SEDIMENTATION AND STRATIGRAPHY OF PART OF THE RICE LAKE GROUP, MANITOBA.

A Thesis
Presented to
the Faculty of Graduate Studies
and Research,
The University of Manitoba

In Partial Fulfilment
of the Requirements for the Degree of
Doctor of Philosophy

by
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May, 1971

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ABSTRACT

The extrusive and volcanic-derived sedimentary rocks of the Rice Lake Group, Manitoba, have been subdivided into eight formations. These units are named and identified here for the first time.

Sedimentary rocks within the lower part of the group were deposited in a rapidly subsiding basin, with syn-depositional volcanic activity.

Three lithofacies have been delineated within the group. They outline the proximal, transitional, and distal facies. These three are persistent throughout the stratigraphic column. Their stratigraphic persistence shows that volcanic activity was localized and consistent throughout the history of the basin. The distribution of the facies is used to delineate their respective sources. At least two volcanic sources have been delineated in this manner, one in the western part of the basin, and the other in the southeast. Size analyses of conglomerate clasts indicates that the fragments have undergone at least one sorting cycle prior to their final deposition.

Primary sedimentary structures typical of turbidites occur throughout the lower part of the stratigraphic sequence and indicate that the major mechanism of deposition was by turbidity currents. Large amounts of coarse detritus deposited in the basin, prior to the extrusion of the basalts, are inter-

preted as a direct consequence of paleoseismic shocks on unstable sediments.

Differentiation of the parent magma at depth is reflected in both the volcanic products, and in the upward increase in the percentage of detrital quartz in the derived sand-sized sediments.

Welded tuffs and agglomerate clasts close to one source show that deposition was at least in part subaerial during the late stages of basinal development. Iron formation deposited during the later history of the basin marks major chemical changes — involving Eh and pH. The iron formation is relatively thin and discontinuous in the proximal facies, but becomes a major unit eastward, in the distal facies.

Rocks within the area have undergone at least two, and possibly three, periods of subsequent deformation.

The geometry of the basin of deposition can be approximated by noting regional variations in the gross lithology and texture of the sediments. Water depth at the sites of deposition may be inferred from some of the lithologic associations.

Sources of sedimentary material can be delineated from the paleocurrent pattern, changes in lithology, and clast size variations. Two possible volcanic sources have been located in this manner.

Correlation of the sediments and volcanic rocks in the vicinity of Rice Lake area with those of the Beresford Lake area is very tenuous, as the Ross River quartz diorite pluton has obliterated much of the original lithologic correlation. However, the stratigraphic succession in each locality is quite similar, and a tentative correlation is proposed.

ACKNOWLEDGEMENTS

The author is indebted to Dr. W.C. Brisbin for his continued guidance, encouragement, and constructive criticism throughout all phases of research. Spirited discussions with Professor E.I. Leith caused the author to rethink more than one concept.

Dr. W.D. McRitchie and Dr. W. Weber of the Manitoba Mines Branch, provided many hours of their time in engaging discussions.

The Manitoba Mines Branch, through Project Pioneer, provided financial assistance during the field seasons. The University of Manitoba supplied financial assistance during the academic year through Graduate Scholarships.

Miss A.V. Apostle conscientiously typed the manuscript. Mr. G. Fraser draughted many of the figures, and provided the author with assistance for many of the others.

Last, but by no means least, I would like to thank my wife, Kadri, without whose assistance and continuing encouragement the project might have been abandoned.

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CHAPTER 1

INTRODUCTION

Statement of Problem

The purpose of this project is to produce a detailed reconstruction of the depositional history, stratigraphic succession, and depostional environment of part of the Rice Lake Group.

The area of detailed study is situated east of Bissett, and comprises most of Twp. 22, R. 16, and part of Twp. 23, R. 16, (see figure 1). The sedimentary rocks at Rathall Lake in Twp. 20, R. 17 were also examined in detail in an attempt to determine their stratigraphic relationships.

The consolidated rocks of the area are all Precambrian. Turek and Peterman (1967, 1971) and Ozard and Russel (1971) have determined numerous Rb/Sr dates for the rocks in this area, but these are all associated with intrusions, and periods of metamorphism.

The predominant structure in the area is a large dome with a northwest-trending axial plane. A small syncline and anticline on the southwestern flank of this dome have been faulted along their common limb.

A penetrative foliation is locally developed and is the most pronounced small-scale structural feature. These sediments have undergone very little post-depositional deformation, and primary sedimentary structures are extremely well-preserved.

Field work was conducted for three weeks in 1967, and for

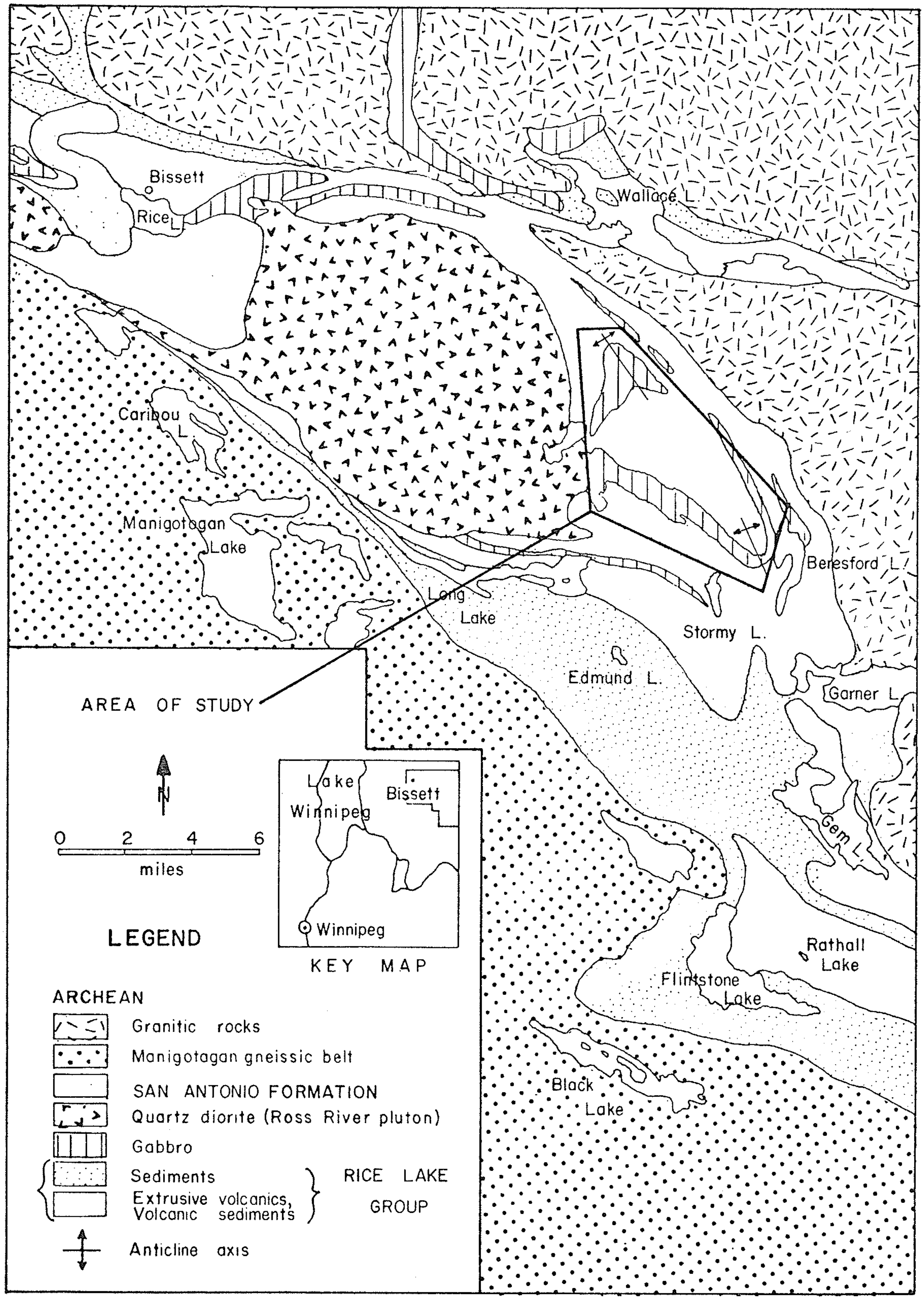


Figure 1 Location map and area of this study.

the entire field season in 1968. The majority of the field work was carried out by pace and compass traversing, with helicopter support for inaccessible areas.

This study has led to the subdivision of the major lithologic units into formations; eight new formation names are proposed and defined for the first time. Detailed examination of field relationships and thin sections has resulted in a subdivision of some of the formations into informal units.

The stratigraphic succession, mineralogy, texture, and form of the sedimentary units indicate that the extrusive and sedimentary units of the sequence are closely interrelated, spatially, temporally, and genetically. Evidence is presented to indicate that periods of extrusive volcanism were followed by periods of quiesence accompanied by sedimentation. Sedimentation was abruptly terminated by fresh outpourings of basalt. In each case, however, the beginning of extrusion is reflected by marked textural changes in the sediments.

The shape of the basin of deposition was studied by noting regional variations in the gross lithology and texture of the sediments.

Sources of sedimentary material in the basin were delineated from paleocurrent patterns, changes in lithology, and clast size variations.

Previous Work

Moore, 1912, first mapped the rocks of the Rice Lake area and subdivided the rocks west of Rice Lake into two series:

(1) The Wanipogow Series, predominantly sedimentary in origin, and

(2) The Rice Lake Series, predominantly volcanic in origin.

He believed the Wanipigow Series rested unconformably on the Rice Lake Series.

Cooke, (1921), mapped a small area around Rice Lake, and combined the rocks into one unit, which he termed the Rice Lake Series.

Wright (1922, p. 45) subdivided the rocks of the Rice Lake Series into three units. From oldest to youngest, these are:

(1) Predominantly volcanic rocks,

(2) Probable sedimentary series, schists,

(3) Predominantly sedimentary rocks — arkose, conglomerate.

Wright, (1925), applied names to these, but with a change in the stratigraphic succession. From oldest to youngest:

(1) Manigotagan Series — schists,

(2) Wanipigow Series — greywacke, arkose, conglomerate,

(3) Rice Lake Series — basic volcanics, minor greywacke.

Wright, (1927), subdivided the Rice Lake Series into three phases, corresponding lithologically to the previous three units. However, these do not correspond to either of the previous two subdivisions by Wright (1922, 1925). The three phases are:

(1) Manigotagan Phase,

(2) Beresford Lake Phase,

(3) Wanipigow Phase.

Wright appeared undecided about the position of the Manigotagan Phase in the sequence. In 1932, he assigned these rocks to the Rice Lake Series, and retained the stratigraphic succession he proposed in 1927 (ref. cit.).

Stockwell, (1937), named the rocks in the Rice Lake area the Rice Lake Group. He noted that some of the sedimentary rocks of the area were interbedded with the volcanic rocks and that other sedimentary units, west of Rice Lake, overlay the volcanics with marked unconformity. Stockwell named the overlying sediments the San Antonio Formation (Stockwell, 1937, p. 3). He noted that the San Antonio rocks were not cut by any intrusives, and they appeared to be younger than the large quartz diorite body to the east. He was, however, not convinced of the relationship.

Davies, (1963), concurred with the stratigraphic succession proposed by Stockwell for the Rice Lake Area. He delineated the unconformity between the San Antonio Formation and the Rice Lake Group, confirming Stockwell's original interpretation.

CHAPTER 2

STRATIGRAPHY

The stratigraphic terminology of the rocks within the area has varied considerably. Figure 2 presents a summary of the stratigraphy to date, and the revised stratigraphic succession proposed by this writer. The writer proposes to name and define the following units, from oldest to youngest:

U.T. Basalt (informal name)

Stovel Lake Formation,

Tinney Lake Formation,

Dove Lake Formation,

Gunnar Formation,

Stormy Lake Formation,

Rathall Lake Formation (Stratigraphic position unclear)

The Narrows Formation,

Edmunds Lake Formation

These units present the most detailed subdivision of the rocks to date. The units are defined, in order, in the following section.

U.T. Basalt (informal name)

This unit outcrops only in the core of the major anti-

WRIGHT (1923)	WRIGHT (1925)	WRIGHT (1927)		STOCKWELL (1939) MAP 810A	STOCKWELL (1939) MAP 809A, 811A	THIS PAPER
Sedimentary Series, arkose, conglomerate,	Rice Lake Series, basic volcanic rocks.	Wanipigow Phase.	San Antonio Formation, quartzite, arkose, conglomerate.			
Possible Sedimentary Series, biotite schist, granite gneiss.	Wanipigow Series, greywacke, arkose, conglomerate.	Beresford Lake Phase.	RICE LAKE GROUP	Sedimentary gneiss, Injection gneiss.	Sedimentary gneiss and schist.	EDMUNDS LAKE FORMATION and "GNEISSIC BELT" where recognizable.
Unnamed Series, interbedded lavas and sediments.	Manigotagan Series, argillite, slate, derived schists.	Manigotagan Phase.		Quartzite, arkose, iron formation, conglomerate, schists.	Quartzite, iron formation, minor greywacke.	THE NARROWS FORMATION.
						STORMY LAKE FORMATION.
				Tuff, conglomerate, arkose, chert.	Acidic volcanic breccia, minor sediments.	GUNNAR FORMATION.
						DOVE LAKE FORMATION.
				Basic flows and derived schists.	Arkose, tuff, chert, breccia.	TINNEY LAKE FORMATION.
						STOVEL LAKE FORMATION.
				Acidic volcanics, minor sediments.	Basic flows and derived schists.	UNNAMED BASALT.

COMPILATION OF PREVIOUS AND PROPOSED STRATIGRAPHIC TERMINOLOGY cline in the central part of the map-area (see figure 3).

All nearby topographic features close to any typical exposure of the unit have not been used elsewhere in terminology, and the U.T. designation was selected for ease of discussion. The western side of Tinney Lake is proposed as the type locality (figure 3).

The base of the unit is nowhere exposed. The upper contact of this basalt unit with the overlying sediments is sharp. On the western and southern shore of Tinney Lake, the basalt is overlain by greywacke and pebble to boulder-sized fragmental volcanics. These fragmental volcanics, however, occur only at the crest of the anticline. At the northern end of Tinney Lake, the pillow basalts are overlain by fine-grained greywackes, siltstones, and minor chert. Nowhere is there evidence of a discontinuity between the two units.

Stovel Lake Formation

The Stovel Lake rocks outcrop near the core of the major anticline in the central part of the map-area (see figure 3). These are the oldest sedimentary rocks in the area.

This formation is named for Stovel Lake, approximately one and one half miles northwest of Tinney Lake, in Twp. 22, R. 16. The rocks of this unit are best exposed in the vicinity of Cliff Lake, but this name has priority of usage in Ontario.

