variability among the different belts described to date (Figure 67), it is clearly premature to attempt to formulate any new model of Archean basin evolution, whether based on current plate tectonic models or not.

General Conclusions

As has been repeatedly stressed throughout the foregoing discussion, any attempt to extract general conclusions from the comparison of the Manitou Group with other greenstone belts is frustrated by the small number of adequately described areas, all of which seem to be significantly different from each other. Figure 67 amply illustrates that it is premature to attempt to describe any model of Archean basin evolution. However, several components of such a model have been identified:

1) the sedimentary or pyroclastic deposits are built upon a submarine mafic volcanic base;

2) emergence of this base commonly occurs, and probably takes place by tectonic uplift rather than volcanic build-up;

3) the submarine or subaerial felsic volcanic piles built upon the mafic base are formed by composite volcanoes with much more tephra than lava;

4) the initial sedimentation is frequently closely associated with intermediate to felsic volcanism, either subaerial or submarine;

5) the Non-marine Association is represented in the Canadian Archean by alluvial fan and braided fluvial deposits, with minor eolian and lacustrine deposits;

6) Non-marine Association sedimentary and subaerial (or submarine) pyroclastic rocks are followed stratigraphically by the Resedimented Association;

7) most Archean sedimentary rocks are of the Resedimented Association, probably formed on submarine fans;

8) the lack of identifiable coastal or shallow-marine deposits between the Non-marine and Resedimented Associations could be accounted for by rapid subsidence of a tectonically active small landmass;

9) sialic plutonic debris is introduced into the basin early in its sedimentary history. An increased sialic component stratigraphically upwards in some belts appears to be related to diminishing local volcanism rather than increased exposure of sialic material in the source area; and 10) the source area for the sediments, other than those derived directly from local volcanoes, was probably a small landmass with high relief and steep shorelines; composed of mixed volcanic and plutonic rocks.

APPENDIX I

A. Vector mean computor program (in Fortran IV) used to calculate grain orientation statistics. Input instructions are included in the listing.

B. Grain orientation data and statistics.

-NT,ND,MR,MH,MZ, and MM are program control parameters. See Program listing.

-NO: MEAS. is the number of grains in this sample.

-DEC. CORR. is the reference azimuth used by the program to relate the raw data to true north.

-The histogram is in 20° segments, starting with 0 - 20° for the line-of-motion option used here.

-THETA is the vector mean.

-VECTOR LENGTH is a measure of the strength of the preferred orientation of grains, and CHI SQUARE tests the orientation distribution for significant difference from randomness:

```
      PROGRAM VM  (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C***** TUKEY CHI SQUARE AND VECTOR MEANS, MARTINI PROGRAM, TECH MEM.652
C***** PROGRAM CLEANED UP BY RGM, NOV., 1974, AND PET, NOV., 1976
C*****   MAXIMUM SPACE FOR SHARED-TIME OPERATION IS 124K.
C
C     ****************************************************************
C
C    INPUT INSTRUCTIONS
C
C
C      CARD 0
C
C        NTOT = NUMBER OF DIFFERENT GROUPS OF SAMPLES
C
C    CARD 1  (FORMAT (I5,I5) )
C
C      M=TOTAL NUMBER OF SAMPLES IN THIS GROUP
C      MM=(NO. SAMPLES-1) IF GROUPED DATA INPUT(HISTOGRAMS),OTHERWISE 0
C      APLACE = NAME OF THIS GROUP OF SAMPLES
C
C    CARD 2  (FORMAT (I3,2X,10A6,F6.0)
C
C      IA IS THE REFERENCE AZIMUTH
C      ANAME REPLACES MARTINIS EL AS SAMPLE DESIGNATION
C      strike=strike of beds at sample site (if 0, "minus strike" option
                                                             disabled)
C    CARD 3  (FORMAT(I5,3(1X,I1)) )
C
C      NT=NUMBER OF READINGS IN EACH SAMPLE FOR INDIVIDUAL DATA INPUT
C      IT=NUMBER OF READINGS IN FIRST SAMPLE FOR GROUPED DATA INPUT
C      NO=1 FOR VECTOR DATA
C      NO=2 FOR LINE OF MOVEMENT DATA
C      NO=4 FOR LINE OF MOVEMENT DATA, 4 THETA TRANSFORMATION
C      MP=1 FOR GROUPED DATA INPUT, OTHERWISE ZERO
C      MZ=1 IF TYPE OUT IS REQUIRED OF THE ORIGINAL DATA TRANSFORMED
C           TO DIRECTION ANGLES FALLING WITHIN 90 DEGREES EITHER SIDE
C           OF THE REFERENCE AZIMUTH
C
C      MM=NUMBER OF SAMPLE BEING CALCULATED.   IT IS CUMULATED BY THE
C           PROGRAM AND IS NOT PUNCHED IN AS DATA
C
C
C    INDIVIDUAL DATA INPUT
C
C      CARD 0 AT BEGINNING OF DATA DECK
C      CARD 1 AT BEGINNING OF EACH GROUP OF SAMPLES
C      CARD 2 AND CARD 3 AT BEGINNING OF EACH SAMPLE DATA SET
C      SAMPLE DATA SET FORMAT (16F5.0)
C
C    GROUPED DATA INPUT
C
C      CARD 0 AT BEGINNING OF DATA DECK
C      CARD 1, CARD2, AND CARD 3, FOLLOWED BY DATA
C      DATA FORMAT (9(1X,I4))
C      ***************************************************************
C
      DIMENSION X(9),Y(9),V(9),L(9),ANAME(10),APLACE(10)
      DIMENSION A(2000),ASTOR(2000),R(2000)
      READ (5,901) NTOT
  901 FORMAT (I5)
      NCNT=0
   30 CONTINUE
      IF(NCNT.EQ.NTOT) GO TO 31
      NCNT=NCNT+1
      READ (5,2002) M,MM,APLACE
 2002 FORMAT (I5,I5,10A6)
      WRITE (6,902) APLACE
  902 FORMAT (1H1,10A6//)
      WRITE (6,2003) M
 2003 FORMAT(26H1***    NUMBER OF SAMPLES =,I5///)
      MM=0
      NTCUM=0
C
C*** NTCUM IS THE CUMULATIVE VALUE OF NT SUMMED FROM EACH SAMPLE
C
 2005 MM=MM+1
      READ(5,100) NA,ANAME,STRIKE
  100 FORMAT (I3,2X,10A6,F6.0)
      WRITE(6,101) ANAME
  101 FORMAT(1H ,10H**********,5H     ,10A5///)
      READ(5,6) NT,NO,MP,MZ
    6 FORMAT(I5,2(1X,I1),1X,I1)
      IF(NT.EQ.0) STOP
      IF(NO.EQ.1) AR=180.0
      IF(NO.EQ.2) AR=90.0
      IF(NO.EQ.4) AR=45.0
      ANT=NT
      RANT=ANT/9.
      XX=SQRT(RANT)
      WRITE(6,3002)NT,NO,MP,MM,MZ,MM
 3002 FORMAT(11H ***    NT =,I4,7H   NO =,I2,7H   MP =,I2,7H   MM =,I4,
     17H   MZ =,I2,7H   MM =,I3///)
      IF (MM.NE.0) GO TO 700
      WRITE (6,105) NT,NA
  105 FORMAT(22H            NO. MEAS. =,I5,25H          DEC. COR.      =,I
     15/)
  700 IF (MP.EQ.1) GO TO 600
      AA=NA
C
C***** READ IN THE INDIVIDUAL DATA IN SAMPLE
C
      READ (5,1)(A(I),I=1,NT)
    1 FORMAT(16F5.0)
      IF(A1.EQ.0.) GO TO 950
C
C***** CHANGE ORIGIN TO TRUE NORTH
C
      DO 900 KK=1,NT
      A(KK)=AA+A(KK)
C   SUBTRACT SAMPLE STRIKE FROM EACH GRAIN ORIENTATION
      A(KK)=A(KK)-STRIKE
```

```
  800 CONTINUE
  850 CONTINUE
C
C ***** STORE DATA IN INDIVIDUAL SAMPLES SEQUENTIALLY IN ASTOR
C ***** FOR FINAL COMPUTATION OF GRAND VECTOR MEAN
C
      DO 2004 JJ=1,NT
 2004 ASTOR(JJ+NTCUM)=A(JJ)
      NTCUM=NTCUM+NT
 2007 CONTINUE
      DO 11 I=1,9
   11 N(I)=0
      SD=0.0
      SC=0.0
      ANT=NT
      DO 10 I=1,NT
      IF(AA.EQ.0.) GO TO 200
      IF(MZ.EQ.0) GO TO 200
      Z(I)=A(I)
      IF(Z(I).LT.(-90.)) Z(I)=Z(I)+180.
      IF(Z(I).GT.90.) Z(I)=Z(I)-180.
  200 IF(NC.NE.1) GO TO 300
C
C ***** SORT INTO 40 DEGREE CLASSES (0-40,40-80, ETC)
C
      K=A(I)/40.0
      N(K+1)=N(K+1)+1
      GO TO 301
C
C ***** SORT INTO 20 DEGREE CLASSES (0-20,20-40,ETC)
C
  300 IF(A(I).LT.0.)  A(I)=A(I)+360.0
      IF(A(I).GE.180.)  A(I)=A(I)-180.0
      K=A(I)/20.0
      N(K+1)=N(K+1)+1
C
C ***** CONVERT TO THETA IN RADIANS
C
  301 A(I)=A(I)*(3.14159/AR)
C
C ***** CALCULATE SUMS OF SINS AND COSINES
C
      D=SIN(A(I))
      C=COS(A(I))
      SD=SD+D
   10 SC=SC+C
      IF(MZ.EQ.0) GO TO 201
      WRITE (6,1) (Z(I),I=1,NT)
C
C ***** CALCULATE R, THETA
C
  201 R=SQRT((SD*SD)+(SC*SC))
      RL=(R/ANT)*100.0
      TH2=(ATAN2(SD,SC))*180.0/3.14159
      IF(NC.NE.1) GO TO 22
      IF(TH2.LT.0.) TH2=360.0+TH2
   22 IF(NC.NE.2) GO TO 21
      IF(TH2.GE.0.) TH2=TH2/2.
      IF(TH2.LT.0.) TH2=(360.0+TH2)/2.
      WRITE(6,6)
   21 IF(NC.EQ.1) WRITE(6,2) N
      IF(NC.EQ.2) WRITE(6,3) N
      IF(NC.EQ.4)  WRITE(6,7) R,RL,TH2
      IF(MM.EQ.0) GO TO 501
  500 READ(5,501)(M(I),I=1,9)
C
C ***** ADD SAMPLE HISTOGRAMS
C
      IF(MM.EQ.0) GO TO 503
      DO 33 NJ=1,MM
      READ(5,501)(L(I),I=1,9)
      DO 33 NI=1,9
      M(NI)=M(NI)+L(NI)
   33 NT=NT+L(NI)
      MMS=MM+1
      WRITE(6,100) NT,NA,MMS
      ANT=NT
      FANT=ANT/9.
      XX=SQRT(FANT)
  503 SD=0.0
      SC=0.0
      SSD=0.0
      SSC=0.0
      SP=0.0
      SG=0.0
      DO 12 I=1,9
      X(I)=(FLOAT(M(I))-FANT)/XX
      IF(NC.EQ.1) GO TO 800
      A(I)=(20.0*FLOAT(I-1))*3.14159/AR
      IF(NC.NE.1) GO TO 801
  800 A(I)=(40.0*FLOAT(I-1))*3.14159/AR
  801 D=SIN(A(I))
      C=COS(A(I))
      SD=SD+(X(I)*D)
      SC=SC+(X(I)*C)
      V(I)=FLOAT(M(I))
      SP=SP+(V(I)*D)
      SG=SG+(V(I)*C)
      SSD=SSD+(D*D)
   12 SSC=SSC+(C*C)
      D=SD/SQRT(SSD)
      C=SC/SQRT(SSC)
      IF(MM.EQ.0) GO TO 594
C
C ***** CALCULATE L, THETA FOR GROUPED DATA
C
      RX=SQRT((SP*SP)+(SG*SG))
      RXL=(RX/ANT)*100.0
      TH2=(ATAN2(SP,SG))*180.0/3.14159
      WRITE(6,505)
      IF(NC.NE.1) GO TO 23
      IF(TH2.GE.0.) TH2=TH2+20.
      IF(TH2.LT.0.) TH2=(360.0+TH2)+20.
   23 IF(NC.NE.2) GO TO 24
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```
      IF(THP.GE.0.) THP=(THP/2.)*10.
      IF(THP.LT.0.) THP=((360.0+THP)/2.)*10.
      WRITE(6,5)
   20 IF(NC.EQ.1) WRITE(6,2) N
      IF(NC.EQ.2) WRITE(6,3) N
      IF(NC.EQ.4) WRITE(6,7) N,RXL,THP
      XL=RXL
      NN=NSS
C
C ***** END OF GROUPED DATA CALCULATION
C
  504 P=N*R*R*2.
      WRITE(6,4) THP, RXL, P
      IF(P.LT.2.77) GO TO 4000
      IF(P.GT.2.77) CHISQ=75.0
      IF(P.GT.4.61) CHISQ=90.0
      IF(P.GT.5.99) CHISQ=95.0
      IF(P.GT.7.38) CHISQ=97.5
      IF(P.GT.9.21) CHISQ=99.0
      IF(P.GT.10.6) CHISQ=99.5
      WRITE(6,4001) CHISQ
 4001 FORMAT(64H ***     THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREAT
     1ER THAN ,F5.1,21H PERCENT, WITH 2 D.F.///)
      GO TO 4002
 4000 CONTINUE
      WRITE(6,4004)
 4004 FORMAT(71H ***     THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT LESS
     1THAN 75 PERCENT///)
 4002 CONTINUE
      WRITE(6,3001)
 3001 FORMAT(52H ************************************************)
      IF(MM.LT.M)GO TO 2005
      IF(MM.EQ.999)GO TO 30
      IF(M.EQ.1) GO TO 30
C
C *****    IF IT GOES TO 2005,IT WILL READ ANOTHER BATCH OF DATA
C *******IF IT GOES TO 30, THE GVM SHOULD ALREADY HAVE BEEN PRINTED OUT.
C *******IF IT CARRIES ON BELOW, IT WILL COMPUTE THE GVM FROM THE DATA
C          PRESENTLY IN ASTOR.
C
      DO 2006 J=1,NTCUM
 2006 A(J)=ASTOR(J)
      NT=NTCUM
      WRITE(6,9027) APLACE
      WRITE(6,2008)
 2008 FORMAT(1H0,49H                 GRAND VECTOR MEAN NOW BEING CALCULATED.///
     1)
      MM=999
      GO TO 2007
  100 FORMAT(13H NT             =,I10,20H , MICRCM. CORREC. =,I4/27H NO. SPL
     1 HISTOGRAMS ADDED =,I5)
  501 FORMAT(8(1X,I4))
  502 FORMAT(10X,19H GROUP DATA CALCUL    )
    5 FORMAT(1H0,21H                 HISTOGRAM =,9I6)
    6 FORMAT(1H0,53H                 ***CALC WITH TWO THETA TRANSF, OUTPUT TRAN
     1SF TO THETA)
    7 FORMAT(13H HISTOGRAM  =,1PI6/13H L          =,F16.3/13H FOUR THETA
     1=,F16.3)
    4 FORMAT(1H0,21H            THETA      =,F15.3,33H                  VECTOR
     1 LENGTH    =,F5.3,33H                 CHI  SQUARE   =,F15.3///)
   30 CONTINUE
      STOP
      END
```

B

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EASTERN AREA OF UPHILL L. FM., EAST.

   NUMBER OF SAMPLES =   5.

********    OT-TAH-1, UPHILL L. FM., NE OF SWAMP L.

   NT = 198   NC = 2   NR = 8   NN =   8   NZ = 8   NN =  1

      NO. MEAS. =  193          DEC.  COR.      =  194

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =      9     8     18     19     21     18     10     19     17
      THETA     =         119.971                   VECTOR  LENGTH   =   24.431                    CHI  SQUARE  =        18.490

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     OT-TAH-2, UPHILL L. FM., S. OF MOSHER B., N. OF SWAMP L.

   NT = 198   NC = 2   NR = 8   NN =   8   NZ = 8   NN =  2

      NO. MEAS. =  193          DEC.  COR.      =  68

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =     17     17     8     9     9     8     16     12     19
      THETA     =          171.069                  VECTOR  LENGTH   =   29.629                    CHI  SQUARE  =        16.759

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
********    OT-TAH-3, UPHILL L. FM., S. OF E. END OF MOSHER B.

   NT = 199   NC = 2   NR = 8   NN =   8   NZ = 8   NN =  3

      NO. MEAS. =  181          DEC.  COR.      =  358

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =      7     6     27     18     19     9     6     6     6
      THETA     =          89.179                   VECTOR  LENGTH   =   47.186                    CHI  SQUARE  =        35.173

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     OT-TAH-4, UPHILL L. FM., S. OF E. END OF MOSHER B.

   NT = 198   NC = 2   NR = 8   NN =   8   NZ = 8   NN =  4

      NO. MEAS. =  193          DEC.  COR.      =  329

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =     18     16     21     29     16     9     1     2     2
      THETA     =          56.195                   VECTOR  LENGTH   =   51.652                    CHI  SQUARE  =        61.896

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     OT-TAH-5, UPHILL L. FM., S OF E END OF MOSHER B.

   NT = 199   NC = 2   NR = 8   NN =   8   NZ = 8   NN =  5

      NO. MEAS. =  181          DEC.  COR.      =  288

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =     18     11     8     18     3     1     16     26     17
      THETA     =          169.769                  VECTOR  LENGTH   =   31.428                    CHI  SQUARE  =        19.769

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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EASTERN AREA OF UPHILL L. FM., EAST.

     GRAND VECTOR MEAN NOW BEING CALCULATED.

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    53    42    71    68    86    53    49    61    69
     THETA     =          87.419                 VECTOR  LENGTH   =    7.668                  CHI  SQUARE   =         36.788

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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EASTERN AREA OF UPHILL L. FM., CENTRAL.

   NUMBER OF SAMPLES =    1

*******     07-73-29, UPHILL L. FM., N. OF SUNSHINE L.

   NT = 180   ND = 2   NF = 0   NH =  0   NZ = 0   NN =  1

     NO. MEAS. =  109          DECL. COR.     =  215
     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    22    12     6     9     8     4     6    12    23
     THETA     =          1.448                  VECTOR  LENGTH   =   38.529                  CHI  SQUARE   =         26.437

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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EASTERN AREA OF UPHILL L. FM., WEST.

   NUMBER OF SAMPLES =    4

*******     07-73-12, UPHILL L. FM., N. OF RUSH B. NARROWS.

   NT = 180   ND = 2   NR = 0   NH =  3   NZ = 0   NN =  1

     NO. MEAS. =  151          DEC.  COR.     =  90
     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    15     8     1     1     4    11    29    21    18
     THETA     =          141.617                VECTOR  LENGTH   =   44.313                  CHI  SQUARE   =         45.609

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     07-73-24, UPHILL L. FM., JUST E. OF INLETTO SURPRISE LAKE.

   NT = 175   ND = 2   NR = 0   NH =  0   NZ = 0   NN =  2

     NO. MEAS. =  173          DEC.  COR.     =  19
     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    12     7     6    16     4    19    23    19    17
     THETA     =          138.611                VECTOR  LENGTH   =   25.591                  CHI  SQUARE   =         16.783

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     07-73-11, UPHILL L. FM., SW OF SURPRISE L.

   NT = 170   ND = 2   NR = 0   NH =  0   NZ = 0   NN =  1

     NO. MEAS. =  151          DEC.  COR.     =  79
     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    19    24    11    15     8    10    11    28    24
     THETA     =          177.371                VECTOR  LENGTH   =   24.398                  CHI  SQUARE   =         16.791

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.
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*******     OT-73-12, UPHILL L. FM., S. OF SUNRISE L.

   NT = 198   NC = 2   NP = 0   NN =  0   NT = 0   NM = 6

     NO. MEAS. = 199         DEC. COR.    =   5

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     3     6     9     2    10     3    13    25    25
     THETA     =         178.292              VECTOR  LENGTH   =   42.967              CHI  SQUARE   =        36.397

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*****************************************************
  EASTERN AREA OF UPHILL L. FM., WEST.

     GRAND VECTOR MEAN NOW BEING CALCULATED.

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    47    45    26    10    38    43    75    93    76
     THETA     =         154.289              VECTOR  LENGTH   =   29.811              CHI  SQUARE   =       376.276

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*****************************************************
UPHILL LAKE AREA

  NUMBER OF SAMPLES =   7

*******     OT-73-12, UPHILL L. FM., W. PUSH B.

   NT = 199   NC = 2   NP = 0   NN =  0   NT = 0   NM = 1

     NO. MEAS. = 194         DEC. COR.    =  255

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    33    31    23     9     8    13    19    16    26
     THETA     =           9.881              VECTOR  LENGTH   =   13.219              CHI  SQUARE   =         9.882

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.0 PERCENT, WITH 2 D.F.

*****************************************************
*******     OT-73-14, UPHILL L. FM., W. EDGE HOOK B.

   NT = 199   NC = 2   NP = 0   NN =  0   NT = 0   NM = 2

     NO. MEAS. = 126         DEC. COR.    =  358

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    19    13    26    19    22    11    12     7     5
     THETA     =          70.889              VECTOR  LENGTH   =   24.858              CHI  SQUARE   =        21.709

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*****************************************************
*******     OT-73-17, UPHILL L. FM., NW EDGE OF HOOK B.

   NT = 148   NC = 2   NP = 0   NN =  0   NT = 0   NM = 3

     NO. MEAS. = 103         DEC. COR.    =  339

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    18    26    25    19     5     1     1     2     3
     THETA     =          49.889              VECTOR  LENGTH   =   66.186              CHI  SQUARE   =        76.298

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*****************************************************
*******     OT-73-16, UPHILL L. FM., NE EDGE HOOK B., ON POINT

   NT = 188   NC = 2   NP = 0   NN =  0   NT = 0   NM = 6

     NO. MEAS. = 101         DEC. COR.    =  169

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     6    15    22    22    28     6     4     3     2
     THETA     =          81.425              VECTOR  LENGTH   =   50.546              CHI  SQUARE   =        68.977

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.
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*******     STATION, UPHILL L. FM., E. HOOK BAY.

  NT = 498   ND = 2   MP = 8   MM = 8   MZ = 8   MN = 5

     NO. MEAS. = 198          DEC. COR.    = 394
     ***CALC WITH THS THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM = [illegible]   3    8   18   13   17   22   13    9
     THETA     =          119.750              VECTOR  LENGTH   =  [illegible]                   CHI  SQUARE   =        22.327

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     STATION, UPHILL L. FM., NE SURPRISE L.

  NT = 198   ND = 2   MP = 8   MM = 8   MZ = 8   MN = 6

     NO. MEAS. = 198          DEC. COR.    = 368
     ***CALC WITH THS THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    19   22   22   22   18   17   16    5   13
     THETA     =          60.216               VECTOR  LENGTH   =  11.979                   CHI  SQUARE   =        18.889

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     STATION, UPHILL L. FM., N SHORE SURPRISE L.

  NT = 198   ND = 2   MP = 8   MM = 8   MZ = 8   MN = 7

     NO. MEAS. = 189          DEC. COR.    = 79
     ***CALC WITH THS THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     8   47   15    8    6    5    2    9   17
     THETA     =          29.107               VECTOR  LENGTH   =  31.588                   CHI  SQUARE   =        23.483

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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UPHILL LAKE AREA

     GRAND VECTOR MEAN NOW BEING CALCULATED.

     ***CALC WITH THS THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    95  177  139  118   96   72   76   83   69
     THETA     =          59.936               VECTOR  LENGTH   =  10.681                   CHI  SQUARE   =       812.878

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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BULADIS BAY AREA

  NUMBER OF SAMPLES =    6

*******     STATION, UPHILL L. FM., SE OF WATSONS.

  NT = 150   ND = 2   MP = 8   MM = 8   MZ = 8   MN = 1

     NO. MEAS. = 153          DEC. COR.    = 367
     ***CALC WITH THS THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     9   19   21   19   21   16   21   17   18
     THETA     =          81.619               VECTOR  LENGTH   =  16.467                   CHI  SQUARE   =         6.612

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  95.0 PERCENT, WITH 2 D.F.
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*******     DI-P1-T1, UPHILL L. FM.,  S. BULBOUS B.

 NT = 106   NC = 2   NP = 8   NN =   8   NT = 8   NN =  2

      NO. MEAS. =  108          DEC.  COR.      =  135

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    16    27    13    12    1    6    6    8    18
      THETA     =          29.583               VECTOR  LENGTH   =   49.786          CHI  SQUARE   =        41.111

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     THI?, UPHILL L. FM., SW OF BULBOUS BAY

   NT = 108   NC = 2   NP = 8   NN =   8   NT = 8   NN =  3

      NO. MEAS. =  101          DEC.  COR.      =  99

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    13    2    6    9    6    6    18    16    32
      THETA     =          199.162              VECTOR  LENGTH   =   46.769          CHI  SQUARE   =        46.087

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     THI3,N,UPHILL L.FM.,SW OF BULBOUS BAY

   NT = 100   NC = 2   NP = 8   NN =   8   NT = 8   NN =  6

      NO. MEAS. =  100          DEC.  COR.      =  169

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    22    16    7    9    6    12    18    18    19
      THETA     =          177.567              VECTOR  LENGTH   =   21.399          CHI  SQUARE   =        6.998

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  97.5 PERCENT, WITH 2 D.F.

*************************************************
*******     THI4, UPHILL L. FM., SW OF BULBOUS BAY

   NT = 108   NC = 2   NP = 8   NN =   8   NT = 8   NN =  9

      NO. MEAS. =  101          DEC.  COR.      =  58

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    17    26    10    1    6    6    6    5    17
      THETA     =          27.761               VECTOR  LENGTH   =   49.944          CHI  SQUARE   =        49.198
   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     THI5,N,UPHILL L.FM.,SW OF BULBOUS B.

   NT = 108   NC = 2   NP = 8   NN =   8   NT = 8   NN =  6

      NO. MEAS. =  109          DEC.  COR.      =  45

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    5    1    1    3    6    11    26    26    22
      THETA     =          166.215              VECTOR  LENGTH   =   61.281          CHI  SQUARE   =        59.069

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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BULBOUS BAY AREA

      GRAND VECTOR MEAN NOW BEING CALCULATED.

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    59    46    66    78    42    48    61    78    116
      THETA     =          174.979              VECTOR  LENGTH   =   28.186          CHI  SQUARE   =        320.966

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.
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CANE FALLS AREA

  NUMBER OF SAMPLES =    5

*******     THTA,M,UPHILL,L. PH,SE SHORE STRAITS,JUST W OF CANE FALLS

  NT = 180   NC = 2   NP = 8   NN =   8   NZ = 8   NN =  1

     NO. MEAS. =  193          DEC. COR.     =   18

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     6     0     5     1    36    32    12     8     1
     THETA     =          103.911                  VECTOR  LENGTH   =   74.788                    CHI  SQUARE   =       101.731

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*********************************************
*******     THTC, UPHILL L. TH., N OF CANE FALLS, OPPOSITE CAMP

  NT = 180   NC = 2   NP = 8   NN =   8   NZ = 8   NN =  2

     NO. MEAS. =  184          DEC. COR.     =   65

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     7     1     6     1    11    36    28     9     7
     THETA     =          117.719                  VECTOR  LENGTH   =   46.787                    CHI  SQUARE   =        42.486

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*********************************************
*******     THTA, UPHILL L.T.,NW SIDE OF STRAITS,NW OF CANE FALLS

  NT = 180   NC = 2   NP = 8   NN =   8   NZ = 8   NN =  1

     NO. MEAS. =  183          DEC. COR.     =   27

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     1     2     4    25    38    16    16     7     2
     THETA     =           97.712                  VECTOR  LENGTH   =   59.539                    CHI  SQUARE   =        63.736

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*********************************************
*******     THTB, UPHILL L. TH., SW SHORE OF STRAITS,NW OF CANE FALLS

  NT = 180   NC = 2   NP = 8   NN =   8   NZ = 8   NN =  4

     NO. [illegible]  183          DEC. COR.     =   27

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     5    11     8    12    22    12    11    10     9
     THETA     =           93.381                  VECTOR  LENGTH   =   28.964                    CHI  SQUARE   =         8.262

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  97.5 PERCENT, WITH 2 D.F.

*********************************************
*******     THTC, UPHILL L. TH.,NW SHORE OF STRAITS,NW OF CANE FALLS

  NT = 180   NC = 2   NP = 8   NN =   8   NZ = 8   NN =  5

     NO. MEAS. =  109          DEC. COR.     =  234

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     1     0     1    12    12    36    11     6     1
     THETA     =          188.562                  VECTOR  LENGTH   =   71.897                    CHI  SQUARE   =        95.768

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     T-9,W. UPHILL L.FM.AT CHERT STRAITS,OPPOSITE T-7

  NT = 100   NC = 2   NP = 8   NM =   8   NT = 8   NN =  6

     NO. MEAS. =  191           DEC.  COR.      =   15

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =      1     1     4    17    42    26     4     5     0
     THETA      =          51.294               VECTOR  LENGTH   =   74.611                    CHI  SQUARE   =        106.791

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     T-19,CANE L.FM.NE OF CANE FALLS

  NT = 100   NC = 2   NP = 8   NM =   8   NT = 8   NN =  7

     NO. MEAS. =  193           DEC.  COR.      =  237

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     23    12    18     4     3     3    13    15    10
     THETA      =         174.232               VECTOR, LENGTH   =   35.481                    CHI  SQUARE   =        328.756

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     T-20, CANE L. FM.,ON HILL NE OF CANE FALLS

  NT = 100   NC = 2   NP = 8   NM =   8   NT = 8   NN =  4

     NO. MEAS. =  194           DEC.  COR.      =  329

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =      4    12     7    11    11    21    22     7     3
     THETA      =         105.448               VECTOR  LENGTH   =   31.144                    CHI  SQUARE   =         15.178

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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 CANE FALLS AREA

     GRAND VECTOR MEAN NOW BEING CALCULATED.