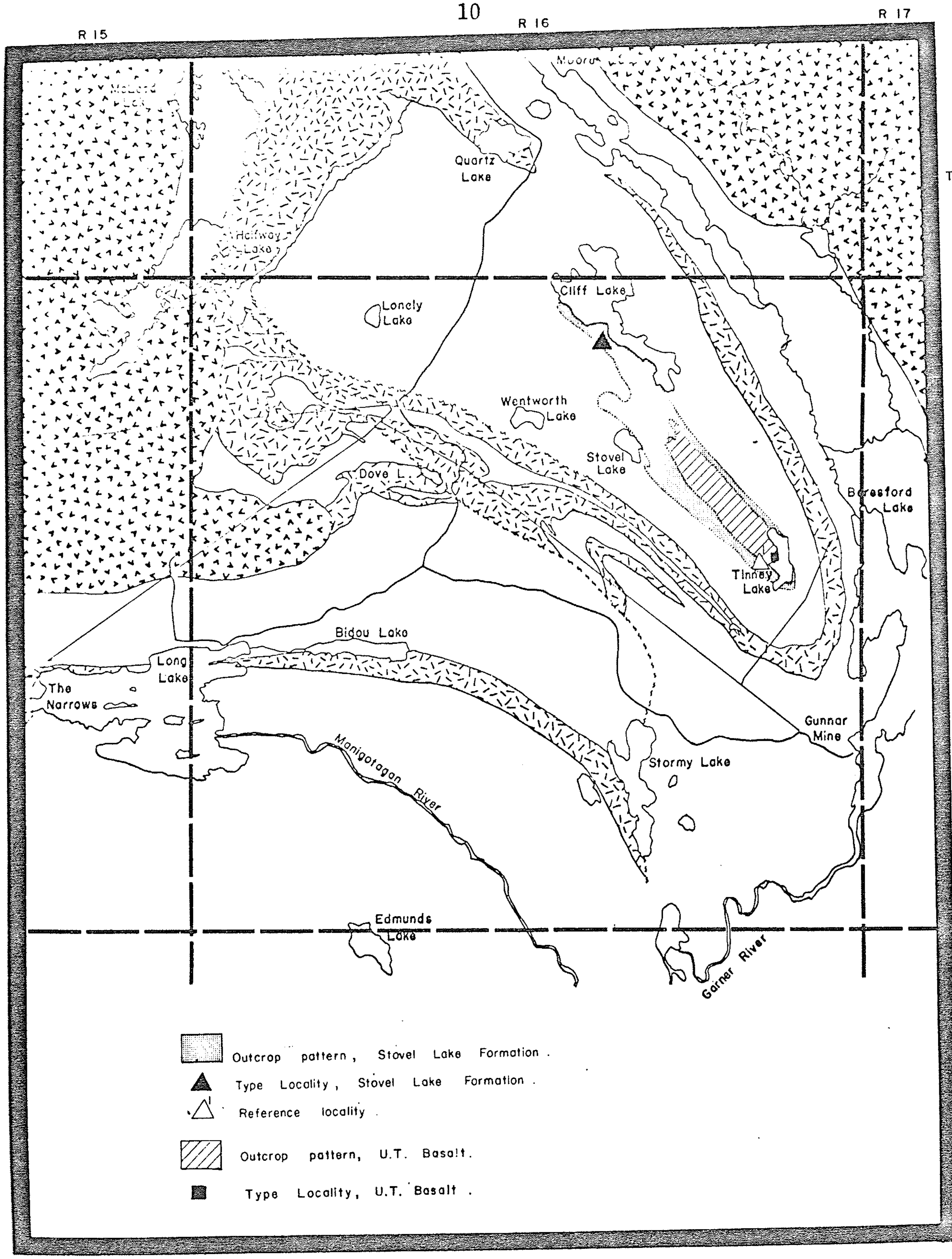


Figure 3 Extent, type localities, and reference localities of the Stovel Lake Formation and the U.T. Basalt.

The type locality of the Stovel Lake Formation is proposed as that section of sedimentary rocks exposed directly south of the small peninsula on the southwestern shore of Cliff Lake, (see figure 3). Here, both the upper and the lower contacts of the formation are exposed. The section is approximately 220 meters thick. The rocks display a remarkable uniformity in texture, composition, and bed thickness. The majority of the sedimentary rocks are fine- to medium-grained feldspathic greywackes. Thin, well-laminated beds of chert and siltstone are traceable over considerable distances.

The type locality, however, does not contain all the rocks typical of the formation. A reference locality on the western shore of the small bay at the south end of Tinney Lake is proposed to supplement the type locality (see figure 3). At the reference locality, the formation is approximately 150 meters thick. The rocks exposed are typical of the coarse fraction present in the formation.

At the reference locality, the formation is divisible into three distinct units. The basal 10 to 30 meters are predominantly well-bedded feldspathic greywacke and minor chert. The overlying 60 to 70 meters are composed of coarse-grained fragmental volcanics, with subordinate grit. The remainder of the unit consists of alternating feldspathic greywacke, siltstone, chert, and minor grit.

The top of this formation is defined as the uppermost sedimentary rocks in the unit, which lie in conformable contact with the pillowed and massive basalts of the overlying Tinney Lake Formation. No structural or depositional discontinuity is evident at any exposure of the contact. Locally, the Tinney Lake basalt was extruded onto soft, semiplastic sediment, as at Cliff Lake, and the sediments at the contact are incorporated as intra-pillow clastics (see figure 61).

Tinney Lake Formation

This formation is named for the small lake near the eastern boundary of Twp. 22, R. 16, (see figure 4). Rocks typical of the formation are exposed on the eastern shore of the lake, and for considerable distances to the north, northwest, south and east.

Over ninty-five per cent of the rocks of the formation are pillow basalts. The pillows are locally well-preserved, and the direction of upward sequence may be inferred from some. Minor thin bands of chert, with minor siltstone, occur within the formation southeast of Cliff Lake. Nowhere are sediments the predominant rock type.

The base of the Tinney Lake rests conformably on the underlying Stovel Lake Formation. The lowermost rocks of the Tinney Lake Formation are pillow basalts. The upper contact of the formation with the overlying Dove Lake rocks is nowhere exposed. The Tinney Lake and the Dove Lake Formations are separated by a thick, continuous sill of gabbro which essentially parallels the contact at all localities. The sill post-dates extrusion of the basalt and

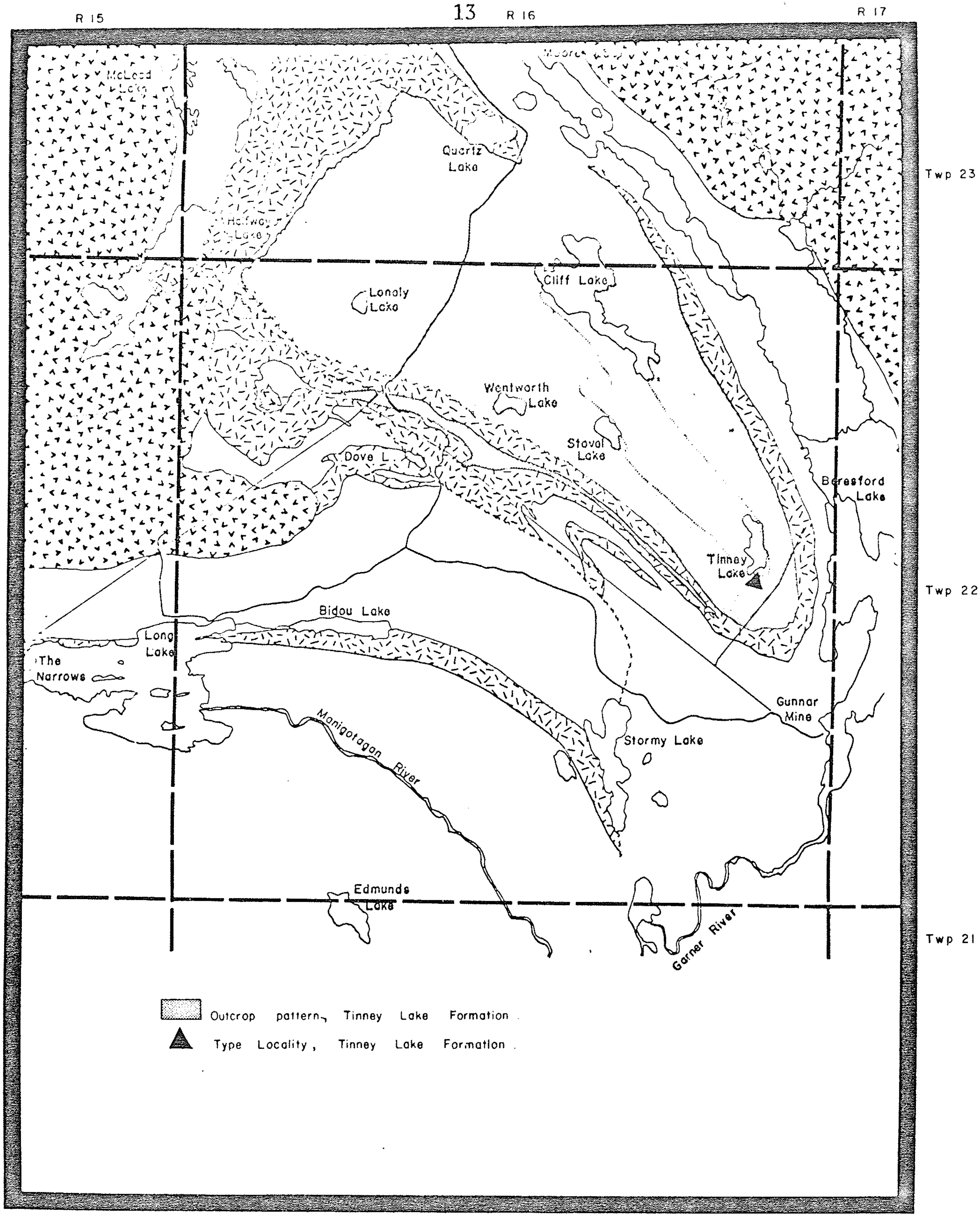


Figure 4 Extent and type locality of the Tinney Lake Formation.

deposition of the sediment. The contacts of the gabbro with both locally show contact metamorphic features.

The Dove Lake Formation does not overlie the Tinney Lake Formation throughout the entire area. In the northwestern part of the area, the Tinney Lake is separated from the Gunnar Formation only by the sill-like gabbro (see figure 4). The contact between the two formations is not exposed in the map-area.

Rocks northwest of Cliff Lake are not entirely of the Tinney Lake Formation. The dome structure within the area has exposed part of the unnamed basalt, which underlies the Stovel Lake Formation. The Stovel Lake Formation does not crop out northwest of Cliff Lake, and it is thus impossible to separate the two units.

For purposes of this study, the rocks are considered to be entirely Tinney Lake Formation, except where underlain by sediments of the Stovel Lake Formation.

The precise thickness of the formation is not known, as the attitude of the unit is not known at all localities. A conservative estimate of the possible maximum thickness is approximately 1500 meters.

Dove Lake Formation

This formation is named for the small lake in the northwestern part of Twp. 22, R. 16 (see figure 5).

The rocks of the formation are entirely sedimentary and volcaniclastic in origin. Numerous small, irregular, gabbro dykes and sills defeat any attempt to measure accurately the thickness of the unit. The maximum exposed thickness of the unit is estimated as 1000 meters. However, west of Beresford Lake, near the Oro Grande Shaft, the exposed thickness is less than 30 meters.

The formation is folded as part of the major anticlinal structure. A subsidiary syncline is developed on the southwestern flank of the dome and is delineated by the formation. A major fault, the Dove Lake Shear, has displaced the syncline and an adjoining anticline some 2000 meters along their common limb.

The contact of the Dove Lake and the underlying Tinney Lake Formation is nowhere exposed. The two are separated by a thick, continuous gabbro sill. There is no apparent structural discordance between them.

The upper contact of the Dove Lake Formation with the Gunnar Formation is well-exposed at many localities. Where the Long Lake-Bissett road crosses this contact south of Dove Lake, coarse breccias and volcanic agglomerates of the Dove Lake Formation are directly overlain by pillow basalts of the Gunnar Formation.

The base of the Dove Lake Formation is defined as the first sediments to rest on the gabbro sill which separates the Dove Lake Formation from the Tinney Lake Formation.

The top of the formation is defined as the first appearance of pillowed basalt resting on the uppermost sediments.

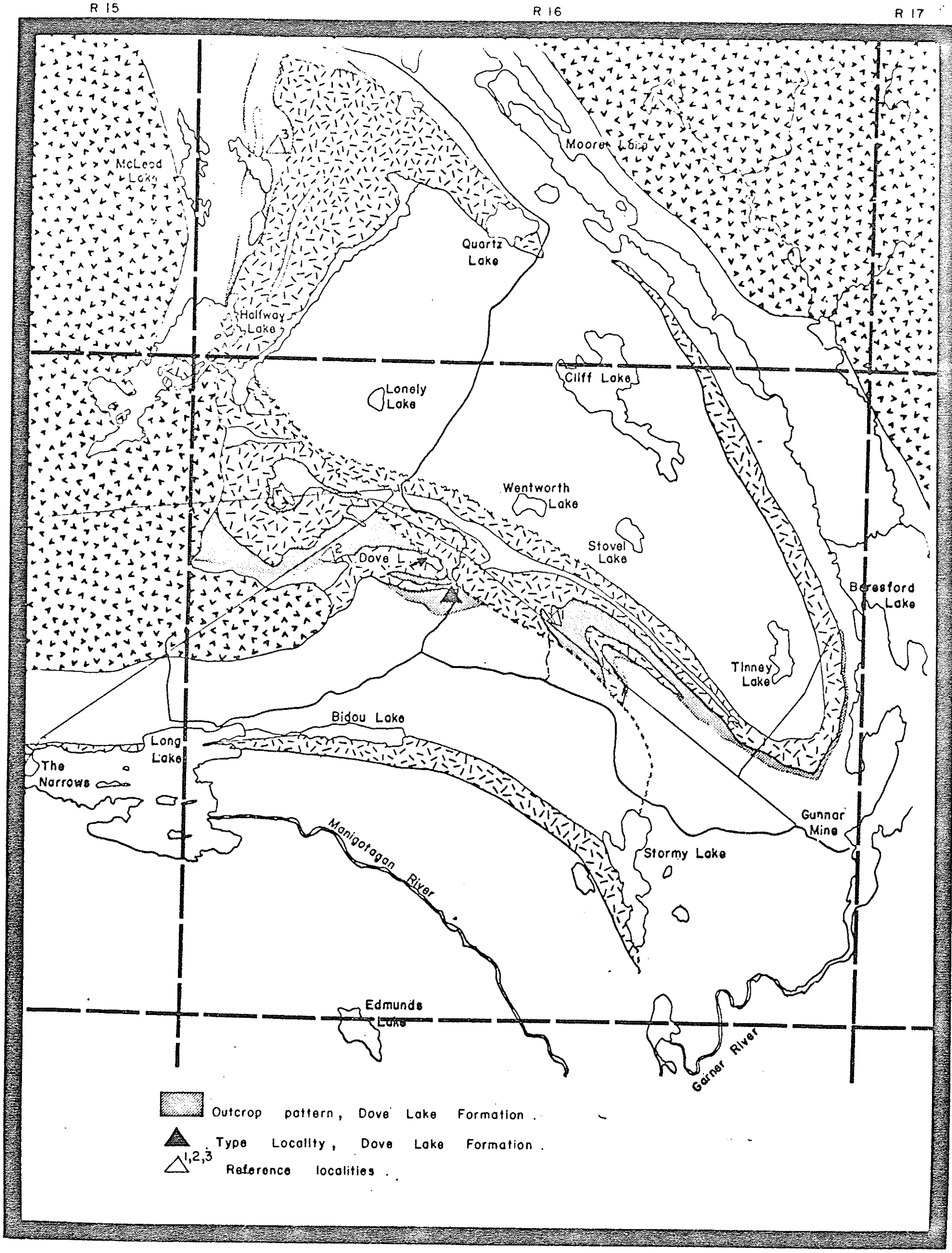


Figure 5 Extent, type locality, and reference localities of the Dove Lake Formation.

At the type locality, (figure 5), the sediments of the Dove Lake Formation consist of feldspathic greywacke, grit, chert, and minor volcanic agglomerate. Near the type locality, the formation is divisible into two distinct parts: a lower, predominantly fine-grained phase, and an upper, coarse-grained, transitional-contact phase. The lower phase of the formation consists of fine and coarse-grained greywackes, chert and siltstone. Volcanic agglomerates and conglomerates comprise the bulk of the upper phase of the formation.

Lateral and vertical lithologic variation is well-developed in the Dove Lake Formation. Sediments near the upper contact of the Dove Lake become much coarser, south and west of the power line between Central Manitoba Mine and Long Lake. Large scour channels and a few large blocks and "rafts" of laminated chert and siltstone indicate a sub-aqueous origin. The majority of the clasts are extremely angular, pebble- to boulder-sized, basalt. Minor, small, well-rounded clasts of porphyritic dacite are also present.

A reference locality should be established in this area, but accessibility is not good, and the precise location of any particular outcrop would be extremely difficult. A possible reference locality is shown on figure 5, (reference locality 2).