     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     15    41    64    96   167   178   187    68    41
     THETA      =         101.449               VECTOR  LENGTH   =   41.489                    CHI  SQUARE   =       2886.751

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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 WESTERN CANE FALLS AREA

  NUMBER OF SAMPLES =    14

*******      T1-4, CANE L. FM., 1/2 MI. SW CANE FALLS

  NT = 100   NC = 2   NP = 8   NM =   8   NT = 8   NN =  1

     NO. MEAS. =  193           DEC.  COR.      =  218

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =      5    12    13    29    19     9     4     4     4
     THETA      =          71.789               VECTOR  LENGTH   =   45.559                    CHI  SQUARE   =         39.879

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     [illegible] CALC L. FM., 1/2 MI. SW CANE FALLS

  NT = 198   NC = 2   NP = 9   NN =   8   NZ = 8   NM = 2

     NO. MEAS. =  101          DEC. COR.     =  118

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     12     9    15    26    28     6    11     8     6
     THETA      =        73.415                 VECTOR LENGTH   =   37.190                    CHI SQUARE   =          38.499

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     [illegible] CALC L. FM., 1/2 MI. SW CANE FALLS

  NT = 198   NC = 2   NP = 8   NN =   8   NZ = 8   NM = 1

     NO. MEAS. =  101          DEC. COR.     =  129

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     2     8     1     9    32    27     8    11     8
     THETA      =        105.668                VECTOR LENGTH   =   53.635                    CHI SQUARE   =          56.899

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     [illegible] CALC L. FM., 1/2 MI. SW OF CANE FALLS

  NT = 198   NC = 2   NP = 9   NN =   8   NZ = 8   NM = 6

     NO. MEAS. =  101          DEC. COR.     =  129

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     6     9     1    16    27    31     6     3     5
     THETA      =        95.181                 VECTOR LENGTH   =   57.168                    CHI SQUARE   =          63.579

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     77HA. CALC L. FM., 3/4 MI. SW CANE FALLS

  NT = 198   NC = 2   NP = 8   NN =   8   NZ = 8   NM = 5

     NO. MEAS. =  101          DEC. COR.     =  129

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     8    18    19    16    16     6     7     8    10
     THETA      =        97.557                 VECTOR LENGTH   =   18.757                    CHI SQUARE   =          8.899

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  97.5 PERCENT, WITH 2 D.F.

**************************************************
*******     77HB. CALC L. FM., 3/4 MI. SW CANE FALLS

  NT = 198   NC = 2   NP = 8   NN =   8   NZ = 8   NM = 6

     NO. MEAS. =  101          DEC. COR.     =  129

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     1     9     5     9    47    32     2     3     2
     THETA      =        94.737                 VECTOR LENGTH   =   74.642                    CHI SQUARE   =          109.969

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     77HC. CALC L. FM., 3/4 MI. SW CANE FALLS.

  NT = 198   NC = 2   NP = 8   NN =   8   NZ = 8   NM = 7

     NO. MEAS. =  101          DEC. COR.     =  129

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     5     9     9    13    17    26    11     7     6
     THETA      =        94.558                 VECTOR LENGTH   =   37.166                    CHI SQUARE   =          19.961

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     [illegible] 3/4 MI. SW CANE FALLS.

  NT = 18[illegible]   NC = 2   NP = 8   NN =   8   NZ = 8   NN = [illegible]

     NO. MEAS. = 1[illegible]          DEC. COR.      = 12[illegible]

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     3     4     6    19    26    16    13     9     6
     THETA     =         9[illegible].11[illegible]                VECTOR  LENGTH   =   47.862                CHI  SQUARE   =         42.831

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

*************************************************
*******     [illegible] 3/4 MI. SW CANE FALLS

  NT = 1[illegible]   NC = 2   NP = 8   NN =   8   NZ = 8   NN = [illegible]

     NO. MEAS. = 180          DEC. COR.      = 12[illegible]

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     1     1     3     8    35    19     4     2     1
     THETA     =         9[illegible].381               VECTOR  LENGTH   =   69.672                CHI  SQUARE   =         96.918

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     [illegible], CANE L. FM., SMALL ROCK AT NARROWS W OF CANE FALLS

  NT = 1[illegible]   NC = 2   NP = 8   NN =   8   NZ = 8   NN = 1[illegible]

     NO. MEAS. = 100          DEC. COR.      = 119

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     2     ?    13    18    19    26     4     9     6
     THETA     =         91.[illegible]95               VECTOR  LENGTH   =   35.232                CHI  SQUARE   =         21.[illegible]

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     [illegible], CANE L. FM., SMALL ROCK AT NARROWS W OF CANE FALLS

  NT = 180   NC = 2   NP = 8   NN =   8   NZ = 8   NN = 11

     NO. MEAS. = 100          DEC. COR.      = 115

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     8    12     7    28    19    16     9     9     6
     THETA     =         [illegible]               VECTOR  LENGTH   =   24.66[illegible]                CHI  SQUARE   =         11.937

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     [illegible], CANE L. FM., SHORE AT NARROWS W OF CANE FALLS

  NT = 180   NC = 2   NP = 8   NN =   8   NZ = 8   NN = 12

     NO. MEAS. = 1[illegible]          DEC. COR.      =  30

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     2     2     4     7     6    14    26    21    17
     THETA     =         137.965               VECTOR  LENGTH   =   62.631                CHI  SQUARE   =         46.988

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     [illegible] SHORE STRAITS, OPPOSITE CANE FALLS

  NT = 180   NC = 2   NP = 8   NN =   8   NZ = 8   NN = 11

     NO. MEAS. = 101          DEC. COR.      = 106

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    11     4     4    13    34    26    11     6     7
     THETA     =         84.817               VECTOR  LENGTH   =   63.921                CHI  SQUARE   =         61.986

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.
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*******     THIRD,UPHILL-CANT FR,NW SHORE STRAITS,W OF CANE FALLS

  NT = 180   NP = 2   NR = 8   NN = 8   NZ = 8   NN = 16

     NO. MEAS. = 144          DEC. COR.     =  319
     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =      6     5     8    71    38     9     6     3     6
     THETA     =          56.079             VECTOR  LENGTH   =   51.3[illegible]                    CHI  SQUARE   =        53.217

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.9 PERCENT, WITH 2 D.F.

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*******     THIRD,UPHILL-CANT FR,NW SHORE STRAITS,W OF CANE FALLS

  NT = 180   NP = 2   NR = 8   NN = 8   NZ = 8   NN = 16

     NO. MEAS. = 189          DEC. COR.     =  225
     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =      8     1     1    11    25    32    16     6     9
     THETA     =          103.794            VECTOR  LENGTH   =   62.987                    CHI  SQUARE   =        76.159

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.9 PERCENT, WITH 2 D.F.
*************************************************
*******     THIRD,UPHILL-CANT FR,NW SHORE STRAITS,W OF CANE FALLS

  NT = 180   NP = 2   NR = 8   NN = 8   NZ = 8   NN = 16

     NO. MEAS. = 101          DEC. COR.     =  222
     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =      8     8     7     4    25    11    10     8     1
     THETA     =          115.581            VECTOR  LENGTH   =   76.826                    CHI  SQUARE   =        113.189

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.9 PERCENT, WITH 2 D.F.

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WESTERN CANE FALLS AREA

     GRAND VECTOR MEAN NOW BEING CALCULATED.

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    76    49   114   221   391   347   176   188    46
     THETA     =          87.187             VECTOR  LENGTH   =   42.422                    CHI  SQUARE   =        8976.223

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.9 PERCENT, WITH 2 D.F.

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[illegible] BAY NOR. OF UPHILL L. FR.

  NUMBER OF SAMPLES =    1

*******     [illegible], RUSH R., NERN. N. OF RUSH B.

  NT = 180   NP = 2   NR = 8   NN = 8   NZ = 8   NN = 1

     NO. MEAS. = 101          DEC. COR.     =  269
     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     13    12    49     7     1     1     1     4     6
     THETA     =          39.176             VECTOR  LENGTH   =   67.535                    CHI  SQUARE   =        89.591

  THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.9 PERCENT, WITH 2 D.F.

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NOTHER BAY FM.

  NUMBER OF SAMPLES =    2

*******    OT-73-20, NOTHER B. FM., UPPER MANITOU STRAITS

   NT = 180   ND = 2   NP = 0 . NM =   0   NZ = 0   NN =  1

      NO. MEAS. =  181          DEC. COR.     =  181
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    17    1     1    0     5     5    13    23    17
      THETA      =         179.947                VECTOR  LENGTH   =   60.581                        CHI  SQUARE   =          83.836

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******    OT-74-11, NOTHER B. FM., LOOSE-PEBBLE COL., IN BUSH.

   NT = 159   ND = 2   NP = 0   NM =   0   NZ = 0   NN =  2

      NO. MEAS. =  159          DEC. COR.     =  68
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    27    17    22    12    16    18    19    17    16
      THETA      =         18.906                VECTOR  LENGTH   =   16.406                        CHI  SQUARE   =          9.668

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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NOTHER BAY FM.

      GRAND VECTOR MEAN NOW BEING CALCULATED.

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    42    17    23    12    21    19    28    40    31
      THETA      =         164.186                VECTOR  LENGTH   =   24.622                        CHI  SQUARE   =          69.828

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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* NO PREFERRED ORIENTATION

  NUMBER OF SAMPLES =    5

*******    OT-73-7, NISHEA N. FM., THOMSONS D.C.

   NT = 158   ND = 2   NP = 0   NM =   0   NZ = 0   NN =  1

      NO. MEAS. =  153          DEC. COR.     =  35
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    13    17    22    11    19    21    12    11    19
      THETA      =         39.155                VECTOR  LENGTH   =   5.109                        CHI  SQUARE   =          .918

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT LESS THAN 75 PERCENT

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*******    OT-73-17, CANE L. FM., IN EDGE HOOK PENINSULA.

   NT = 170   ND = 2   NP = 0   NM =   0   NZ = 0   NN =  2

      NO. MEAS. =  156          DEC. COR.     =  78
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    16    21    7    11    22    25    26    9    11
      THETA      =         107.262                VECTOR  LENGTH   =   12.159                        CHI  SQUARE   =          4.551

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  75.0 PERCENT, WITH 2 D.F.
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*******     OT-PS-7, UPHILL L. FM., S. OF E. END MOSHER B.

   NT = 158   NP = 2   NM = 0   NN =   0   NZ = 0   NN = 16

      NO. MEAS. = 193          DEC. COR.     = 248

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    18    24    19     9    14    16    16     9    29
      THETA     =         13.918                  VECTOR  LENGTH   =   12.636                 CHI  SQUARE   =        6.298

   THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.0 PERCENT, WITH 2 D.F.

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*******     OT-PS-12, UPHILL L. FM., W OF SURPRISE L.

   NT = 198   NP = 2   NM = 9   NN =   0   NZ = 0   NN = 4

      NO. MEAS. = 194          DEC. COR.     = 389

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    31    19    17    19    11    15    12    16    22
      THETA     =         23.536                  VECTOR  LENGTH   =   11.639                 CHI  SQUARE   =        6.688

   THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.0 PERCENT, WITH 2 D.F.

**********************************************
*******     THIS, UPHILL L. FM., S. OF BULGOUS BAY

   NT = 187   NP = 2   NM = 0   NN =   0   NZ = 0   NN = 4

      NO. MEAS. = 197          DEC. COR.     = 147

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    11     9    16     7    17    19     8     5     8
      THETA     =         87.837                  VECTOR  LENGTH   =   19.239                 CHI  SQUARE   =        8.787

   THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.0 PERCENT, WITH 2 D.F.

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 NO PREFERRED ORIENTATION

      GRAND VECTOR MEAN NOW BEING CALCULATED.

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    56    92    21    98    91    96    72    68    39
      THETA     =         61.654                  VECTOR  LENGTH   =    3.613                 CHI  SQUARE   =       18.661

   THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.0 PERCENT, WITH 2 D.F.

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 TECTONIC [illegible]

   NUMBER OF SAMPLES =   17

*******     OT-PS-4, MOSHER B. FM., 1/4 MILE SW OF THOMSONS OUTCROP.

   NT = 58   NP = 2   NM = 0   NN =   3   NZ = 0   NN = 1

      NO. MEAS. =   58          DEC. COR.     =  48

      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =     1     8     8     8     2    10    26     9     2
      THETA     =        129.467                  VECTOR  LENGTH   =   61.789                 CHI  SQUARE   =       66.421

   THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.9 PERCENT, WITH 2 D.F.

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*******   07-23-19, UPHILL L. FM., E. RUTH R.

   NT = 58   NC = 2   NR = 8   NN =   8   NT = 8   NN = 2

      NO. MEAS. =  58          DEC. COR.     =  78
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =     7     8     4     2     1     1     4     8    13
      THETA     =        176.629                VECTOR  LENGTH   =   44.153                     CHI  SQUARE   =        19.818

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

****************************************************
*******     07-23-19, RUTH R. MBR., MAY E. OF CAMP BLAVENHEAD

   NT = 67   NC = 2   NR = 8   NN =   8   NT = 8   NN = 1

      NO. MEAS. =  67          DEC. COR.     = 278
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    11     1     8     8     8     6     8    19    31
      THETA     =        187.901                VECTOR  LENGTH   =   69.959                     CHI  SQUARE   =        99.163

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

****************************************************
*******     07-23-27, UPHILL L. FM., NE OF SURPRISE L.

   NT = 58   NC = 2   NR = 8   NN =   8   NT = 8   NN = 4

      NO. MEAS. =  58          DEC. COR.     = 257
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    32    10     4     1     1     8     1     1     4
      THETA     =         14.979                VECTOR  LENGTH   =   79.499                     CHI  SQUARE   =        97.411

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

****************************************************
*******     07-24-27, UPHILL L. FM., N. SHORT SURPRISE L.

   NT = 188   NC = 2   NR = 8   NN =   8   NT = 8   NN = 9

      NO. MEAS. = 131          DEC. COR.     = 269
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =    41     7     8     1     4     8     7    13    29
      THETA     =        177.168                VECTOR  LENGTH   =   45.938                     CHI  SQUARE   =        37.716

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     07-24-13, CAKE L. FM., N. OF CANE FALLS.

   NT = 58   NC = 2   NR = 8   NN =   5   NT = 8   NN = 6

      NO. MEAS. =  51          DEC. COR.     =  45
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =     4     1     8     8     2     4     4    17    11
      THETA     =        169.819                VECTOR  LENGTH   =   66.829                     CHI  SQUARE   =        42.496

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

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*******     07-24-14, RUSH R. MBR., COD L.

   NT = 59   NC = 2   NR = 8   NN =   8   NT = 8   NN = 7

      NO. MEAS. =  56          DEC. COR.     =  11
      ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
      HISTOGRAM =     1     1     8     1     2    19    24     2     8
      THETA     =        171.161                VECTOR  LENGTH   =   89.511                     CHI  SQUARE   =        74.526

   THIS VALUE OF CHI SQUARED IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.
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*******     [illegible], PUSH B, HORZ., COT L.

 NT = [illegible]   NC = [illegible]   NP = 8   NM =   8   NT = 8   NN = 8

     NO. MEAS. = [illegible]          DEC. COR.     = [illegible]

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     1     0     0     0     0     1    17    29     1
     THETA     =          1[illegible].000              VECTOR  LENGTH   =  [illegible]      CHI  SQUARE   =        82.971

 THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     [illegible], PUSH B, [illegible], COT L. SECTION.

 NT = [illegible]   NC = 2   NP = 8   NM =   8   NI = 8   NN = 9

     NO. MEAS. =   [illegible]          DEC. COR.     =  10.

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     2     1     1    13    20     6     1     8     0
     THETA     =          [illegible]              VECTOR  LENGTH   =  [illegible]      CHI  SQUARE   =        43.[illegible]

 THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     [illegible], PUSH B, HORZ., COT L. SECTION.

 NT = [illegible]   NC = 2   NP = 8   NM =   8   NT = 8   NN = 10

     NO. MEAS. =   [illegible]          DEC. COR.     =  47

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =    [illegible]     8    17     8     2     6     1     [illegible]     0
     THETA     =          6.091              VECTOR  LENGTH   =  74.[illegible]      CHI  SQUARE   =        [illegible]

 THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.
**************************************************
*******     [illegible], PUSH B, HRZ., BULBOUS B. SECTION.

 NT = [illegible]   NC = 2   NI = 2   NM =   8   NI = 8   NN = 11

     NO. MEAS. =   [illegible]          DEC. COR.     =  38

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     1     [illegible]    [illegible]    16     2     2     1     8     1
     THETA     =          [illegible]              VECTOR  LENGTH   =  74.821      CHI  SQUARE   =        54.117

 THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.

**************************************************
*******     [illegible] UPHILL [illegible] OF BULBOUS [illegible]

 NT = 150   NC = 2   NP = 8   NM =   8   NI = 8   NN = 12

     NO. MEAS. = [illegible]          DEC. COR.     =  [illegible]

     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =     6     8     1     6    16    17    17    26    15
     THETA     =          136.613              VECTOR  LENGTH   =  56.098      CHI  SQUARE   =        [illegible]

 THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.
**************************************************

TECTONIC REGIME

     GRAND VECTOR MEAN NOW BEING CALCULATED.


     ***CALC WITH TWO THETA TRANSF, OUTPUT TRANSF TO THETA
     HISTOGRAM =   116    68    67    96    71    70   117   127   118
     THETA     =          [illegible]              VECTOR  LENGTH   =  [illegible]      CHI  SQUARE   =        [illegible]

 THIS VALUE OF CHI SQUARE IS SIGNIFICANT AT GREATER THAN  99.5 PERCENT, WITH 2 D.F.
**************************************************
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Appendix II. Modal composition of the sandstones and tuffs of the Manitou Gp.

Sample	Quartz	K-felds	Plag	Rock Fragments:			Matrix	Rock type
				Volc	Plutonic	chert		(Pettijohn, 1975)
Etta L. Sediments								
T-73- 38			20.0	21.2			58.8	tuff
T-74- 31	1.8		15.8	25.8			56.6	volc. graywacke
T-74- 32	1.2		16.2	29.0			53.6	volc. graywacke
T-74- 37	0.2		19.6	39.8			40.4	tuff
T-74- 38	3.0		7.2	25.0			64.8	tuff
Sediments associated with the Sunshine L. Fm.								
T-72- 45	0.8		7.2	13.6			78.4	volc. mudstone
Cane Lake Formation								
T-72-175			0.4	73.4			26.2	lithic tuff
T-72-214			20.8				79.2	crystal tuff
T-72-231			7.0	65.8			27.2	lithic tuff
T-72-232			0.8	87.2			12.0	lithic tuff
T-7[illegible]- 11	3.2		2.0	15.0			79.8	mudstone
T-73- 25			18.4	34.8			46.8	lithic-crystal tuff
T-73- 36	0.2		2.2	10.0		1.6	86.0	lithic tuff
T-73- 46			13.6	41.0			45.4	lithic tuff
T-74- 10	0.6		0.6	76.2			22.6	lithic tuff
T-74- 21			1.4	10.6			88.0	mudstone
T-74- 22			6.4	32.8			60.8	lithic tuff
T-74- 23			4.2	51.6			44.2	lithic tuff
T-74- 24			3.2	11.0			85.8	mudstone
OT-74-13			17.4	70.0			12.6	volc. arenite
Western Uphill L. Fm.								
T-72-160	0.2		35.4	41.0			22.6	volc. lithic graywacke
T-72-205			26.4	57.0			14.8	volc. lithic graywacke

(CONT.)

Appendix II. Modal composition of the sandstones and tuffs of the Manitou Gp. (CONT.)

Sample	Quartz	K-felds	Plag	Rock Fragments: Volc.	Plutonic	chert	Matrix	Rock type (Pettijohn, 1975)
Western Uphill L. Fm. (CONT.)								
T-72-207			2.0	70.4			27.6	volc. lithic graywacke
T-72-208	2.8		38.8	19.6			38.8	arkosic graywacke
T-72-251A	1.6		13.8	22.6			62.0	volc. lithic graywacke
Eastern Uphill L. Fm.								
T-72- 43	14.4		5.8	41.8			38.0	volc. lithic graywacke
T-72- 79			6.0	33.7			60.3	volc. lithic graywacke
T-72- 98	2.0	0.2	7.8	41.6			48.4	volc. lithic graywacke
T-72-107	3.4	0.4		79.0	5.0		11.4	volc. lithic arenite
T-72-194	2.6		1.4	4.0		1.6	90.4	mudstone
T-72-198	0.2		5.8	21.4			72.6	volc. lithic graywacke
T-72-241	3.4		12.4	70.8			13.4	volc. lithic arenite
T-73- 20	4.2		12.6	23.8			59.4	volc. lithic graywacke
T-73- 21	13.8		9.2	40.6			36.4	volc. lithic graywacke
T-73- 23	13.6		9.0	37.6			39.8	volc. lithic graywacke
T-73- 24	9.2		13.8	17.8			59.2	volc. lithic graywacke
T-73- 33	10.6		15.8	42.2			31.4	volc. lithic graywacke
OT-73-25	5.2		2.8	3.0			89.0	mudstone
OT-74- 1	12.8		14.2	26.4	1.8	2.6	42.2	volc. lithic graywacke
OT-74- 6	10.2		10.4	39.6	2.0	1.8	36.0	volc. lithic graywacke
OT-74- 7	10.0		10.2	40.0	1.8	0.6	37.4	volc. lithic graywacke
OT-74- 8	4.0		6.6	13.4	0.6		75.4	mudstone
OT-74- 9	7.0		11.8	40.6	2.8	0.8	37.0	volc. lithic graywacke
Central Uphill L. Fm.								
T-72- 9	1.0		26.4	31.2			41.4	volc. lithic graywacke
T-72- 52B			14.0	60.0			26.0	volc. lithic graywacke
T-72- 58	0.8		29.6	45.4			24.2	volc. lithic graywacke
T-72- 64	6.6		28.8	12.4			52.2	? tuff
(CONT.)								

Appendix II. Modal composition of the sandstones and tuffs of the Manitou Gp. (CONT.)

Sample	Quartz	K-felds	Plag	Rock fragments:			Matrix	Rock type
				Volc.	Plutonic	chert		(Pettijohn, 1975)
Central Uphill L. Fm. (CONT.)								
T-72- 64A	2.2		13.4	72.8			11.6	volc. lithic arenite
T-72- 73			16.5	43.5			40.0	volc. lithic graywacke
T-72-108	2.0		3.4	70.6			24.0	volc. lithic graywacke
T-72-109	3.2		3.6	74.8			18.4	volc. lithic graywacke
T-72-129	2.8	3.0	7.0	22.2			65.0	volc. lithic graywacke
T-72-188	1.4		0.2	60.8			37.6	volc. lithic graywacke
T-72-197	2.2	3.6	3.4	39.6			51.2	volc. lithic graywacke
T-72-200	0.8	4.6	1.6	64.2			28.8	volc. lithic graywacke
T-73- 2	0.8		14.6	58.6			26.0	volc. lithic graywacke
T-73- 27	0.8		16.0	57.8			25.4	volc. lithic graywacke
T-73- 32		0.6	9.2	70.8		2.2	17.2	volc. lithic graywacke
T-73- 34	4.6		18.0	6.0			71.4	arkosic graywacke
OT-73-27	2.0	0.4	10.2	74.6			12.8	volc. lithic arenite
OT-74- 3	2.2		5.6	73.6			18.6	volc. lithic graywacke
Rush Bay Member of the Uphill L. Fm.								
T-72- 13A	6.6		0.6	24.6			71.0	volc. lithic graywacke
T-72-164	2.6		16.4	16.4			64.6	volc. lithic graywacke
T-72-182	1.6	4.0	2.8	58.0			33.6	volc. lithic graywacke
T-72-186	1.0		4.2	39.4			55.4	lithic tuff
T-72-192	0.8		2.0	72.0			25.2	volc. lithic graywacke
T-72-202	1.0		6.2	45.4			47.4	volc. lithic graywacke
T-72-203			12.6	53.4			34.0	volc. lithic graywacke
T-72-212	2.6		4.8	51.6			41.0	lithic tuff
T-73- 5	12.8		2.4	17.8			67.0	crystal-lithic tuff
T-73- 15	1.4		14.0	6.8			77.8	mudstone
T-73- 40	10.4		4.8	8.6			76.2	mudstone
T-73- 41	3.8		9.2	6.4			80.6	mudstone

(CONT.)

Appendix II. Modal composition of the sandstones and tuffs of the Manitou Gp. (CONT.)

Sample	Quartz	K-felds	Plag	Rock fragments: Volc.	Plutonic	chert	Matrix	Rock type (Pettijohn, 1975)
Rush Bay Member of the Uphill L. Fm. (CONT.)								
T-73- 42	4.8		1.4	1.4			92.4	mudstone
T-74- 12	21.0	0.2	2.8	22.8			53.2	volc. lithic graywacke
T-74- 13	24.8		4.8	16.2			54.2	volc. lithic graywacke
T-74- 25	12.0	0.4	5.4	5.4			76.8	mudstone
T-74- 26	15.4		5.2	0.8			78.6	mudstone
T-74- 27	24.0		6.2	3.0	0.8	1.8	64.2	arkosic graywacke
T-74- 43			3.0	67.6			29.4	lithic tuff
T-74- 44	5.0		3.4	4.2			87.4	mudstone
OT-74-18	23.8		9.4	14.2	1.2	5.6	45.8	volc. lithic graywacke
OT-74-19			13.2	40.8		0.6	45.4	volc. lithic graywacke
Mosher Bay Fm								
T-72- 2	18.6	9.4	2.2	3.2	1.2		65.4	arkosic graywacke
T-72- 25	17.8	2.4	1.0	15.4	0.8		62.6	volc. lithic graywacke
T-72- 34	22.6	1.4	14.7	12.8	5.0		43.2	arkosic graywacke
T-72-127	15.4		11.6	1.4	2.6		69.0	arkosic graywacke
T-72-142	20.2	8.8	3.4	6.2	1.8		59.6	arkosic graywacke
T-72-170	17.0		11.4	17.0	2.2		52.4	volc. lithic graywacke
T-73- 1	7.8		11.2	1.8	2.4		76.4	mudstone
T-73- 3	15.8		15.0	7.2	6.2		61.4	feldspathic graywacke
T-73- 13	19.0		7.4	1.2	2.4		69.6	arkosic graywacke
T-74- 42	17.4	1.2	12.0	8.2	2.8	0.6	57.8	arkosic graywacke
OT-73- 4	6.6	0.4	4.2			0.2	88.6	mudstone
Conglomeratic lenses of the Mosher B. Fm.								
T-72- 80	13.0	1.4	16.6	4.6	1.2		63.2	feldspathic graywacke
S-73- 1	13.2		10.0	15.8			61.0	volc. lithic graywacke
S-73- 2	11.6		18.8	24.2	1.2		44.2	volc. lithic graywacke

(CONT.)

Appendix II. Modal composition of the sandstones and tuffs of the Manitou Gp. (CONT.)

Sample	Quartz	K-felds	Plag	Rock fragments: Volc.	Plutonic	chert	Matrix	Rock type (Pettijohn, 1975)
Conglomeratic lenses of the Mosher Bay Fm. (CONT.)								
S-73- 3	16.4		18.8	21.4	1.8		41.6	volc. lithic graywacke
S-73- 4	11.4	0.2	9.6	14.8	1.0		63.0	volc. lithic graywacke
S-73- 5	11.4	0.6	8.4	27.4	1.2		51.0	volc. lithic graywacke
S-73- 6	13.8		7.8	24.8	1.4		52.2	volc. lithic graywacke

Appendix III. Clast composition of conglomerates and tuff-breccias of the Manitou Group.

Unit	M	Basalts 1	Basalts 2	Basalts 3	Basalts 4	Intermed. 1	Intermed. 2	Felsite 1	Felsite 2	Felsite 3	Porphyry Felds	Porphyry Qtz	Gran-ite	Qtz	Iron Fm.	Chert	Sand-stone	Slate	Matrix
1. CL	5	9.20	2.46	1.00		7.74		4.16	0.98	29.28	3.52	2.04	2.32			0.54	6.22		30.54
2. CL	5	30.2						35.0											34.8
3. CL	5	19.0						19.4			27.8								33.2
4. CL	5	2.98	8.84		18.10	0.20	0.82	2.94		9.76	23.82	1.54	0.80						30.20
5. CL	4	8.32	10.34		1.00	5.48		18.13	3.8	24.64	1.87								26.43
6. CL	5	8.23	35.82			2.63		3.15		29.06									21.11
7. CL	5	44.0						23.9			7.1								25.0
8. WUL	5	20.5						29.4			33.1								17.0
9. WUL	5	37.2				3.5		22.4			5.6					0.8			30.6
10.CUL	5	6.7						27.3			33.2					0.2			32.6
11.EUL	5	53.1						19.4			3.4		5.7		2.0	3.3			13.1
12.RBM	5	26.5						17.5			41.5								14.5
13.RBM	2	6.1	12.3			3.00	7.55	12.60	1.8	1.80	22.20	1.10			0.95	0.45	4.75		26.25
14. MB	5	12.3						14.5			3.3		5.3		3.1	9.5			52.0
15. MB	5	3.74	0.78			2.94		13.63	1.2		0.77	0.31	5.13	1.74	0.15	2.08	7.08	1.80	58.67
16. MB	2	2.10	2.70			0.50		15.55		8.30	4.80	4.90	8.85		0.30	7.85	3.00	2.65	38.50
17. MB	5	0.40				1.75	0.81	2.49		10.49	0.75	3.19	32.42		7.29	1.04	2.19	3.49	33.69
18. MB	4	0.18				3.44		7.00		7.31		0.82	19.16	1.00	4.07	3.40	4.24	1.64	47.74
19. MB	5	3.18				0.73		2.46	4.2	27.56	0.14	6.83	4.42		3.46	7.25	2.73		37.03
20. MB	6	0.62				1.03		6.90	1.1	6.87	1.72	4.65	14.67	0.25	4.40	1.75	4.63	0.25	51.13
21. MB	8	3.08				0.80		7.29	2.2	4.95	2.06	4.30	10.80	0.58	9.94	2.50	6.10	0.35	45.09
22. MB	5	2.30	1.78	0.26		3.96	0.32	12.11	2.3	4.89	4.92	8.93	3.97		4.09	7.41			42.76
23. MB	6	0.58	0.47			2.32		9.87	1.1	4.85	2.93	2.57	11.71	2.03	10.50	3.67	1.63	1.05	44.75

See Fig. 61 for locations
M = metres measured at locality

KEY TO CLAST TYPES

Basalt
1. Massive
2. Porphyritic, feldspar phenocrysts
3. mafic, fine-grained, with rare quartz phenos.
4. porphyritic, mafic and felds. phenocrysts

Intermediate Volcanic Clasts
1. massive
2. porphyritic

Felsite
1. massive, aphanitic
2. with rare small quartz &/or felds phenocrysts
3. fine-grained (not aphanitic)

Porphyry
Felds - feldspar phenocrysts
Qtz - quartz phenocrysts

Slate - siltstone and mudstone, bedded in places

Appendix IV. Chemical analyses of selected rocks of the Manitou Group.

NOTE:

Samples 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16, 20,21,22,24,25,31,32,33,34,35,38,39, and 53 were analysed by the Mineral Research Branch of the Ontario Geological Survey. The listings are the output from their norm program.

- ALTERATIONS refers to the analysis recalculated to 100% anhydrous, and the calculation of % FeO using the method of Irvine and Baragar (1971).
- The letters to the right of the analyses refer to the method of analysis: A = atomic absorption, X = X-ray fluorescence, C = wet chemical.

Samples 15,17,18,19,23,26,27,28,29,30,36,37, 40,41,45,46,37, and 48 were analysed by Fred Longstaffe at McMaster University using X-ray fluorescence. The listings are the output from the CIPW norm program he used in his work.

1. T-72- 10 , Andesite, Sunshine Lake Fn.

```
         ANALYSIS(WT%)       ALTERATIONS     CATION %
SIO2          60.0 A             61.3          56.4
AL2O3         14.6 A             14.9          16.2
FE2O3         5.70 A             2.14          1.49
FEO            .00               3.31          2.61
MGO           3.90 A             3.98          5.47
CAO           6.00 A             6.13          6.05
NA2O          3.95 A             4.03          7.20
K2O           3.45 A             3.52          4.14
TIO2           .60 A              .61           .42
P2O5           .00                .00           .00
S              .00                .00           .00
MNO            .08 A              .08           .00
CO2     1.61  1.10 C              .00           .00
H2O+           .00                              .00
H2O-           .00       CR2O3    .00           .00
TOTAL         99.4       NIO      .00           .00
SPEC. GR.

   TRACES(PPM)              NORMS   MOLECULAR    WEIGHT
    AG   -                   AP       .000        .000
    AU   -                   PO       .000        .000
    AS   -                   IL       .643       1.164
    BA   -                   OR     20.721      20.840
    BE   -                   AB     36.012      34.130
    BI   -                   AN     12.097      12.164
    CO   -                   C        .000        .000
    CR   -                   AC       .000        .000
    CU   -                   MT      2.230       3.109
    GA   -                   HM       .000        .000
    HG   -                   WO       .000        .000
    LI   -                   EN      5.195       4.713
    MN   -                   FS      1.372       1.636
    MO   -                   Q       7.015       7.617
    NB   -                   DI     11.477      11.229
    NI   -                   FO       .000        .000
    PB   -                   FA       .000        .000
    RB   -                   NE       .000        .000
    SB   -                   LC       .000        .000
    SC   -                   KP       .000        .000
    SN   -                   HE      3.032       3.599
    SR   -                   CC       .000        .000
    TI   -                   RU       .000        .000
    V    -                   NS       .000        .000
    Y    -                   KS       .000        .000
    ZN   -                   CM       .000        .000
    ZR   -                   LN       .000        .000

                             SALIC=  75.85  FEMIC=  24.15

                         NORM RATIOS(MOLECULAR)
OR/AB+5/3NE/AN          30.10     52.32     17.58
Q/AB/OR                 11.00     56.49     32.50
NE/AB/OR                  .00     63.48     36.52
LC/NE/OR                  .00       .00    100.00
OL/OR/LC                  .00    100.00       .00
OL/HY/AG                  .00     31.16     68.84
Q/HY/AG                 24.97     23.38     51.65
HY/OR/Q                 19.14     60.41     20.45
OL/HY/OR                  .00     24.07     75.93
Q/PL/OR                  9.25     63.43     27.32
AG/HY/PL                20.97      9.49     69.54
OL/HY/PL                  .00     12.01     87.99
Q/HY/PL                 11.37     10.65     77.98
NE+/OL+/QL+             43.57     46.50      9.93
OL+/AG/Q+               17.53     51.65     30.82
OL+/PL/Q+                7.98     77.98     14.03 ADJUSTED FOR CORUNDUM
AG/PL/HY+MO             14.92     49.47     35.61
NE/AB+OR/NCI+             .06     70.14     29.86
AB/AN/NCI+              49.83     16.74     33.43
MG/MG+FE2               79.10
FE2/MG+FE2              20.90
                      CATION %
FE3/FE2+FE3             36.64
MG/FE2/NA+K             20.23     33.16     58.60
MG/FE2+FE3/NA+K         26.22     19.35     54.43
                      WEIGHT %
A/F/M                   45.04     31.22     23.74

NORMATIVE PLAGIOCLASE COMPOSITION=  25.15
DIFFERENTIATION INDEX= 63.75(MOLECULAR) 62.59(WEIGHT)  COLOUR INDEX= 24.15(MOLECULAR) 25.25(WEIGHT)
   ROCK NAME - CALC-ALKALINE ANDESITE                         MASS ABSORPTION= 59.15578
```

2. T-72- 45 , andesite ,Sunshine Lake Fm.

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         ANALYSIS(WT%)      ALTERATIONS.     CATION %
SIO2        61.9 A             62.3            57.8
AL2O3       15.2 A             15.3            16.7
FE2O3       6.00 A             2.32            1.62
FEO          .00               3.35            2.60
MGO         4.30 A             4.33            5.98
CAO         5.30 A             5.34            5.30
NA2O        3.42 A             3.44            6.19
K2O         2.65 A             2.67            3.16
TIO2         .60 A              .81             .56
P2O5         .00                .00             .00
S            .00                .00             .00
MNO          .10 A              .10             .00
CO2   LOI   1.32 C              .00             .00
H2O+         .00        CR2O3   .00             .00
H2O-         .00        NIO     .00             .00
TOTAL      101.0
SPEC. GR.

    TRACES(PPM)                NORMS   MOLECULAR   WEIGHT       NORM RATIOS(MOLECULAR)
     AG   -                     AP        .000      .000     OR/AB+5/3NE/AN    24.23    47.48    28.29
     AU   -                     PO        .000      .000     Q/AB/OR           22.35    51.41    26.24
     AS   -                     IL       1.123     1.530     NE/AB/OR            .00    66.21    33.79
     BA   -                     OR      15.797    15.785     LC/NE/OR            .00      .00   100.00
     BE   -                     AB      30.949    29.140     OL/OR/LC            .00   100.00      .00
     BI   -                     AN      18.441    18.421     OL/HY/AG            .00    63.76    36.24
     CO   -                     C         .000      .000     Q/HY/AG           43.04    36.32    20.64
     CR   -                     AC        .000      .000     HY/OR/Q           27.96    38.90    33.14
     CU   -                     MT       2.429     3.358     OL/HY/OR            .00    41.82    58.18
     GA   -                     HM        .000      .000     Q/PL/OR           17.11    62.80    20.09
     HG   -                     WO        .000      .000     AG/HY/PL           9.60    16.90    73.50
     LI   -                     EN       9.317     8.398     OL/HY/PL            .00    18.69    81.31
     MN   -                     FS       2.038     2.414     Q/HY/PL           18.14    15.30    66.56
     MO   -                     Q       13.457    14.317     NE+/Q+/OL+        33.30    51.43    15.27
     NB   -                     OL       5.295     5.147     OL+/AG/Q+         27.24    20.64    52.12
     NI   -                     FO        .000      .000     OL+/PL/Q+         11.46    66.56    21.96 ADJUSTED FOR CORUNDUM
     PB   -                     FA        .000      .000     AG/PL/HY+Q         5.33    40.81    53.86
     RB   -                     NE        .000      .000     NE/AB+OR/NCI+       .00    68.64    31.36
     SB   -                     LC        .000      .000     AB/AN/NCI+        43.75    26.07    30.19
     SC   -                     KP        .000      .000     MG/MG+FE2         82.05
     SN   -                     HL       1.150     1.250     FE2/MG+FE2        17.95
     SR   -                     CC        .000      .000                     CATION %
     TI   -                     RU        .000      .000     FE3/FE2+FE3       30.33
     V    -                     NS        .000      .000     MG/FE2/NA+K       33.36    14.50    52.14
     Y    -                     KS        .000      .000     MG/FE2+FE3/NA+K   30.61    21.56    47.83
     ZN   -                     CR        .000      .000                     WEIGHT %
     ZR   -                     LN        .000      .000     A/F/M             38.49    34.24    27.27

                        SALIC=  78.64  FEMIC=  21.36  NORMATIVE PLAGIOCLASE COMPOSITION=  37.34

DIFFERENTIATION INDEX= 60.20(MOLECULAR) 59.44(WEIGHT)  *COLOUR INDEX= 21.36(MOLECULAR) 22.14(WEIGHT)
    ROCK NAME - CALC-ALKALINE ANDESITE                       MASS ABSORBTION= 55.25584
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3. T-72- 65 , andesite ,Sunshine Lake Fm.

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       ANALYSIS(WT%)      ALTERATIONS :   CATION %
SIO2        57[illegible] A          58.8          59.0
AL2O3       13.4 A          13.7          19.9
FE2O3       6.60 A          2.36          1.63
FEO          .00            3.96          3.12
MGO         5.50 A          5.69          7.71
CAO         7.00 A          7.17          7.06
NA2O        3.77 A          3.86          6.88
K2O         3.45 A          3.59          4.15
TIO2         .80 A           .82           .57
P2O5         .00             .00           .00
S            .00             .00           .00
MNO          .10 A           .10           .00
CO2    L O I 1.28 C.         .00           .00
H2O+         .00    CR2O3    .00           .00
H2O-         .00    NIO      .00           .00
TOTAL       99.3
SPEC. GR.

   TRACES(PPM)                 NORMS  MOLECULAR   WEIGHT                           NORM RATIOS(MOLECULAR)
    AG    -                     AP      .000       .000      OR/AB+5/3NE/AN        32.03     53.19     14.83
    AU    -                     PO      .000       .000      Q/AB/OR                4.35     59.67     35.97
    AS    -                     IL     1.132      1.557      NE/AB/OR                .00     62.39     37.61
    BA    -                     OR    20.733     20.911      LC/NE/OR                .00       .00    100.00
    BE    -                     AB    34.392     32.684      OL/OR/LC                .00    100.00       .00
    BI    -                     AN     9.598      9.677      OL/HY/AG                .00     29.59     70.41
    CO    -                     C       .000       .000      Q/HY/AG                7.91     27.25     64.84
    CR    -                     AC      .000       .000      HY/OR/Q               27.10     65.04      7.86
    CU    -                     MT     2.493      3.417      OL/HY/OR                .00     29.41     70.59
    GA    -                     HM      .000       .000      Q/PL/OR                3.73     65.43     30.84
    HG    -                     WO      .000       .000      AG/HY/PL              28.09     11.80     60.11
    LI    -                     EN     7.045      6.403      OL/HY/PL                .00     16.41     83.59
    MN    -                     FS     1.593      1.904      Q/HY/PL                4.55     15.67     79.78
    MO    -                     Q      2.567      2.730      NE*/Q*/OL*            45.31     40.46     14.23
    NB    -                     DI    16.765     16.499      OL*/AG/Q*             20.44     64.84     14.72
    NI    -                     FO      .000       .000      OL*/PL/Q*             11.75     79.78      8.46 ADJUSTED FOR CORUNDUM
    PB    -                     FA      .000       .000      OR/PL/HY+Q            24.70     52.86     22.43
    RB    -                     NE      .000       .000      NE/AB+OR/NC1*           .00     62.72     37.28
    SB    -                     LC      .000       .000      AB/AN/NC1*            44.80     12.50     42.69
    SC    -                     KP      .000       .000      MG/MG+FE2             81.56
    SN    -                     HY     3.791      4.262      FE2/MG+FE2            18.44
    SR    -                     CC      .000       .000                        CATION %
    TI    -                     MU      .000       .000      FE3/FE2+FE3           34.85
    V     -                     NS      .000       .000      MG/FE2/NA+K           35.41     13.98     50.61
    Y     -                     KS      .000       .000      MG/FE2+FE3/NA+K       32.95     19.96     47.09
    ZN    -                     CR      .000       .000                        WEIGHT %
    ZR    -                     LH      .000       .000      A/F/M                 38.69     31.83     29.48

                         SALIC=  67.23  FEMIC=  32.77  NORMATIVE PLAGIOCLASE COMPOSITION=  21.82

DIFFERENTIATION INDEX= 57.63(MOLECULAR) 56.32(WEIGHT)  *COLOUR INDEX= 32.77(MOLECULAR) 34.00(WEIGHT)
  ,ROCK NAME - CALC-ALKALINE ANDESITE                              MASS ABSORPTION= 57.98549
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4. T-72- 87 , andesite ,Sunshine Lake.Fm.

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         ANALYSIS(WT%)       ALTERATIONS        CATION %
SIO2        59.2 A              62.2             57.5
AL2O3       14.2 A              14.9             16.3
FE2O3       5.50 A              2.31             1.61
FEO          .00                3.12             2.46
MGO         3.90 A              4.10             5.64
CAO         4.30 A              4.52             4.47
NA2O        3.24 A              3.40             6.10
K2O         4.42 A              4.64             5.48
TIO2         .70 A               .74              .51
P2O5         .00                 .00              .00
S            .00                 .00              .00
MNO          .06 A               .06              .00
CO2   L O I 4.46 C               .00              .00
H2O+         .00        CR2O3    .00              .00
H2O-         .00        NIO      .00              .00
TOTAL      100.0
SPEC. GR.

     TRACES(PPM)                  NORMS    MOLECULAR     WEIGHT                             NORM RATIOS(MOLECULAR)
      AG   -                        AP        .000         .000          OR/AB+5/3NE/AN      39.39     43.83     16.78
      AU   -                        PO        .000         .000          Q/AB/OR             13.64     45.49     40.88
      AS   -                        IL       1.022        1.397          NE/AB/OR              .00     52.67     47.33
      BA   -                        OR      27.403       27.465          LC/NE/OR              .00       .00    100.00
      BE   -                        AB      30.492       28.978          OL/OR/LC              .00    100.00       .00
      BI   -                        AN      11.677       11.701          OL/HY/AG              .00     52.10     47.90
      CO   -                        C         .000         .000          Q/HY/AG             33.66     34.46     31.88
      CR   -                        AC        .000         .000          HY/OR/Q+            20.29     59.77     19.94
      CU   -                        MT       2.411        3.351          OL/HY/CA              .00     25.34     74.66
      GA   -                        HM        .000         .000          Q/PL/OR             11.61     53.57     34.81
      HG   -                        WO        .000         .000          AG/HY/PL            14.25     15.50     70.26
      LI   -                        EN       7.732        6.990          OL/HY/PL              .00     18.07     81.93
      MN   -                        FS       1.570        1.665          Q/HY/PL             15.08     15.35     69.57
      MO   -                        Q        9.191        9.891          NE+/Q+/OL+          37.39     48.36     14.26
      NB   -                        DI       7.108        6.950          OL+/AG/Q+           25.64     31.68     42.48
      NI   -                        FO        .000         .000          OL+/PL/Q+           11.51     69.57     18.92 ADJUSTED FOR CORUNDUM
      PB   -                        FA        .000         .000          AG/PL/HY+Q           8.85     43.65     47.49
      RB   -                        NE        .000         .000          NE/AN+OR/NC1+         .00     73.12     26.88
      SB   -                        LC        .000         .000          AB/AN/NC1+          48.05     18.40     33.54
      SC   -                        KP        .000         .000          MG/MG+FE2           83.12
      SN   -                        HE       1.493        1.612          FE2/MG+FE2          16.88
      SR   -                        CC        .000         .000                            CATION %
      TI   -                        RU        .000         .000          FE3/FE2+FE3         40.00
      V    -                        NS        .000         .000          MG/FE2/NA+K         28.74     12.28     58.98
      Y    -                        KS        .000         .000          MG/FE2+FE3/NA+K     26.57     18.92     54.51
      TH   -                        CM        .000         .000                            WEIGHT %
      ZN   -                        LN        .000         .000          A/F/M               46.40     29.98     23.62

                              SALIC=  78.71  FEMIC=  21.29  NORMATIVE PLAGIOCLASE COMPOSITION=  27.69

DIFFERENTIATION INDEX= 67.04(MOLECULAR) 66.15(WEIGHT)  *COLOUR INDEX= 21.29(MOLECULAR) 22.19(WEIGHT)
    ROCK NAME - CALC-ALKALINE ANDESITE                                 MASS ABSORPTION= 53.62075)
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5. T-72-113 , trachybasalt, Sunshine Lake Fm.

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          ANALYSIS(WT%)      ALTERATIONS     CATION %
 SIO2         54.8 A             57.1          52.5
 AL2O3        17.5 A             18.2          19.7
 FE2O3        6.70 A             2.29          1.58
 FEO           .00               4.22          3.35
 MGO          2.90 A             3.02          4.19
 CAO          5.50 A             5.84          5.74
 NA2O         4.04 A             4.21          7.50
 K2O          4.10 A             4.27          5.01
 TIO2          .70 A              .73           .50
 P2O5          .00                .00           .00
 S             .00                .00           .00
 MNO           .09 A              .09           .00
 CO2   L O I  3.29 C              .00           .00
 H2O+          .00        CR2O3   .00           .00
 H2O-          .00        NIO     .00           .00
 TOTAL        99.7
 SPEC. GR.

     TRACES(PPM)              NORMS   MOLECULAR    WEIGHT                      NORM RATIOS(MOLECULAR)
      AG   -                   AP        .000        .000     OR/AB+5/3NE/AN     31.08     46.49     22.43
      AU   -                   PO        .000        .000     Q/AB/OR              .00     59.93     40.07
      AS   -                   IL       1.008       1.305     NE/AB/OR             .00     59.93     40.07
      BA   -                   OR      25.663      25.267     LC/NE/OR             .00       .00    100.00
      BE   -                   AB      37.403      35.613     OL/OR/LC            6.59     93.41       .00
      BI   -                   AN      10.009      10.231     OL/HY/AG           11.08     35.68     53.24
      CO   -                   C         .000        .000     Q/HY/AG              .00     40.13     59.87
      CR   -                   AC        .000        .000     HY/OR/Q            18.53     81.47       .00
      CU   -                   MT       2.377       3.323     OL/HY/OR            5.44     17.52     77.04
      GA   -                   HM        .000        .000     Q/PL/OR              .00     68.92     31.08
      HG   -                   WO        .000        .000     AG/HY/PL           12.19      8.17     79.64
      LI   -                   EN       3.031       3.469     OL/HY/PL            2.81      9.04     88.15
      MN   -                   FS       1.869       2.233     Q/HY/PL              .00      9.30     90.70
      MO   -                   Q         .000        .000     NE+/Q+/AL+         50.03     36.52     13.44
      NB   -                   DI       5.716       5.606     OL+/AG/Q+          37.84     53.24      8.92
      NI   -                   FO       1.169       1.010     OL+/PL/Q+           9.59     88.15      2.26 ADJUSTED FOR CORUNDUM
      PB   -                   FA        .509        .719     AG/PL/HY+Q         12.19     79.64      8.17
      RB   -                   NE        .000        .000     NE/AB+OR/NCI+        .00     76.37     23.63
      SB   -                   LC        .000        .000     AB/AN/NCI+         50.03     24.14     25.83
      SC   -                   KP        .000        .000     MG/MG+FE2          67.21
      SN   -                   HL       2.799       3.133     FE2/MG+FE2         32.79
      SR   -                   CC        .000        .000                     CATION %
      TH   -                   RU        .000        .000     FE3/FE2+FE3        32.84
      V    -                   NS        .000        .000     MG/FE2/NA+K        20.80     16.30     62.90
      Y    -                   KS        .000        .000     MG/FE2+FE3/NA+K    19.27     22.48     58.26
      ZN   -                   CR        .000        .000                     WEIGHT %
      ZR   -                   TN        .000        .000     A/F/M              47.69     35.32     16.99

                         SALIC=  80.64  FEMIC=  19.36  NORMATIVE PLAGIOCLASE COMPOSITION=  32.55

DIFFERENTIATION INDEX= 62.55(MOLECULAR) 60.88(WEIGHT)  *COLOUR INDEX= 19.36(MOLECULAR) 20.89(WEIGHT)
    ROCK NAME - TRACHYBASALT, POTASSIC ALKALIC SERIES                MASS ABSORPTION= 57.09417
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6. T-72-122 , andesite , Sunshine Lake Fm.

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        ANALYSIS(WT%)      ALTERATIONS      CATION %
SIO2       58.6 A             60.8           56.3
AL2O3      14.6 A             15.1           16.5
FE2O3      6.30 A             2.38           1.66
FEO         .00               3.73           2.96
MGO        3.40 A             3.53           4.87
CAO        5.50 A             5.70           5.66
NA2O       3.50 A             3.63           6.52
K2O        4.02 A             4.17           4.93
TIO2        .80 A              .83            .58
P2O5        .06                .00            .00
S           .00                .00            .00
MNO         .09 A              .09            .00
CO2  L.O.I. 1.95 C             .00            .00
H2O+        .00        CR2O3   .00            .00
H2O-        .00        NIO     .00            .00
TOTAL      98.8
SPEC. GR.

    TRACES(PPM)               NORMS   MOLECULAR    WEIGHT          NORM RATIOS(MOLECULAR)
     AG   -                    AP       .000        .000      OR/AB+5/3NE/AN    35.25    46.59    18.16
     AU   -                    PO       .000        .000      Q/AN/OR           11.33    50.48    38.19
     AS   -                    IL      1.155       1.576      NE/AB/OR            .00    56.93    43.07
     BA   -                    OR     24.658      24.669      LC/NE/OR            .00      .00   100.00
     BE   -                    AB     32.509      30.715      OL/OR/LC            .00   100.00      .00
     BI   -                    AN    12.702      12.701      OL/HY/AB            .00    34.60    65.40
     CO   -                    C        .000        .000      Q/HY/AE           27.71    25.01    47.27
     CR   -                    AC       .000        .000      HY/OR/Q           17.12    63.92    18.96
     CU   -                    MT      2.491       3.459      OL/HY/OR            .00    21.13    78.87
     GA   -                    TN       .000        .000      Q/PL/OR            9.47    58.62    31.91
     HG   -                    WO       .000        .000      AB/HY/PL          19.39    10.26    70.35
     LI   -                    EN      5.005       4.515      OL/HY/PL            .00    12.73    87.27
     MN   -                    FS      1.599       1.696      Q/HY/PL           12.36    11.15    76.49
     MO   -                    Q       7.316       7.900      NE*/Q*/OL*        42.04    47.31    10.65
     NB   -                    DI      9.459       9.204      OL*/AB/Q*         18.76    47.27    33.96
     NI   -                    FO       .000        .000      OL*/PL/Q*          8.37    76.49    15.14 ADJUSTED FOR CORUNDUM
     PB   -                    FA       .000        .000      AB/PL/HY+MO       13.33    48.37    38.31
     RB   -                    NE       .000        .000      NE/AB+OR/NCI*       .00    71.57    28.43
     SB   -                    LC       .000        .000      AB/AN/ACI*        47.91    18.67    33.42
     SC   -                    KP       .000        .000      MG/MG+FE2         75.78
     SN   -                    HE      3.023       3.370      FE2/MG+FE2        24.22
     SR   -                    CC       .000        .000                      CATION %
     TI   -                    RU       .000        .000      FE3/FE2+FE3       36.51
     V    -                    NS       .000        .000      MG/FE2/NA+K       25.34    15.05    59.61
     Y    -                    KS       .000        .000      MG/FE2+FE3/NA+K   23.32    21.02    55.66
     ZN   -                    CM       .000        .000                      WEIGHT %
     ZR   -                    LM       .000        .000      A/F/M             45.33    34.17    20.50

                        SALIC=  77.26  FEMIC=  22.74  NORMATIVE PLAGIOCLASE COMPOSITION=  28.05

DIFFERENTIATION INDEX= 64.56(MOLECULAR) 63.28(WEIGHT)  *COLOUR INDEX= 22.74(MOLECULAR) 24.02(WEIGHT)
   ROCK NAME - CALC-ALKALINE ANDESITE                           MASS ABSORPTION= 56.30375
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7. 72B-240 , basalt (Blackburn, 1976 and written communication) Sunshine Lake Fm.

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         ANALYSIS(WT%)      ALTERATION%    CATION %
SIO2          53.7 X            54.0          50.0
AL2O3         13.5 X            13.6          14.6
FE2O3         8.98 X            2.45          1.68
FEO            .00              6.04          4.01
MGO           9.03 )            9.21         12.53
CAO           6.15 )            6.27          6.14
NA2O          3.08 C            3.14          5.56
K2O           3.39 C            3.46          4.03
TIO2           .90 X             .92           .63
P2O5           .00               .00           .00
S              .00               .00           .00
F              .00 X             .00           .00
CO2            .00 C             .00           .00
H2O+           .00      CR2O3    .00           .00
H2O-           .00      MNO      .00           .00
TOTAL         98.7
SPEC. GR.
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   TRACES(PPM)         NORMS  MOLECULAR   WEIGHT                 NORM RATIOS(MOLECULAR)
    AG   -              AP      .000       .000   OR/AB+5/8NE/AN      33.03     43.56     23.41
    AU   -              PO      .000       .000   Q/AB/OR               .00     57.97     42.03
    AS   -              IL     1.261      1.745   NE/AB/OR              .00     57.97     42.03
    BA   -              OR    20.157     20.496   LC/NE/OR              .00       .00    100.03
    BE   -              AB    27.809     26.572   OL/OR/LC            32.20     67.80       .00
    BI   -              AN    13.061     13.247   OL/HY/AG            27.20     32.70     40.09
    CO   -              L       .000       .000   Q/HY/AG               .00     45.00     55.00
    CR   -              AC      .003       .000   HY/OP/Q             36.39     63.61       .00
    CU   -              MT     2.523      3.548   OL/HY/OR            23.20     27.79     48.85
    GA   -              HM      .000       .000   Q/PL/OR               .00     66.97     33.03
    LI   -              RU      .000       .000   AG/HY/PL            21.23     17.34     61.40
    LI   -              EN    -9.219      8.435   OL/HY/PL            15.45     13.61     65.91
    MN   -              FS     2.310      2.777   Q/HY/PL               .00     22.01     77.91
    MO   -              Q       .000       .000   HEM/Q+/OL+          34.11     28.63     37.26
    NI   -              DI    11.270     11.120   OL+/AG/Q+           51.77     40.09      8.19
    NI   -              FO     7.656      6.545   OL+/PL/Q+           29.49     61.44      9.05 ADJUSTED FOR CORUNDUM.
    PB   -              FA     1.910      2.375   AG/PL/HY+OL         21.20     61.46     17.35
    RB   -              NE      .000       .000   NE/AB+OR/LC+          .00     55.16     44.84
    SB   -              LC      .000       .000   AN/AB/NC+           34.02     16.36     48.62
    SC   -              KP      .000       .000   MG/MG+FE2           79.96
    SN   -              HE     2.824      3.192   FE2/MG+FE2          20.09
    SR   -              CC      .000       .000                  CATION %
    TE   -              MU      .000       .000   FE3/FE2+FE3         26.73
    V    -              NS      .000       .000   MG/FE2/NA+K         46.67     17.25     35.08
    Y    -              KS      .000       .000   MG/FE2+FE3/NA+K     44.10     22.14     33.76
    ZN   -              CH      .000       .000                  WEIGHT %
    ZR   -              CH      .000       .000   A/F/M               27.49     34.27     38.24

                         SALIC=  61.02  FEMIC=  38.98  NORMATIVE PLAGIOCLASE COMPOSITION=  31.97

DIFFERENTIATION INDEX= [illegible](MOLECULAR) 47.02(WEIGHT)  COLOUR INDEX= 38.90(MOLECULAR) 37.74(WEIGHT)
   ROCK TYPE - CALC-ALKALINE BASALT                                 MASS ABSORPTION= 01.59940
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8. 72B-220 , dacite (Blackburn, 1976 and written communication) Sunshine Lake Fm.

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         ANALYSIS(WT)       ALTERATIONS      CATION %
 SIO2      65.6 X              65.9            60.8
 AL2O3     15.6 X              15.9            17.3
 FE2O3     5.03 X              2.01            1.40
 FEO        .00                3.20            2.53
 MGO       3.01 X              3.07            4.16
 CAO       2.63 X              2.65            2.61
 NA2O      4.71 C              4.73            8.47
 K2O       2.01 C              2.02            2.39
 TIO2       .50 X               .50             .35
 P2O5       .00                 .00             .00
 S          .00                 .00             .00
 MNO        .00 X               .00             .00
 CO2        .00 C               .00             .00
 H2O+       .00                 .00             .00
 H2O-       .00        CR2O3    .00             .00
 TOTAL     99.9        NIO      .00             .00
 SPEC. GR.

      TRACES(PPM)             NORMS   MOLECULAR    WEIGHT
       AG   -                  AP        .000        .000
       AU   -                  PR        .000        .000
       AS   -                  IL        .697        .959
       BA   -                  OR      11.902      11.976      OR/AB+5/3NE/AN     17.60   62.90   19.41
       BE   -                  AB      42.330      40.690      Q/AB/OR            24.30   57.09   18.61
       BI   -                  AN      13.066      15.110      NE/AB/OR             .00   78.06   21.94
       CO   -                  C        1.193       1.029      LC/NE/OR             .00     .00  100.00
       CR   -                  AC        .000        .000      OL/OXT/LC            .00  100.00     .00
       CU   -                  MT       2.024       2.919      OL/HY/AQ             .00  100.00     .00
       GA   -                  HM        .000        .000      Q/HY/AQ            69.66   30.34     .00
       HG   -                  WO        .000        .000      HY/OR/Q            27.01   21.31   52.00
       LI   -                  EN       8.320       7.532      OL/HY/OR             .00   48.69   51.31
       MO   -                  FS       2.973       3.537      Q/PL/OR            20.56   65.40   14.05
       NB   -                  Q       17.415      18.065      AC/HY/PL             .00   16.93   83.07
       NI   -                  NE        .002        .000      OL/HY/PL             .00   16.93   83.07
       PB   -                  FO        .003        .000      Q/HY/PL            20.70   13.93   65.37
       RB   -                  FA        .000        .000      NE+/Q+/OL+         35.76   52.32   11.92
       SB   -                  LC        .000        .000      OL+/AG/Q+          49.50     .00   50.50
       SC   -                  KP        .000        .000      OL+/PL/Q+          10.66   66.58   22.76  ADJUSTED FOR CORUNDUM
       SN   -                  HL        .000        .000      AC/PL/HY+MG          .00   40.63   59.37
       SR   -                  CC        .000        .000      PL/AN+OR/NC1+        .00   79.39   20.61
       TI   -                  NS        .000        .000      AB/AN/NC1+         60.73   19.00   20.27
       V    -                  KS        .000        .000      MG/MG+FE2          73.67
       Y    -                  CM        .000        .000      FE2/MG+FE2         26.33
       ZN   -                  TH        .000        .000                        CATION %
       ZR   -                  LA        .000        .000      FE3/FE2+FE3        35.52
                                                               MG/FE2/NA+K        23.71   14.95   61.34
                                                               MG/FE2+FE3/NA+K    21.97   20.75   57.29
                                                                                 WEIGHT %
                                                               A/F/M              45.92   31.24   20.34

                         SALIC= 85.92  FEMIC= 14.08  NORMATIVE PLAGIOCLASE COMPOSITION= 23.60
 DIFFERENTIATION INDEX= 71.65(MOLECULAR) 70.73(WEIGHT)  COLOR INDEX= 14.00(MOLECULAR) 14.08(WEIGHT)
     ROCK NAME - CALC-ALKALIC DACITE                     MASS ABSORPTION= 51.0301
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9. 72B-166 , andesite (Blackburn, 1976 and written communication), Mafic Sill.