One prime reference locality is proposed in the section of sediment exposed northeast of the Dove Lake Shear, south of Wentworth Lake (see figure 5). The locality is accessible along a trail which begins at the road between Long Lake and Beresford Lake. The Dove Lake Formation at this locality lies directly on top of the gabbro sill which separates it from the Tinney Lake Formation. The sediments are predominantly medium-grained feldspar greywacke, chert, and minor grit. The lowermost exposed unit is a medium- to coarse-grained volcanic agglomerate. The agglomerate contains angular, volcanic clasts, and rare large blocks of laminated chert. The base of this bed rests with marked unconformity on laminated cherts and greywacke. The sole is marked by large scour channels; the largest of which shows relief greater than 4 meters. This agglomerate is the only coarse-grained sediment exposed at or near the base of the formation.

Coarse clastics occur near the top of the formation, south of Tinney Lake. There, the fine-grained sediments are interbedded with thin beds of agglomerate containing angular clasts of basalt and gabbro.

Sediments northwest of Halfway Lake are correlated with the Dove Lake Formation. These sediments resemble the Dove Lake Formation in all respects. They are separated from the pillow basalts of the Tinney Lake Formation by a thick gabbro sill. A reference locality is proposed at McLeod Lake East (see figure 5). Graded bedding and other primary sedimentary structures are not as prominent in this part of the Dove Lake as in that to the south.

Isolated remnants of sediments occur within the gabbro sill which separates the Tinney Lake from the sediments in the McLeod Lake area.

Gunnar Formation

The Gunnar Formation is named for the abandoned gold mine in Twp. 22, Rge. 16, near Beresford Lake (see figure 6).

Basalt, both pillowed and massive, is the predominant lithology in the formation. Minor agglomerate is present west of Beresford Lake. Thin beds of chert are locally interlayered with basalt, close to the contact with the underlying Dove Lake Formation.

The lower contact of the Gunnar Formation with the Dove Lake Formation locally is well-defined throughout the map-area. The rocks of the Gunnar overlie the rocks of the Dove Lake with no apparent structural or depositional discontinuity.

The formations are everywhere in discontinuous contact except in the northeast, at the north end of Beresford Lake. There, the Dove Lake pinches out, and the Gunnar Formation is separated from the Tinney Lake by a thin gabbro sill (see figure 1). The thinning of the Dove Lake in this area may indicate either an area of non-deposition, erosion, or a structural separation. A combination of the latter two is considered most probable.

The top of the Gunnar Formation is defined as the last

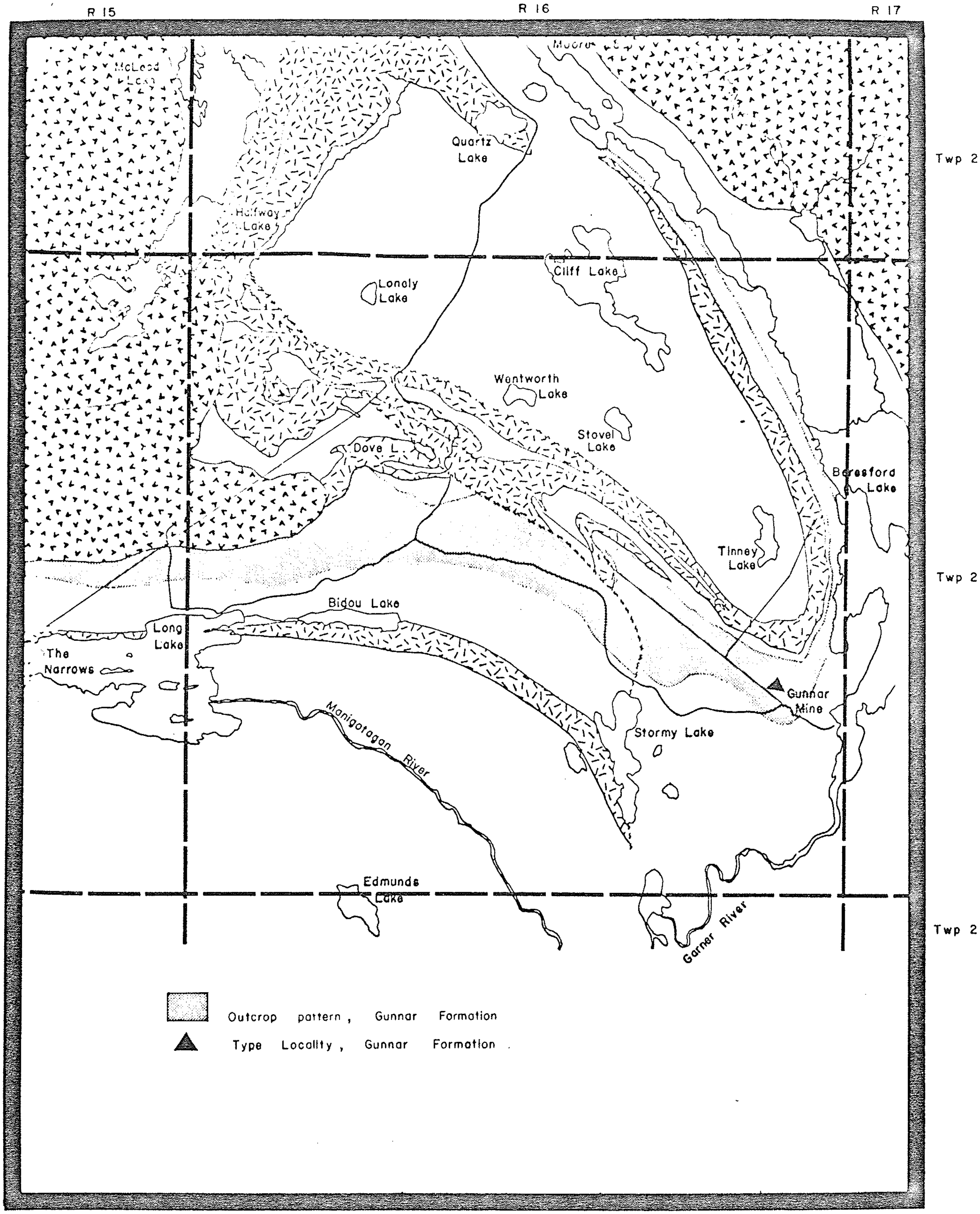


Figure 6 Extent and type locality of the Gunnar Formation.

appearance of pillowed basalt beneath the overlying sediments. The Gunnar Formation consists entirely of pillow basalt at the contact with the overlying Stormy Lake Formation. This contact is only locally well-exposed. The rocks of the Stormy Lake vary from volcanic agglomerate to coarse-grained volcanic wacke at the contact.

As with other units in the area, gabbro dykes make estimates of the thickness of the formation extremely difficult. The maximum thickness exposed is estimated at 600 meters.

Stormy Lake Formation

The Stormy Lake Formation is named for the small lake in Twp. 22, R. 16, south of Tinney Lake (see figure 7).

This unit was first described informally by Zwanzig (1968, p. 3), as that series of sediments and extrusive volcanic rocks which directly overlie the massive and pillowed basalts of the Gunnar Formation.

The outcrop pattern of the Stormy Lake Formation reflects the regional structure. It is folded as part of the regional anticline, and is displaced by the Dove Lake Shear.

The Stormy Lake Formation overlies the Gunnar Formation

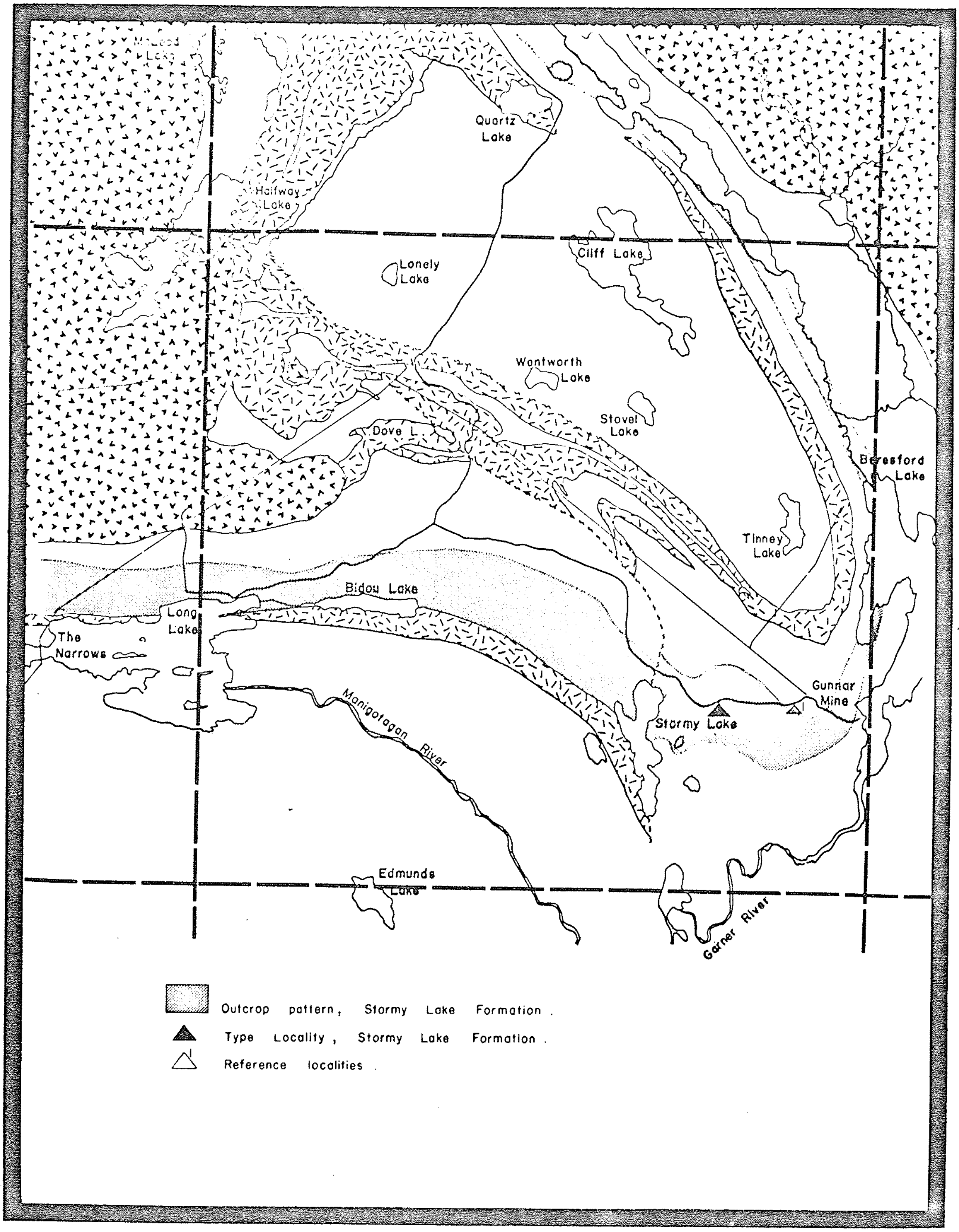


Figure 7 Extent and type locality of the Stormy Lake Formation.

with no apparent structural or depositional discontinuity. The base of the Stormy Lake is defined here as the first sedimentary rocks to overlie stratigraphically the exposed pillow basalt. The upper contact of the Stormy Lake with The Narrows Formation is locally marked by a coarse-grained fragmental volcanic unit. This is the first coarse-grained rudaceous unit to appear above the discontinuous conglomerate which occurs as the base of the Stormy Lake, and is defined as the top of the formation.

The gross lithology of the formation is given by Zwanzig, (1967, p. 7):

1d andesite or basalt

1c volcanic pisolite

1b iron formation

1a arkosic greywacke, (*feldspathic greywacke) chert, arkose

Sediments are locally the predominant rock type within the formation. The unit is relatively consistent in lithology throughout its entire extent. The unit is distinctive in that quartz first appears as a major detrital constituent.

The type locality of the Stormy Lake is shown in figure 7. All the lithologic units described by Zwanzig are present at the type locality. A reference locality for the top of the formation is not present, and requires the use of a reference locality. This is also shown on figure 7.

(* this author's insertion)

The Narrows Formation

Pyroclastic and detrital volcanic rocks which conformably overlie the Stormy Lake Formation were informally termed the Long Lake Formation by Zwanzig (1969, p. 7). This name, however, has priority of usage, and a new name, The Narrows Formation is proposed here for these rocks.

The name is chosen for the narrow part of Long Lake, where the power line crosses the lake. The name appears on topographic and geologic maps of the area, and the locality is well known by local residents (see figure 8).

Zwanzig informally subdivided the formation into four lithologic units (1969, p. 7):

2d volcanic breccia and tuff breccia of intermediate to acidic composition, minor sandstone.

2c crystall tuff of intermediate composition.

2b volcanic breccia and tuff breccia of intermediate composition, minor shale and sandstone.

2a volcanic breccia intermediate to basic composition, minor sandstone.

The eastern end of Long Lake is proposed as the type locality of the formation. There, this subdivision is very well-exposed (see figure 8).

The base of the formation is defined as the first appear-

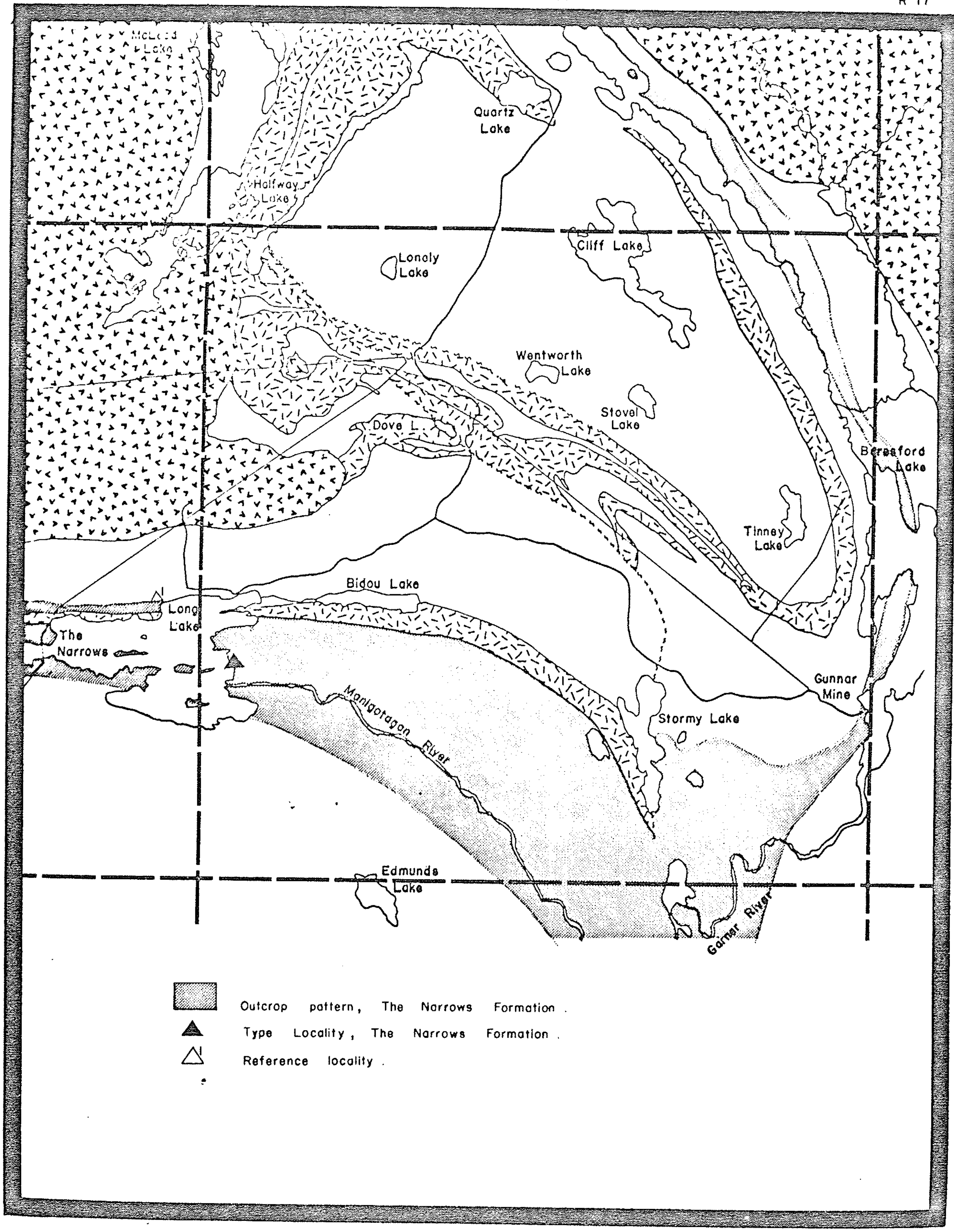


Figure 8 Extent, type locality, and reference locality of the Narrows Formation.

ance of the volcanic agglomerate/breccia overlying the basalts of the Stormy Lake Formation. This unit is very well-exposed on the north shore of Long Lake, between Mr. J. Johnson's wild rice mill and the shore. There, the breccia is in direct contact with the basalt of the Stormy Lake. Clasts are up to 300 mm. in length, with the majority between 5 and 30 mm. The rock has a characteristically unsorted appearance, and shows poorly preserved layering which is almost obliterated by the foliation.

The top of the formation is defined as the top of the uppermost agglomerate, where the agglomerate is in direct contact with the shales and fine-grained greywackes of the Edmunds Lake Formation. The contact is well-exposed on an island near the south shore of the lake (see figure 8) and is proposed as a second reference locality.

Edmunds Lake Formation

The Edmunds Lake Formation is named for the small lake southeast of the eastern end of Long Lake, in Twp. 21, R. 15 (see figure 9). The unit was first informally proposed by Zwanzig (1969) for those sediments which conformably overlie The Narrows Formation (Long Lake Formation of Zwanzig). Zwanzig (1969, p. 12) subdivided the formation into three units in his area of study. From youngest to oldest these are:

C - interbedded arkosic greywacke (feldspathic greywacke*) and shale with isolated lenses of chert and iron formation.

* This author's insertion

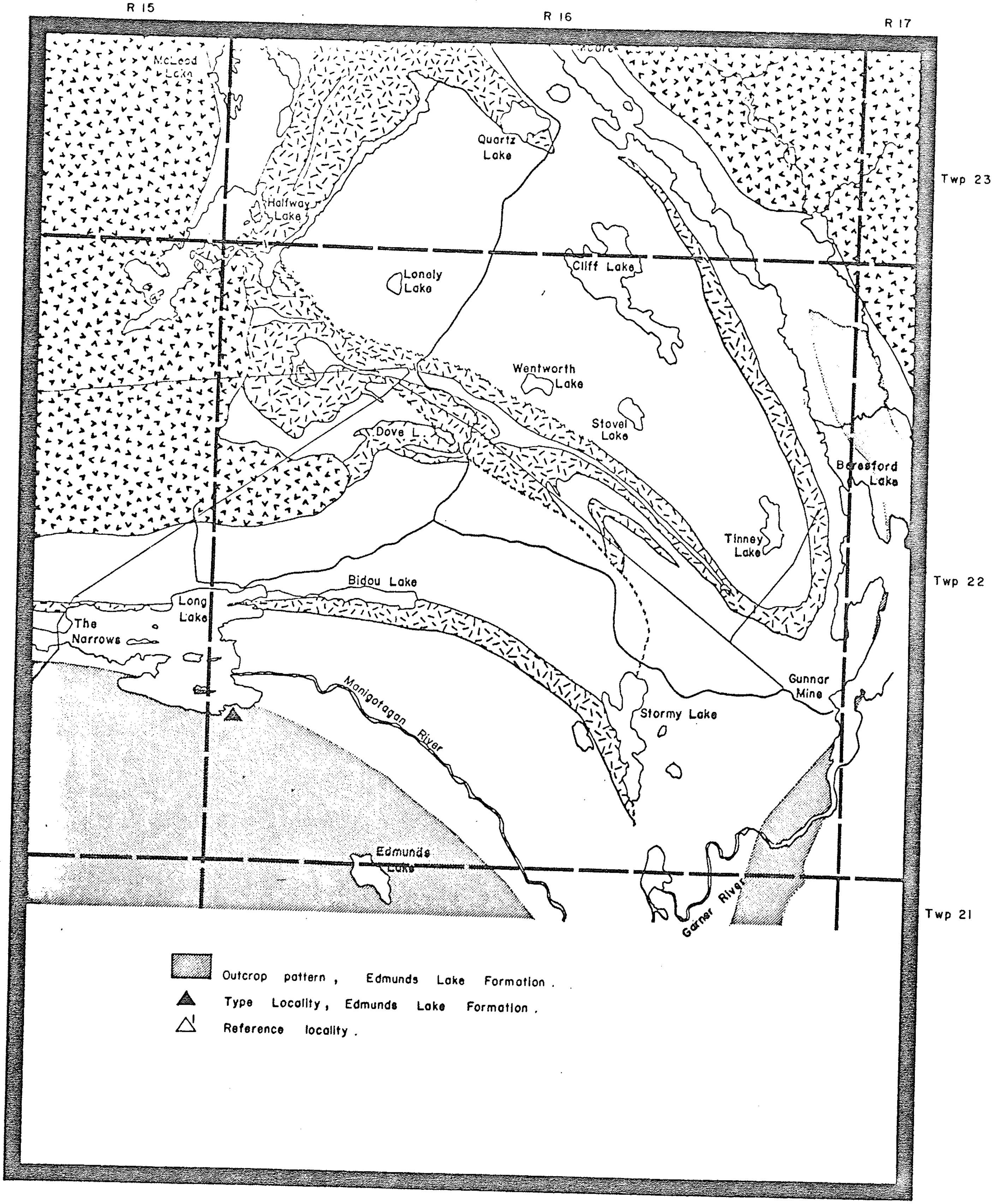


Figure 9 Extent, type locality, and reference locality of the Edmunds Lake Formation.

B - quartzose greywacke with isolated beds of shale and sandstone.

A - massive arkosic sandstone and pebble conglomerate.

Sediments within the area mapped by Zwanzig vary from predominantly feldspathic greywacke and shales near the base, to quartz-rich greywacke upward in the formation.

The Edmunds Lake Formation is continuous from Caribou Lake (west of the map-area) to the Manitoba-Ontario border south-east of Rathall Lake.

The base of the formation is defined as the first occurrence of fine-grained sandstone and argillite overlying the volcanic agglomerate at the top of The Narrows Formation. The top of the Formation is nowhere exposed.

The true thickness of the Edmunds Lake is unknown. Zwanzig (1969, p. 51) recognized at least three periods of deformation. Complex folding is recognized only in the Long Lake area, where exposure is continuous. Equivalent deformation is suspected throughout the entire formation. The minimum thickness is estimated as 2300 meters.

Sedimentation units in the Edmunds Lake Formation are markedly different from those of the Dove Lake and Stovel Lake Formations. They are better-sorted, thinner, and the clasts are more rounded. Graded bedding is common in the lower part of the formation. The formation consists of thin- to medium-bedded sub-greywacke and arkose, with minor chert. The amount of fine-grained sediment decreases upward. A thick pebble conglomerate occurs south of Edmunds Lake (Dr. W.D. McRitchie, personal communication, 1968).

Each of the fine-grained beds, however, shows a remarkably uniform thickness, generally less than 40 cms. Typically, the units show graded bedding. Infrequently, they show well-developed parallel lamination.

Chert is not a major constituent in the formation, and is best developed where interbedded with "iron formation" near the base of the formation. The "iron formation" is not well-developed in the Edmunds Lake, and occurs as a thin (less than 5 meters) lens-like body on the south shore of Long Lake, near the base of the formation.

The Edmunds Lake is characterized by the following:

(1) Thin-bedded units (classification after Ingram, 1955),

(2) Well-sorted sediments, markedly different in lithology from the underlying sediments,

(3) Uniform grain-size,

(4) Laterally continuous beds,

(5) Absence of cross-lamination,

(6) Abundant graded bedding,

(7) Conglomerate, which increases in abundance and thickness upward in the formation.

McRitchie (1971) has suggested that the entire Edmunds Lake has been folded into a northwesterly-plunging syncline.

The metamorphic grade increases southwest of Long Lake.

This southwestern part of the syncline is informally termed the "Gneissic Belt", (McRitchie and Weber, 1971).

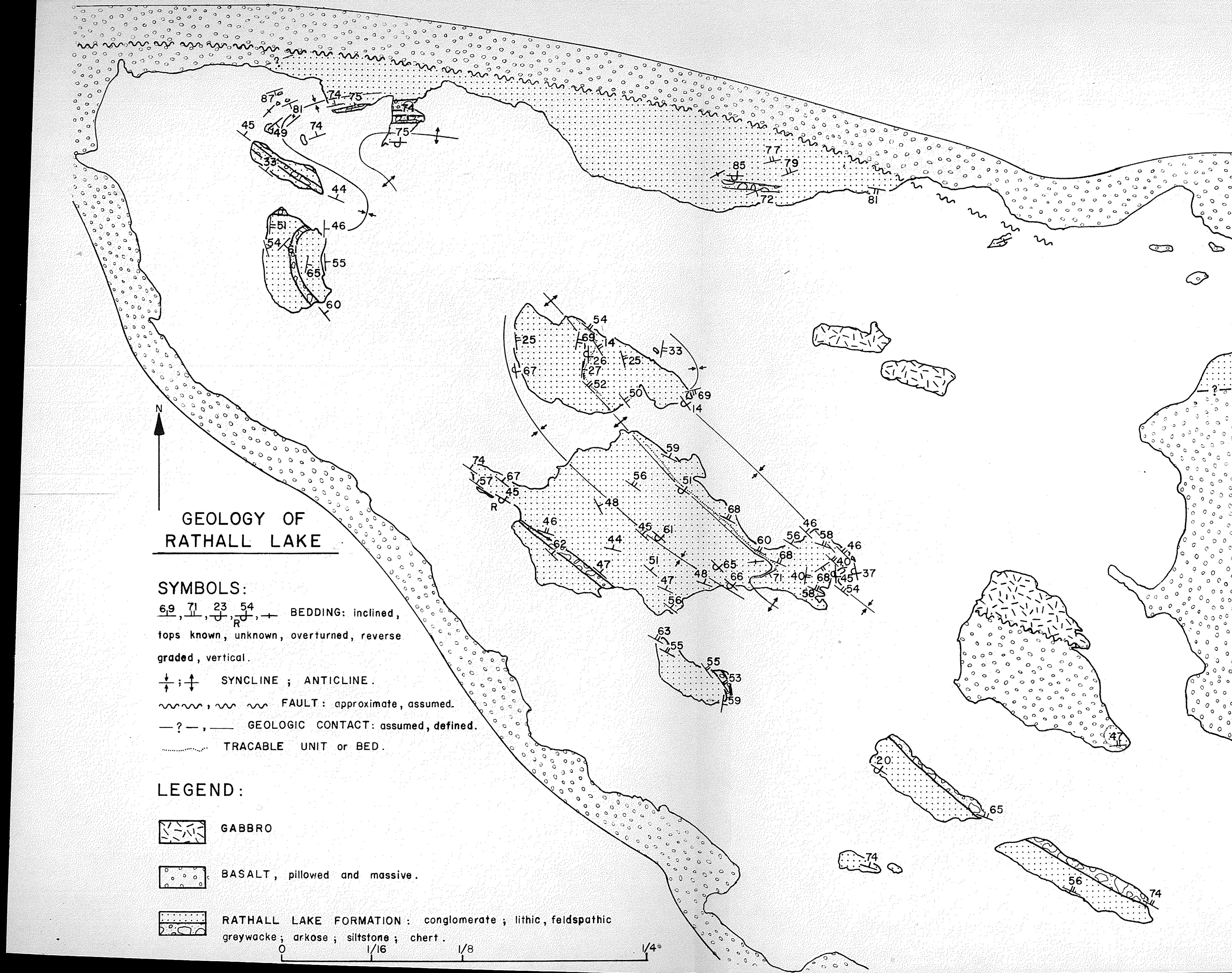
The axis of the major fold within the Edmunds Lake is approximately defined by a thin pebbly mudstone or conglomerate. The clasts in the conglomerate are predominantly metasiltstone, with minor, recrystallized, volcanic flow (?) fragments. The conglomerate is continuous from south of Edmunds Lake, to a short distance northwest of Gem Lake. It attains a thickness of some 300 meters and is the sole mappable unit within the formation. The conglomerate does not crop out on the southwest side of the synclinal axis.

Rathall Lake Formation

The Rathall Lake Formation is named for the small lake in Twp. 20, R. 16, just east of Flintstone Lake (see figure 1).

The rocks of this formation are entirely sedimentary. The majority of the rocks are feldspathic greywacke and arkose, with minor siltstone and shale. Very coarse-grained boulder conglomerate, however, is the most outstanding rock-type formation. Two conglomerate beds are presently recognized.

The Rathall Lake Formation crops out only on the islands in Rathall Lake, and for a short distance on the northern shore of the Lake. The lower contact of the formation is nowhere exposed. The formation appears to be in fault contact with the overlying massive and pillowed basalt to the north.


GEOLOGY OF
RATHALL LAKE
N
SYMBOLS:
BEDDING: inclined, tops known, unknown, overturned, reverse graded, vertical.
SYNCLINE ; ANTICLINE.
FAULT: approximate, assumed.
GEOLOGIC CONTACT: assumed, defined.
TRACABLE UNIT or BED.
LEGEND:
GABBRO
BASALT, pillowed and massive.
RATHALL LAKE FORMATION: conglomerate ; lithic, feldspathic greywacke ; arkose ; siltstone ; chert.
0
1/16
1/8
1/4

The type area of the formation is on the largest island in Rathall Lake (see figure 10). There, the greywacke, arkose, siltstone and chert comprise approximately 90% of the rocks exposed; conglomerate comprises the remainder of the formation.

The composition of the fine-grained sedimentary rocks of the formation varies considerably. The majority of the sand-sized sediments are feldspathic greywacke, and subgreywacke (Pettijohn, 1957, p. 292). Minor arkose and feldspathic quartzite are also present.

The composition of the boulders within the conglomerates is relatively uniform. The majority of the boulders are sheared porphyritic volcanics. The clasts are extremely large, and for the most part, very well rounded. Maximum clast size is approximately 1.15 meters. The intersticies of the conglomerate are filled with smaller pebbles and sand-sized material. No clasts of basalt or other basic volcanic material were found.

The gross lithology, clast size and absence of basaltic material from the conglomerate indicates that this could be a basal conglomerate. However, as its thickness is unknown, these sediments could occupy almost any stratigraphic position relative to the source.

CHAPTER III

PETROLOGY

All the rocks within the map-area are thermally metamorphosed to the lower greenschist facies. Locally, as near the Dove Lake Shear, the rocks have undergone dynamic metamorphism. There, the pillows of the basalts are altered to chlorite and sericite schist, are kink folded, and are elongated with length/width ratios as high as 15:1.

The matrix of the sandstones has been altered to a mixture of fine-grained chlorite, carbonate, epidote, sericite, isolated flakes of biotite and possibly secondary albite. The sandstones contain secondary hematite and carbonate along veins and fractures. Internal primary sedimentary textures are consequently not well-preserved. Chlorite, hematite and minute grains of pyrite are frequently concentrated in distinct layers within the chert beds.

Sandstones within the Rice Lake Group are classified according to the four-component tetrahedral classification of Pettijohn (1957, p. 256).

Any rock with only three constituents will lie on one of the four planes. When four constituents are present, the rock plots within the tetrahedron. An "exploded" tetrahedron is shown in figure 11.