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        ANALYSIS(WT%)        ALTERATIONS     CATION %
SIO2       59.2  X              60.6           51.1
AL2O3      15.5  X              16.0           15.6
FE2O3      6.91  X              2.38           1.63
FEO        -.00  X              6.15           4.69
MGO        7.86  X              8.13          11.04
CAO        5.70  X              5.89           5.75
NA2O       4.03  C              4.17           7.36
K2O        2.41  C              2.49           2.90
TIO2        .80  X               .83            .57
P2O5        .00                  .00            .00
S           .00                  .00            .00
MNO         .00  X               .00            .00
CO2         .00  C               .00            .00
H2O+        .00                  .00            .00
H2O-        .00  O.    CR2O3     .00            .00
TOTAL      97.6        NIO       .00            .00
SPEC. GR.

   TRACES(PPM)                    NORMS   MOLECULAR   WEIGHT
    AG    -                        AP        .000       .000
    AU    -                        PO        .000       .000
    AS    -                        IL       1.134      1.570
    BA    -                        OR      14.501     14.734
    BE    -                        AB      36.008     35.243
    BI    -                        AN      11.829     12.016
    CO    -                        C         .000       .000
    CR    -                        AC        .000       .000
    CU    -                        MT       2.466      3.557
    GA    -                        HM        .000       .000
    HG    -                        RU        .000       .000
    LI    -                        EN      10.152      9.304
    MN    -                        FS       3.039      3.661
    MO    -                        Q         .000       .000
    NB    -                        OI      10.433     10.312
    NI    -                        FO       5.030      4.300
    PB    -                        FA       1.506      1.860
    RB    -                        NE        .000       .000
    SB    -                        LC        .000       .000
    SC    -                        KP        .000       .000
    SN    -                        HE       3.124      3.537
    SR    -                        CC        .000       .000
    TI    -                        WO        .000       .000
    V     -                        NS        .000       .000
    Y     -                        KS        .000       .000
    ZN    -                        CM        .000       .000
    ZR    -                        CH        .000       .000

                              NORM RATIOS(MOLECULAR)
      OR/AB+5/3NE/AN        22.97      66.30      10.73
      Q/AB/OR                 .00      71.74      28.26
      NE/AB/OR                .00      71.74      28.26
      LC/NE/OR                .00        .00     100.00
      OL/OR/LC              31.07      68.93        .00
      Q/HY/AG               19.64      39.63      40.73
      Q/HY/AG                 .00      49.32      50.68
      HY/OL/Q               47.64      52.36        .00
      OL/HY/OR              19.10      38.54      42.37
      Q/PL/OR                 .00      77.03      22.97
      AG/HY/PL              17.98      17.50      64.52
      OL/HY/PL               9.56      19.30      71.14
      Q/HY/PL                 .00      21.34      78.66
      NE+/OL+/QL+           39.06      31.88      29.06
      OL+/AG/QL             49.36      40.73       9.91
      OL+/PL/Q              24.03      71.19       4.82  ADJUSTED FOR CORUNDUM
      AG/AN/HY+             17.98      64.52      17.50
      DI/AB+OR/HC+            .00      58.19      41.81
      AB/AN/HC+             43.05      13.83      43.11
      MG/MG+FE2             76.96
      FE2/MG+FE2            23.04
                           CATION %
      FE3/FE2+FE3           25.01
      MG/FE2/NA+K           42.47      18.05      39.47
      MG/FE2+FE3/NA+K       39.97      22.88      37.16
                           WEIGHT %
      A/F/M                 28.80      35.92      35.27

                 SALIC=  63.19  FEMIC=  36.86  NORMATIVE PLAGIOCLASE COMPOSITION=  24.72
DIFFERENTIATION INDEX=  50.51(MOLECULAR)  49.98(WEIGHT)  *COLOR INDEX=  36.06(MOLECULAR)  36.01(WEIGHT)
   ROCK NAME - CALC-ALKALIC ANDESITE                         MASS ABSORPTION=  29.99503
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10. 72B-156 , andesite (Blackburn, 1976 and written communication) Mafic Sill.

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        ANALYSIS(TOTAL)    ALTERATIONS    CATION %
SIO2      57.54 X             61.9         55.5
AL2O3     17.0  X             17.3         19.6
FE2O3      7.57 X              2.39         1.81
FEO         .00                4.02         3.69
MGO        4.33 X              4.40         6.01
CAO        4.57 X              4.64         4.56
NA2O       4.51 C              4.70         8.19
K2O        2.75 C              2.79         3.27
TIO2        .00 X               .81          .56
P2O5        .00                 .00          .00
S           .00                 .00          .00
MNO         .00 X               .00          .00
CO2         .00 C               .00          .00
H2O+        .00      CH/O3      .00          .00
H2O-        .00      H2O        .00          .00
TOTAL     99.0
SPEC. GR.

  TRACES(PPM)            NORMS    MOLECULAR    WEIGHT     NORM RATIOS(MOLECULAR)
   AG   -                 AP        .000        .000      OR/AB+5/3AN/AN      21.75    59.15    19.10
   AU   -                 PO        .000        .000      Q/AB/OR              9.06    64.02    27.32
   AS   -                 IL       1.120       1.593      NE/AB/OR              .00    71.34    28.66
   BA   -                 OR      16.395      16.514      LC/NE/OL              .00      .00   100.00
   BE   -                 AB      40.696      38.736      OL/CH/LC              .00   100.00      .00
   BI   -                 AN      18.104      18.290      CL/HY/AG              .00    79.80    20.20
   CO   -                 C         .000        .000      Q/HY/AG             13.07    69.37    17.56
   CR   -                 AC        .000        .000      HY/OL/Q             45.60    40.16     8.21
   CU   -                 DI       2.516       4.306      CL/HY/OH              .00    47.51    52.49
   GA   -                 WO        .000        .000      Q/PL/OR              3.57    75.45    20.97
   HG   -                 HO        .000        .000      AG/HY/PL             4.04    19.13    76.83
   LI   -                 EN      10.663       9.717      OL/HY/PL              .00    20.10    79.90
   MN   -                 FS       4.129       4.599      Q/HY/PL              3.05    17.37    79.58
   MO   -                 Q        2.706       3.039      AB+/Q+/CL+          41.90    39.06    19.04
   NB   -                 OL       2.699       2.653      OL+/AG/Q+           52.03    17.56    30.41
   NI   -                 FO        .000        .000      OL+/PL/Q+           19.53    79.57     0.90 ADJUSTED FOR CORUNDUM
   PB   -                 FA        .000        .000      AG/PL/HY+AC          9.23    60.46    30.31
   RB   -                 NE        .000        .000      IK/AN+OR/NC+          .00    72.10    27.90
   SB   -                 LC        .000        .000      AB/AN/NC+           50.32    22.39    27.29
   SC   -                 KP        .000        .006      MG/MG+FE2           72.09
   SN   -                 MT       1.055       1.177      FE2/MG+FE2          27.91
   SR   -                 CC        .000        .000                      CATION %
   TH   -                 HU        .000        .000      FE3/FE2+FE3         30.38
   V    -                 NS        .000        .000      MG/FE2/NA+K         23.46    17.49    59.05
   Y    -                 KS        .000        .000      MG/FE2+FE3/NA+K     26.44    23.34    50.22
   ZN   -                 CS        .000        .000                      WEIGHT %
   ZR   -                 LN        .000        .000      A/F/M               39.45    37.02    23.53

               SALIC= 77.93  FEMIC= 22.07  NORMATIVE PLAGIOCLASE COMPOSITION= 30.80

DIFFERENTIATION INDEX= 57.42(MOLECULAR) 56.29(WEIGHT)  [illegible] INDEX= 22.07(CATION) 47.92(WEIGHT)
  ROCK NAME - CALC-ALKALINE ANDESITE
         HIGH ALUMINA                                 MASS ABSORPTION= 57.21
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11. 72B-238 , andesite (Blackburn, 1976 and written communication) Mafic Sill,

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        ANALYSIS(WT%)     ALTERATIONS   CATION %
SIO2      59.0 X             60.15        55.2
AL2O3     14.2 X             14.3         15.4
FE2O3     6.00 X             2.31         1.00
FEO        .00               5.35         2.57
MGO       5.67 X             5.70         7.80
CAO       5.01 X             5.84         5.75
NA2O      3.66 C             3.60         6.55
K2O       3.05 C             3.07         4.54
TIO2       .80 X              .80          .56
P2O5       .00                .00          .00
S          .00                .00          .00
MNO        .00 X              .00          .00
CO2        .00 C              .04          .00
H2O-       .00        CR2O3   .00          .00
H2O+       .00        NIO     .00          .00
TOTAL     99.8
SPEC. GR.  -

    TRACES(PPM)         NORMS  MOLECULAR  WEIGHT                         NORM RATIOS(MOLECULAR)
     AG    -            AP      .000       .000    OR/AB+S/NE/AN        34.21    49.36    16.43
     AU    -            PO      .000       .000    Q/AB/OR               8.26    51.19    37.55
     AS    -            IL     1.111      1.520    NE/AB/OR               .00    59.07    40.93
     BA    -            OR    22.692     22.906    LC/NE/OR               .00      .00   100.00
     BE    -            AB    32.746     31.147    LC/OR/LC               .00   100.00      .00
     BI    -            AN    10.903     11.002    OL/HY/AG               .00    43.32    50.68
     CO    -            C       .000       .000    Q/HY/AG              16.55    36.15    47.30
     CR    -            AC      .000       .000    HY/OR/Q              20.25    50.02    12.93
     CU    -            MT     2.396      3.354    OL/HY/OR               .00    32.45    67.55
     GA    -            HM      .000       .000    Q/PL/OR               7.00    61.19    31.81
     HG    -            WO      .000       .000    AG/HY/PL             20.73    15.64    63.63
     LI    -            EN     9.430      8.580    OL/HY/PL               .00    19.98    60.02
     MO    -            FS     1.470      1.759    Q/HY/PL               6.30    10.31    73.31
     NB    -            Q      4.990      5.436    NE+/Q+/OL+           90.40    92.79    16.01
     NI    -            DI    12.339     12.110    OL+/AG/Q+            27.11    47.30    25.59
     NB    -            FO      .000       .000    OL+/PL/Q+            13.73    73.31    12.96 ADJUSTED FOR CORUNDUM
     PB    -            FA      .000       .006    AG/PL/DI+HG          16.67    49.17    34.76
     RB    -            NE      .000       .000    NE/AB+OR/AC+         .00      65.91    39.09
     SB    -            LC      .000       .000    AB/AN/AC+            45.20    19.96    39.04
     SC    -            KP      .000       .000    MG/MG+FE2            86.51
     SN    -            HE     1.927      2.164    FE2/MG+FE2           13.49
     SR    -            CC      .000       .000                     CATION %
     TI    -            NO      .000       .000    FE3/FE2+FE3          30.33
     V     -            KS      .000       .000    MG/FE2/ALK           50.35    11.90    51.00
     Y     -            AS      .000       .000    MG/FE2+FE3/ALK       33.63    13.06    90.60
     ZN    -            LA      .000       .000                     WEIGHT %
     ZR    -            LN      .000       .000    A/F/M                50.42    23.00    30.52

                 SALIC=  71.33  FEMIC=  28.67  NORMATIVE PLAGIOCLASE COMPOSITION=  24.05

DIFFERENTIATION INDEX= 60.45(MOLECULAR) 59.59(WEIGHT)   COLOR INDEX= 28.67(MOLECULAR) 29.51(WEIGHT)
    ROCK NAME - CALC-ALKALINE ANDESITE                       MASS ABSORPTION= 56.33269
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12. T-72-232 , dacitic lithic tuff

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         ANALYSIS(WT%)      ALTERATIONS      CATION %
SIO2         66.2 A             68.5           63.4
AL2O3        16.2 A             16.8           18.3
FE2O3        2.90 A             2.17           1.51
FEO          /.00                .74            .61
MGO          1.40 A             1.45           2.00
CAO          2.70 A             2.79           2.77
NA2O         4.31 A             4.46           8.01
K2O          2.41 A             2.49           2.95
TIO2          .60 A              .62            .43
P2O5          .00                .00            .00
S             .00                .00            .00
MNO           .04 A              .04            .00
CO2   LOI    2.07 C              .00            .00
H2O+          .00       CR2O3    .00            .00
H2O-          .00       NIO      .00            .00
TOTAL        98.8
SPEC. GR.

    TRACES(PPM)            NORMS   MOLECULAR   WEIGHT                          NORM RATIOS(MOLECULAR)
     AG    -                AP        .000       .000     CA/AB+5/3NE/AN     21.48    58.32    20.19
     AU    -                PO        .000       .000      Q/AB/OR           29.59    51.46    18.95
     AS    -                IL        .865      1.179      NE/AB/OR            .00    73.08    26.92
     BA    -                OR      14.745     14.745      LC/NE/OR            .00      .00   100.00
     BE    -                AB      40.028     37.718      OL/OR/LC            .00   100.00      .00
     BI    -                AN      13.859     13.055      OL/HY/AG            .00   100.00      .00
     CO    -                C        1.796      1.645      Q/HY/AG           85.20    14.80      .00
     CR    -                AC        .000       .000      HY/OR/Q            9.57    35.31    55.12
     CU    -                MT        .531       .736      OL/HY/OR            .00    21.33    78.67
     GA    -                HM       1.160      1.669      Q/PL/OR           25.12    58.80    16.09
     NB    -                WO        .000       .000      AG/HY/PL            .00     6.91    93.09
     LI    -                EN       3.990      5.606      OL/HY/PL            .00     6.91    93.09
     MN    -                FS        .000       .000      Q/HY/PL           28.45     4.94    66.61
     MO    -                Q       23.019     24.851      NE+/OR/OL+        35.82    59.71     4.47
     NB    -                OL        .000       .000      OL+/AG/OR+        11.10      .00    88.90
     NI    -                FO        .000       .000      OL+/PL/OR+         5.04    67.65    27.31 ADJUSTED FOR CORUNDUM
     PB    -                FA        .000       .000      AG/PL/HY+MQ         .00    35.93    64.07
     RB    -                NE        .000       .000      NE/AB+OR/MCI+       .00    89.31    10.69
     SB    -                LC        .000       .000      AB/AN/MCI+        66.23    22.93    10.84
     SC    -                KP        .000       .000      MG/MG+FE2        100.00
     SN    -                HL        .000       .000      FE2/MG+FE2          .00
     SR    -                CC        .000       .000                      CATION %
     TI    -                RU        .000       .000      FE3/FE2+FE3       72.41
     V     -                NS        .000       .000      MG/FE2/NA+K       14.77     4.26    80.96
     Y     -                KS        .000       .000      MG/FE2+FE3/NA+K   13.29    13.90    72.81
     ZN    -                CM        .000       .000                      WEIGHT %
     ZR    -                EN        .000       .000      A/F/M             62.63    24.32    13.05

                          SALIC=  93.45  FEMIC=   6.55  NORMATIVE PLAGIOCLASE COMPOSITION=  25.72

DIFFERENTIATION INDEX= 77.79(MOLECULAR) 77.31(WEIGHT)  *COLOUR INDEX=  6.55(MOLECULAR)  7.19(WEIGHT)
    ROCK NAME - CALC-ALKALINE.DACITE
               *HIGH ALUMINA*                                 MASS ABSORPTION= 45.21634
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13.  T-72-118 , andesitic tuff

           ANALYSIS(WT%)     ALTERATIONS       CATION %
SIO2          61.8 A             63.1            50.4
AL2O3         15.2 A             15.5            16.9
FE2O3         7.20 A             2.25            1.56
FEO            .00               4.59            3.62
MGO           4.10 A             4.19            5.78
CAO           3.20 A             3.27            3.24
NA2O          3.95 A             4.03            7.24
K2O           2.25 A             2.30            2.72
TIO2           .70 A              .71             .50
P2O5           .00                .00             .00
S              .00                .00             .00
MNO            .08 A              .08             .00
CO2  LOI      2.55 C              .00             .00
H2O+           .00       CR2O3    .00             .00
H2O-           .00       NIO      .00             .00
TOTAL        101.0
SPEC. GR.

     TRACES(PPM)                 NORMS   MOLECULAR    WEIGHT                 NORM RATIOS(MOLECULAR)
      AG   -                      AP        .000        .000     OR/AB+S/3NE/AN      20.58     54.85     24.56
      AU   -                      PO        .000        .000     Q/AN/OR             21.90     56.79     21.31
      AS   -                      IL        .995       1.357     NE/AB/OR              .00     72.71     27.29
      BA   -                      OR      13.580      13.583     LC/NE/OR              .00       .00    100.00
      BE   -                      AB      36.191      34.109     OL/OR/LC              .00    100.00       .00
      BI   -                      AN      16.204      16.203     OL/HY/AG              .00    100.00       .00
      CO   -                      C         .498        .456     Q/HY/AG             46.22     53.78       .00
      CR   -                      AC        .000        .000     HY/OR/Q             37.09     31.03     31.88
      CU   -                      MT       2.347       3.256     OL/HY/OR              .00     54.45     45.55
      GA   -                      HM        .000        .000     Q/PL/OR             17.46     65.55     16.99
      HG   -                      WO        .000        .000     AG/HY/PL              .00     23.65     76.35
      LI   -                      EN      11.551      10.421     OL/HY/PL              .00     23.65     76.35
      MN   -                      FS       4.681       5.549     Q/HY/PL             16.90     19.66     63.45
      MO   -                      Q       13.952      15.666     NE*/Q*/OL*          32.71     48.94     18.34
      NB   -                      OL        .000        .000     OL*/AG/Q*           40.33       .00     59.67
      NI   -                      FO        .000        .000     OL*/PL/Q*           14.92     63.80     21.27 ADJUSTED FOR CORUNDUM
      PB   -                      FA        .000        .000     AG/PL/HY+MO           .00     42.11     57.89
      RB   -                      NE        .000        .000     NE/AB+OR/NCT*         .00     71.77     28.23
      SB   -                      LC        .000        .000     AB/AN/NCT*          50.29     22.52     27.20
      SC   -                      KP        .000        .000     MG/MG+FE2           71.16
      SN   -                      HL        .000        .000     FE2/MG+FE2          28.84
      SR   -                      CC        .000        .000                      CATION %
      TH   -                      RU        .000        .000     FE3/FE2+FE3         30.56
      V    -                      NS        .000        .000     MG/FE2/NA+K         29.95     18.44     51.61
      Y    -                      KS        .000        .000     MG/FE2+FE3/NA+K     27.70     24.56     47.74
      ZN   -                      CS        .000        .000                      WEIGHT %
      ZR   -                      LN        .000        .000     A/F/M               36.95     38.61     24.44

                        SALIC=  80.43  FEMIC=  19.57  NORMATIVE PLAGIOCLASE COMPOSITION=  30.93

DIFFERENTIATION INDEX= 63.72(MOLECULAR) 62.76(WEIGHT)   *COLOUR INDEX= 19.57(MOLECULAR) 20.58(WEIGHT)
    ROCK NAME - CALC-ALKALINE ANDESITE                               MASS ABSORPTION= 55.11739
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14. T-72- 12 , andesitic tuff

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           ANALYSIS(WT%)       ALTERATIONS      CATION %
SIO2          63.6 A              65.8            60.7
AL2O3         15.5 A              16.0            17.4
FE2O3         4.10 A              2.07            1.44
FEO            .00                1.96            1.55
MGO           2.90 A              3.00            4.12
CAO           3.50 A              3.62            3.58
NA2O          4.31 A              4.46            7.97
K2O           2.33 A              2.41            2.89
TIO2           .50 A               .52             .36
P2O5           .00                 .00             .00
S              .00                 .00            7.00
MNO            .05 A               .05             .00
CO2  L.O.I.  3.00 C                .00             .00
H2O+           100      CR2O3      .00             .00
H2O-           .00      NIO        .00             .00
TOTAL         99.6
SPEC. GR.

    TRACES(PPM)                  NORMS   MOLECULAR    WEIGHT
     AG   -                       AP       .000        .000        OR/AB+5/3NE/AN     20.11     56.45     23.44
     AU   -                       PO       .000        .000        Q/AB/OR            23.67     56.28     20.04
     AS   -                       IL       .718        .983        NE/AB/OR             .00     73.74     26.26
     BA   -                       OR     14.200      14.270        LC/NE/OR             .00       .00    100.00
     BE   -                       AB     39.674      37.757        OL/OR/LC             .00    100.00       .00
     BI   -                       AN     16.555      16.651        OL/HY/AG             .00     88.97     11.03
     CO   -                       C        .000        .000        Q/HY/AG            63.28     32.67      4.05
     CR   -                       AC       .000        .000        HY/OR/Q            21.85     35.84     42.32
     CU   -                       MT      2.155       3.002        OL/HY/OR             .00     37.87     62.13
     GA   -                       HM       .000        .000        Q/PL/OR            19.19     64.57     16.25
     HG   -                       WO       .000        .000        AG/HY/PL            1.62     13.08     85.29
     LI   -                       EN      7.768       7.041        OL/HY/PL             .00     13.30     86.70
     MN   -                       FS       .888       1.058        Q/HY/PL            20.49     10.58     68.94
     MO   -                       Q      16.769      18.192        NE+/OR+/OL+        36.64     53.42      9.94
     NB   -                       DI       .963        .992        OL+/AG/Q+          24.50      4.05     71.45
     NI   -                       FO       .000        .000        OL+/PL/Q+           7.93     68.94     23.13 ADJUSTED FOR CORUNDUM
     PB   -                       FA       .000        .000        AG/PL/HY+Q           .01     42.35     56.84
     RB   -                       NE       .000        .000        NE/AB+OR/NCI+        .00     81.10     19.90
     SB   -                       LC       .000        .000        AN/AN/NCI+         57.76     23.98     18.26
     SC   -                       KP       .000        .030        MG/MG+FE2          89.74
     SN   -                       HL       .110        .123        FE2/MG+FE2         10.26
     SR   -                       CC       .000        .000                       CATION %
     TH   -                       RU       .000        .000        FE3/FE2+FE3        40.78
     V    -                       NS       .000        .000        MG/FE2/NA+K        25.08      9.17     65.75
     Y    -                       KS       .000        .000        MG/FE2+FE3/NA+K    23.06     16.47     60.47
     ZN   -                       CR       .000        .000                       WEIGHT %
     ZR   -                       LN       .000        .000        A/F/M              50.19     27.89     21.92

                             SALIC=  87.40  FEMIC=  12.60  NORMATIVE PLAGIOCLASE COMPOSITION=  29.34

DIFFERENTIATION INDEX= 70.84(MOLECULAR) 70.22(WEIGHT)  *COLOUR INDEX= 12.60(MOLECULAR) 13.15(WEIGHT)
    ROCK NAME - CALC-ALKALINE ANDESITE
             *HIGH ALUMINA*                                  MASS ABSORPTION= 98.27368
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                         CIPW NORM CALCULATION OF NORMALIZED RESULTS
15. UT-73-17, andesitic tuff,  Cano Lake Fm.
                              THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
  SIO2      TIO2     AL2O3     FE2O3      FEO       MNO       MGO       CAO       NA2O      K2O       P2O5      CO2       SUM
 65.050     .560    15.270     7.019     [illegible]  .330    2.160     3.240     [illegible]  2.444    .[illegible]  ----    100.010
                                               MOLECULAR PROPORTIONS
 1.0827    .0066    .1498     .0441     [illegible]  .0011     .0585     .0578     .0626     .0259     .0007    0.0000
                                          C.I.P.W. NORM (IN WEIGHT PERCENT)
CALCITE                  0.000          MAGNESITE                 0.000          SIDERITE                  0.000
SODIUM CARBONATE         0.000          POTASSIUM CARBONATE       0.000          TOTAL DIOPSIDE            [illegible]
APATITE                   .[illegible]  ALBITE                   32.[illegible]    DIOPSIDE (WO)          [illegible]
ILMENITE                  .[illegible]  ANORTHITE                15.[illegible]    DIOPSIDE (EN)          [illegible]
SPHENE                   1.[illegible]  CORUNDUM                  1.[illegible]    DIOPSIDE (FS)          [illegible]
RUTILE                   [illegible]    MAGNETITE                 [illegible]    TOTAL HYPERSTHENE        [illegible]
K2-METASILICATE          [illegible]    HEMATITE                  7.[illegible]    ENSTATITE              [illegible]
HALITE                   [illegible]    QUARTZ                   23.[illegible]    FERROSILITE            [illegible]
LEUCITE                  [illegible]    TOTAL OLIVINE             [illegible]    WOLLASTONITE             [illegible]
ORTHOCLASE               15.[illegible]   FORSTERITE              [illegible]    ACMITE                   [illegible]
NA-METASILICATE          [illegible]      FAYALITE                [illegible]
NEPHELINE                0.000            CA-ORTHOSILICATE        0.000
                                             SUM          [illegible]
TOTAL FEMIC CONTENT =       9.398   TOTAL ALKALI CONTENT =    6.370   TOTAL IRON CONTENT =    7.010
DIFFERENTIATION INDEX =    70.555   SOLIDIFICATION INDEX =   16.072   MAFIC INDEX =     74.067   FELSIC INDEX =  66.109
MAFIC-FELSIC INDEX =       78.[illegible]   ALKALIC INDEX =          [illegible]   LARSEN INDEX =   10.527
ALBITE RATIO (CIPW) =        .7[illegible]   ALBITE RATIO (NIGGLI) =    .675.   IRON INDEX =       7.22[illegible]   CRYSTALLIZATION INDEX = [illegible]
RITTMANN SIGMA =    1.[illegible]  SO THE ROCK IS IN THE PACIFIC SUITE
             IRON, MAGNESIUM AND ALKALIES SUMMED TO 100% FOR THE DIAGRAMS
        TOTAL IRON =   [illegible]   TOTAL MAGNESIUM =       15.[illegible]   TOTAL ALKALIES = [illegible]
                                          NIGGLI NUMBERS
AL = [illegible]  FM = [illegible]  C = [illegible]  ALK = [illegible]  SI = [illegible]  TI = [illegible]  K = [illegible]  QZ = [illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT, = [illegible]   DEGREE OF SI SATURATION = [illegible]  DEGREE OF ACIDITY =   [illegible]
                                       PARAMETER CHARACTERISTICS
SMALL A = [illegible]  SMALL C = [illegible]  SMALL F = [illegible]  SMALL B = [illegible]  SMALL S = [illegible]  Q = [illegible]
[illegible]   SMALL K = [illegible]
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =  71.65[illegible]   II =   7.560   CI =  [illegible]

      PERALKALINITY  INDEX  =  .6
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16. OT-74- 15 , andesitic tuff

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          ANALYSIS(WT%)     ALTERATIONS    CATION %
SIO2       62.6 A             65.7          60.0
AL2O3      15.3 A             16.1          17.5
FE2O3      3.70 A             2.10          1.46
FEO         .00               1.61          1.37
MGO        2.90 A             3.09          4.20
CAO        3.90 A             4.09          4.06
NA2O       3.68 A             3.86          6.93
K2O        2.65 A             2.78          3.29
TIO2        .50 A              .52           .37
P2O5        .00                .00           .00
S           .00                .00           .00
MNO         .16 A              .17           .00
CO2  L.O.I. 4.60 C             .00           .00
H2O+        .00        CR2O3   .00           .00
H2O-        .00        NIO     .00           .00
TOTAL     100.1
SPEC. GR.

     TRACES(PPM)            NORMS  MOLECULAR   WEIGHT                       NORM RATIOS(MOLECULAR)
      AG   -                 AP      .000       .000      OR/AB+5/3NE/AN     23.71    49.97    26.32
      AU   -                 PO      .000       .000      Q/AN/OR            26.02    50.18    23.80
      AS   -                 IL      .731       .997      NE/AB/OR             .00    67.82    32.18
      BA   -                 OR    16.437     16.461      LC/NE/OR             .00      .00   100.00
      BE   -                 AB    34.250     32.698      OL/OR/LC             .00   100.00      .00
      BI   -                 AN    18.230     18.271      OL/HY/AG             .00    83.25    16.75
      CO   -                 C       .000       .000      Q/HY/AG            64.78    29.32     5.90
      CR   -                 AC      .000       .000      HY/OR/Q            19.12    38.64    42.24
      CU   -                 MT     2.193      3.055      OL/HY/OR             .00    33.10    66.90
      GA   -                 HM      .000       .000      Q/PL/OR            20.58    60.59    18.83
      HG   -                 WO      .000       .000      AG/HY/PL            2.61    12.93    84.46
      LI   -                 EN     7.623      6.891      OL/HY/PL             .00    13.33    86.67
      MN   -                 FS      .505       .600      Q/HY/PL            22.74    10.30    66.96
      MO   -                 Q     17.969     19.427      NE*/Q*/OL*         34.22    55.74    10.04
      NB   -                 DI     1.535      1.495      OL*/AG/Q*          21.99     5.90    72.11
      NI   -                 FO      .000       .000      OL*/PL/Q*           7.72    66.96    25.32 ADJUSTED FOR CORUNDUM
      PB   -                 FA      .000       .000      AG/PL/HY+MG         1.22    39.32    59.47
      RB   -                 NE      .000       .000      NE/AN+OR/NC*         .00    80.10    19.90
      SB   -                 LC      .000       .000      AB/AN/NC*          52.83    27.82    19.35
      SC   -                 KP      .000       .000      MG/MG+FE2          93.79
      SN   -                 HE      .102       .113      FE2/MG+FE2          6.21
      SR   -                 CC      .000       .000                     CATION %
      TI   -                 RU      .000       .000      FE3/FE2+FE3        59.65
      V    -                 NS      .000       .000      MG/FE2/NA+K        26.81     7.94    65.25
      Y    -                 KS      .000       .000      MG/FE2+FE3/NA+K    24.52    15.80    59.68
      ZN   -                 CM      .000       .000                     WEIGHT %
      ZR   -                 LN      .000       .000      A/F/M              50.40    26.51    23.09

                           SALIC=  87.31  FEMIC=  12.69  NORMATIVE PLAGIOCLASE COMPOSITION=  34.50

DIFFERENTIATION INDEX= 69.06(MOLECULAR) 68.59(WEIGHT)  *COLOUR INDEX= 12.69(MOLECULAR) 13.14(WEIGHT)
    ROCK NAME - CALC-ALKALINE ANDESITE
              *HIGH ALUMINA*                             MASS ABSORPTION= 40.03833
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17. T-73- 25 , dacitic lithic-crystal tuff , Cano Lake Fm.

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                              CIPW NORM CALCULATION OF NORMALIZED RESULTS
                              THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2      TIO2     AL2O3     FE2O3     FEO      MNO      MGO      CAO      NA2O     K2O      P2O5     CO2      SUM
71.170     .310    14.500     1.090    0.000     .060    2.280    2.980    2.450    3.590     .150     ----   100.000

1.1844     .0165    .1422     .0191    MOLECULAR PROPORTIONS
                                       0.0000    .0560   .0565    .0357    .0452    .0381    .0011   0.0000
                              C.I.P.W. NORM (IN WEIGHT PERCENT)
CALCITE                [illegible]   MAGNESITE                0.000                SIDERITE               0.000
SODIUM CARBONATE       [illegible]   POTASSIUM CARBONATE      [illegible]          TOTAL DIOPSIDE         [illegible]
APATITE                [illegible]   ALBITE                   2[illegible]         DIOPSIDE (WO)          [illegible]
ILMENITE               [illegible]   ANORTHITE                [illegible]          DIOPSIDE (EN)          [illegible]
SPHENE                 [illegible]   CORUNDUM                 [illegible]          DIOPSIDE (FS)          [illegible]
RUTILE                 [illegible]   MAGNETITE                [illegible]          TOTAL HYPERSTHENE      [illegible]
K-METASILICATE         0.000         HEMATITE                 [illegible]          ENSTATITE              [illegible]
KALIOPHILITE           [illegible]   QUARTZ                   3[illegible]         FERROSILITE            [illegible]
LEUCITE                0.000         TOTAL OLIVINE            [illegible]          WOLLASTONITE           [illegible]
ORTHOCLASE             21.216        FORSTERITE               [illegible]          ACMITE                 0.000
NA-METASILICATE        [illegible]   FAYALITE                 [illegible]
NEPHELINE              [illegible]   CA-ORTHOSILICATE         [illegible]
                                     SUM                    100.001
TOTAL FEMIC CONTENT =      5.370   TOTAL ALKALI CONTENT =   6.390   TOTAL IRON CONTENT =   1.330
DIFFERENTIATION INDEX =   73.011   SOLIDIFICATION INDEX =  19.380   MAFIC INDEX =   57.542   FELSIC INDEX =  76.182
MAFIC-FELSIC INDEX =      66.852   ALKALIC INDEX =                56.142   LARSEN INDEX =   23.031
ALBITE RATIO (CIPW) =       .749   ALBITE RATIO (NIGGLI) =          .645   IRON INDEX=             1.215 , CRYSTALLIZATION INDEX = 1[illegible]
RITTMANN-SIGMA =   1.45   SO THE ROCK IS IN THE PACIFIC SUITE
            IRON,MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
            TOTAL IRON =   26.276   TOTAL MAGNESIUM =   17.148   TOTAL ALKALIES = 56.[illegible]
AL = [illegible]  FM = [illegible]  C = [illegible]  ALK = [illegible]   NIGGLI NUMBERS
ORDINATE FOR THE FELSPAR VARIATION PLOT, [illegible]   .14   SI = [illegible]  DEGREE OF SI SATURATION = [illegible]  K = [illegible]  MG = [illegible]  DEGREE OF ACIDITY =   .77
                              ZAVARITSKY CHARACTERISTICS
SMALL A = [illegible], SMALL C = [illegible], SMALL B = [illegible], SMALL S = [illegible], Q = [illegible]
[illegible]                                                                         SMALL N = 56.2499
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =   83.919   II =   3.419   CI =   12.662

PERALKALINITY INDEX = .56
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                              CIPW NORM CALCULATION OF NORMALIZED RESULTS
18.  T-72-119 , andonitic tuff , Cono Lake Fm.
                                   THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2     TIO2    AL2O3    FE2O3    FEO      MNO     MGO      CAO      NA2O     K2O      P2O5     CO2      SUM
63.3[illegible]  .5[illegible]  15.5[illegible]  5.35[illegible]  0.000  .1[illegible]  3.220  3.160  3.35[illegible]  2.600  .220  ----  100.000

                                        MOLECULAR PROPORTIONS
1.0[illegible]  .00[illegible]  .15[illegible]  .0335  0.0000  .00[illegible]  .0797  .0563  .0542  .0276  .0015  0.0000
                                  C.I.P.W. NORM IN WEIGHT PERCENTS

CALCITE                 0.000        MAGNESITE              0.000        SIDERITE               0.000
SODIUM CARBONATE        0.000        POTASSIUM CARBONATE    0.000
APATITE                  .5[illegible]        ALBITE                28.4[illegible]        TOTAL DIOPSIDES        0.000
ILMENITE                 .[illegible]        ANORTHITE             1[illegible]           DIOPSIDE (WO)          0.000
[illegible]              [illegible]        CORUNDUM              [illegible]            DIOPSIDE (EN)          0.000
RUTILE                  [illegible]        MAGNETITE             0.[illegible]          DIOPSIDE (FS)          0.000
[illegible]             [illegible]        HEMATITE              [illegible].35[illegible]  TOTAL HYPERSTHENE   [illegible]
[illegible]             [illegible]        QUARTZ                25.4[illegible]          ENSTATITE           [illegible]
LEUCITE                 [illegible]        TOTAL OLIVINE          0.3[illegible]          FERROSILITE            0.000
ORTHOCLASE             15.[illegible]        FORSTERITE             0.0[illegible]          WOLLASTONITE           0.000
NA-METASILICATE         0.000        FAYALITE               0.000        ACMITE                 0.000
NEPHELINE               0.000        CA-ORTHOSILICATE       0.000
                                       SUM          100.00[illegible]
TOTAL FEMIC CONTENT =      8.570   TOTAL ALKALI CONTENT =   5.960   TOTAL IRON CONTENT =   5.35[illegible]
DIFFERENTIATION INDEX =   69.216   SOLIDIFICATION INDEX =  22.161   MAFIC INDEX =    62.427   FELSIC INDEX =  65.351
MAFIC-FELSIC INDEX =   63.[illegible]   ALKALIC INDEX =            43.624   LARSEN INDEX =   10.65[illegible]
ALBITE RATIO (CIPW) =       .645   ALBITE RATIO (NIGGLI) =   .592   IRON INDEX=         5.470   CRYSTALLIZATION INDEX = 18.070
RITTMANN SIGMA =   1.50   SO THE ROCK IS IN THE PACIFIC SUITE
                   IRON, MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
           TOTAL IRON =   36.4[illegible]   TOTAL MAGNESIUM =        22.161   TOTAL ALKALIES, = 41.019
                                     NIGGLI NUMBERS
AL = [illegible]   FM = [illegible]   C = [illegible]   ALK = 10.5[illegible]   SI = 2[illegible]   MG = [illegible]   K = [illegible]   QZ = [illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT, P = .6[illegible]   DEGREE OF SI SATURATION = [illegible]   DEGREE OF ACIDITY =   .[illegible]
                                 ZAVARITSKY CHARACTERISTICS
SMALL A = [illegible]   SMALL C = 3.755   SMALL C BAR = [illegible]   SMALL B = [illegible]   SMALL S = 7[illegible]   Q = 20.6[illegible]
[illegible] = [illegible]   [illegible] = [illegible]   [illegible] = 0.[illegible]   [illegible] = [illegible]   [illegible] = 0.[illegible]   SMALL N = [illegible]
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =  74.626   II =   5.[illegible]   CI =  13.479

     PERALKALINITY  INDEX  =  .5
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                              CIPW NORM CALCULATION OF NORMALIZED RESULTS
19.  T-72-214 , dacitic crystal tuff , Cano Lake Fm.
                                 THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
  SIO2      TIO2     AL2O3     FE2O3      FEO      MNO      MGO      CAO      NA2O     K2O      P2O5     CO2      SUM
[illegible] [illegible] [illegible] [illegible] [illegible] .054 1.380 2.050 4.160 2.491 [illegible] ----  100.000

                                          MOLECULAR PROPORTIONS
1.1171    .0066     .1611     .0261     0.0000    .0086     .0342     .0364     .0752     .0264     .0016    0.0000
                                        C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE                 [illegible]     MAGNESITE                  [illegible]     SIDERITE               0.000
SODIUM CARBONATE        [illegible]     POTASSIUM CARBONATE        [illegible]
APATITE                 [illegible]     ALBITE                     [illegible]     TOTAL DIOPSIDE         [illegible]
ILMENITE                [illegible]     ANORTHITE                  [illegible]       DIOPSIDE (WO)        [illegible]
SPHENE                  [illegible]     CORUNDUM                   [illegible]       DIOPSIDE (EN)        [illegible]
RUTILE                  [illegible]     MAGNETITE                  [illegible]       DIOPSIDE (FS)        [illegible]
K-METASILICATE          [illegible]     HEMATITE                   [illegible]     TOTAL HYPERSTHENE      [illegible]
KALIOPHILITE            [illegible]     QUARTZ                     [illegible]       (EN)ENSTATITE        [illegible]
LEUCITE                 [illegible]     TOTAL OLIVINE              [illegible]       (FS)FERROSILITE      [illegible]
ORTHOCLASE              [illegible]       FORSTERITE               [illegible]     WOLLASTONITE           [illegible]
NA-METASILICATE         [illegible]       FAYALITE                 [illegible]     ACMITE                 0.000
NEPHELINE               [illegible]       CA-ORTHOSILICATE         [illegible]
                                            SUM        100.001
TOTAL FEMIC CONTENT =      5.231   TOTAL ALKALI CONTENT =   7.150   TOTAL IRON CONTENT =   3.150
DIFFERENTIATION INDEX =   88.451   SOLIDIFICATION INDEX =  11.147   MAFIC INDEX =   73.814   FELSIC INDEX =  77.052
MAFIC-FELSIC INDEX =     75.784   ALKALIC INDEX =          54.075   LARSEN INDEX =  21.860
ALBITE RATIO (CIPW) =     .449   ALBITE RATIO (NIGGLI) =   .715   IRON INDEX=      3.516   CRYSTALLIZATION INDEX =  9.416
RITTMANN SIGMA =   2.07   SO THE ROCK IS IN THE PACIFIC SUITE
                IRON,MAGNESIUM AND ALKALIES SUMMED TO 100. FOR AMF DIAGRAMS
          TOTAL IRON =    31.093   TOTAL MAGNESIUM =          11.147   TOTAL ALKALIES = 57.754
                                             NIGGLI NUMBERS
AL = [illegible]  FM = [illegible]  C = [illegible]  ALK = [illegible]  SI = [illegible]  TI = [illegible]  P = [illegible]  K = .26  MG = [illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT, A =  .77   DEGREE OF SI SATURATION = 3.44   DEGREE OF ACIDITY =   .75
                                       ZAVARITSKY CHARACTERISTICS
SMALL A = [illegible]  SMALL C = [illegible]  SMALL C DASH = [illegible]  SMALL B = [illegible]  SMALL S = [illegible]  Q = [illegible]
[illegible] =[illegible]  [illegible] =[illegible]  [illegible] = [illegible]  [illegible] =[illegible]  [illegible] = [illegible]  SMALL N =[illegible]
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100.
DI =  85.775   II =   4.156   CI =  10.079

     PERALKALINITY  INDEX =  .6
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20. T-72-208 , arkosic graywacke , Western Uphill Lake Fm.

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        ANALYSIS(WT%)     ALTERATIONS     CATION %
SIO2      64.6 A              66.1          61.2
AL2O3     17.0 A              17.4          19.0
FE2O3     3.00 A              1.94          1.35
FEO        .00                1.75          1.40
MGO       1.60 A              1.64          2.26
CAO       4.30 A              4.40          4.36
NA2O      4.31 A              4.41          7.92
K2O       1.05 A              1.07          2.24
TIO2       .40 A               .41           .28
P2O5       .00                 .00           .00
S          .00                 .00           .00
MNO        .06 A               .06           .00
CO2 L.O.I. 2.00 C              .00           .00
H2O+       .00         CR2O3   .00           .00
H2O-       .00         NIO     .00           .00
TOTAL     99.9
SPEC. GR.

    TRACES(PPM)             NORMS   MOLECULAR    WEIGHT                          NORM RATIOS(MOLECULAR)
     AG   -                  AP        .000        .000      OR/AB+5/3NE/AN      15.92     54.52     30.06
     AU   -                  PO        .000        .000      Q/AB/OR             27.55     56.48     15.97
     AS   -                  IL        .570        .777      NE/AB/OR.             .00     77.96     22.04
     BA   -                  OR      11.191      11.197      LC/NE/OR              .00       .00    100.00
     BE   -                  AB      39.579      37.313      OL/OR/LC              .00    100.00       .00
     BI   -                  AN      21.024      21.028      OL/NE/AQ              .00    100.00       .00
     CO   -                  C         .097        .091      Q/NE/AQ             78.1      21.05       .00
     CR   -                  AC        .000        .000      NE/OR/Q             15.04     31.18     53.78
     CU   -                  MT       2.032       2.819      OL/NE/OR              .00     32.54     67.46
     GA   -                  HM        .000        .000      Q/PL/OR             21.01     66.81     12.18
     HG   -                  WO        .000        .000      AG/NE/PL              .00      8.08     91.92
     LI   -                  EN       4.518       4.077      OL/NE/PL              .00      8.08     91.92
     MN   -                  FS        .081       1.045      Q/NE/PL             22.42      6.27     71.31
     MO   -                  Q       19.397      20.853      NE+/Q+/OL+          36.94     56.76      6.30
     NB   -                  DI        .000        .000      OL+/AG/Q+           16.39       .00     83.61
     NI   -                  FO        .000        .000      OL+/PL/Q+            4.77     71.35     23.08 ADJUSTED FOR CORUNDUM
     PB   -                  FA        .000        .000      AG/PL/NE+KQ           .00     42.63     57.37
     RB   -                  NE        .000        .000      NE/(Q+OR/NC+)         .00     86.39     13.61
     SB   -                  LC        .000        .000      AB/AN/NC+           57.03     31.45     11.53
     SC   -                  KP        .000        .000      MG/MG+FE2           83.68
     SN   -                  HL        .000        .000      FE2/MG+FE2          16.32
     SR   -                  CC        .000        .000                      CATION %
     TE   -                  NC        .000        .000      FE3/FE2+FE3         50.00
     V    -                  NS        .000        .000      MG/FE2/NA+K         16.41      9.84     73.75
     Y    -                  KS        .000        .000      MG/FE2+FE3/NA+K     14.94     17.91     67.15
     ZN   -                  CR        .000        .000                      WEIGHT %
     ZR   -                  TN        .000        .000      A/F/M               55.10     30.59     14.31

                          SALIC=  92.00  FEMIC=   8.00  NORMATIVE PLAGIOCLASE COMPOSITION=  35.59
DIFFERENTIATION INDEX= 76.00(MOLECULAR) 69.36(WEIGHT)  *COLOUR INDEX=  8.00(MOLECULAR)  8.72(WEIGHT)
    ROCK NAME - CALC-ALKALINE DACITE
               *HIGH ALUMINA*                                  MASS ABSORPTION= 48.18616
```

21. T-72-251A, volcanic lithic graywacke , Weston Uphill Lake Fm.

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        ANALYSIS(WT%)      ALTERATIONS      CATION %
SIO2       65.3 A             67.2            62.5
AL2O3      16.1 A             16.6            18.1
FE2O3      3.70 A             2.06            1.49
FEO         .00               1.57            1.26
MGO        2.10 A             2.16            2.99
CAO        3.80 A             3.91            3.89
NA2O       3.77 A             3.88            6.99
K2O        2.01 A             2.07            2.46
TIO2        .50 A              .51             .36
P2O5        .00                .00             .00
S           .00                .00             .00
MNO         .05 A              .05             .00
SO4+LOI    2.60 C              .00             .00
H2O+        .00        CR2O3   .00             .00
H2O-        .00        NIO     .00             .00
TOTAL      99.9
SPEC. GR.

     TRACES(PPM)             NORMS   MOLECULAR    WEIGHT
      AG   -                  AP        .008        .000      NORM RATIOS(MOLECULAR)
      AU   -                  PY        .000        .000     OR/AB+5/3NE/AN   18.41    52.40    29.19
      AS   -                  IL        .719        .977     Q/AB/OR          32.89    49.66    17.44
      BA   -                  OR      12.276      12.237     NE/AB/OR           .00    74.01    25.99
      BE   -                  AB      34.952      32.029     LC/NE/OR           .00      .00   100.00
      BI   -                  AN      19.471      19.403     CL/OR/LC           .00   100.00      .00
      CO   -                  C         .916        .836     OL/HY/AG           .00   100.00      .00
      CR   -                  AC        .000        .000     Q/HY/AG          78.46    21.54      .00
      CU   -                  MT       2.159       2.965     HY/OR/Q          15.21    29.38    55.41
      GA   -                  HM        .000        .000     OL/HY/OR           .00    34.11    65.89
      HG   -                  WO        .000        .000     Q/PL/OR          25.77    60.57    13.66
      LI   -                  EN       5.907       5.303     AG/HY/PL           .00    10.46    89.54
      MN   -                  FS        .367        .436     DI/HY/PL           .00    10.46    89.54
      MO   -                  Q       23.151      24.913     Q/HY/PL          27.58     7.57    64.84
      NB   -                  DI        .000        .000     NE+/OR+/CL+      32.53    60.07     7.40
      NI   -                  FO        .000        .000     OL+/AG/OR+       16.16      .00    83.84
      PB   -                  FA        .000        .000     OL+/PL/Q+         6.29    65.43    21.28 ADJUSTED FOR CORUNDUM
      RB   -                  NL        .000        .000     AG/PL/HY+Q         .00    35.48    64.52
      SB   -                  LC        .000        .000     NE/AB+OR/NC+       .00    83.64    16.36
      SC   -                  KP        .000        .000     AB/AN/NC+        54.91    30.59    14.51
      SN   -                  NE        .000        .000     MG/MG+FE2        94.19
      SR   -                  CC        .000        .000     FE2/MG+FE2        5.81
      TI   -                  RU        .000        .000                   CATION %
      V    -                  NS        .000        .000     FE3/FE2+FE3      54.05
      Y    -                  KS        .000        .000     MG/FE2/NA+K      21.91     8.96    69.14
      ZN   -                  CR        .000        .000     MG/FE2+FE3/NA+K  19.02    17.63    62.55
      ZR   -                  -LH.      .000        .000                   WEIGHT %
                                                             A/F/M            51.56    29.70    18.73
                     SALIC=  90.77  FEMIC=   9.23  NORMATIVE PLAGIOCLASE COMPOSITION=  35.78
DIFFERENTIATION INDEX= 70.38(MOLECULAR) 69.90(WEIGHT)  *COLOUR INDEX=  9.23(MOLECULAR)  9.78(WEIGHT)
  ROCK NAME - CALC-ALKALINE ANDESITE
           *HIGH ALUMINA*
                                                    MASS ABSORPTION= 47.66385
```

22. OT-73- 21 , volcanic lithic graywacke , Western Uphill Lake Fm.

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         ANALYSIS(WT%)       ALTERATIONS       CATION %
SIO2         69.2 A              65.9             61.5
AL2O3        16.0 A              16.4             18.1
FE2O3        5.00 A              2.26             1.59
FEO           .00                2.59             2.08
MGO          2.60 A              2.67             3.71
CAO          3.60 A              3.70             3.70
NA2O         3.33 A              3.42             6.19
K2O          2.17 A              2.23             2.66
TIO2          .70 A               .72              .50
P2O5          .00                 .00              .00
S             .00                 .00              .00
MNO           .07 A               .07              .00
CO2  ( 0 1   2.02 C               .00              .00
H2O+          .00       CR2O3     .00              .00
H2O-          .00       NIO       .00              .00
TOTAL        99.7
SPEC. GR.

      TRACES(PPM)                  NORMS   MOLECULAR    WEIGHT                         NORM RATIOS(MOLECULAR)
       AG    -                      AP        .000        .000     OR/AB+5/5NE/AN      21.18     49.34     29.48
       AU    -                      PO        .000        .000     Q/AN/OR             34.33     45.95     19.72
       AS    -                      IL       1.009       1.365     NE/AB/OR              .00     69.96     30.04
       BA    -                      OR      13.277      13.180     LC/NE/CA              .00       .00    100.00
       BE    -                      AB      30.929      28.929     OL/OR/LC              .00    100.00       .00
       BI    -                      AN      10.480      18.339     OL/NE/AG              .00    100.00       .00
       CO    -                      C        1.037       1.470     Q/HY/AG             72.01     27.99       .00
       CR    -                      AC        .000        .000     HY/OR/C             19.80     29.27     50.93
       CU    -                      MT       2.379       3.275     OL/NE/OR              .00     40.35     59.65
       GA    -                      HM        .000        .000     Q/PL/OR             26.93     57.59     15.46
       HG    -                      WO        .000        .000     AG/HY/PL              .00     15.38     84.62
       LI    -                      EN       7.425       6.448     OL/HY/PL              .00     15.39     84.62
       MN    -                      FS       1.556       1.851     Q/HY/PL             28.35     11.02     60.63
       MO    -                      Q       23.107      24.763     NC+/Q+/OL+          29.45     59.86     10.69
       NB    -                      DI        .000        .000     OL+/AG/Q+           20.99       .00     79.01
       NI    -                      FO        .000        .000     OL+/PL/Q+            9.33     62.06     28.61 ADJUSTED FOR CORUNDUM
       PB    -                      FA        .000        .000     AG/PL/HY+Q            .00     32.76     67.24
       RB    -                      NE        .000        .000     NE/AB+OR/NC+          .00     78.14     21.86
       SB    -                      LC        .000        .000     AB/AN/NC+           50.06     29.91     20.02
       SC    -                      KP        .000        .000     MG/MG+FE2           82.67
       SN    -                      HL        .000        .000     FE2/MG+FE2          17.33
       SR    -                      CC        .000        .000                     CATION %
       TI    -                      RU        .000        .000     FE3/FE2+FE3         49.00
       V     -                      NS        .000        .000     MG/FE2/NA+K         25.48     13.85     60.67
       Y     -                      KS        .000        .000     MG/FE2+FE3/NA+K     22.98     22.31     54.71
       ZN    -                      CM        .000        .000                     WEIGHT %
       ZR    -                      LN        .000        .000     A/F/M               43.65     35.71     20.64

                          SALIC= 87.63  FEMIC= 12.37  NORMATIVE PLAGIOCLASE COMPOSITION=  37.40

DIFFERENTIATION INDEX= 67.31(MOLECULAR) 66.07(WEIGHT)  *COLOUR INDEX= 12.37(MOLECULAR) 13.12(WEIGHT)
   ROCK NAME - CALC-ALKALINE ANDESITE
               *HIGH ALUMINA*                                MASS ABSORBTION= 50.61240
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                 CIPW NORM CALCULATION OF NORMALIZED RESULTS
23. OT-73- 2 , volcanic lithic graywacke,Wentern Uphill Lake Fm.
                 THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
```
 SIO2      TIO2     AL2O3     FE2O3     FEO       MNO       MGO       CAO       NA2O      K2O       P2O5      CO2       SUM
 [illegible] [illegible] [illegible] [illegible] [illegible] .05[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] ----  100.010

                                        MOLECULAR PROPORTIONS
 1.0762    .0061     .1623     .0252     0.0000    .0007     .0618     .0620     [illegible] .0236   .0011     0.0000
                                   C.I.P.W. NORM (IN WEIGHT PERCENT)

 CALCITE                [illegible]   MAGNESITE               [illegible]   SIDERITE               0.000
 SODIUM CARBONATE       [illegible]   POTASSIUM CARBONATE     [illegible]
 APATITE                [illegible]   ALBITE                  [illegible]   TOTAL DIOPSIDE         [illegible]
 ILMENITE               [illegible]   ANORTHITE               [illegible]     DIOPSIDE (WO)        [illegible]
 SPHENE                 [illegible]   CORUNDUM                [illegible]     DIOPSIDE (EN)        [illegible]
 RUTILE                 [illegible]   MAGNETITE               [illegible]     DIOPSIDE (FS)        [illegible]
 K-METASILICATE         [illegible]   HEMATITE                [illegible]   TOTAL HYPERSTHENE      [illegible]
 KALIOPHILITE           [illegible]   QUARTZ                  [illegible]     ENSTATITE            [illegible]
 LEUCITE                [illegible]   TOTAL OLIVINE           [illegible]     FERROSILITE          [illegible]
 ORTHOCLASE             [illegible]     FORSTERITE            [illegible]   WOLLASTONITE           [illegible]
 NA-METASILICATE        [illegible]     FAYALITE              [illegible]   ACMITE                 [illegible]
 NEPHELINE              [illegible]     CA-ORTHOSILICATE      [illegible]
                                          SUM         100.011
 TOTAL FEMIC CONTENT =      6.528   TOTAL ALKALI CONTENT =    6.470   TOTAL IRON CONTENT =    4.030
 DIFFERENTIATION INDEX =   70.601   SOLIDIFICATION INDEX =   19.169   MAFIC INDEX =    61.010   FELSIC INDEX =  62.573
 MAFIC-FELSIC INDEX =      62.196   ALKALIC INDEX =          34.001   LARSEN INDEX =   17.717
 ALBITE RATIO (CIPW) =       .687   ALBITE RATIO (NIGGLI) =    .661   IRON INDEX=       4.117   CRYSTALLIZATION INDEX = 26.790
 RITTMANN SIGMA =    1.83   SO THE R[illegible]S IN THE PACIFIC SUITE
            IRON, MAGNESIUM A[illegible]S SUMMED TO 100% FOR AMF DIAGRAMS
      TOTAL IRON =   31.074   [illegible]GNESIUM =   19.169   TOTAL ALKALIES = 49.[illegible]
                                    NIGGLI NUMBERS
 AL = 37.19  FM = 25.87  C = 15.81  ALK = 21.13  SI = 231.11  MG = .55  K = .25  QZ = [illegible]
 ORDINATE FOR THE FELDSPAR VARIATION PLOT, R = .72  DEGREE OF SI SATURATION = 1.16  DEGREE OF [illegible] = .77
                                    ZAVARITSKY CHARACTERISTICS
 SMALL A = [illegible]  SMALL B = [illegible]  SMALL C = [illegible]  SMALL S = [illegible]  Q = 20.1[illegible]
 (PRIME) [illegible]  (PRIME) [illegible]  (PRIME) [illegible]  (PRIME) [illegible]  (PRIME) [illegible]  SPACE N = [illegible]
 DIFFERENTIATION INDEX(DI), FROM INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
 DI =   71.987   II =   4.331   CI =   21.7[illegible]

    PERALKALINITY INDEX =  .6
```

24. T-72- 9 ; volcanic lithic graywacke , Central uphill Lake Fm.

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          ANALYSIS(WT%)   ALTERATIONS    CATION %
SIO2        65.8 A           67.6          62.9
AL2O3       15.1 A           15.5          16.9
FE2O3        3.70 A           2.65          1.45
FEO           .00             1.57          1.26
MGO          2.80 A           2.88          3.96
CAO          3.20 A           3.29          3.26
NA2O         4.22 A           4.34          7.77
K2O          2.09 A           2.15          2.54
TIO2          .50 A            .51           .36
P2O5          .00              .00           .00
S             .00              .00           .00
MNO           .06 A            .06           .00
CO2   L.O.I. 2.50 C            .00           .00
H2O+          .00      CR2O3   .00           .00
H2O-          .00      NIO     .00           .00
TOTAL       100.0
SPEC. GR.

     TRACES(PPM)             NORMS   MOLECULAR   WEIGHT                          NORM RATIOS(MOLECULAR)
      AG   -                  AP        .000      .000     OR/AB+5/3NE/AN     18.69    57.29    24.01
      AU   -                  PO        .000      .000     Q/AB/OR            28.87    53.63    17.50
      AS   -                  IL        .718      .976     NE/AB/OR             .00    75.40    24.60
      BA   -                  OR      12.679    12.705     LC/NE/OR             .00      .00   100.00
      BE   -                  AB      38.062    36.655     OL/OR/LC             .00   100.00      .00
      BI   -                  AN      16.287    16.316     OL/HY/AB             .00   100.00      .00
      CO   -                  C         .086      .079     Q/HY/AB            71.56    28.44      .00
      CR   -                  AC        .000      .000     HY/OL/Q            19.83    30.26    49.91
      CU   -                  MT       2.145     2.910     OL/HY/OR             .00    39.60    60.40
      GA   -                  HM        .000      .000     Q/PL/OR            23.57    62.14    14.20
      HG   -                  WO        .000      .000     AG/HY/PL             .00    13.10    86.90
      LI   -                  EN       7.929     7.166     OL/HY/PL             .00    13.10    86.90
      MN   -                  FS        .383      .455     Q/HY/PL            24.79     9.85    65.36
      MO   -                  Q       20.916    22.627     HY+/DI+/OL+        34.24    56.60     9.16
      NB   -                  DI        .000      .000     OL+/AG/DI+         21.33      .00    78.67
      NI   -                  FO        .000      .000     OL+/PL/DI+          7.44    65.42    27.14 ADJUSTED FOR CORUNDUM
      PB   -                  FA        .000      .000     AG/PL/HY+MO          .00    37.48    62.52
      RB   -                  NE        .000      .000     NE/AB+OR/HC+         .00    82.19    17.81
      SB   -                  LC        .000      .000     AB/AN/HC+          58.60    24.56    16.84
      SC   -                  KP        .000      .000     MG/MG+FE2          95.39
      SN   -                  HL        .000      .000     FE2/MG+FE2          4.61
      SR   -                  CC        .000      .000                     CATION %
      TH   -                  RU        .000      .000     FE3/FE2+FE3        54.05
      V    -                  NS        .000      .000     MG/FE2/NA+K       -25.60     7.85    66.56
      Y    -                  KS        .000      .000     MG/FE2+FE3/NA+K    23.43    15.64    60.93
      ZN   -                  CM        .000      .000                     WEIGHT %
      ZR   -                  TN        .000      .000     A/F/M              50.73    26.76    22.51

                      SALIC=  88.83  FEMIC=  11.17  NORMATIVE PLAGIOCLASE COMPOSITION=  29.55

DIFFERENTIATION INDEX= 72.96(MOLECULAR) 72.05(WEIGHT)   +COLOUR INDEX= 11.17(MOLECULAR) 11.60(WEIGHT)
    ROCK NAME - CALC-ALKALINE DACITE                              MASS ABSORPTION= 47.22191
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25. T-72- 52B, volcanic lithic graywacke , Central Uphill Lake Fm.

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        ANALYSIS(WT%)        ALTERATIONS     CATION %
SIO2        67.4 A               68.3          63.5
AL2O3       15.4 A               15.6          17.1
FE2O3       3.70 A               2.13          1.49
FEO          .00                 1.46          1.17
MGO         2.70 A               2.79          3.78
CAO         3.00 A               3.64          3.02
NA2O        3.95 A               4.00          7.20
K2O         2.09 A               2.12          2.51
TIO2         .60 A                .61           .42
P2O5         .00                  .00           .00
S            .00                  .00           .00
MNO          .05 A                .05           .00
CO2   LOI   2.05 C                .00           .00
H2O+         .00        CR2O3     .00           .00
H2O-         .00        NIO       .00           .00
TOTAL      100.9
SPEC. GR.