The percentages of constituents present were determined by

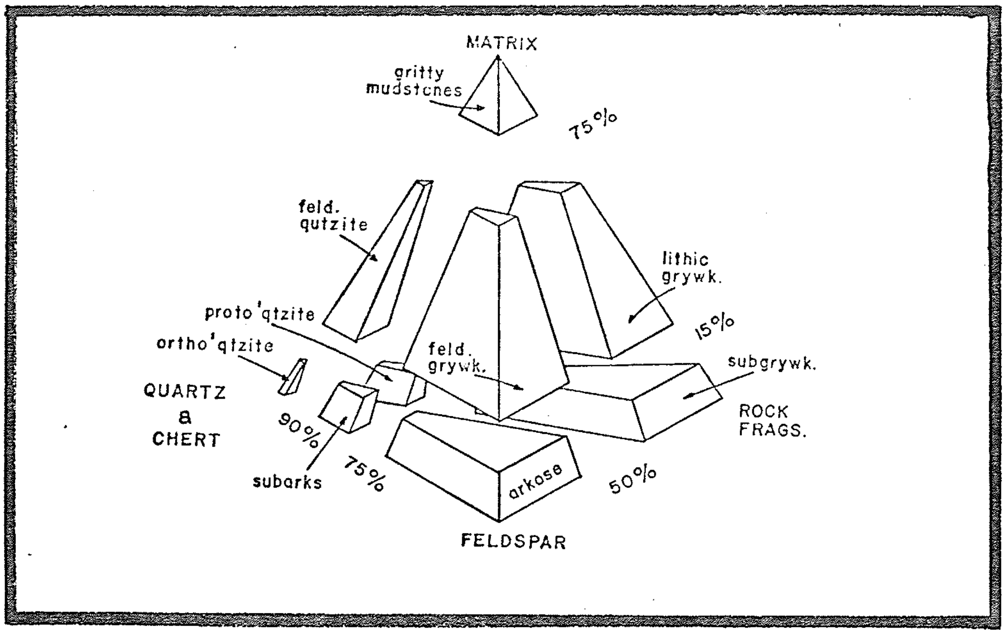


Figure 11: Tetrahedral classification of sandstones. The tetrahedron is "exploded" to show the subdivisions (after Pettijohn, 1957).

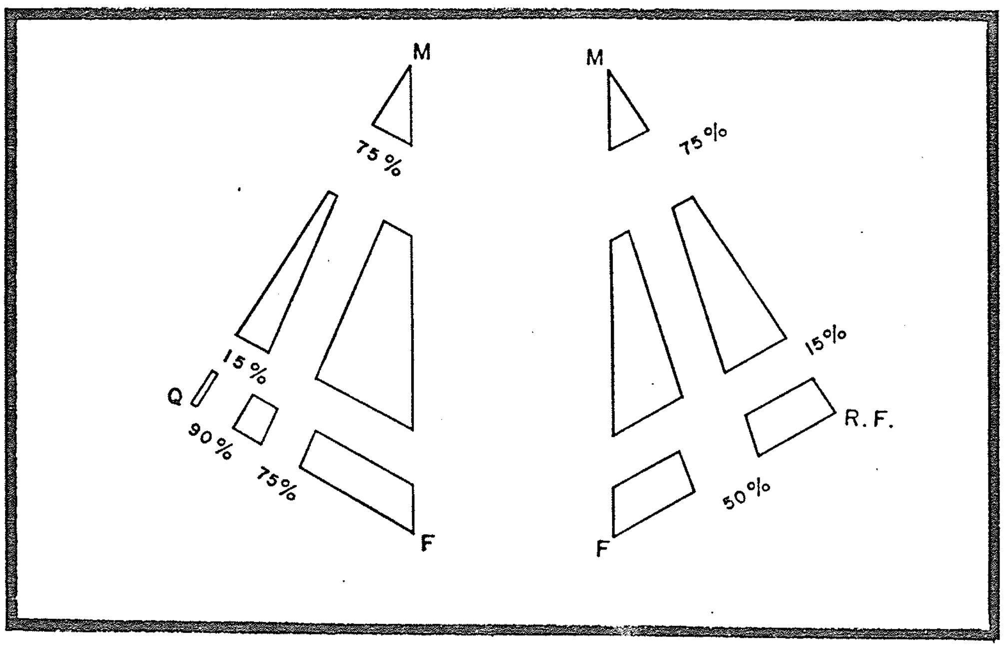


Figure 12: The two faces of the tetrahedron used in this classification.

point-counting an average of 500 grains in each of the thin sections. No fewer than 400, or more than 1100 grains were counted in any particular thin section.

Figure 12 shows two faces of the classification tetrahedron. These have the matrix-feldspar edge in common. The position of each point on the adjoining faces can be used to determine the precise rock composition.

The sedimentary rocks of the various formations within the area are described below.

Sandstones of the Dove Lake and Stovel Lake Formations

The epidote, sericite, chlorite and carbonate assemblage is characteristic of the lower greenschist facies of Eskola. Chlorite and epidote never exceed 10% of the rock. Both occur in the matrix.

The chlorite, commonly fibrous masses and small plates, occurs within the matrix and gives the rocks their characteristic greenish colour.

Discrete grains of epidote are rare. Most commonly, it occurs as fine, disaggregated masses. These show high relief, and are typically brassy yellow in colour, usually with smaller, "pin point" highlights. In some cases, epidote occurs as small semi-opaque "prussian-blue" aggregates or grains.

Plagioclase clasts are replaced by saussurite in varying amounts. The saussurite may replace the rims of faintly zoned crystals, leaving the interior of the fragment intact. In other cases, the cores of the zoned feldspars are altered, and the rims remain intact (see figure 13).

All but four of the rocks analysed from the Dove Lake and Stovel Lake Formations are greywackes (see figure 14). The majority are feldspathic greywacke. Matrix is commonly greater than 50%. Plagioclase feldspar is frequently the sole sand-sized material present.

Figure 15 illustrates sandstone typical of the Dove Lake and Stovel Lake Formations.

The sandstones consist predominantly of plagioclase feldspar, rock fragments and matrix, altered in varying degrees to saussurite, carbonate, sericite and epidote.

The majority of the modal analyses lie on or near the matrix-feldspar-rock fragments plane of the tetrahedron, showing the low percentage or absence of detrital quartz. Detrital quartz is conspicuous by its absence in the sandstones of the Dove Lake and Stovel Lake Formations. Fine-grained, possibly secondary quartz is frequently present in the matrix; sand-sized quartz is extremely rare. It never exceeds 5% of the sand-sized material.

All the feldspar grains are plagioclase. The composition of these varies from Ab_{95} to Ab_{85}, or albite-oligoclase. Some 50 feldspar determinations were carried out; and all lie within these limits.

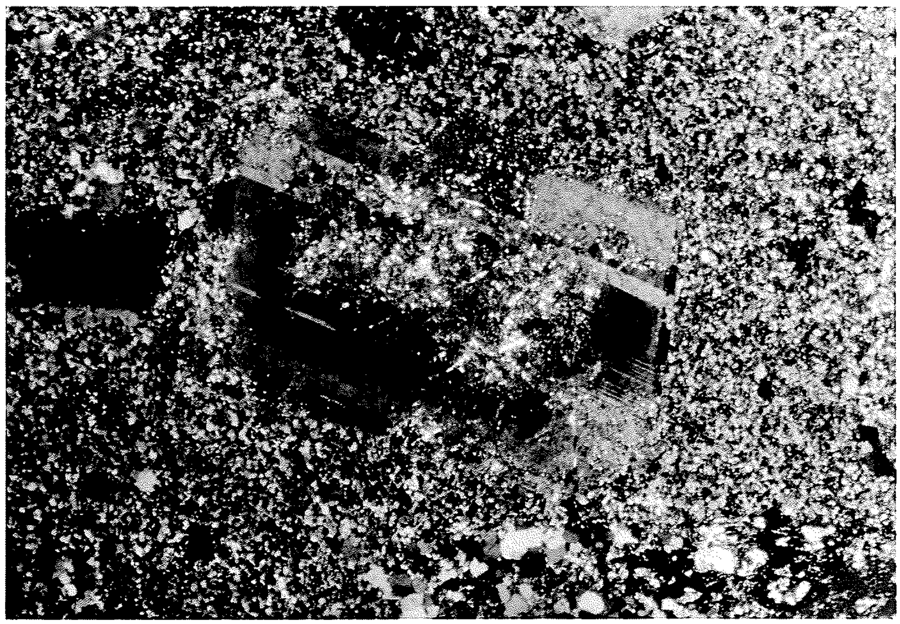


Figure 13: Detrital feldspar, with an altered core in the Dove Lake Formation, (x10, cross nicols)

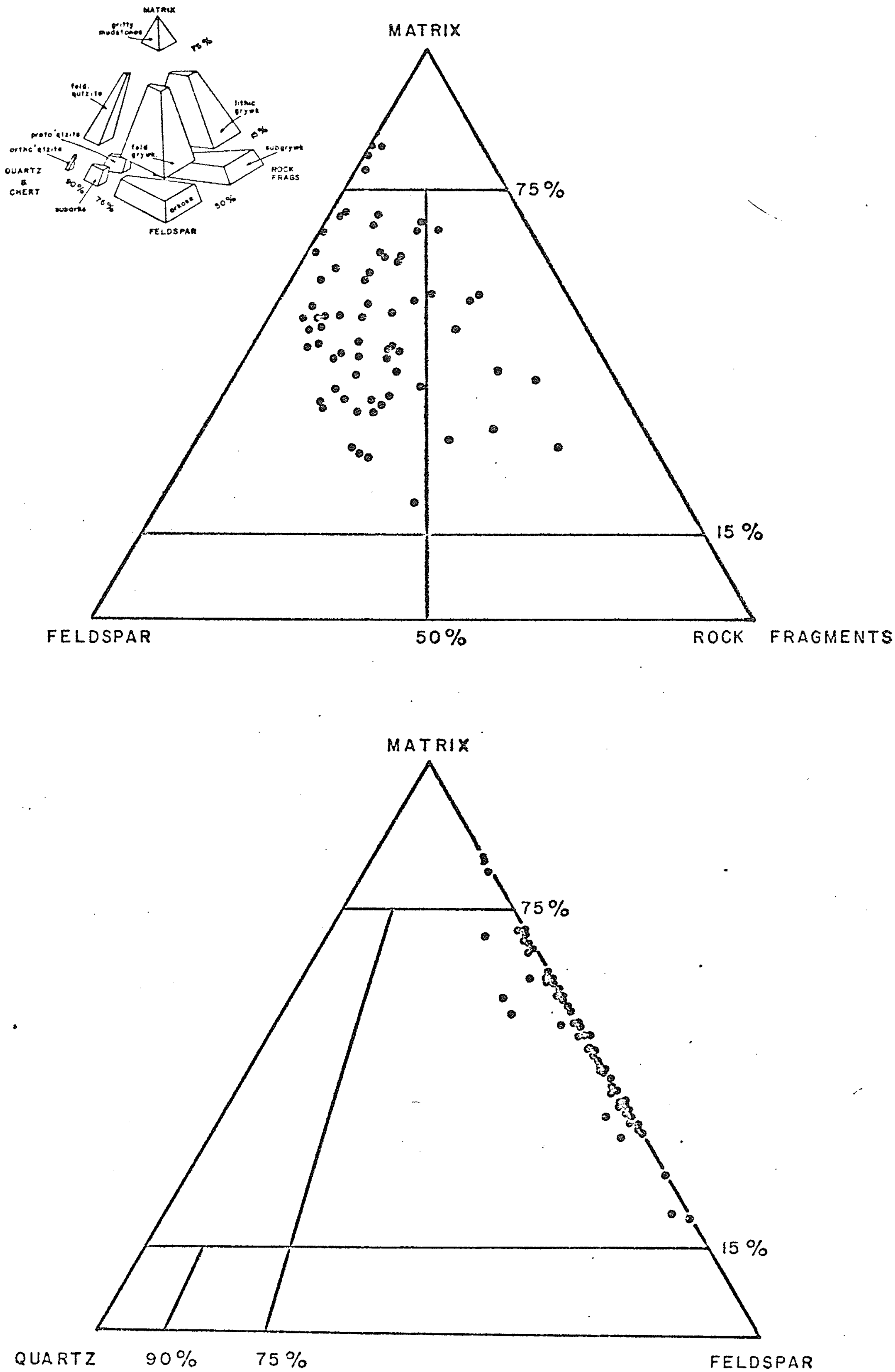


Figure 14: Sandstones of the Stovel Lake and Dove Lake Formations plotted on the tetrahedron faces.

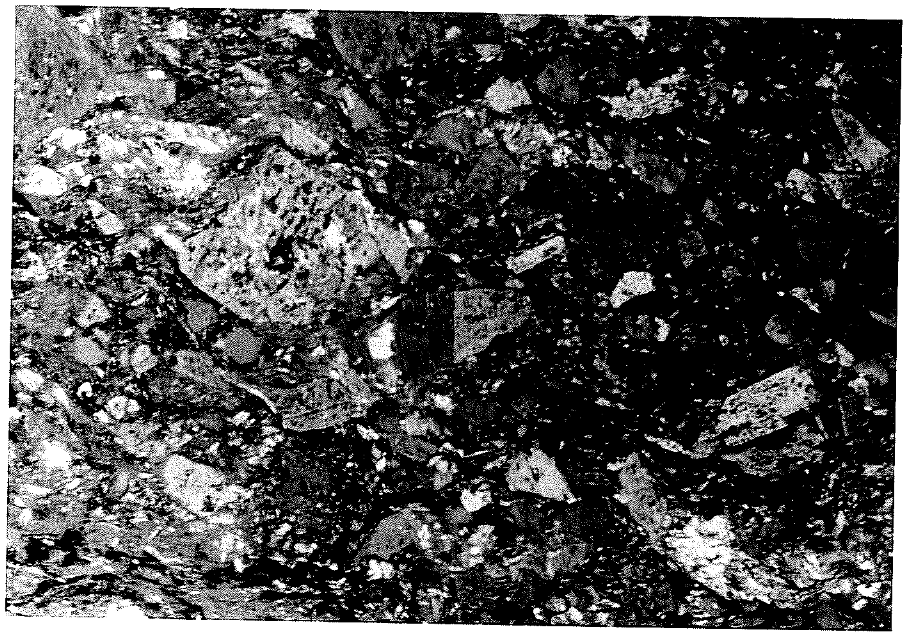


Figure 15: Photomicrograph of a typical sandstone of the Dove Lake and Stovel Lake Formations (x10, crossed nicols).

The feldspars are commonly lath-shaped to blocky, subrounded to angular, and occur in all sizes up to 4 mm. Almost every grain shows albite twinning. Some grains have been broken or fractured along a twin plane, either during compaction or metamorphism. The twinning and "interlocking" texture of the fragments present can be used to determine the original shape of the grain, (see figure 16). All the feldspar grains are altered in varying degrees to a mosaic of saussurite, quartz, epidote, and carbonate. Secondary carbonate is common, and in some cases, replacement of the feldspar by calcite is complete.

Faintly zoned plagioclase crystals occur in all the sediments within this part of the Rice Lake Group. Well-zoned crystals are very rare and were noted in only one sample. The grains are subhedral, with subrounded to angular terminations set in a fine-grained, possibly tuffaceous, matrix (see figure 17). All the grains are broken, giving a "spotted" appearance to the hand specimen. The bed containing the zoned feldspars shows poorly developed, discontinuous grading. The zoned clasts never exceed 30% of the rock. The gross appearance of the unit is tuffaceous. However, it is both under and overlain by "normal" feldspathic greywacke and chert. The rock may represent a redeposited crystal tuff.