    TRACES(PPM)                NORMS   MOLECULAR   [illegible]                       NORM RATIOS(MOLECULAR)
     AG    -                    AP        .000       .0[illegible]   OR/AB+5/3NE/AN     19.71    56.55    23.74
     AU    -                    PO        .000       .000        Q/AB/OR            33.46    49.34    17.20
     AS    -                    IL        .640      1.159        NE/AB/OR             .00    74.15    25.85
     BA    -                    OR      12.544     12.521        LC/NE/OR             .00      .00   100.00
     BE    -                    AB      35.956     35.050        OL/OR/LC             .00   100.00      .00
     BI    -                    AN      15.106     15.075        OL/NE/AG             .00   100.00      .00
     CO    -                    C        1.312      1.199        Q/NE/AG            76.31    23.69      .00
     CR    L                    AC        .000       .000        HY/OR/Q            17.01    28.18    54.81
     CU    -                    MT       2.226      3.089        OL/HY/OR             .00    37.65    62.35
     GA    -                    HM        .000       .000        Q/PL/OR            27.72    58.04    14.25
     HG    -                    WO        .000       .000        AG/HY/PL             .00    12.91    87.09
     LI    -                    EN       7.569      6.810        OL/HY/PL             .00    12.91    87.09
     MN    -                    FS        .003       .011        Q/HY/PL            29.37     9.12    61.51
     MO    -                    Q       24.900     26.255        NE+/OR+/OL+-       31.77    59.87     8.36
     NB    -                    OL        .000       .000        OL+/AG/Q+          17.76      .00    82.24
     NI    -                    FO        .000       .000        OL+/PL/Q+           7.66    62.50    29.84 ADJUSTED FOR CORUNDUM
     PB    -                    FA        .000       .000        AG/PL/HY+NO          .00    37.70    62.30
     RB    -                    NE        .000       .000        NE/AB+OR/HCI+        .00    82.01    17.99
     SB    -                    LC        .000       .000        AB/AN/HCI+         58.29    23.47    17.25
     SC    -                    KP        .0[illegible]       .000        MG/MG+FE2          99.88
     SN    -                    HL        .000       .000        FE2/MG+FE2           .12
     SR    -                    CC        .000       .000                         CATION %
     TI    -                    NC        .000       .000        FE3/FE2+FE3        56.76
     V     -                    NS        .000       .000        MG/FE2/NA+K        25.87     7.74    66.39
     Y     -                    KS        .000       .000        MG/FE2+FE3/NA+K    23.48    16.25    60.27
     ZN    -                    CR        .000       .000                         WEIGHT %
     ZR    -                    LM        .000       .000        A/F/M              50.04    27.58    22.37

                          SALIC=  89.35  FEMIC=  10.65  NORMATIVE PLAGIOCLASE COMPOSITION=  29.57

DIFFERENTIATION INDEX= 72.93(MOLECULAR) 72.67(WEIGHT)  *COLOUR INDEX= 10.65(MOLECULAR) 11.06(WEIGHT)
    ROCK NAME - CALC-ALKALINE DACITE                          MASS ABSORPTION= 47.61059
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26. T-72-109 , volcanic lithic graywacke , Central Uphill Lake Fm.

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                    CIPW NORM CALCULATION OF NORMALIZED RESULTS
                    THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2      TIO2     AL2O3     FE2O3     FEO      MNO      MGO      CAO      NA2O     K2O      P2O5     CO2      SUM
61.750     .750    14.850     4.700    0.000     .130    4.100    5.950    2.594    1.750     .320     ----    99.930

                                        MOLECULAR PROPORTIONS
1.0193     .0094     .1370     .0545    0.0000    .0018    .1017    .1061    .0402    .0186    .0021    0.0000
                                 C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE                 0.000     MAGNESITE                [illegible]     SIDERITE               0.000
SODIUM CARBONATE        0.000     POTASSIUM CARBONATE      0.000           TOTAL DIOPSIDES        [illegible]
APATITE                  .751     ALBITE                   [illegible]       DIOPSIDE (WO)        [illegible]
ILMENITE                 .274     ANORTHITE                [illegible]       DIOPSIDE (EN)        [illegible]
SPHENE                  1.511     CORUNDUM                 0.000             DIOPSIDE (FS)        0.000
RUTILE                  0.000     MAGNETITE                0.000           TOTAL HYPERSTHENE      [illegible]
K-METASILICATE          0.000     HEMATITE                 4.700             ENSTATITE            [illegible]
KALIOPHILITE            0.000     QUARTZ                   [illegible]       FERROSILITE          0.000
LEUCITE                 0.000     TOTAL OLIVINE            0.000           WOLLASTONITE           0.000
ORTHOCLASE             10.342       FORSTERITE             0.000           ACMITE                 0.000
NA-METASILICATE         0.000       FAYALITE               0.000
NEPHELINE               0.000     CA-ORTHOSILICATE         0.000
                                    SUM          99.992

TOTAL FEMIC CONTENT =      12.000   TOTAL ALKALI CONTENT =      4.740   TOTAL IRON CONTENT =    4.700
DIFFERENTIATION INDEX =    56.501   SOLIDIFICATION INDEX =     21.375   MAFIC INDEX =      67.069   FELSIC INDEX =   44.361
MAFIC-FELSIC INDEX =       56.155   ALKALIC INDEX =            36.920   LARSEN INDEX =     12.117
ALBITE RATIO (CIPW) =        .562   ALBITE RATIO (NIGGLI) =      .576   IRON INDEX =           0.970   CRYSTALLIZATION INDEX = 29.036
RITTMANN SIGMA =     1.23   SO THE ROCK IS IN THE PACIFIC SUITE
                    IRON,MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
          TOTAL IRON =    45.601     TOTAL MAGNESIUM =        21.375     TOTAL ALKALIES = 33.024
                                        NIGGLI NUMBERS
AL = 26.15   FM = 40.41   C = 20.28   ALK = 13.72   SI = 194.81   MG =    .64   K =    .23   QZ = 45.741
ORDINATE FOR THE FELDSPAR VARIATION PLOT, W =    .65   DEGREE OF SI SATURATION =   1.23   DEGREE OF ACIDITY =    .6C
                                    PARAMETRIC CHARACTERISTICS
SMALL A =  9.015  SMALL C =  4.723  SMALL C HAT =  0.000  SMALL B = 16.616  SMALL S = 69.550  Q =  35.23
FIRAIPES =[illegible]  MIPPIPES =[illegible]  CIPPIPES =[illegible]  AIPPIPES = 0.0000  NIPPIPES = 9.0000  SMALL N =[illegible]
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =  59.233   II =    9.413   CI =  31.152

     PERALKALINITY  INDEX  =  .5
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                         CIPW NORM CALCULATION OF NORMALIZED RESULTS
27.  T-73- 32 , volcanic lithic graywacke , Central Uphill Lake Fm.
                       THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2      TIO2     AL2O3     FE2O3     FEO      MNO      MGO      CAO      NA2O      K2O      P2O5      CO2      SUM
66.770 ,   .630     15.740    4.551     4.910    .060     2.500    1.750    4.250     2.550    .210      ----     95.930

1.1020     .0079    .1544     .0284     MOLECULAR PROPORTIONS
                                        [illegible]     .0008     .0520    .0500    .0691    .0266    .0015    0.0000
                              C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE                    0.000          MAGNESITE                  0.000          SIDERITE                   0.000
SODIUM CARBONATE           0.000          POTASSIUM CARBONATE        0.000
APATITE                    [illegible]    ALBITE                     [illegible]    TOTAL DIOPSIDE             [illegible]
ILMENITE                   [illegible]    ANORTHITE                  [illegible]    DIOPSIDE [illegible]       [illegible]
[illegible]                [illegible]    CORUNDUM                   [illegible]    DIOPSIDE [illegible]       [illegible]
[illegible]                [illegible]    MAGNETITE                  [illegible]    DIOPSIDE [illegible]       [illegible]
K-METASILICATE             [illegible]    HEMATITE                   [illegible]    TOTAL HYPERSTHENE          [illegible]
KALIOPHILITE               [illegible]    QUARTZ                     [illegible]    ENSTATITE                  [illegible]
LEUCITE                    [illegible]    TOTAL OLIVINE              [illegible]    FERROSILITE                [illegible]
ORTHOCLASE                 [illegible]    FORSTERITE                 [illegible]    WOLLASTONITE               [illegible]
NA-METASILICATE            [illegible]    FAYALITE                   [illegible]    ACMITE                     [illegible]
NEPHELINE                  [illegible]    CA-ORTHOSILICATE           [illegible]
                                              SUM        [illegible]
TOTAL FEMIC CONTENT =      7.039   TOTAL ALKALI CONTENT =     6.790   TOTAL IRON CONTENT =    4.510
DIFFERENTIATION INDEX =   73.152   SOLIDIFICATION INDEX =    10.098   MAFIC INDEX =    [illegible]   FELSIC INDEX =  67.679
MAFIC-FELSIC INDEX =      66.035   ALKALIC INDEX =          [illegible]   LARSEN INDEX =   16.650
ALBITE RATIO (CIPW) =       .730   ALBITE RATIO (NIGGLI) =     .702   IRON INDEX        4.650   CRYSTALLIZATION INDEX = 17.153
RITTMANN SIGMA =    1.96   SO THE ROCK IS IN THE PACIFIC SUITE
          IRON, MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
          TOTAL IRON =   37.770     TOTAL MAGNESIUM =        15.030     TOTAL ALKALIES = 49.137
                                        NIGGLI NUMBERS
[illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT,  [illegible]     DEGREE OF SI SATURATION = [illegible]  DEGREE OF ACIDITY =    [illegible]
                                        ZAVARITSKY CHARACTERISTICS
[illegible]
[illegible]
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
 DI =  77.030    II =    4.965    CI =   18.005

     PERALKALINITY  INDEX  =  .6
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                         CIPW NORM CALCULATION OF NORMALIZED RESULTS.
28. OT-74-  4 , volcanic lithic graywacke , Central Uphill Lake Fm.-
                         THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
  SIO2      TIO2      AL2O3     FE2O3     FEO       MNO       MGO       CAO       H2O       K2O       P2O5      CO2       SUM
 65.670     .478    16.128     1.258    [illegible]  .058     1.840     3.194    [illegible]  1.648     .138     [illegible]  100.010

                                          MOLECULAR PROPORTIONS.
 1.1473     .0053     .1581     .0206   [illegible]  .0007     .0456     .0569     .0765     .0174     .0009    0.0000
                                   C.I.P.W. NORM IN WEIGHT PERCENTS

 CALCITE              [illegible]      MAGNESITE               [illegible]      SIDERITE              0.000
 SODIUM CARBONATE     [illegible]      POTASSIUM CARBONATE     [illegible]      TOTAL DIOPSIDE        [illegible]
 APATITE              [illegible]      ALBITE                  [illegible]       DIOPSIDE (WO)        [illegible]
 ILMENITE             [illegible]      ANORTHITE               [illegible]       DIOPSIDE (EN)        [illegible]
 SPHENE               [illegible]      CORUNDUM                [illegible]       DIOPSIDE (FS)        [illegible]
 RUTILE               [illegible]      MAGNETITE               [illegible]      TOTAL HYPERSTHENE     [illegible]
 K-METASILICATE       [illegible]      HEMATITE                [illegible]       ENSTATITE            [illegible]
 KALIOPHILITE         [illegible]      QUARTZ                  [illegible]       FERROSILITE          [illegible]
 LEUCITE              [illegible]      TOTAL OLIVINE           [illegible]      WOLLASTONITE          [illegible]
 ORTHOCLASE           [illegible]        FORSTERITE            [illegible]      ACMITE                0.000
 NA-METASILICATE      [illegible]        FAYALITE              [illegible]
 NEPHELINE            [illegible]        CA-ORTHOSILICATE      [illegible]
                                          SUM         100.011

TOTAL FEMIC CONTENT =      5.651   TOTAL ALKALI CONTENT =   6.388   TOTAL IRON CONTENT =   1.350
DIFFERENTIATION INDEX =   75.744   SOLIDIFICATION INDEX =  15.746   MAFIC INDEX =   64.356   FELSIC INDEX =  66.667
MAFIC-FELSIC INDEX =      65.512   ALKALIC INDEX =         25.705   LARSEN INDEX =  19.540
ALBITE RATIO (CIPW) =       .745   ALBITE RATIO (NIGGLI) =   .704   IRON INDEX =     1.357   CRYSTALLIZATION INDEX = 16.759
RITTMANN SIGMA =   1.50   SO THE ROCK IS IN THE PACIFIC SUITE
                    IRON,MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
           TOTAL IRON =   [illegible]   TOTAL MAGNESIUM =   15.756   TOTAL ALKALIES = 55.610
                                   NIGGLI NUMBERS.
AL = [illegible]  FM = [illegible]  C = [illegible]  ALK = [illegible]  SI = [illegible]  MG = [illegible]  C = [illegible]  QZ = [illegible]
ORTHITE FOR THE FELDSPAR VARIATION PLOT, B = .75  DEGREE OF SI SATURATION = [illegible]  DEGREE OF ACIDITY = .76
                                   ZAVARITSKY CHARACTERISTICS
SMALL A = [illegible]  SMALL C = [illegible]  SMALL F BAR = [illegible]  SMALL M = 6.788  SMALL S = 76.910  Q = 26.85
[illegible] = [illegible]  [illegible] = [illegible]  [illegible] = 0.0000  [illegible] = [illegible]  [illegible] = 0.0000  SMALL N = [illegible]
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =  76.955   II =   1.537   CI =  17.560

     PERALKALINITY  INDEX  =  .6
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CIPW NORM CALCULATION OF NORMALIZED RESULTS

29. CT-74- 6 , volcanic lithic graywacke , Eastern Uphill Lake Fm.

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                         THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
SIO2      TIO2     AL2O3     FE2O3     FEO       MNO       MGO       CAO       NA2O      K2O       P2O5      CO2       SUM
[illegible] [illegible] [illegible] [illegible] [illegible] .15[illegible] [illegible] 5.13[illegible] [illegible] [illegible] [illegible] ----  100.000

                                       MOLECULAR PROPORTIONS
1.0[illegible]96  .0072[illegible]  .1[illegible]67  .0312  [illegible]  [illegible]  .0357  .0915  .0435  .0162  .0006  0.0000
                                   C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE              [illegible]     MAGNESITE              0.000          SIDERITE              0.000
SODIUM CARBONATE     [illegible]     POTASSIUM CARBONATE    0.000
APATITE              [illegible]     ALBITE                 2[illegible]   TOTAL DIOPSIDE        2.[illegible]
ILMENITE             [illegible]     ANORTHITE              1[illegible]   DIOPSIDE (WO)         [illegible]
SPHENE               [illegible]     CORUNDUM               [illegible]    DIOPSIDE (EN)         [illegible]
PYRITE               [illegible]     MAGNETITE              [illegible]    DIOPSIDE (FS)         [illegible]
K-METASILICATE       [illegible]     HEMATITE               [illegible]    TOTAL HYPERSTHENE     [illegible]
KALIOPHILITE         [illegible]     QUARTZ                 2[illegible]   ENSTATITE             [illegible]
LEUCITE              [illegible]     TOTAL OLIVINE          [illegible]    FERROSILITE           [illegible]
ORTHOCLASE           7.319           FORSTERITE             [illegible]    WOLLASTONITE          [illegible]
NA-METASILICATE      [illegible]     FAYALITE               [illegible]    ACMITE                0.000
NEPHELINE            [illegible]     CA-ORTHOSILICATE       [illegible]
                                          SUM      1[illegible].002

TOTAL FEMIC CONTENT =     12.110   TOTAL ALKALI CONTENT =    4.410   TOTAL IRON CONTENT =   [illegible].170
DIFFERENTIATION INDEX =   53.135   SOLIDIFICATION INDEX =   21.952   MAFIC INDEX =    67.154   FELSIC INDEX =  41.226
MAFIC-FELSIC INDEX =      56.793   ALKALIC INDEX =          33.185   LARSEN INDEX =   1[illegible]
ALBITE RATIO (CIPW) =     [illegible]   ALBITE RATIO (NIGGLI) =   .581   IRON INDEX =    [illegible]   CRYSTALLIZATION INDEX = 20.[illegible]
RITTMANN SIGMA =     .95   SO THE ROCK IS IN THE PACIFIC SUITE
           IRON,MAGNESIUM AND ALKALIES SUMMED TO 100. FOR AMF DIAGRAMS
   TOTAL IRON =   [illegible].195   TOTAL MAGNESIUM =        21.952   TOTAL ALKALIES = 26.661
                                   NIGGLI NUMBERS
AL = 22.35   FM = [illegible]   C = 1[illegible].57   ALK = [illegible].95   SI = 215.[illegible]   FG = [illegible]   K = .22   QZ = [illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT, P =   .64   DEGREE OF SI SATURATION =  1.42   DEGREE OF ACIDITY =  .68
                                  ZAVARITSKY CHARACTERISTICS
SMALL A = [illegible]   SMALL C = [illegible].765   SMALL C PAR = [illegible]   SMALL B = 14.[illegible]   SMALL S = [illegible]   Q = [illegible]
[illegible] = [illegible]   [illegible] = [illegible]   [illegible] = [illegible]   [illegible] = [illegible]   [illegible] = [illegible]   SMALL N = [illegible]

DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100.
DI =  [illegible].516   II =   [illegible]   CI =  [illegible].550

     PERALKALINITY  INDEX  =  .5
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                              CIPW NORM CALCULATION OF NORMALIZED RESULTS
30. OT-73- 25 , mudstone , Eastern Uphill Lake Fm.
                              THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2      TIO2     AL2O3     FE2O3     FEO      MNO      MGO      CAO      NA2O     K2O      P2O5     CO2      SUM
[illegible] [illegible] [illegible] [illegible] [illegible] .07[illegible] 2.2[illegible] [illegible] [illegible] 2.[illegible] .0[illegible] ----  100.000

                              MOLECULAR PROPORTIONS
1.1012    .0651    .1565    .0245    [illegible]    .0011    .0561    .0595    .0720    .0293    .0006    0.0000
                              C.I.P.W. NORM (IN WEIGHT PERCENT).

CALCITE              [illegible]      MAGNESITE              [illegible]      SIDERITE             0.000
SODIUM CARBONATE     [illegible]      POTASSIUM CARBONATE    [illegible]      TOTAL DIOPSIDE       [illegible]
APATITE              [illegible]      ALBITE                 [illegible]        DIOPSIDE (EN)      [illegible]
ILMENITE             [illegible]      ANORTHITE              [illegible]        DIOPSIDE (FS)      [illegible]
SPHENE               [illegible]      CORUNDUM               [illegible]        DIOPSIDE (WO)      [illegible]
RUTILE               [illegible]      MAGNETITE              [illegible]      TOTAL HYPERSTHENE    [illegible]
K-METASILICATE       [illegible]      HEMATITE               [illegible]        ENSTATITE          [illegible]
KALIOPHILITE         [illegible]      QUARTZ                 [illegible]        FERROSILITE        [illegible]
LEUCITE              [illegible]      TOTAL OLIVINE          [illegible]      WOLLASTONITE         [illegible]
ORTHOCLASE           [illegible]        FORSTERITE           [illegible]      ACMITE               [illegible]
NA-METASILICATE      [illegible]        FAYALITE             [illegible]
NEPHELINE            [illegible]        CA-ORTHOSILICATE     [illegible]
                                          SUM          100.00[illegible]

TOTAL FEMIC CONTENT =       6.100   TOTAL ALKALI CONTENT =    7.270   TOTAL IRON CONTENT =    3.923
DIFFERENTIATION INDEX =    72.972   SOLIDIFICATION INDEX =   16.666   MAFIC INDEX =    63.[illegible]   FELSIC INDEX =   65.928
MAFIC-FELSIC INDEX =       65.179   ALKALIC INDEX =          39.227   LARSEN INDEX =    10.657
ALBITE RATIO (CIPW) =        .713   ALBITE RATIO (NIGGLI) =    .722   IRON INDEX =       4.070   CRYSTALLIZATION INDEX = 20.[illegible]
RITTMANN SIGMA =    2.25   SO THE ROCK IS IN THE PACIFIC SUITE

              IRON,MAGNESIUM AND ALKALIES SUMMED TO 100, FOR AMF DIAGRAMS
       TOTAL IRON =   23.[illegible]   TOTAL MAGNESIUM =      16.666   TOTAL ALKALIES = 53.[illegible]

                              NIGGLI NUMBERS
AL = 36.[illegible]   FM = 25.[illegible]   C = 16.[illegible]   ALK = 21.[illegible]   SI = 2[illegible]   MG = .[illegible]   K = .[illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT, P = .7[illegible]   DEGREE OF SI SATURATION = 1.11   DEGREE OF ACIDITY = [illegible].72

                              ZAVARITSKY CHARACTERISTICS
SMALL A = 13.651  SMALL C = 3.726  SMALL B = [illegible]  SMALL M = [illegible]  SMALL S = 74.[illegible]  Q = 13.[illegible]
[illegible] = [illegible]   [illegible] = [illegible]   [illegible] = [illegible]   [illegible] = [illegible]   [illegible] = 0.0000   SMALL N =71.0[illegible]

DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100.
DI =  74.816    II =   4.171    CI =  21.011

     PERALKALINITY  INDEX  =  .6
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31. T-72- 49 , argillite , Surprise Lake Member.

```
          ANALYSIS(WT%)      ALTERATIONS     CATION %
 SIO2        56.6 A              59.4           55.4
 AL2O3       17.1 A              18.0           19.7
 FE2O3       6.70 A              7.09           4.94
 FEO          .00                 .00            .06
 MGO         3.50 A              3.68           5.11
 CAO         3.40 A              3.57           3.57
 NA2O        2.79 A              2.93           5.29
 K2O         4.26 A              4.47           5.33
 TIO2         .80 A               .84            .59
 P2O5         .00                 .00            .00
 S            .00                 .00            .00
 MNO          .07 A               .07            .00
 CO2  L.O.I  3.47 C               .00            .00
 H2O+         .00      CR2O3      .00            .00
 H2O-         .00      NIO        .00            .00
 TOTAL       98.7
 SPEC. GR. =

      TRACES(PPM)          NORMS    MOLECULAR    WEIGHT
       AG    -              AP         .000        .000
       AU    -              PO         .000        .000
       AS    -              IL         .116        .157
       BA    -              OR       26.626      26.463
       BE    -              AB       26.471      24.790
       BI    -              AN       17.629      17.715
       CO    -              C         1.977       1.890
       CR    -              AC         .000        .000
       CU    -              NS         .000        .000
       GA    -              HM        4.935       7.036
       HG    -              WO         .000        .000
       LI    -              EN       10.211       9.154
       MN    -              FS         .000        .000
       MO    -              Q        11.304      12.120
       NB    -              DI         .000        .000
       NI    -              FO         .000        .000
       PB    -              FA         .000        .000
       RB    -              NE         .000        .000
       SB    -              LC         .000        .000
       SC    -              KP         .000        .000
       SN    -              HL         .000        .000
       SR    -              CC         .000        .000
       TI    -              RU         .531        .757
       V     -              NS         .000        .000
       Y     -              KS         .000        .000
       ZN    -              CM         .000        .000
       ZR    -              LM         .000        .000

                                NORM RATIOS(MOLECULAR)
 OR/AB+5/3NE/AN          37.54      37.32      25.14
 Q/AB/OR                 17.55      41.10      41.34
 NE/AB/OR                  .00      49.85      50.15
 LC/NE/OR                  .00        .00     100.00
 OL/OR/LC                  .00     100.00        .00
 OL/HY/AG                  .00     100.00        .00
 Q/HY/AG                 52.54      47.46        .00
 HY/OL/Q                 21.21      55.31      23.48
 OL/HY/OR                  .00      27.72      72.28
 Q/PL/OR                 13.75      53.87      32.38
 AG/HY/PL                  .00      18.73      81.27
 OL/HY/PL                  .00      18.73      81.27
 Q/HY/PL                 17.17      15.51      67.31
 NE+/Q+/OL+              33.10      30.94      15.96
 OL+/AG/Q+               35.60        .00      64.40
 OL+/PL/Q+               12.74      68.63      18.62  ADJUSTED FOR CORUNDUM'
 AG/PL/HY+Q                .00      44.42      55.58
 NE/AB+OR/NC+              .00      77.67      22.33
 AB/AN/NC+               44.44      29.93      25.62
 MG/MG+FE2              100.00
 FE2/MG+FE2                .00
                       CATION %
 FE3/FE2+FE3            100.00
 MG/FE2/NA+K             32.47        .00      67.53
 MG/FE2+FE3/NA+K         24.71      23.69      51.40
                       WEIGHT %
 A/F/M                   42.52      36.36      21.11

            SALIC=  84.21  FEMIC=  15.79  NORMATIVE PLAGIOCLASE COMPOSITION=  40.25
DIFFERENTIATION INDEX= 64.40(MOLECULAR) 63.38(WEIGHT)  *COLOUR INDEX= 15.26(MOLECULAR) 16.35(WEIGHT)
MASS ABSORPTION= 55.06645
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32. T-72-78, argillite, Surprise Lake Member.

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      ANALYSIS(WT%)      ALTERATIONS      CATION %
SIO2      62.4 A             64.2            59.5
AL2O3     16.1 A             16.6            18.1
FE2O3     5.80 A             5.96            4.16
FEO        .00                .00             .03
MGO       3.30 A             3.39            4.69
CAO       1.60 A             1.64            1.69
NA2O      3.86 A             3.97            7.14
K2O       3.45 A             3.55            4.20
TIO2       .70 A              .72             .50
P2O5       .00                .00             .00
S          .00                .00             .00
MNO        .09 A              .09             .00
CO2 LOI.  2.73 C              .00             .00
H2O+       .00        CR2O3   .00             .00
H2O-       .00        NIO     .00             .00
TOTAL    100.0
SPEC. GR.

   TRACES(PPM)                NORMS   MOLECULAR    WEIGHT                          NORM RATIOS(MOLECULAR)
    AG    -                    AP        .000        .000    OR/AB+5/3NE/AN        32.39    55.01    12.60
    AU    -                    PO        .000        .000    Q/AB/OR               23.62    48.07    28.31
    AS    -                    IL        .065        .088    NE/AB/OR                .00    62.94    37.06
    BA    -                    OR      21.017      20.904    LC/NE/OR                .00      .00   100.00
    BE    -                    AB      35.695      33.502    OL/OR/LC                .00   100.00      .00
    BI    -                    AN       8.178       8.162    OL/HY/AQ                .00   100.00      .00
    CO    -                    C        3.490       3.192    Q/HY/AQ               65.15    34.85      .00
    CR    -                    AC        .000        .000    HY/OR/Q               19.57    43.09    36.58
    CU    -                    MT        .000        .000    OL/HY/CR                .00    30.87    69.13
    GA    -                    HM       4.169       5.964    Q/PL/OR               21.28    53.23    25.50
    HG    -                    WO        .000        .000    AQ/HY/PL                .00    17.62    82.38
    LI    -                    EN       9.303       8.456    OL/HY/PL                .00    17.62    82.38
    MN    -                    FS        .000        .000    Q/HY/PL               24.77    13.25    61.97
    MO    -                    Q       17.538      18.964    NE+/Q+/CL+            54.20    34.56    11.24
    NB    -                    DI        .000        .000    OL+/AG/Q+             26.14      .00    73.86
    NI    -                    FO        .000        .000    OL+/PL/Q+             11.88    64.72    23.39 ADJUSTED FOR CORUNDUM
    PB    -                    FA        .000        .000    AG/PL/HY+MO             .00    35.55    64.45
    RB    -                    NE        .000        .000    NE/AN+GP/NCT+           .00    80.64    19.36
    SB    -                    LC        .000        .000    AB/AN/NCT+            62.09    14.23    23.68
    SC    -                    KP        .000        .000    MG/MG+FE2            100.00
    SN    -                    HL        .000        .000    FE2/MG+FE2              .00
    SR    -                    CC        .000        .000                       CATION %
    TE    -                    RU        .420        .675    FE3/FE2+FE3          100.00
    V     -                    NS        .000        .000    MG/FE2/NA+K           29.26      .00    70.74
    Y     -                    KS        .000        .000    MG/FE2+FE3/NA+K       23.23    20.62    56.16
    ZN    -                    CM        .000        .000                       WEIGHT %
    ZR    -                    TN        .000        .000    A/F/M                 46.18    32.97    20.85
                         SALIC= 85.92  FEMIC= 14.00  NORMATIVE PLAGIOCLASE COMPOSITION= 18.64
DIFFERENTIATION INDEX= 74.25(MOLECULAR) 73.47(WEIGHT)  *COLOUR INDEX= 13.61(MOLECULAR) 14.50(WEIGHT)
MASS ABSORPTION= 51.40865
```

33. T-72- 14 , argillite , Rush Bay Member,

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          ANALYSIS(WT%)      ALTERATIONS      CATION %
SIO2          60.0 A             63.1           59.3
AL2O3         16.8 A             17.7           19.6
FE2O3         6.00 A             7.16           5.05
FEO            .00                .00            .08
MGO           3.20 A             3.37           4.71
CAO           2.20 A             2.32           2.33
NA2O          2.79 A             2.94           5.34
K2O           2.57 A             2.70           3.24
TIO2           .60 A              .63            .45
P2O5           .00                .00            .00
S              .00                .00            .00
MNO            .09 A              .09            .00
CO2    1.6 X  4.50 C              .00            .00
H2O+,          .00       CH2O3    .00            .00
H2O-           .00       H1O      .00            .00
TOTAL         99.6
SPEC. GR.

     TRACES(PPM)                  NORMS % MOLECULAR   WEIGHT
       AG    -                     AP        .000      .000
       AU    -                     PO        .000      .000
       AS    -                     IL        .151      .203
       BA    -                     OR      16.266    15.993
       BE    -                     AB      26.707    24.835
       BI    -                     AN      11.639    11.403
       CO    -                     C        6.316     5.709
       CR    -                     AC        .000      .000
       CU    -                     MT        .000      .000
       GA    -                     HM       5.053     7.154
       MO    -                     RU        .000      .000
       LI    -                     EN       9.419     8.304
       NB    -                     FS        .000      .000
       MO    -                     Q       24.137    25.715
       NI    -                     DI        .000      .000
       NI    -                     FO        .000      .000
       PB    -                     FA        .000      .000
       RB    -                     NE        .000      .000
       SB    -                     LC        .000      .000
       SC    -                     KP        .000      .000
       SN    -                     HL        .000      .000
       SR    -                     CC        .000      .000
       TI    -                     NC        .370      .525
       V     -                     NS        .000      .000
       Y     -                     KS        .000      .000
       ZN    -                     CS        .000      .000
       ZR    -                     LN        .000      .000

  OR/AB+5/3NE/AN      NORM RATIOS(MOLECULAR)
                        29.71     49.96     21.34
  Q/FO/OR               36.00     39.83     24.17
  NE/AB/OR                .00     62.33     37.77
  LC/NE/OR                .00       .00    100.00
  OL/OR/LC                .00    100.00       .00
  CA/MT/AG                .00    100.00       .00
  Q/MT/AG               71.93     28.07       .00
  MT/OR/C               18.93     32.57     48.50
  OL/HY/OR                .00     36.76     63.24
  Q/PL/OR               30.67     48.73     20.60
  AG/MT/PL                .00     19.72     80.28
  DI/MT/PL                .00     19.72     80.28
  Q/MT/PL               33.57     13.10     53.33
  NE+/Q+/OL+            26.59     61.69     11.72
  OL+/AG/Q+             21.05       .00     78.95
  OL+/PL/Q+             12.99     59.59     27.42 ADJUSTED FOR CORUNDUM
  AG/PL/MT+90             .00     26.57     73.43
  NE/AB+OR/NC+            .00     74.58     25.42
  AB/AN/NC+             50.42     21.97     27.61
  MG/MG+FE2            100.00
  FE2/MG+FE2              .00
                     CATION %
  FE3/FE2+FE3          100.00
  MG/FE2/NAK            35.43       .00     64.57
  MO/FE2+FE3/NAK        25.67     27.55     46.78
                     WEIGHT %
  A/F/M                 36.52     41.68     21.80

                  SALIC= 85.01  FEMIC= 14.99  NORMATIVE PLAGIOCLASE COMPOSITION= 30.35
DIFFERENTIATION INDEX= 67.05(MOLECULAR) 66.54(WEIGHT)  *COLOUR INDEX= 14.62(MOLECULAR) 15.74(WEIGHT)
MASS ABSORPTION= 52.73290
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34. T-72-145 , argillite , Rush Bay Member.

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          ANALYSIS(WT%)      ALTERATIONS      CATION %
SIO2         60.4 A              62.9            59.1
AL2O3        17.7 A              18.4            20.4
FE2O3         7.60 A              7.92            5.60
FEO            .00                 .00            .06
MGO           3.30 A              3.44            4.81
CAO            .90 A               .94            .94
NA2O          2.79 A              2.91            5.30
K2O           2.57 A              2.68            3.21
TIO2           .70 A               .73            .52
P2O5           .00                 .00            .00
S              .00                 .00            .00
MNO            .07 A               .07            .00
CO2           3.68 C               .00            .00
H2O+           .00       CR2O3     .00            .00
H2O-           .00       NIO       .00            .00
TOTAL        99.7
SPEC. GR.

  TRACES(PPM)              NORMS   MOLECULAR    WEIGHT           NORM RATIOS(MOLECULAR)
   AG    -                  AP       .000        .000    OR/AB+5/3NE/AN     33.99    56.02     9.99
   AU    -                  PO       .000        .000    Q/AB/OR            30.74    30.13    23.14
   AS    -                  IL       .116        .156    NE/AB/OR             .00    62.23    37.77
   BA    -                  OR     16.067      15.030    LC/NE/OR             .00      .00   100.00
   BE    -                  AB     26.474      24.581    OL/OR/LC             .00   100.00      .00
   BI    -                  AN      4.721       4.650    OL/NE/AB             .00   100.00      .00
   CO    -                  C      10.028       9.049    Q/HY/AG            73.64    26.36      .00
   CR    -                  AC       .000        .000    HY/OR/Q            18.31    30.55    51.15
   CU    -                  MT       .000        .000    OL/HY/OR             .00    37.47    62.53
   GA    -                  HM      5.593       7.914    Q/PL/OR            36.27    42.06    21.66
   HG    -                  WO       .000        .000    AG/HY/PL             .00    23.59    76.41
   LI    -                  EN      9.630       8.550    OL/HY/PL             .00    23.59    76.41
   MN    -                  FS       .000        .000    Q/HY/PL            39.72    14.22    46.06
   MO    -                  Q      26.903      28.615    NE*/DI/OL*         25.21    63.33    11.46
   NB    -                  DI       .000        .000    OL*/AG/Q*          19.77      .00    80.23
   NI    -                  FO       .000        .000    OL*/PL/Q*          15.07    57.53    27.40 ADJUSTED FOR CORUNDUM
   PB    -                  FA       .000        .000    AG/PL/HY+MO          .00    21.02    78.98
   RB    -                  NE       .000        .000    NE/AB+OR/NC*         .00    73.49    26.51
   SB    -                  LC       .000        .000    AB/AN/NC*          56.69    10.34    32.97
   SC    -                  KP       .000        .000    MG/MG+FE2         100.00
   SN    -                  HL       .000        .000    FE2/MG+FE2           .00
   SR    -                  CC       .000        .000                     CATION %
   TI    -                  RU       .457        .457    FE3/FE2+FE3       100.00
   V     -                  NS       .000        .000    MG/FE2/NA+K        36.14      .00    63.06
   F     -                  KS       .000        .000    MG/FE2+FE3/NA+K    25.44    29.59    44.97
   ZN    -                  CM       .000        .000                     WEIGHT %
   ZR    -                  TN       .000        .000    A/F/M              34.58    44.12    21.29

                           SALIC=  84.20  FEMIC=  15.80  NORMATIVE PLAGIOCLASE COMPOSITION=  15.13

DIFFERENTIATION INDEX= 69.45(MOLECULAR) 69.03(WEIGHT)  *COLOUR INDEX= 15.35(MOLECULAR) 16.63(WEIGHT)

MASS ABSORPTION= 53.53926
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35. T-74-44, argillite, Rush Bay Member.

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           ANALYSIS(WT%)      ALTERATIONS    CATION %
SIO2         65.1 A              67.2          63.0
AL2O3        16.0 A              16.5          16.3
FE2O3         5.40 A              5.57          3.93
FEO            .00                 .00           .07
MGO           3.10 A              3.20          4.47
CAO           1.20 A              1.24          1.26
NA2O          2.97 A              3.05          5.57
K2O           2.41 A              2.49          2.98
TIO2           .60 A               .62           .44
P2O5           .00                 .00           .00
S              .00                 .00           .00
MNO            .08 A               .08           .00
CO2, LOI      3.19 C               .00           .00
H2O+           .00         CR2O3   .09           .00
H2O-           .00         NIO     .00           .00
TOTAL       100.1
SPEC. GR.

     TRACES(PPM)                 NORMS   MOLECULAR    WEIGHT
       AG   -                     AP        .000        .000
       AU   -                     PR        .000        .000
       AS   -                     IL        .131        .177
       BA   -                     OR      14.900      14.717
       BE   -                     AB      27.674      25.953
       BI   -                     AN       6.285       6.146
       CO   -                     C        7.215       6.527
       CR   -                     AC        .000        .000
       CU   -                     MT        .000        .000
       GA   -                     HM       3.933       5.575
       HG   -                     WO        .000        .000
       LI   -                     EN       8.946       7.970
       MN   -                     FS        .000        .000
       MO   -                     Q       30.402      32.534
       NB   -                     DI        .000        .000
       NI   -                     FO        .000        .000
       PB   -                     FA        .000        .000
       RB   -                     NE        .000        .000
       SB   -                     LC        .000        .000
       SC   -                     KP        .000        .000
       SN   -                     HL        .000        .000
       SR   -                     CC        .000        .000
       TI   -                     RU        .371        .526
       V    -                     NS        .000        .000
       Y    -                     KS        .000        .000
       ZN   -                     CR        .000        .000
       ZR   -                     CM        .000        .000

                         NORM RATIOS(MOLECULAR) .
 OR/AB+5/SNE/AN      30.41     56.09     12.70
 Q/AB/OR             41.55     38.09     20.36
 NE/AB/OR              .00     65.17     34.83
 LC/NE/OR              .00       .00    100.00
 OL/OR/LC              .00    100.00       .00
 OL/NE/AG              .00    100.00       .00
 Q/HY/AS             77.26     22.74       .00
 HY/OR/Q             16.49     27.47     56.04
 OL/HY/OR              .00     37.52     62.48
 Q/PL/OR             38.29     42.95     18.77
 AG/HY/PL              .00     20.78     79.22
 OL/HY/PL              .00     20.78     79.22
 Q/HY/PL             41.39     12.18     46.43
 NE+/Q+/OL+          24.88     65.14      9.98
 OL+/AG/Q+           17.78       .07     82.15
 OL+/PL/Q+           12.75     54.83     32.43 ADJUSTED FOR CORUNDUM
 AG/PL/HY+MO           .00     20.71     79.29
 NE/AG+OL/NC+          .00     76.68     23.32
 AB/AN/NC+           59.17     13.21     27.62
 MG/MG+FE2          100.00
 FE2/MG+FE2            .00
                    CATION %
 FE3/FE2+FE3        100.00
 MG/FE2/NAK          34.33       .00     65.67
 MG/FE2+FE3/NAK      26.37     23.20     50.43
                    WEIGHT %
 A/F/M               40.33     36.43     23.24

               SALIC=  86.62  FEMIC=  13.38  NORMATIVE PLAGIOCLASE COMPOSITION= 18.25
DIFFERENTIATION INDEX= 73.18(MOLECULAR) 73.08(WEIGHT)  COLOUR INDEX= 13.01(MOLECULAR) 13.72(WEIGHT)
MASS ABSORPTION= 49.34129
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36. T-72-220 , argillite , Rush Bay Member.

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                         THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
SIO2      TIO2      AL2O3     FE2O3     FEO       MNO       MGO       CAO       NA2O      K2O       P2O5      CO2       SUM
[illegible] [illegible] 17.[illegible] 6.150 0.000 [illegible] 1.11[illegible] 1.900 2.[illegible] 2.[illegible]70 .260 ----  99.[illegible]50

                                    MOLECULAR PROPORTIONS
1.0717    .0010     .1736     .0[illegible]    0.0000    .0[illegible]10     .0771     .0339     .0561     .0276     .0015     0.0000
                                C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE              0.000         MAGNESITE                0.000        SIDERITE             0.000
SODIUM CARBONATE     0.000         POTASSIUM CARBONATE      0.000        TOTAL DIOPSIDES      0.000
APATITE              [illegible]   ALBITE                   2[illegible]       DIOPSIDE (MG)        0.000
ILMENITE             [illegible]   ANORTHITE                [illegible]       DIOPSIDE (FE)        0.000
SPHENE               [illegible]   CORUNDUM                 [illegible]       TOTAL HYPERSTHENE    [illegible]
RUTILE               [illegible]   MAGNETITE                [illegible]       ENSTATITE            [illegible]
K-METASILICATE       [illegible]   HEMATITE                 [illegible]       FERROSILITE          [illegible]
KALSILITE            [illegible]   QUARTZ                   [illegible]       WOLLASTONITE         0.000
LEUCITE              [illegible]   TOTAL OLIVINE            0.000        ACMITE               0.000
ORTHOCLASE           15.[illegible]45  FORSTERITE           0.000
NA-METASILICATE      0.000         FAYALITE                 0.000
NEPHELINE            0.000         CA-ORTHOSILICATE         0.000
                                      SUM              99.[illegible]81

TOTAL FEMIC CONTENT =       9.[illegible]60   TOTAL ALKALI CONTENT =    5.[illegible]90   TOTAL IRON CONTENT =    6.150
DIFFERENTIATION INDEX =    6[illegible].956   SOLIDIFICATION INDEX =   20.[illegible]01   MAFIC INDEX =    6[illegible].[illegible]25   FELSIC INDEX =  76.290
MAFIC-FELSIC INDEX =       [illegible]0.[illegible]07   ALKALIC INDEX =          67.771   LARSEN INDEX =   19.077
ALBITE RATIO (TEHME) =      .[illegible]15   ALBITE RATIO (HIGGINS) =    .[illegible]53   IRON INDEX =     6.540   CRYSTALLIZATION INDEX =  10.910
RITTMANN SIGMA =    1.[illegible]   SO THE ROCK IS IN THE PACIFIC SUITE

                IRON,MAGNESIUM AND ALKALIES SUMMED TO 100% FOR THE DIAGRAMS
        TOTAL IRON =   5[illegible].[illegible]75   TOTAL MAGNESIUM =   [illegible]9.001   TOTAL ALKALIES = 16.722

                                       NIGGLI NUMBERS
AL = [illegible]   FM = [illegible]   C = [illegible]   ALK = 16.49   SI = 25[illegible]   TI = [illegible]   K = .[illegible]   MG = .[illegible]   QZ = [illegible]6.579
QUANTITY FOR THE FELDSPAR VARIATION PLOT, B =  .63   DEGREE OF SI SATURATION =  1.56   DEGREE OF ACIDITY =  .71

                                   ZAVARITSKY CHARACTERISTICS
SMALL A = [illegible]   SMALL C = [illegible]   SMALL B = [illegible]   SMALL S = [illegible]   SMALL S = [illegible]   Q = [illegible]
[illegible]

DIFFERENTIATION INDEX(DI),IRON INDEX(II),AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =  [illegible]0.065   II =   7.[illegible]   CI =  1[illegible]

      PERALKALINITY INDEX =  .5[illegible]
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57. T-72-222 , argillite , Hugh Bay member:

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                                  CIPW NORM CALCULATION OF NORMALIZED RESULTS
                                  THE CHEMICAL COMPOSITION OF THE ROCK(IN WEIGHT PERCENT
  SIO2       TIO2      AL2O3      FE2O3      FEO        MNO       MGO        CAO        NA2O       K2O       P2O5      CO2       SUM
 76.730      .400     14.030      4.310 .    0.000      .053      2.110      2.476      2.470      .538      .154      ----    100.010

                                          MOLECULAR PROPORTIONS
 1.1701     .0060     .1456      .0259      0.0083      .0007     .0571      .0169      .0511      .0269     .0010     0.0000
                                    C.I.P.W. NORM(IN WEIGHT PERCENT)

 CALCITE                    0.000           MAGNESITE                  0.000          SIDERITE                   0.000
 SODIUM CARBONATE           0.000           POTASSIUM CARBONATE        0.045
 APATITE                     .365           ALBITE                     2.221          TOTAL DIOPSIDE             0.000
 ILMENITE                    .102           ANORTHITE                  7.800            DIOPSIDE (WO)            0.000
 SPHENE                                     CORUNDUM                   5.431            DIOPSIDE (EN)            0.000
 RUTILE                     1.550           MAGNETITE                  0.060            DIOPSIDE (FS)            0.000
 K-METASILICATE             0.000           HEMATITE                   4.117          TOTAL HYPERSTHENE          5.721
 KALIOPHILITE               0.000           QUARTZ                    38.517            ENSTATITE                5.721
 LEUCITE                    0.000           TOTAL OLIVINE              0.300            FERROSILITE              0.000
 ORTHOCLASE                15.252             FORSTERITE               0.003          WOLLASTONITE               0.000
 NA-METASILICATE            0.000             FAYALITE                 0.000          ACMITE                     0.460
 NEPHELINE                  0.000             FE-ORTHOSILICATE         0.003
                                                SUM                  100.021
 TOTAL FEMIC CONTENT =          6.441    TOTAL ALKALI CONTENT =     5.700    TOTAL IRON CONTENT =     4.310
 DIFFERENTIATION INDEX =       75.955    SOLIDIFICATION INDEX =    19.055    MAFIC INDEX =      65.110   FELSIC INDEX =   71.527
 MAFIC-FELSIC INDEX =          67.877    ALKALIC INDEX =           58.655    LARSEN INDEX =     21.757
 ALBITE RATIO (CIPW) =           .751    ALBITE RATIO (NIGGLI) =     .512    IRON INDEX =        4.237   CRYSTALLIZATION INDEX = 11.307
 RITTMANN SIGMA =    .37    SO THE ROCK IS IN THE PACIFIC SUITE
                    IRON,MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
         TOTAL IRON =   35.483    TOTAL MAGNESIUM =            19.855    TOTAL ALKALIES = 44.676
                                                     NIGGLI NUMBERS
 AL = 48.21   FM = 30.29   C = 10.19   ALK = 13.11    SI = 125.24   MG =   .57   K =  .16   QZ = 152.811
 ORDINATE FOR THE FELDSPAR VARIATION PLOT, A =   .65   DEGREE OF SI SATURATION =   1.44   DEGREES OF ACIDITY =   .76
                                                ZAVARITSKY CHARACTERISTICS
 SMALL A =   9.019   SMALL C =   2.109   SMALL C BAR =   0.016   SMALL B = 12.929   SMALL S = 76.517   Q =   17.57
 FIPRIMEI =27.7664   NPRIME =18.7910   CIPRIME =  0.3309   AIPRIME =51.2826   NPRIME =  0.0000   SMALL N =61.5966
 DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%.
 DI =  82.571    II =    4.601    CI =   12.927

      PERALKALINITY  INDEX =   .5
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38. T-72-104 , argillite , Hoshor Bay Fm.

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        ANALYSIS(WT%)      ALTERATIONS      CATION %
SIO2        62.1 A             64.7           60.9
AL2O3       16.5 A             17.2           19.1
FE2O3       6.60 A             7.09           5.02
FEO          .00                .00            .07
MGO         2.90 A             3.02           4.24
CAO         1.90 A             1.90           2.00
NA2O        3.24 A             3.38           6.16
K2O         1.61 A             1.60           2.02
TIO2         .80 A              .03            .59
P2O5         .00                .00            .00
S            .00                .00            .00
MNO          .08 A              .00            .00
CO2  L.O.I. 4.43 C              .00            .00
H2O+         .00       CR2O3    .00            .00
H2O-         .00       NIO      .00            .00
TOTAL      100.9
SPEC. GR.

     TRACES(PPM)                NORMS   MOLECULAR   WEIGHT                           NORM RATIOS(MOLECULAR)
      AG   -                     AP       .000       .000     OR/AB+5NE/AN       19.82     60.55     19.63
      AU   -                     PO       .000       .000     Q/AN/OR            40.77     44.62     14.61
      AS   -                     IL       .133       .170     NE/AB/OR             .00     75.34     24.66
      BA   -                     OR     10.076      9.927     LC/NE/OR             .00       .00    100.00
      BE   -                     AB     30.702     28.576     OL/OR/LC             .00    100.00       .00
      BI   -                     AN      9.977      9.826     OL/HY/AG             .00    100.00       .00
      CO   -                     C       6.099      6.225     Q/HY/AG            76.85     23.15       .00
      CR   -                     AC       .000       .000     HY/OR/Q            18.15     21.59     60.26
      CU   -                     MT       .000       .000     OL/HY/OR             .00     45.67     54.33
      GA   -                     HM      5.015      7.000     Q/PL/OR            35.62     51.62     12.76
      HG   -                     WO       .000       .000     AG/HY/PL             .00     17.21     82.79
      LI   -                     EN      8.472      7.520     OL/HY/PL             .00     17.21     82.79
      MN   -                     FS       .000       .000     Q/HY/PL            36.36     10.95     52.69
      MO   -                     Q      28.122     29.911     NE+/Q+/OL+         27.41     63.16      9.43
      NB   -                     DI       .000       .000     OL+/AG/Q+          17.36       .00     82.64
      NI   -                     FO       .000       .000     OL+/PL/Q+          11.76     59.16     29.00 ADJUSTED FOR CORUNDUM
      PB   -                     FA       .000       .000     AG/PL/HY+Q           .00     25.20     74.00
      RB   -                     NE       .000       .000     NE/AN+OR/NC+         .00     75.00     25.00
      SB   -                     LC       .000       .000     AB/AN/NC+          66.61     18.35     25.05
      SC   -                     KP       .000       .000     MG/MG+FE2         100.00
      SN   -                     NE       .000       .000     FE2/MG+FE2           .00
      SR   -                     CC       .000       .000                     CATION %
      TI   -                     RU       .523       .790     FE3/FE2+FE3       100.00
      V    -                     NS       .000       .000     MG/FE2/NA+K        34.14       .00     65.86
      Y    -                     KS       .000       .000     MG/FE2+FE3/NA+K    24.31     20.79     46.90
      ZN   -                     CR       .000       .000                     WEIGHT %
      ZR   -                     LN       .000       .000     A/F/M              34.97     44.12     20.91

                          SALIC=  85.06  FEMIC=  14.14  NORMATIVE PLAGIOCLASE COMPOSITION=  24.48
DIFFERENTIATION INDEX= 68.90(MOLECULAR) 68.41(WEIGHT)  *COLOUR INDEX= 13.62(MOLECULAR) 14.00(WEIGHT)
MASS ABSORPTION= 52.11008
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39. T-73- 14 , argillite , Hoshor Bay Fm.

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         ANALYSIS(WT%)     ALTERATIONS     CATION %
SIO2         60.7 A            63.1          59.2
AL2O3        17.7 A            18.4          20.4
FE2O3        7.20 A            7.49          5.29
FEO           .00               .00           .06
MGO          2.00 A            2.91          4.07
CAO          1.60 A            1.56          1.57
NA2O         3.15 A            3.20          5.96
K2O          2.41 A            2.51          3.00
TIO2          .60 A             .62           .44
P2O5          .00               .00           .00
S             .00               .00           .00
MNO           .07 A             .07           .00
CO2   L.O.I. 4.96 C             .00           .00
H2O+          .00         CR2O3 .00           .00
H2O-          .00         NIO   .00           .00
TOTAL       101.1
SPEC. GR.

     TRACES(PPM)             NORMS   MOLECULAR   WEIGHT                         NORM RATIOS(MOLECULAR)
      AG    -                 AP       .000       .000      OR/AB+5/3NE/AN      28.52     66.69     14.89
      AU    -                 PO       .000       .000      Q/AB/OR             35.93     42.60     21.47
      AS    -                 IL       .116       .156      NE/AB/OR              .00     66.49     33.51
      BA    -                 OR     15.021     14.829      LC/NE/OR              .00       .00    100.00
      BE    -                 AB     29.802     27.724      OL/OR/LC              .00    100.00       .00
      BI    -                 AN      7.844      7.741      OL/HY/AQ              .00    100.00       .00
      CO    -                 C       8.261      7.469      Q/HY/AG             75.53     24.47       .00
      CR    -                 AC       .000       .000      HY/OR/Q             16.06     31.69     52.04
      CU    -                 MT       .000       .000      OL/HY/OR              .00     35.16     64.84
      GA    -                 HM      5.208      7.490      Q/PL/OR             32.31     48.38     19.31
      HG    -                 WO       .000       .000      AO/HY/PL              .00     17.79     82.21
      LI    -                 EN      8.146      7.259      OL/HY/PL              .00     17.79     82.21
      MN    -                 FS       .000       .000      Q/HY/PL             35.44     11.48     53.07
      MO    -                 Q      25.140     26.795      NE+/OI/OL+          28.34     61.97      9.68
      NB    -                 DI       .000       .000      OL+/AG/Q+           18.35       .00     81.65
      NI    -                 FO       .000       .000      OL+/PL/Q+           12.86     60.91     26.24 ADJUSTED FOR CORUNDUM
      PB    -                 FA       .000       .000      AO/PL/LT+NO           .00     25.72     74.28
      RB    -                 NE       .000       .000      NE/AB+CO/NCI+         .00     76.79     23.21
      SB    -                 LC       .000       .000      AB/AN/NCI+          58.21     15.32     26.47
      SC    -                 KP       .000       .000      MG/MG+FE2          100.00
      SN    -                 HL       .000       .000      FE2/MG+FE2            .00
      SR    -                 CC       .000       .000                     CATION %
      TI    -                 RU       .383       .542      FE3/FE2+FE3        100.00
      V     -                 NS       .000       .000      MG/FE2/NA+K         31.24       .00     68.76
      Y     -                 KS       .000       .000      MG/FE2+FE3/NA+K     22.22     28.86     46.92
      ZN    -                 CM       .000       .000                     WEIGHT %
      ZR    -                 LN       .000       .000      A/F/M               37.47     43.66     18.87

                        SALIC= 86.07  FEMIC= 13.03  NORMATIVE PLAGIOCLASE COMPOSITION= 20.84

DIFFERENTIATION INDEX= 69.96(MOLECULAR) 69.35(WEIGHT)  *COLOUR INDEX= 13.55(MOLECULAR) 14.90(WEIGHT)

MASS ABSORPTION= 63.17644
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                              CIPW NORM CALCULATION OF NORMALIZED RESULTS
40. T-72- 38 , argillite , Moshor Bay Fm.
                              THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
  SIO2      TIO2     AL2O3     FE2O3     FEO      MNO      MGO      CAO      NA2O     K2O      P2O5     CO2      SUM
 63.[illegible]  .610  17.[illegible]  6.780  0.000   .090    2.660    1.430    3.120    2.970    .070     ....     99.790

                                        MOLECULAR PROPORTIONS
 1.0631     .0076    .1752     .0420   0.0000    .0013    .0660    .0255    .0[illegible]    .0315    .0005    0.0000
                                   C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE                [illegible]   MAGNESITE                 [illegible]   SIDERITE               0.000
SODIUM CARBONATE       [illegible]   POTASSIUM CARBONATE       [illegible]   TOTAL DIOPSIDE         [illegible]
APATITE                [illegible]   ALBITE                    31.[illegible]   DIOPSIDE (WO)       [illegible]
ILMENITE               [illegible]   ANORTHITE                 [illegible]   DIOPSIDE (EN)          [illegible]
SPHENE                 [illegible]   CORUNDUM                  [illegible]   DIOPSIDE (FS)          [illegible]
RUTILE                 [illegible]   MAGNETITE                 [illegible]   TOTAL HYPERSTHENE      [illegible]
K-METASILICATE         [illegible]   HEMATITE                  [illegible]   ENSTATITE              [illegible]
KALIOPHILITE           [illegible]   QUARTZ                    2[illegible]   FERROSILITE         [illegible]
LEUCITE                [illegible]   TOTAL OLIVINE             [illegible]   WOLLASTONITE           [illegible]
ORTHOCLASE             1[illegible]   FORSTERITE               [illegible]   ACMITE                 [illegible]
NA-METASILICATE        [illegible]     FAYALITE                [illegible]
NEPHELINE              [illegible]     CA-ORTHOSILICATE        [illegible]
                                          SUM         99.991
TOTAL FEMIC CONTENT =      9.368  TOTAL ALKALI CONTENT =   6.090  TOTAL IRON CONTENT =    6.780
DIFFERENTIATION INDEX =   73.455  SOLIDIFICATION INDEX =  16.971  MAFIC INDEX =     71.581  FELSIC INDEX =  52.319
MAFIC-FELSIC INDEX =     76.985  ALKALIC INDEX =           44.395  LARSEN INDEX =    20.173
ALBITE RATIO (CIPW) =      .666  ALBITE RATIO (NIGGLI) =    .589  IRON INDEX =       6.491   CRYSTALLIZATION INDEX =, 9.503
RITTMANN SIGMA =   2.14  SO THE ROCK IS IN THE PACIFIC SUITE
            IRON, MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
     TOTAL IRON =   41.765    TOTAL MAGNESIUM =   16.573   TOTAL ALKALIES =  41.662
                                             NIGGLI NUMBERS
AL = 39.9  FM = 26.67  C = 5.75  ALK = 28.65  SI = 239.70  MG = .44  K = .35  QZ = 57.10
ORDINATE FOR THE FELDSPAR VARIATION PLOT, R =  .69  DEGREE OF SI SATURATION =  1.31  DEGREE OF ACIDITY =   .71
                                  ZAVARITSKY CHARACTERISTICS
SMALL A = 11.457  SMALL C = 1.650  SMALL C BAR = [illegible]  SMALL B = 17.220  SMALL S = 69.703  Q = 13.22
F(PRIME) = [illegible]  M(PRIME) = [illegible]  C(PRIME) = [illegible]  A(PRIME) = [illegible]  N(PRIME) = [illegible]  SMALL N = 65.559
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =  81.752   II =   7.671   CI =  10.577

      PERALKALINITY INDEX  =  .5
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41. T-72-152 , argillite , Hoohor Bay Fm.