The quartz grains in the sandstones are well-rounded, with pitted borders. No inclusions were seen. All the grains show vary-

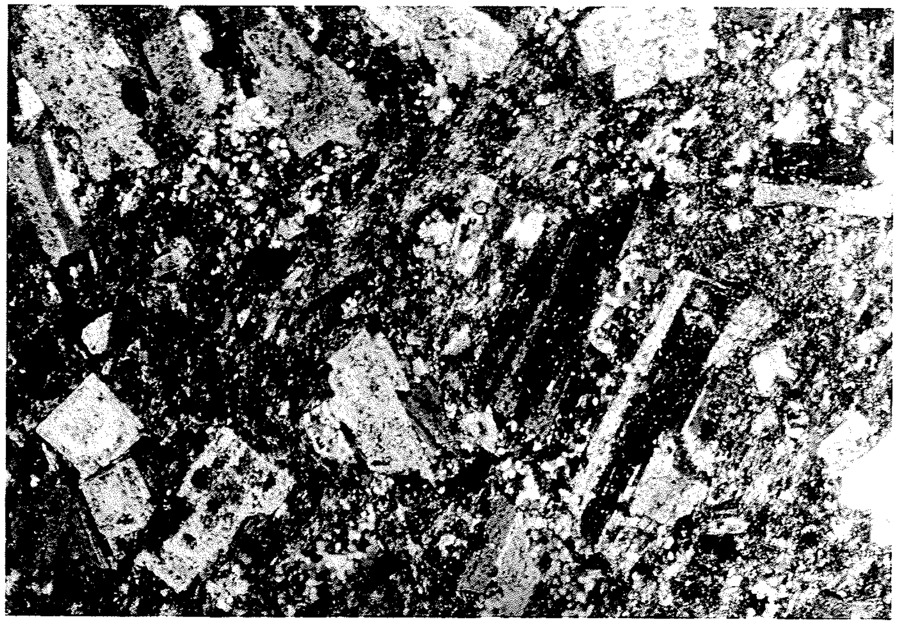


Figure 16: Photomicrograph of a "disrupted" detrital feldspar grain (x10, crossed nicols)

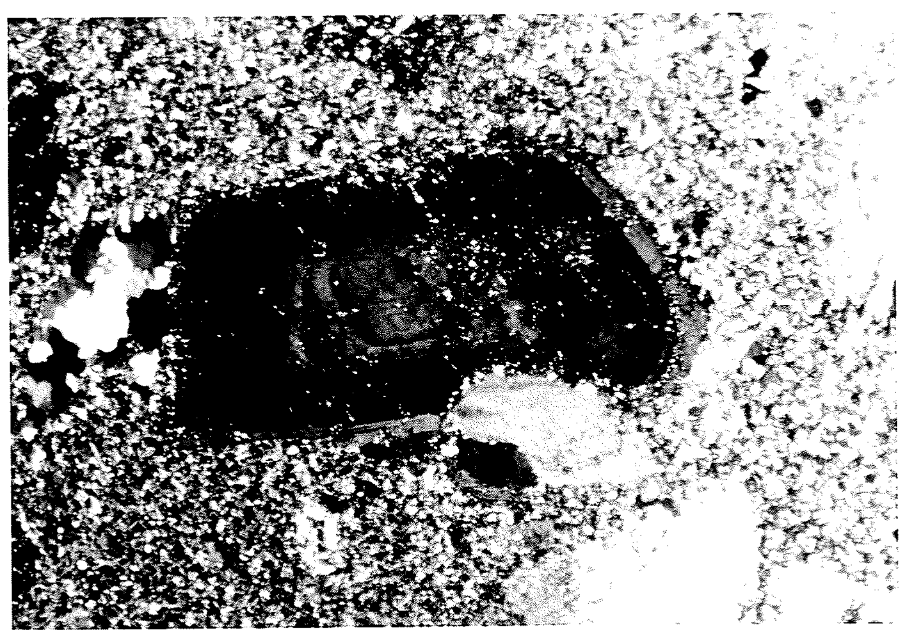


Figure 17: Photomicrograph of a zoned detrital feldspar grain, (x10, crossed nicols)

ing degrees of undulose extinction. Each of the quartz grains appears to have been derived from an igneous source, as none have a clastic texture. Quartz smaller than sand-size was always considered to be part of the matrix. The low interference colours of quartz, albite, and microcline, together with the very fine-grain size, make the quartz in the matrix nearly impossible to identify in thin section.

A number of sandstones, as well as conglomerates, were etched with HF and stained with sodium cobaltinitrate to test for the presence of K-feldspar. The slabs rarely retained any of the stain. K-feldspar only occurred near small fractures or quartz veins.

No ferromagnesian clasts were noted within the sandstones. One small pebble in a conglomerate showed excellent outlines of relict amphiboles (?), or pyroxenes (see figure 18). However, the internal framework had been sufficiently destroyed to make identification of these grains impossible.

Rock fragments which occur in both the Dove Lake and Stovel Lake Formations are extremely difficult to identify. Often, they so closely resemble the fine-grained matrix that their boundaries may only be seen in plane-polarized light. The fine-grained clastic texture shows the sedimentary nature of the clasts. They do not appear to have been recrystallized. None contain any sand-sized detrital quartz, and the majority appear very similar to the siltstones and microwackes common to the entire Rice Lake Group (see figure 19).

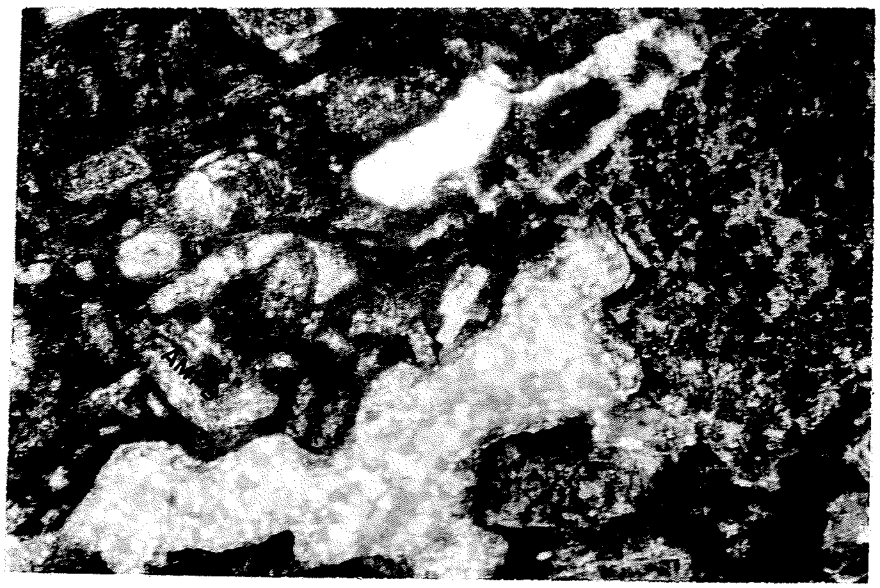


Figure 18: Photomicrograph of a possible amphibole or pyroxene in a clast within the Dove Lake Formation (x10, crossed nicols)

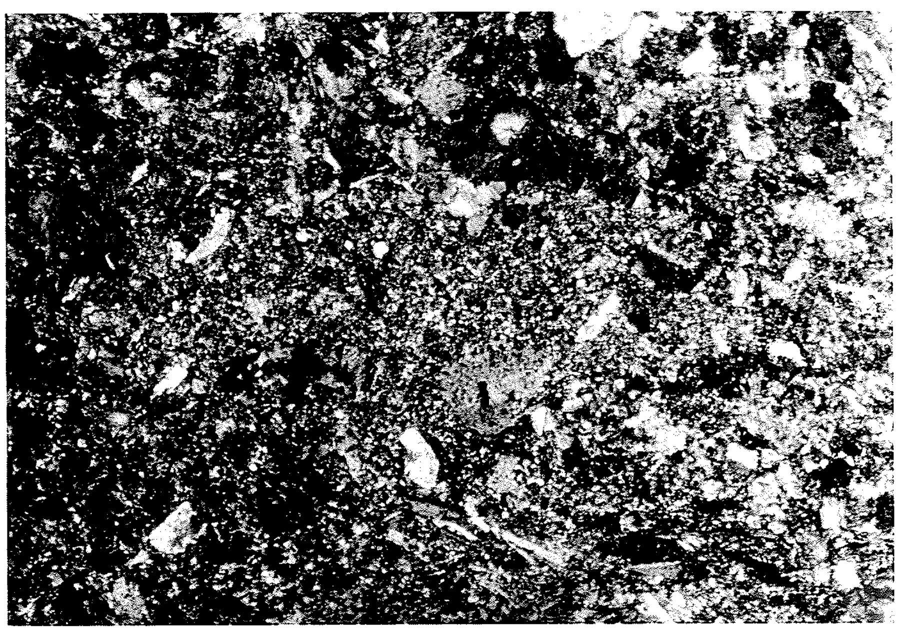


Figure 19: Photomicrograph of a fine-grained pebble of sedimentary origin in a conglomerate from the Dove Lake Formation (x10, crossed nicols)

Under plane light these fragments are frequently surrounded by a thin rim of hematite. Secondary quartz and carbonate are developed in pressure shadows around the larger clasts (see figure 20).

Magnetite is the most common opaque mineral in the sandstones. It never exceeds 3% of the rock, and in most is less than 1%. The magnetite is invariably rimmed by leucoxene, which appears as a felted white mass in reflected light.

Disseminated pyrite occurs in many sandstones as small, thin, fibrous masses subparallel or parallel to the bedding. It also occurs in the fine-grained siltstones and cherts as either distinct laminations, or at the bases of coarser laminae.

Conglomerate Matrix

Modal analyses of the matrix of several conglomerates were conducted. The conglomerate matrix material always lies within the greywacke field. Rock fragments are more abundant within the conglomerate matricies than in the sandstones.

The Dove Lake and the Stovel Lake Formations both contain isolated occurrences of "pisolite", interbedded with laminated chert and/or greywacke, (see figure 21).

The pisolites in the Rice Lake Group appear as discrete, subrounded ellipsoids up to 1 cm. long on the weathered surface, and as indefinite-sized ellipses on the fresh surface. Commonly,

Figure 20: Photomicrograph of secondary quartz developed in a "pressure shadow" zone around a feldspar clast (x10, crossed nicols)

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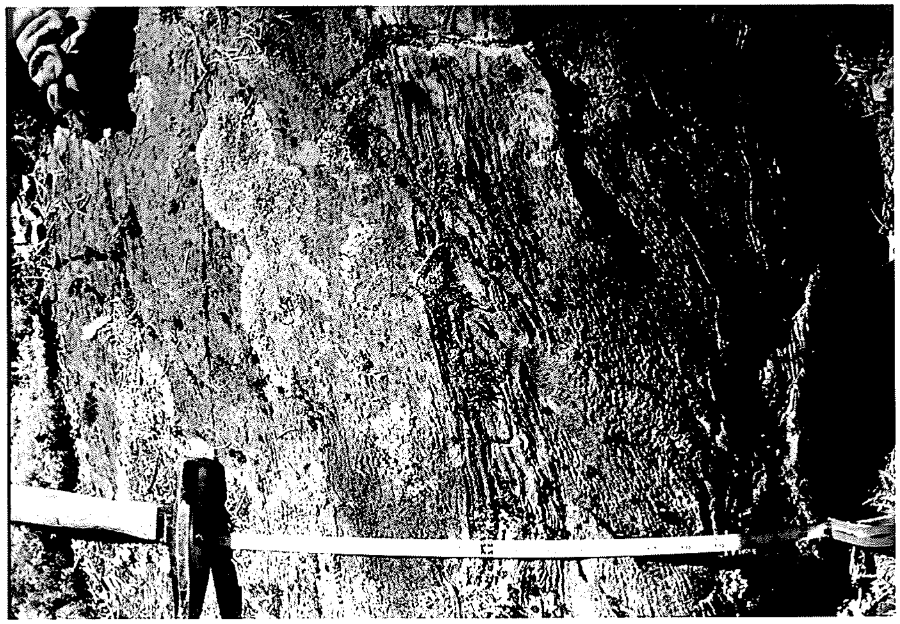
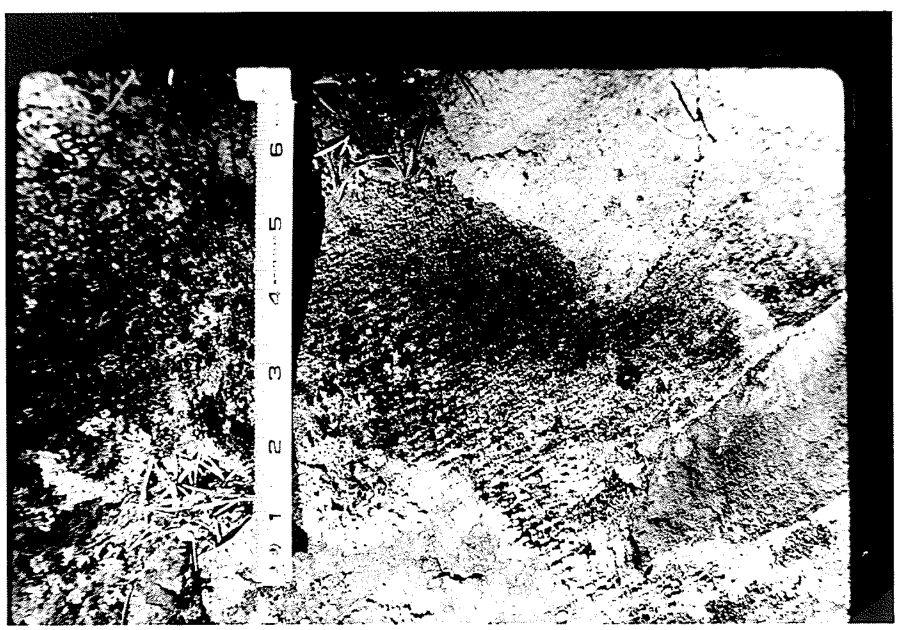


Figure 21: Pisolitic greywacke interbedded with chert and siltstone.



↑

Figure 22: Pisolitic greywacke showing faint positive grading.

they weather out with a higher relief (2-5 mm.) above the surrounding "matrix", and never occur as depressions. The boundaries are always abrupt on weathered surfaces, but appear gradational on fresh surfaces. Nowhere do the pisolites occur in direct contact with each other. They are always separated by "matrix" material. The internal grain size of the pisolites is not appreciably different from that of the surrounding matrix. Infrequently, they show a faint sense of positive grading (see figure 22).

There is no discernible difference in thin section between the pisolites and the matrix, other than a slightly higher quartz content and slightly fewer flakes of chlorite in the former (see figure 23).

Frequently, as at the type locality of the Stormy Lake Formation, the pisolites have a preferred orientation. The orientation is probably a result of rotation of the long axes of the ellipsoids parallel to the penetrative foliation. At the south end of Tinney Lake, the ellipsoids show no preferred orientation.

South of McLeod Lake East, and south of Cliff Lake, similar "ellipsoidal" clasts were observed. However, these are chert in a fine-grained greywacke matrix (see figure 24). These chert clasts were completely detached from their source, and were incorporated as small rip-ups into the enclosing greywacke matrix. They were first noted by their distinct weathering pattern, abrupt grain size, and colour contrast.

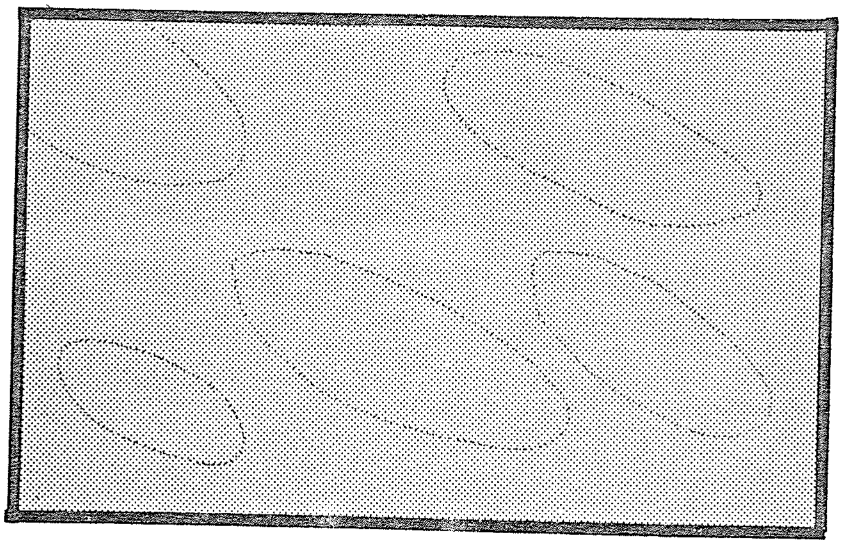


Figure 23 Diagram of a thin section of pisolitic greywacke. Approximately x10, plane polarized light.