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                          CIPW NORM CALCULATION OF NORMALIZED RESULTS
                              THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2     TIO2     AL2O3    FE2O3    FEO      MNO      MGO      CAO      NA2O     K2O      P2O5     CO2      SUM
57.960    .920    23.090    8.440   0.000     .070    1.860     .660    3.090    3.830     .090     ----   100.020

 .9647    .0115    .2265    .0528   MOLECULAR PROPORTIONS
                                    0.0000    .0010    .0461    .0118    .0499    .0407    .0006   0.0000
                                 C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE                [illegible]      MAGNESITE               [illegible]      STOEPITE                0.000
SODIUM CARBONATE       [illegible]      POTASSIUM CARBONATE     [illegible]      TOTAL DIOPSIDE          [illegible]
APATITE                [illegible]      ALBITE                  [illegible]        DIOPSIDE (WO)         [illegible]
ILMENITE               [illegible]      ANORTHITE               [illegible]        DIOPSIDE (EN)         [illegible]
SPHENE                 [illegible]      CORUNDUM                [illegible]        DIOPSIDE (FS)         [illegible]
RUTILE                 [illegible]      MAGNETITE               [illegible]      TOTAL HYPERSTHENE       [illegible]
K-METASILICATE         [illegible]      HEMATITE                [illegible]        ENSTATITE             [illegible]
KALIOPHILITE           [illegible]      QUARTZ                  [illegible]        FERROSILITE           [illegible]
LEUCITE                [illegible]      TOTAL OLIVINE           [illegible]      WOLLASTONITE            [illegible]
ORTHOCLASE             [illegible]        FORSTERITE            [illegible]      ACMITE                  [illegible]
NA-METASILICATE        [illegible]        FAYALITE              [illegible]
NEPHELINE              [illegible]        CA-ORTHOSILICATE      [illegible]
                                           SUM             100.021

TOTAL FEMIC CONTENT =       10.388   TOTAL ALKALI CONTENT =   6.920   TOTAL IRON CONTENT =    8.440
DIFFERENTIATION INDEX =     78.766   SOLIDIFICATION INDEX =  10.881   MAFIC INDEX =      81.942   FELSIC INDEX =  91.293
MAFIC-FELSIC INDEX =        86.617   ALKALIC INDEX =         85.347   LARSEN INDEX =     20.633
ALBITE RATIO (CIPW) =        1.000   ALBITE RATIO (NIGGLI) =   .423   IRON INDEX=         8.590   CRYSTALLIZATION INDEX =  3.242
RITTMANN SIGMA =      3.20   SO THE ROCK IS IN THE PACIFIC SUITE
              IRON,MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
        TOTAL IRON =      49.813    TOTAL MAGNESIUM =      10.001    TOTAL ALKALIES = 40.186

                                          NIGGLI NUMBERS
AL = [illegible]  FM = [illegible]  C = [illegible]  ALK = 16.08  SI = 280.13  MG = [illegible]  K = [illegible]  QZ = 25.151
ORDINATE FOR THE FELDSPAR VARIATION PLOT, P =  .57   DEGREE OF SI SATURATION =  1.16   DEGREE OF ACIDITY =   .67

                                   ZAVARITSKY CHARACTERISTICS
SMALL A = 11.516  SMALL C =   .750  SMALL C ALP = [illegible]  SMALL B = 25.503  SMALL S = 62.212  Q = [illegible]
F(PRIME) =[illegible]  M(PRIME) =11.5272  C(PRIME) = 0.0000  A(PRIME) =62.0605  N(PRIME) = 0.0000  SMALL N =55.0795

DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =   65.675   II =   10.399   CI =    1.926

     PERALKALINITY  INDEX  =  .4
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                              CIPW NORM CALCULATION OF NORMALIZED RESULTS
45.  S-73-  2 , volcanic lithic graywacke , Hosher Bay Fm.
                              THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2      TIO2     AL2O3     FE2O3     FEO      MNO      MGO      CAO      NA2O     K2O      P2O5     CO2      SUM
66.610     .460    13.926     4.460    0.000     .100    3.750    2.670    4.760    1.420    .070     ----   100.010

                                          MOLECULAR PROPORTIONS
1.1110    .0058     .1365     .0279    0.0000    .0014    .0926    .0476    .0768    .0151    .0005    0.0000
                              C.I.P.W. NORM (IN WEIGHT PERCENTS)

CALCITE               [illegible]    MAGNESITE              [illegible]    SIDERITE              0.000
SODIUM CARBONATE      [illegible]    POTASSIUM CARBONATE    [illegible]    TOTAL DIOPSIDE        [illegible]
APATITE               [illegible]    ALBITE                 [illegible]      DIOPSIDE (WO)       [illegible]
ILMENITE              [illegible]    ANORTHITE              [illegible]      DIOPSIDE (EN)       [illegible]
SPHENE                [illegible]    CORUNDUM               [illegible]      DIOPSIDE (FS)       [illegible]
RUTILE                [illegible]    MAGNETITE              [illegible]    TOTAL HYPERSTHENE     [illegible]
K-METASILICATE        [illegible]    HEMATITE               [illegible]      ENSTATITE           [illegible]
KALIOPHILITE          [illegible]    QUARTZ                 [illegible]      FERROSILITE         [illegible]
LEUCITE               [illegible]    TOTAL OLIVINE          [illegible]    WOLLASTONITE          [illegible]
ORTHOCLASE            [illegible]      FORSTERITE           [illegible]    ACMITE                [illegible]
NA-METASILICATE       [illegible]      FAYALITE             [illegible]
NEPHELINE             [illegible]    CA-ORTHOSILICATE       [illegible]
                                         SUM      100.011
TOTAL FEMIC CONTENT =      9.000   TOTAL ALKALI CONTENT =   6.180   TOTAL IRON CONTENT =   4.460
DIFFERENTIATION INDEX =   71.520    SOLIDIFICATION INDEX =  23.406   MAFIC INDEX =   61.037 - FELSIC INDEX =  69.031
MAFIC-FELSIC INDEX =      69.035   ALKALIC INDEX =          22.977   LARSEN INDEX =  17.200
ALBITE RATIO (CIPW) =      .777   ALBITE RATIO (NIGGLI) =    .775   IRON INDEX=      6.274   CRYSTALLIZATION INDEX = 10.099
RITTMANN SIGMA =   1.60   SO THE ROCK IS IN THE PACIFIC SUITE
              IRON,MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
        TOTAL IRON =   37.921   TOTAL MAGNESIUM =         23.406   TOTAL ALKALIES = 38.673
                                           NIGGLI NUMBERS
AL = 38.61   FM = 30.12   C = 10.67   ALK = 20.60   SI = 254.25   MG =  .55   K =  .16   QZ = 82.[illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT, S =  .50   DEGREE OF SI SATURATION =  1.37   DEGREE OF ACIDITY =   .71
                                     ZAVARITSKY CHARACTERISTICS
SMALL A = [illegible]  SMALL C = [illegible]  SMALL C BAR = [illegible]  SMALL B = [illegible]  SMALL S = [illegible]  Q = [illegible]
F(PRIME) = [illegible]  M(PRIME) = [illegible]  C(PRIME) = [illegible]  F(PRIME) = [illegible]  N(PRIME) = [illegible]  SMALL N = [illegible]

DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =  74.585   II =   6.541   CI =  18.875

     PERALKALINITY  INDEX  =  .7
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                               CIPW NORM CALCULATION OF NORMALIZED RESULTS
46.  8-73-  5 ; volcanic lithic graywacke , Hoohor Bay Fm.
                                    THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2      TIO2     AL2O3     FE2O3     FEO      MNO      MGO      CAO      NA2O     K2O      P2O5     CO2       SUM
67.950     .450    [illegible]  6.100    0.000     .100    2.940    2.460    4.170    2.050     .060    ----   100.000

                                        MOLECULAR PROPORTIONS
1.1315     .0056    .1342     .0382    0.0000     .0014    .0729    .0439    .0673    .0218    .0004    0.0000
                                   C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE                [illegible]       MAGNESITE              [illegible]       SIDERITE                0.000
SODIUM CARBONATE       [illegible]       POTASSIUM CARBONATE    [illegible]       TOTAL DIOPSIDE          [illegible]
APATITE                 .142             ALBITE                 35.286               DIOPSIDE (WO)        [illegible]
ILMENITE                .215             ANORTHITE              [illegible]          DIOPSIDE (EN)        [illegible]
SPHENE                 [illegible]       CORUNDUM               [illegible]          DIOPSIDE (FS)        [illegible]
RUTILE                 [illegible]       MAGNETITE              [illegible]       TOTAL HYPERSTHENE       [illegible]
K-METASILICATE         [illegible]       HEMATITE               [illegible]          ENSTATITE            [illegible]
KALIOPHILITE           [illegible]       QUARTZ                 [illegible]          FERROSILITE          [illegible]
LEUCITE                [illegible]       TOTAL OLIVINE          [illegible]       WOLLASTONITE            [illegible]
ORTHOCLASE             12.115              FORSTERITE           [illegible]       ACMITE                  [illegible]
NA-METASILICATE        [illegible]         FAYALITE             [illegible]
NEPHELINE              [illegible]         CA-ORTHOSILICATE     [illegible]
                                               SUM              100.001
TOTAL FEMIC CONTENT =      9.840   TOTAL ALKALI CONTENT =    6.220   TOTAL IRON CONTENT =   6.100
DIFFERENTIATION INDEX =   76.058   SOLIDIFICATION INDEX =   19.266   MAFIC INDEX =    67.470   FELSIC INDEX =  71.659
MAFIC-FELSIC INDEX =      69.560   ALKALIC INDEX =          32.950   LARSEN INDEX =   19.313
ALBITE RATIO (CIPW) =       .764   ALBITE RATIO (NIGGLI) =    .749   IRON INDEX=       6.316   CRYSTALLIZATION INDEX = 16.763
RITTMANN SIGMA =    1.55   SO THE ROCK IS IN THE PACIFIC SUITE
                 IRON,MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
          TOTAL IRON =   39.974   TOTAL MAGNESIUM =          19.266   TOTAL ALKALIES = 40.760
                                             NIGGLI NUMBERS
[illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT, A =   .48   DEGREE OF SI SATURATION = [illegible]  K = [illegible] 1.46   DEGREE OF ACIDITY =   .73
                                             ZAVARITSKY CHARACTERISTICS
[illegible]
[illegible]                                                                                                  SMALL N =78.5590
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100%
DI =   77.015   II =   6.560   CI =   16.397

     PERALKALINITY  INDEX  =  .7
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                        CIPW NORM CALCULATION OF NORMALIZED RESULTS
47. OT-73-  5 , volcanic lithic graywacke , Hooher Bay Fm.
                          THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
 SIO2     TIO2    AL2O3    FE2O3    FEO     MNO     MGO     CAO     NA2O    K2O     P2O5    CO2     SUM
69.310    .460   12.580    5.400   0.000    .100   3.130   3.050   4.380    .920    .120    ----  100.000

1.1516   .0058   .1232    .0174   MOLECULAR PROPORTIONS
                                  0.0000  .0014   .0776   .0542   .0707   .0098   .0008   0.0000
                          C.I.P.W. NORM (IN WEIGHT PERCENT)
CALCITE               0.000    MAGNESITE                 [illegible]    SIDERITE                 0.000
SODIUM CARBONATE      0.000    POTASSIUM CARBONATE       [illegible]    TOTAL DIOPSIDE           [illegible]
APATITE               [illegible]    ALBITE                    [illegible]      DIOPSIDE (WO)          [illegible]
ILMENITE              [illegible]    ANORTHITE                 [illegible]      DIOPSIDE (EN)          [illegible]
SPHENE                [illegible]    CORUNDUM                  [illegible]      DIOPSIDE (FS)          [illegible]
RUTILE                [illegible]    MAGNETITE                 [illegible]    TOTAL HYPERSTHENE        [illegible]
K-METASILICATE        [illegible]    HEMATITE                  [illegible]      ENSTATITE              [illegible]
KALIOPHILITE          [illegible]    QUARTZ                    [illegible]      FERROSILITE            [illegible]
LEUCITE               [illegible]    TOTAL OLIVINE             [illegible]    WOLLASTONITE             [illegible]
ORTHOCLASE            5.437      FORSTERITE              [illegible]    ACMITE                   0.000
NA-METASILICATE       [illegible]      FAYALITE                [illegible]
NEPHELINE             0.000      CA-ORTHOSILICATE          [illegible]
                                    SUM                    100.001
TOTAL FEMIC CONTENT =        9.110   TOTAL ALKALI CONTENT =   5.300   TOTAL IRON CONTENT =   5.900
DIFFERENTIATION INDEX =     72.409   SOLIDIFICATION INDEX =  21.721   MAFIC INDEX =   65.142   FELSIC INDEX =  63.549
MAFIC-FELSIC INDEX =        65.596   ALKALIC INDEX =         17.350   LARSEN INDEX =   17.051
ALBITE RATIO (CIPW) =         .757   ALBITE RATIO (NIGGLI) =   .760   IRON INDEX=       6.194   CRYSTALLIZATION INDEX = 17.910
RITTMANN SIGMA =   1.07   SO THE ROCK IS IN THE PACIFIC SUITE
          IRON, MAGNESIUM AND ALKALIES SUMMED TO 100% FOR AMF DIAGRAMS
     TOTAL IRON =    61.499    TOTAL MAGNESIUM =    21.721    TOTAL ALKALIES =  16.710
                                        NIGGLI NUMBERS
AL = 24.97   FM = 37.39   C = 15.17   ALK = 19.51   SI = 250.11   MG =   .50   K =   .12   QZ = 101.391
ORDINATE FOR THE FELDSPAR VARIATION PLOT, R =   .73   DEGREE OF SI SATURATION =  1.17   DEGREE OF ACIDITY =   .76
                                   ZAVARITSKY CHARACTERISTICS
SMALL A = 10.516  SMALL C =  2.000  SMALL B = [illegible]  SMALL S = 10.750  SMALL Q = 74.975  Q =  27.95
FIFNMZS = 55.1721  NIPNIPCI = 17.5622  CIPPIPCI =  6.1608  SIPAINZI =  0.0330  NIPNIPCI =  0.0000  SMALL N = 87.6515
DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100.
DI =  74.993   II =   6.405   CI =  18.601

     PERALKALINITY  INDEX =  .7
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48. T-74- 42 , arkosic graywacke , Hoohor Bay Fg.

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                         CIPW NORM CALCULATION OF NORMALIZED RESULTS
                         THE CHEMICAL COMPOSITION OF THE ROCK IN WEIGHT PERCENT
SIO2     TIO2    AL2O3    FE2O3    FEO     MNO     MGO     CAO     NA2O    K2O     P2O5    CO2     SUM
[illegible] [illegible] 14.[illegible] 5.270 0.000 .050 2.190 .900 4.210 1.720 [illegible] ....  99.990

                                   MOLECULAR PROPORTIONS
1.1716   .0058   .1428   .0330   0.0000   .0007   .0543   .0160   .0682   .0183   .0006   0.0000
                         C.I.P.W. NORM (IN WEIGHT PERCENT)

CALCITE              [illegible]   HALITE               [illegible]   SIDERITE             0.000
SODIUM CARBONATE     [illegible]   POTASSIUM CARBONATE  [illegible]   TOTAL DIOPSIDE       [illegible]
APATITE              [illegible]   ALBITE               [illegible]     DIOPSIDE (WOL)     [illegible]
ILMENITE             [illegible]   ANORTHITE            [illegible]     DIOPSIDE (EN)      [illegible]
SPHENE               [illegible]   CORUNDUM             [illegible]     DIOPSIDE (FS)      [illegible]
RUTILE               [illegible]   MAGNETITE            [illegible]   TOTAL HYPERSTHENE    [illegible]
K-METASILICATE       [illegible]   HEMATITE             [illegible]     ENSTATITE          [illegible]
KALIOPHILITE         [illegible]   QUARTZ               [illegible]     FERROSILITE        [illegible]
LEUCITE              [illegible]   TOTAL OLIVINE        [illegible]   WOLLASTONITE         [illegible]
ORTHOCLASE           [illegible]     FORSTERITE         [illegible]   ACMITE               [illegible]
NA-METASILICATE      [illegible]     FAYALITE           [illegible]
NEPHELINE            [illegible]   CA-ORTHOSILICATE     [illegible]
                                     SUM              99.991

TOTAL FEMIC CONTENT =       7.460  TOTAL ALKALI CONTENT =    5.930  TOTAL IRON CONTENT =   5.270
DIFFERENTIATION INDEX =    80.659   SOLIDIFICATION INDEX =  16.331   MAFIC INDEX =    70.643   FELSIC INDEX =  31.191
MAFIC-FELSIC INDEX =      70.752  ALKALIC INDEX =          80.918  LARSEN INDEX =  22.137
ALBITE RATIO (CIPW) =       .935  ALBITE RATIO (NIGGLI) =    .768  IRON INDEX=         5.377   CRYSTALLIZATION INDEX =  6.290
RITTMANN SIGMA =    1.29  SO THE ROCK IS IN THE PACIFIC SUITE

          IRON,MAGNESIUM AND ALKALIES SUMMED TO 100, FOR AMF DIAGRAMS
          TOTAL IRON =  39.293   TOTAL MAGNESIUM =  16.331   TOTAL ALKALIES =  44.378

                                   NIGGLI NUMBERS
AL = [illegible]  FM = [illegible]  C = [illegible]  ALK = [illegible]  SI = [illegible]  MG = [illegible]  K = [illegible]  TI = [illegible]  QZ = [illegible]
ORDINATE FOR THE FELDSPAR VARIATION PLOT, R =  .15   DEGREE OF SI SATURATION =  1.45   DEGREE OF ACIDITY =   .76

                                   ZAVARITSKY CHARACTERISTICS
SMALL A = [illegible]  SMALL C = [illegible]  SMALL B = [illegible]  SMALL S = [illegible]  SMALL Q = [illegible]  SMALL N = 70.6924
[illegible]

DIFFERENTIATION INDEX(DI),IRON INDEX(II) AND CRYSTALLIZATION INDEX(CI) SUMMED TO 100.
DI =  87.163   II =   5.[illegible]   CI =   6.51[illegible]

     PERALKALINITY INDEX =  .6
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53. T-74-40, Felsic Body, N. E. of Uphill Lake.

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         ANALYSIS(WT%)      ALTERATIONS    CATION %
SIO2        70.0 A            71.3           66.3
AL2O3       16.2 A            16.5           18.1
FE2O3       2.30 A            2.09           1.43
FEO          .00               .27            .21
MGO         1.00 A            1.02           1.41
CAO         2.00 A            2.04           2.03
NA2O        4.31 A            4.39           7.91
K2O         1.85 A            1.88           2.24
TIO2         .50 A             .51            .36
P2O5         .00               .00            .00
S            .00               .00            .00
MNO          .03 A             .03            .00
CO2  L O I. 2.30 C             .00            .00
H2O+         .00      CR2O3    .00            .00
H2O-         .00      NIO      .00            .00
TOTAL      100.5
SPEC. GR.

    TRACES(PPM)            NORMS   MOLECULAR   WEIGHT
     AG    -                AP       .000        .000
     AU    -                PO       .000        .000
     AS    -                IL       .976        .646
     BA    -                OR     11.189      11.140
     BE    -                AB     39.571      37.149
     BI    -                AN     10.149      10.108
     CO    -                C       3.074       3.535
     CR    -                AC       .000        .000
     CU    -                MT       .000        .000
     GA    -                HM      1.426       2.037
     HG    -                WO       .000        .000
     LI    -                EN      2.623       2.537
     MN    -                FS       .000        .000
     MO    -                Q      30.374      32.609
     NB    -                DI       .000        .000
     NI    -                FO       .000        .000
     PB    -                FA       .000        .000
     RB    -                NE       .000        .000
     SB    -                LC       .000        .000
     SC    -                KP       .000        .000
     SN    -                HL       .000        .000
     SR    -                CC       .000        .000
     TI    -                RU       .118        .169
     V     -                NS       .000        .000
     Y     -                KS       .000        .000
     ZN    -                CM       .000        .000
     ZR    -                LN       .000        .000

                                            NORM RATIOS(MOLECULAR)
                          OR/AB+5/3NE/AN     18.37     64.97     16.66
                          Q/AB/OR            37.44     48.77     13.79
                          NE/AB/OR             .00     77.96     22.04
                          LC/NE/OR             .00       .00    100.00
                          OL/OR/LC             .00    100.00       .00
                          OL/HY/AG             .00    100.00       .00
                          Q/HY/AG            91.50      8.50       .00
                          HY/OR/Q             6.36     25.21     68.43
                          OL/HY/OR             .00     20.15     79.85
                          Q/PL/OR            33.27     54.47     12.26
                          AG/HY/PL             .00      5.37     94.63
                          OL/HY/PL             .00      5.37     94.63
                          Q/HY/PL            36.63      3.40     59.96
                          NE+/Q+/OL+         32.63     64.46      2.91
                          OL+/AG/Q+           6.38       .00     93.62
                          OL+/PL/Q+           8.31     59.84     31.85 ADJUSTED FOR CORUNDUM
                          AG/PL/HY+Q           .00     28.57     71.43
                          NE/AB+OR/NCI+        .00     91.49      8.51
                          AB/AN/NCI+         72.60     18.64      8.68
                          MG/MG+FE2         100.00
                          FE2/MG+FE2           .00
                                          CATION %
                          FE3/FE2+FE3        86.46
                          MG/FE2/NA+K        11.97      1.82     86.20
                          MG/FE2+FE3/NA+K    10.69     12.42     76.89
                                          WEIGHT %
                          A/F/M              66.74     22.42     10.83

                  SALIC= 95.16  FEMIC=  4.84  NORMATIVE PLAGIOCLASE COMPOSITION=  20.41
DIFFERENTIATION INDEX= 81.13(MOLECULAR) 80.90(WEIGHT)  *COLOUR INDEX=  4.72(MOLECULAR)  8.22(WEIGHT)
    ROCK NAME - CALC-ALKALINE DACITE
            *HIGH ALUMINA*
                                                     MASS ABSORPTION= 43.39810
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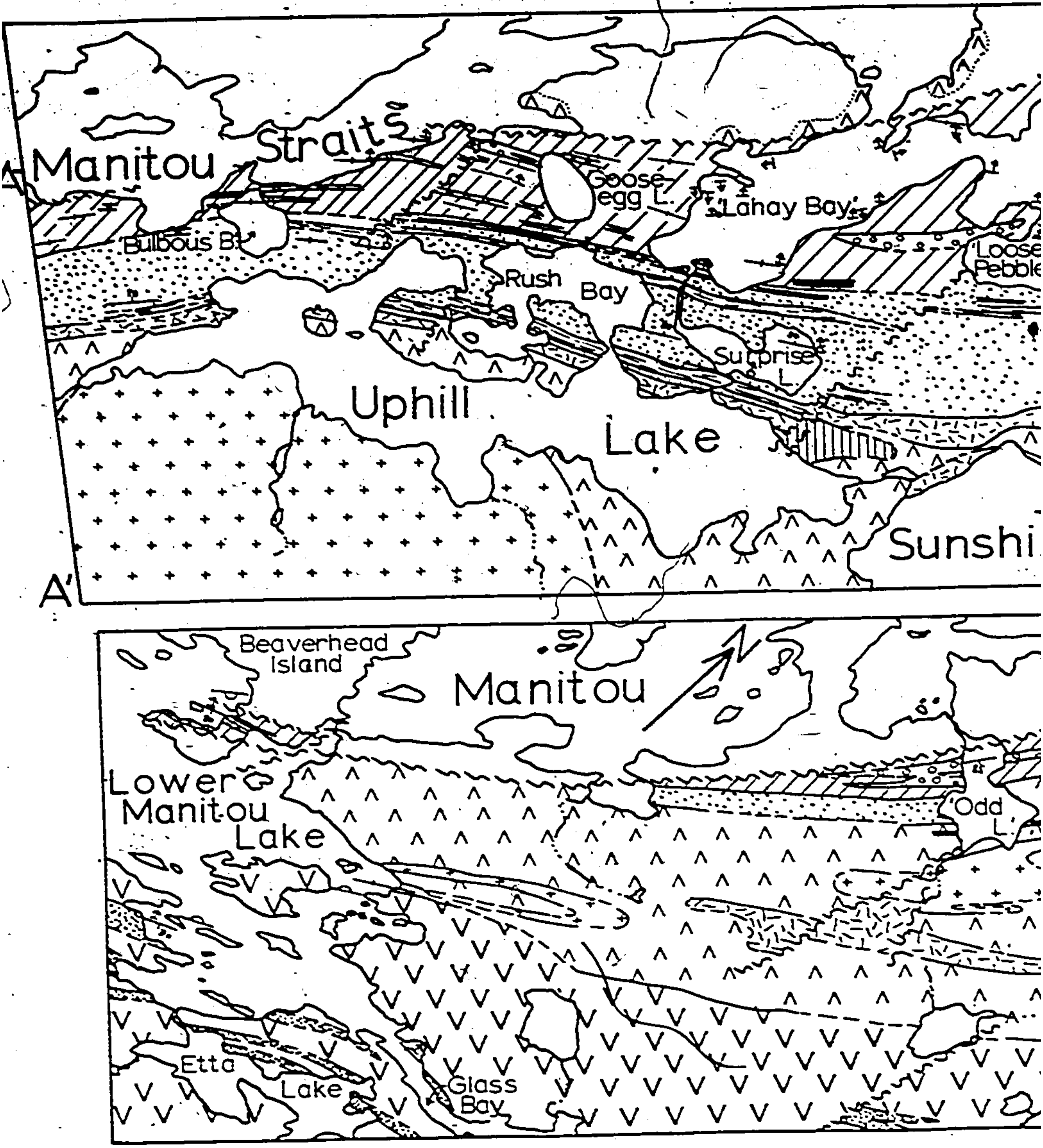
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Etta Lake
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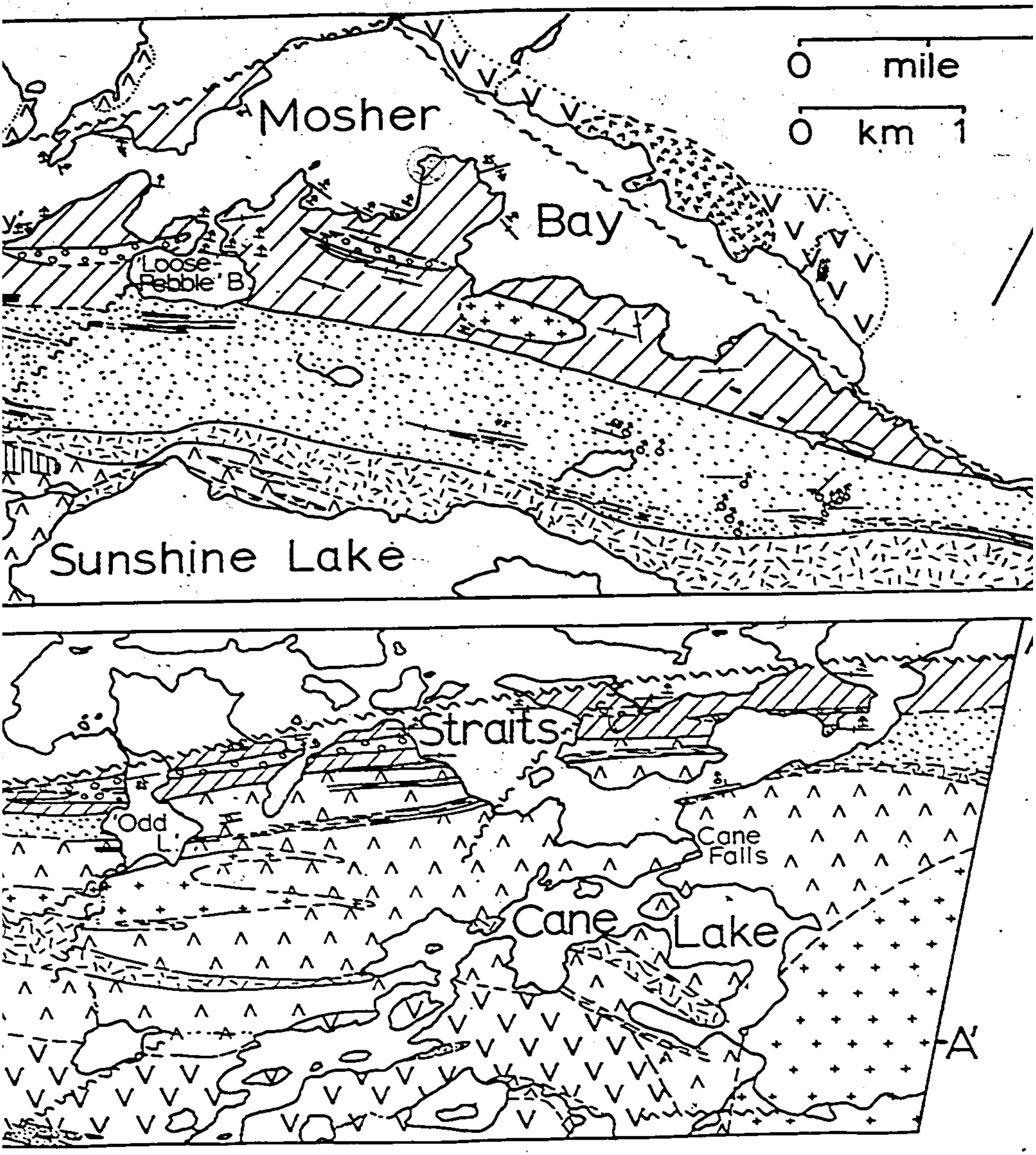
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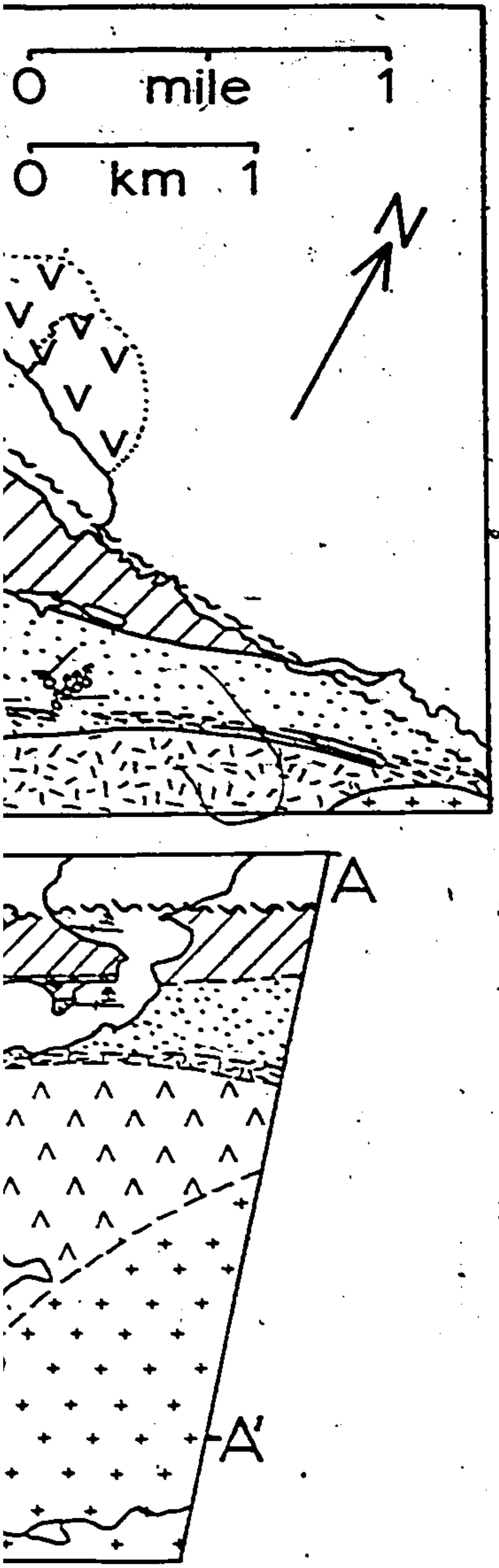

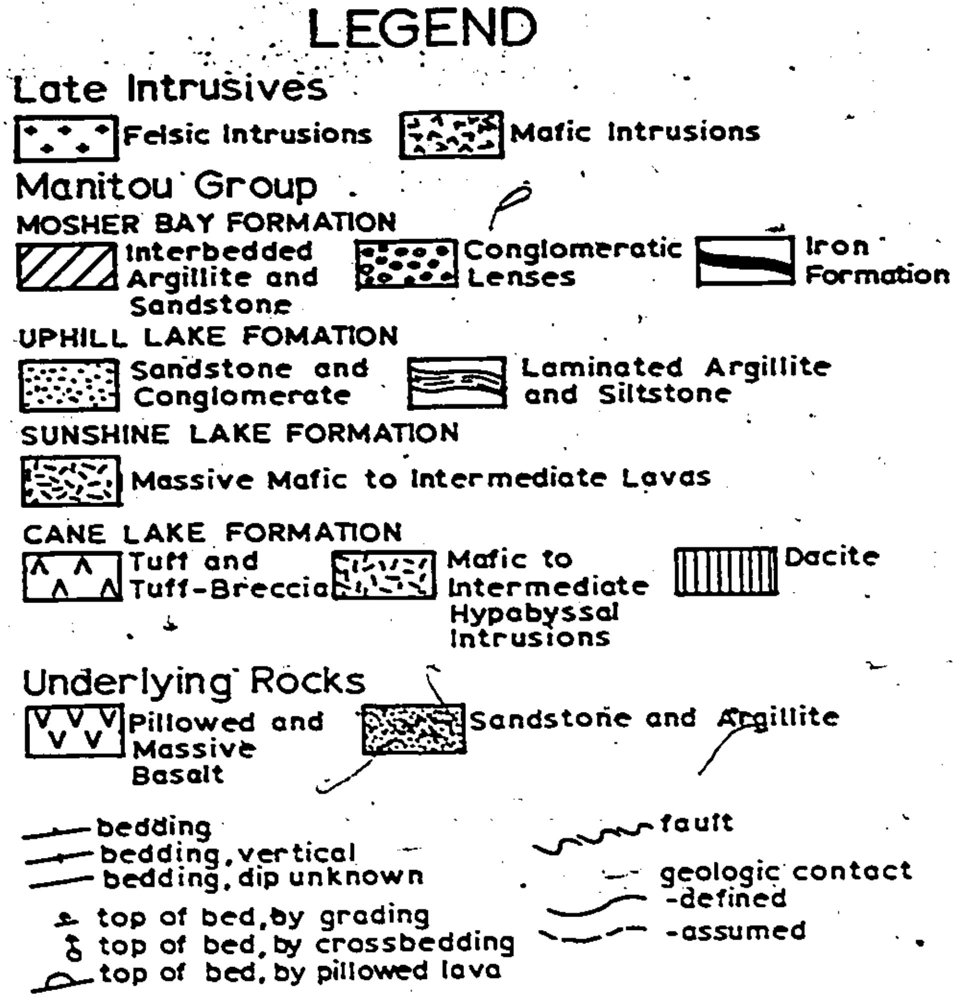

Geology by P. Rae Teal, 1972 - 1974.

Figure 3. General Geology of the Manitou Group, derived from large shoreline exposures and smaller inland outcrops. See Figure 4 for stratigraphic subdivision and Figure 8 for structural geology.

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