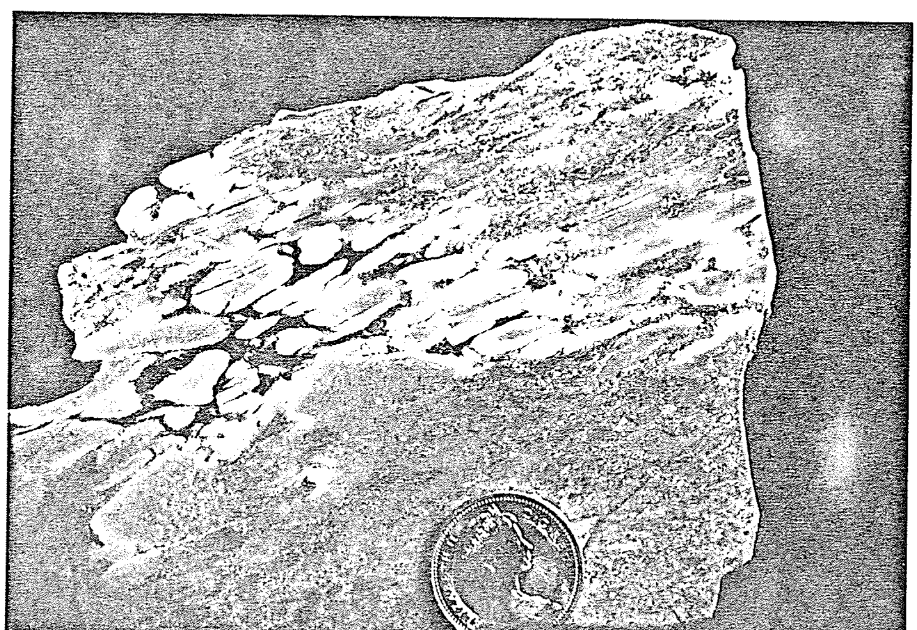


Figure 24 Ellipsoidal chert rip-ups similar to the pisolites in the pisolitic greywacke.

The origin of the pisolites is at present unknown. McRitchie (personal communication, 1969) postulated that they are relict albite porphyroblasts, but could not account for their internal clastic texture. Church (1968) suggested that they are "accretionary lapilli" formed by rain falling on or through volcanic ash. This, however, does not account for their association with chert, iron formation, graded greywacke and other submarine sediments, as lapilli should dissintegrate on contact with water.

It is suggested here that the pisolites represent small rip-ups of approximately the same grain size and composition as the matrix. These intraformational clasts could have become incorporated into the bed when the matrix material flowed rapidly over a semi-consolidated unit.

There is no evidence to indicate that the pisolites were small pull-apart structures which have been rotated or "rolled" into their present shape. The uniform grain size of the pisolites is not indicative of a rip-up origin, and could not be accounted for.

Sandstones of the Stormy Lake Formation

The sediments of the Stormy Lake Formation are described more fully by Weber (1971), and only a short reference to them will be made here.

The majority of the sandstones closely resemble those of the Dove and Stovel Lake Formations. The matrix of the greywackes of the Stormy Lake is nearly identical in all respects to that of the Dove Lake and Stovel Lake Formations including alteration and silicification (see figures 25 and 14).

The predominant sand-sized clasts are well- to poorly-twinned plagioclase feldspar. Typically, these are sub-rounded to angular, and are frequently broken.

Quartz is more abundant in the greywackes of the Stormy Lake than in those of the Dove Lake. The grains generally show a composite undulose extinction, and are sub-rounded to well-rounded. Where a foliation is well-developed, the quartz grains show a good pressure shadow effect.

Rock fragments are not abundant in the Stormy Lake Formation. The rock fragments are predominantly volcanic and/or sedimentary in origin, but are more easily distinguished than those in the underlying sedimentary formations. The rocks of the Stormy Lake closely resemble the Dove Lake and Stovel Lake on the basis of feldspar/rock fragment ratios (compare figures 14 and 25).

The Stormy Lake Formation is unique also in that it contains the first "iron formation" in the Rice Lake Group in this area. The unit is well-exposed on the road from Long Lake to the Ogama-Rockland Mines. The unit is discontinuous and consists of interbedded siltstone, chert, fine-grained greywacke, "pisolithic greywacke", and siliceous magnetite-hematite. The unit crops out

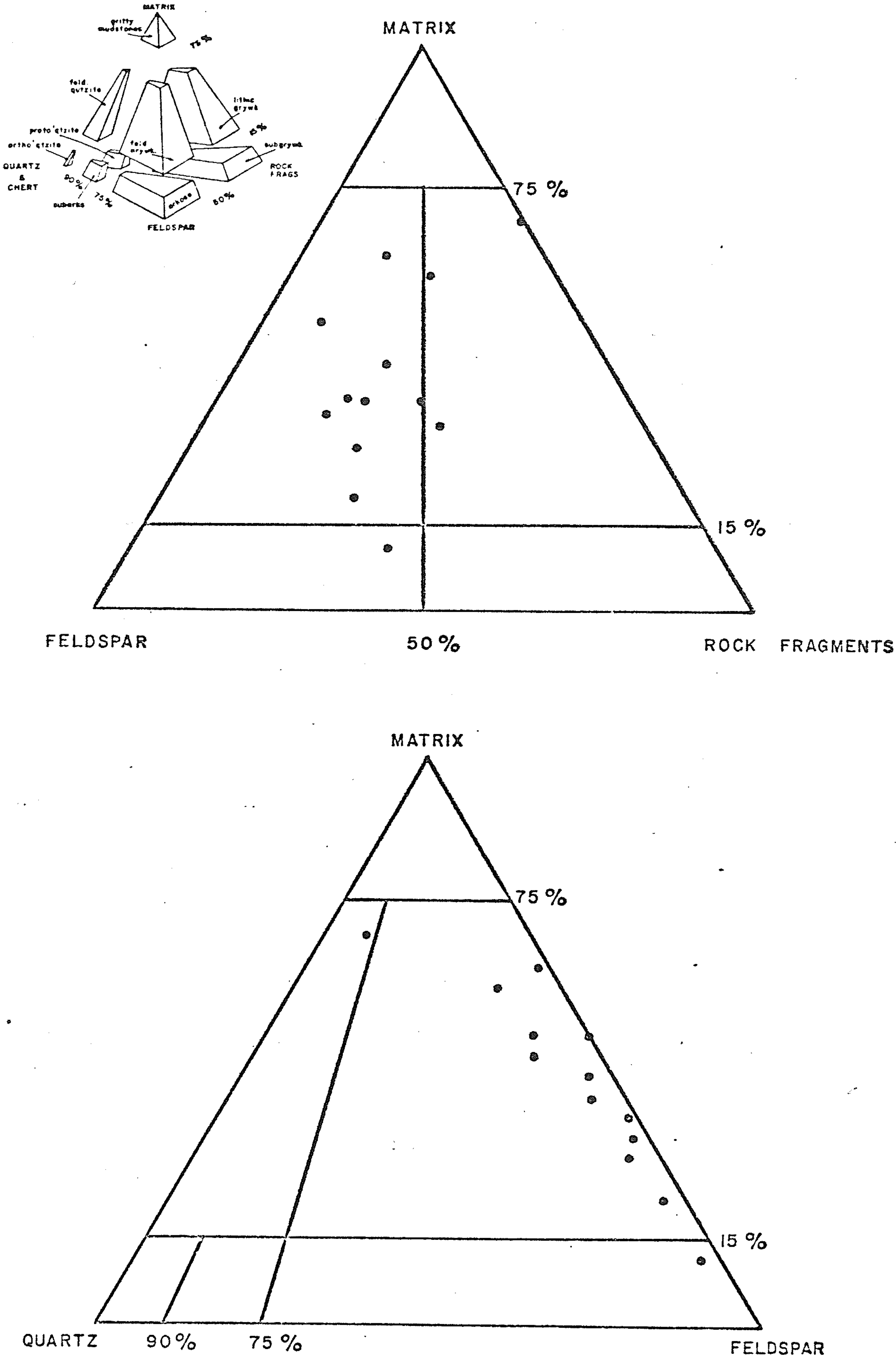


Figure 25: Sandstones of the Stormy Lake Formation plotted on the tetrahedron faces.

approximately in the center of the formation, and may be traced, scantily, from the power line at the west side of the area, to the north end of Beresford Lake.

Sandstones of The Narrows Formation

This unit consists predominantly of fragmental volcanics, with very minor greywacke. Too few thin sections were available for an accurate analysis of the sedimentary types.

The formation is characterized by very coarse fragmental volcanics or agglomerates. Zwanzig (1968) identified a number of separate units within the formation at Long Lake.

The formation contains numerous dykes and sills of gabbro and diorite. Some of these are shown in the accompanying map, (in rear pouch).

All the units within the formation were identified by Zwanzig as tuffaceous rocks. The unit is transitional upwards into the Edmunds Lake Formation. This transition zone is best exposed along the power line south of the Narrows at Long Lake.

The formation records the last episode of extrusive volcanic activity in this area.

Sandstones of the Edmunds Lake Formation

The Edmunds Lake Formation is the uppermost stratigraphic unit presently recognized in the Rice Lake Group. The formation is predominantly sandstone. Zwanzig (1968) worked in the lower part of the formation at Long Lake, and was able to subdivide the formation into a series of sub-units.

The Edmunds Lake is continuous from Caribou Lake in the west, to the Ontario border southeast of Flintstone Lake.

The Edmunds Lake Formation is entirely sedimentary and contains no recognized volcanic rocks. The sandstones of the formation record the first appearance of detrital quartz as a major constituent. Near the base of the formation, the rocks have a high percentage of matrix. Upward in the formation, quartz increases at the expense of matrix and feldspar. Quartz never exceeds 40% and normally varies from 7% to 15%. Figure 26 shows the variations in composition of the sandstones in the Edmunds Lake Formation.

The sandstone matrix is a fine-grained mosaic of quartz, sericite, chlorite, epidote, feldspar and carbonate. Small, faintly twinned, plagioclase grains and a high percentage of carbonate are the most distinctive features of the matrix. Carbonate is always present in varying amounts up to 35%. Secondary quartz in small veinlets oblique to the bedding is common.

Carbonate and quartz may occur in the same veinlet. Secondary veinlets of pure calcite also occur.

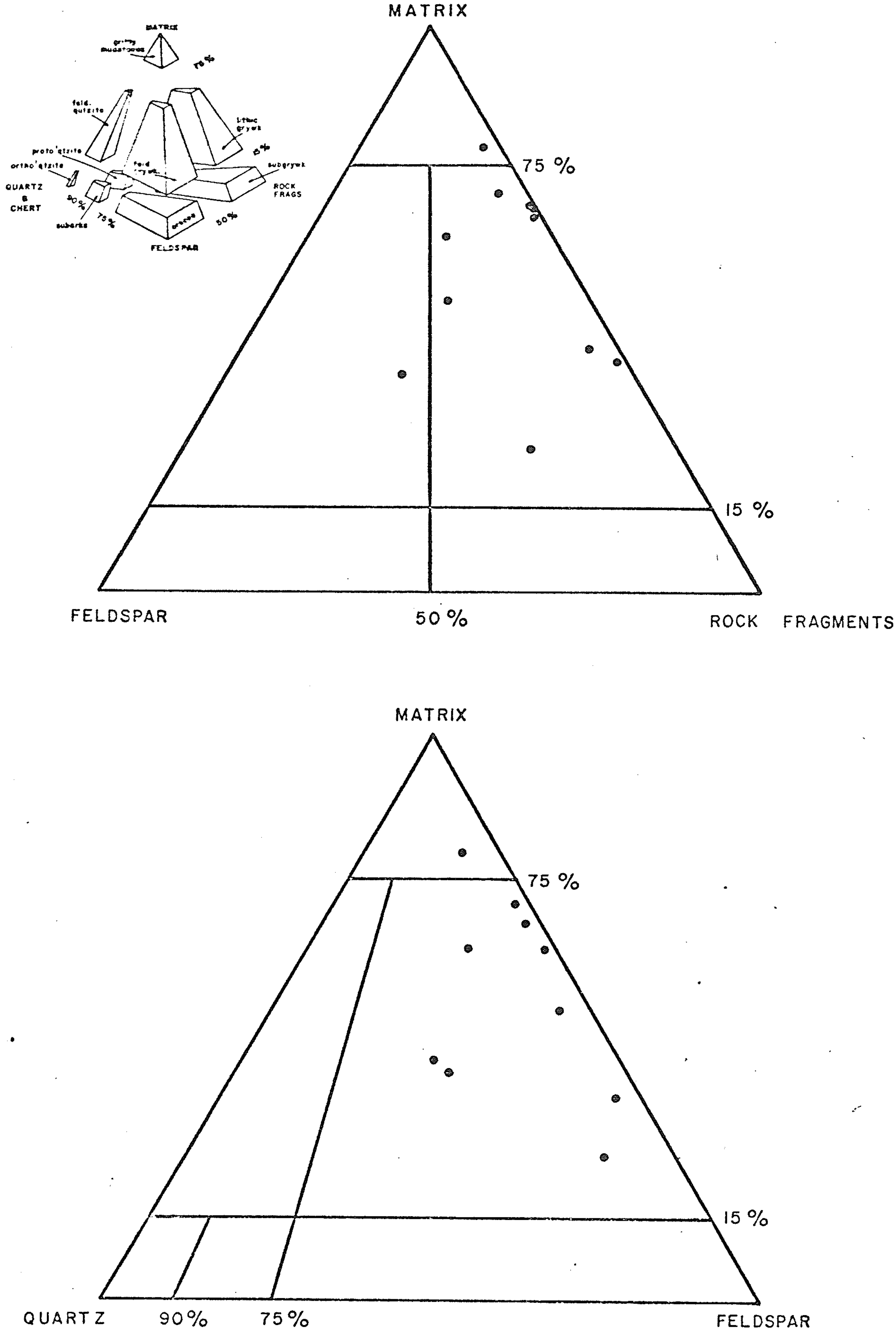


Figure 26: Sandstones of the Edmunds Lake Formation plotted on the tetrahedron faces.

Detached portions of the quartz veinlets may have produced some of the quartz-rich grains which may be mistaken for rock fragments. These "orthoquartzite" clasts show a pseudodetrital texture. However, the deformed quartz veinlets show a granular to saccharoidal texture identical to that of the fragments.

Feldspar and rock fragments are the predominant sand-sized materials present in the sandstones of the Edmunds Lake. The feldspar is all plagioclase, sub-rounded to angular or broken, generally blocky in cross-section, with poorly- to well-developed albite-twinning. These grains have been altered in varying degrees to saussurite. In some cases, the rims of poorly-developed zoned feldspar grains show preferrential saussuritization. The cores may contain small patches of carbonate. The entire grain is rarely replaced by carbonate.

Very few of the rock fragments show volcanic textures. The majority are sedimentary in origin. The rock fragments vary in shape, but the majority are sub-rounded to blocky, with secondary quartz and/or carbonate developed in the pressure shadows when a strong foliation is present. Fine-grained rock fragments are difficult to distinguish from the matrix under crossed nicols but are most easily defined in plane light. Many of the grains show a faint rim of hematite.

Rock fragments appear to have replaced feldspar as the dominant detrital component in the sandstones. In one sample, the sandstone contains only 1.0% feldspar, 31.2% rock fragments, and 27.2% quartz (sample 12-67-1167). Here, both quartz and rock fragments have increased at the expense of feldspar.

Quartz occurs as discrete clasts and as optically discontinuous grains. The latter appear to be either fractured grains which have been welded or cemented together, or broken vein quartz. The quartz grains vary from angular to rounded and are, in general, slightly better-rounded than the feldspar clasts. A typical quartz grain is subrounded, with a composite undulose extinction, (Folk, 1965, p. 72), has slightly to highly pitted borders, and rare mineral trains developed in the pressure shadows (see figure 20). The matrix generally shows no preferred orientation at the grain boundaries, except where a foliation is present. Then, the small grains close to the more resistant quartz fragments are "warped around" the grain boundaries, and secondary pressure-shadow development is pronounced. No inclusions were noted in any of the quartz grains. It was not possible to determine precisely the origin of the quartz either by optical or textural characteristics.

In general, the sandstones of the Edmunds Lake Formation can be easily distinguished from those of the Dove Lake and Stovel Lake Formations as the former have a feldspar/rock fragment ratio less than 1.

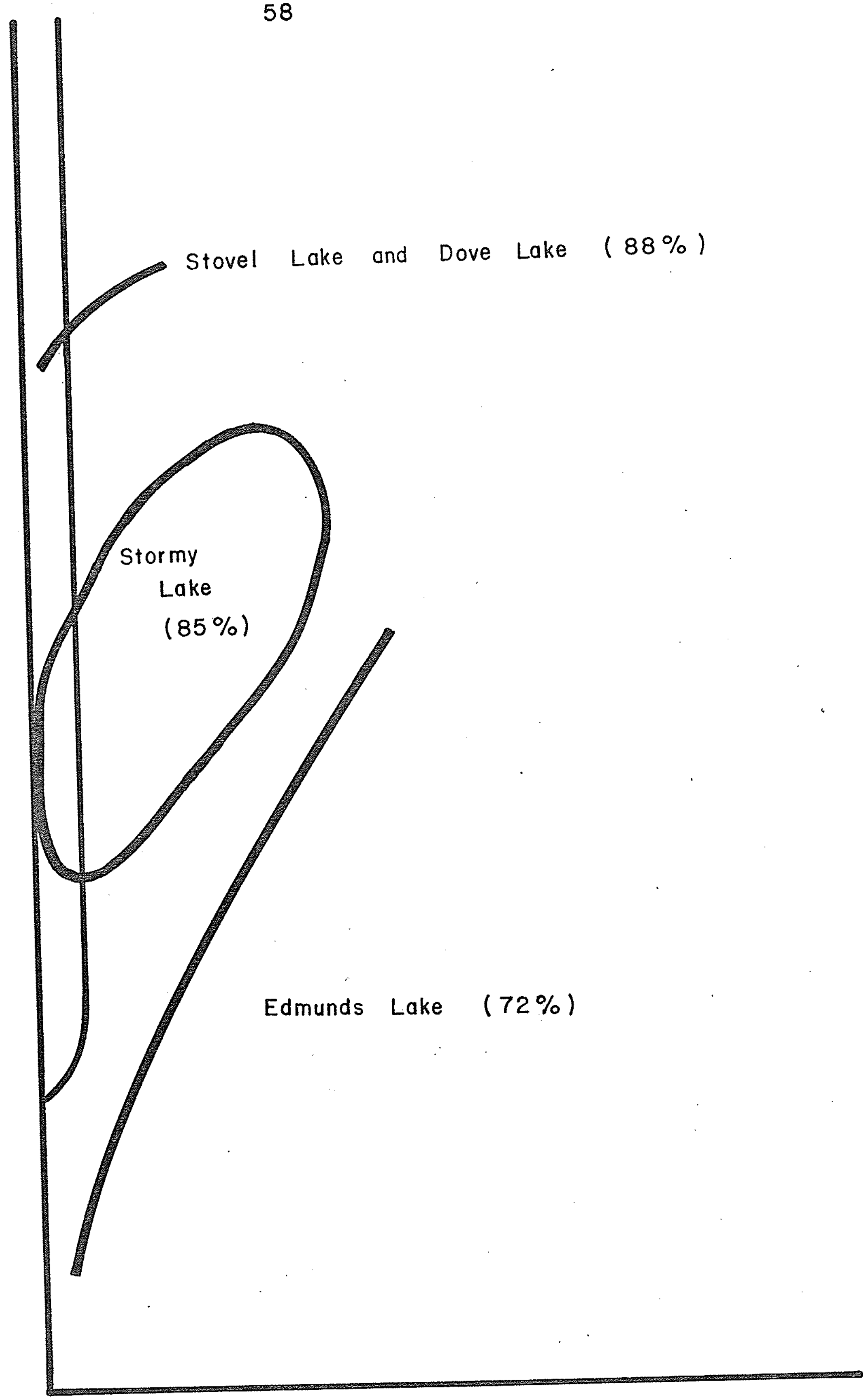
Figure 27 shows a comparison of the three formations. The approximate limits of each is outlined on the diagram. The boundary between the Dove Lakes and Stormy Lake Formations is a well-defined line at approximately 5% quartz. The Stormy Lake Formation has only a small area of overlap into the Dove-Stovel field. The figures in brackets indicate the percentage of modal analyses from each group in the respective field.

The diagram indicates that the two are distinct lithologic types. The main basis of separation is the percentage of sand-sized detrital quartz present in the three formations.

The source of the quartz in the Stormy Lake may be attributed to the infrequent granite boulders which occur in the conglomerate at the base of the formation. This conglomerate marks the first appearance of a plutonic rock as a detrital component in stratigraphic column. If a granite pluton was unroofed at this time the percentage of quartz being supplied to the basin would increase upward in the Rice Lake Group. This is reflected in the sediments (see figure 27).

Sandstones of the Rathall Lake Formation

The sandstones of the Rathall Lake Formation resemble those elsewhere in the area except that rock fragments are more abundant, at the expense of quartz and feldspar. Quartz is a frequent and occasionally abundant constituent. Figure 28 shows the sandstones of the Rathall Lake Formation plotted on the tetrahedron faces.



Overlay showing approximate formational composition "fields".
Bracketed figures are percentages of samples within each "field."

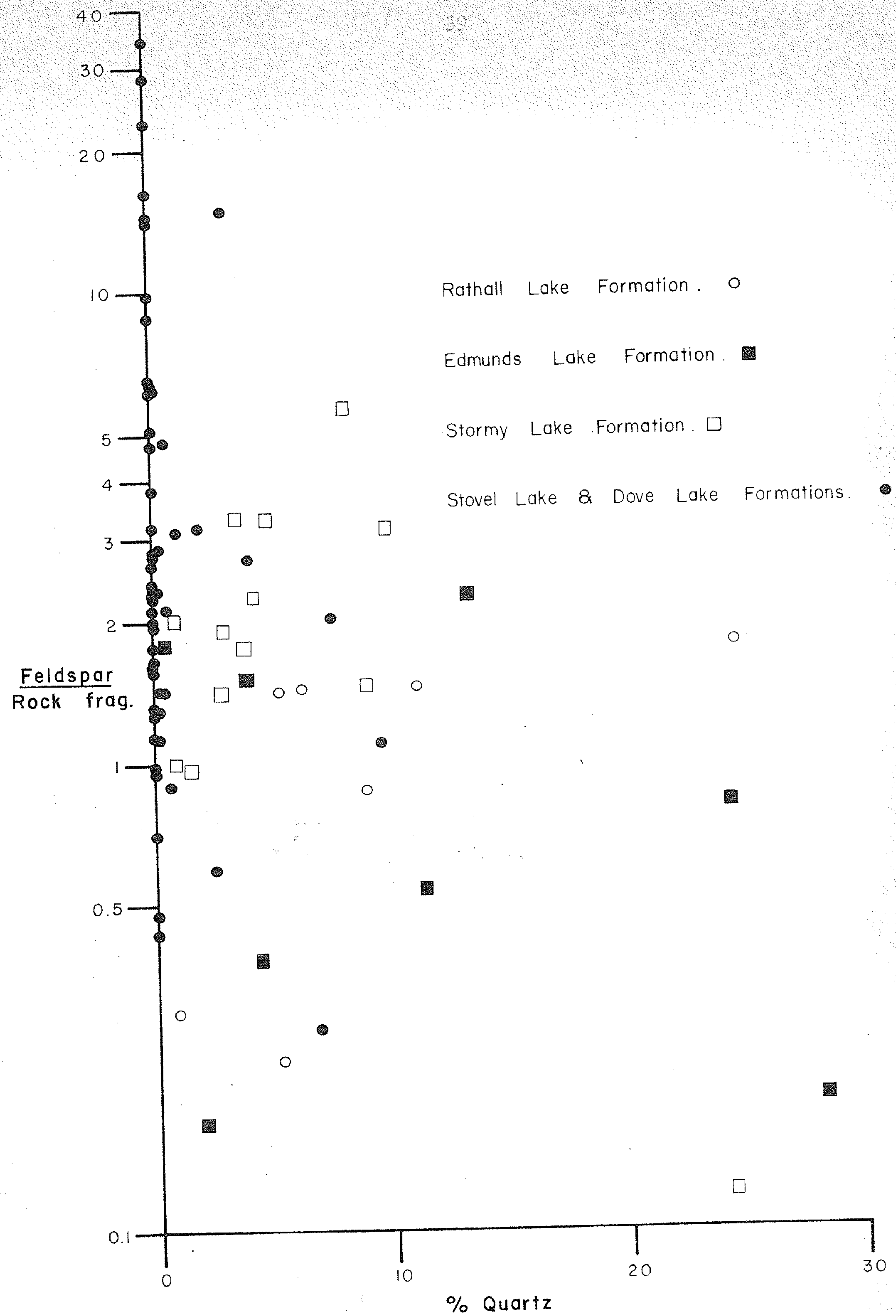


Fig. 27: Variation in clast type by formation.

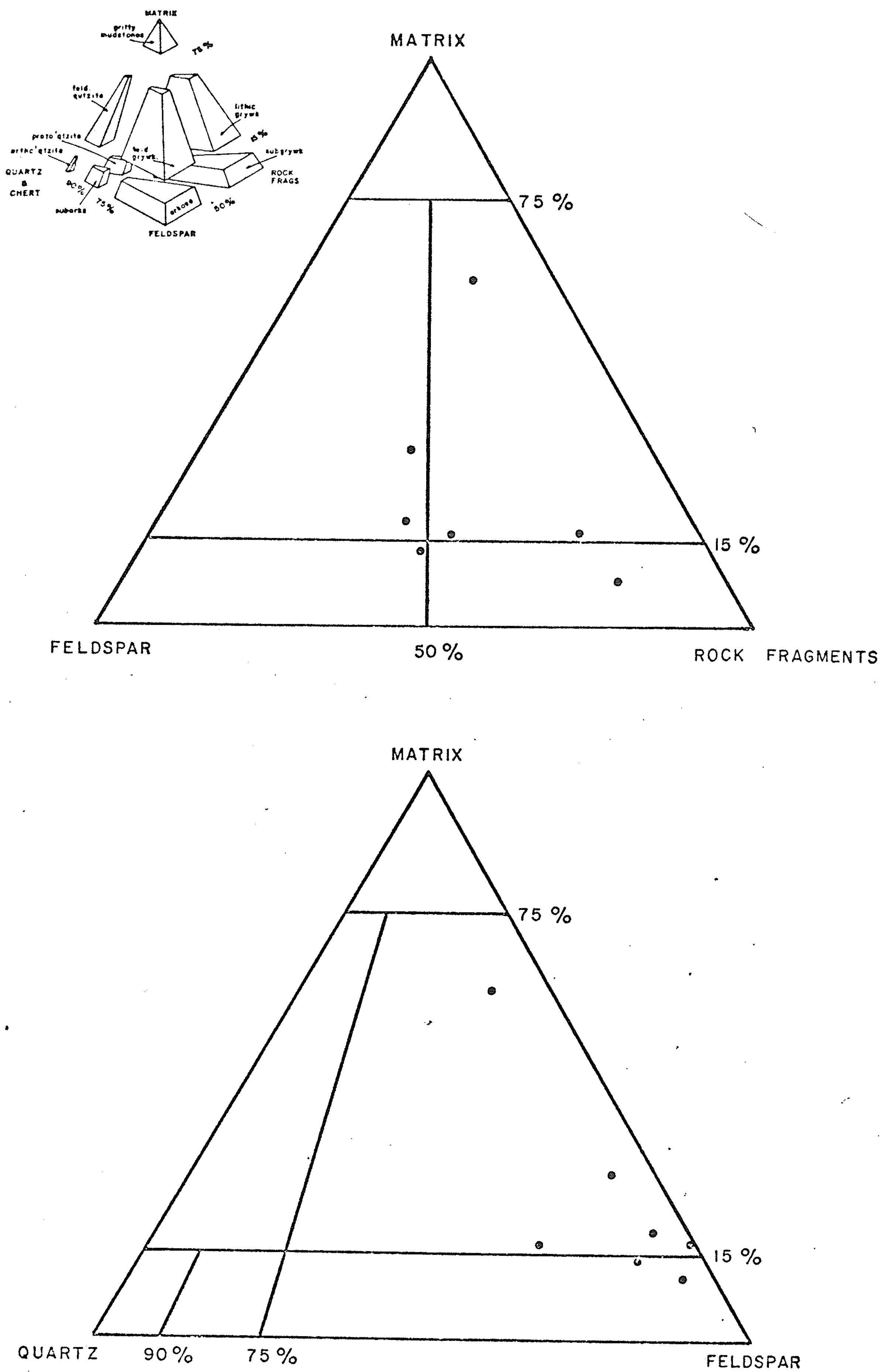


Figure 28: Sandstones of the Rathall Lake Formation plotted on the tetrahedron faces.

The quartz grains are fair to poorly-rounded, and occasionally broken. The feldspars show well-preserved albite twinning, but are not usually as large as those in the Dove Lake or Stovel Lake Formations.

The rock fragments vary from fine-grained sedimentary clasts similar to those shown in figure 19, to porphyritic volcanic fragments similar to those shown in figure 77.

The sandstones are invariably sheared, and pressure-shadow effects are frequently developed around the larger grains. Some show secondary quartz growth in these zones.

Grit is also abundant in the Rathall Lake. No appreciable difference in composiiton was noted between the grit and the sandstones.

Interpretation of Sandstone Composition

There is no significant lateral or vertical variation in sandstone composition within either the Stovel Lake or Dove Lake Formations. The rocks from both formations plot randomly on the tetrahedron planes.

The lithologic similarity of these sedimentary formations indicates that they may be dealt with as a single type of unit, for the following reasons:

(1) Both are over- and underlain by pillowed basalt-andesite.

(2) Sandstones within both contain recognizable extrusive volcanic rock fragments.

(3) The feldspar clasts within the sandstones cannot be differentiated by composition.

(4) Primary sedimentary structures, textures, and internal sedimentary fabrics are essentially the same.

The stratigraphic position and lithology of the Stovel Lake Formation indicates that it was deposited away from the major source of the sediments. Periods of quiesence during Stovel Lake time are represented by fine-grained siltstones, chert and micro-wacke.

The increase upward in the amount of quartz in the sediments reflects a gradual change in the source of the clastics. Quartz is a major constituent in the Edmunds Lake Formation. The welded acidic tuff present in the underlying Narrows Formation could have been the source for some of this quartz. However, most of the quartz is fairly well-rounded, indicating a detrital, as opposed to volcanic source.

Granitic clasts present in the thin conglomerate near the base of the Stormy Lake Formation indicate that a new source of material was being uncovered early in the depositional history of the basin. These granitic clasts are not, however, highly angular, indicating they had undergone a relatively long transport time.

The clasts may have been derived from an earlier, older conglomerate.

The increase upward in rounded detrital quartz, is attributed to the uplift and erosion of an earlier, quartz-rich sedimentary sequence, coincident with cessation of volcanic activity.

The "basic" nature of the sandstones, together with the clast shapes and stratigraphy, strongly indicates that the sediments were derived from "basic" volcanics, for the following reasons:

(1) The absence of quartz from the sediments indicates that the source of sandstones was predominantly "basic".

(2) The majority of the rock fragments are basic and intermediate volcanic rocks.

(3) The clastic plagioclase crystals are typical of phenocrysts derived from basalt and andesite.

(4) The zoned plagioclase crystals may have been derived from volcanic ash or tuff.

(5) The interlayered nature of the sediments and basalt indicates a ready source of sedimentary detritus.

CHAPTER IV

PRIMARY SEDIMENTARY STRUCTURES

Numerous different types of primary sedimentary structures are present in the sediments of the Rice Lake Group in this area. Most of these have not previously been noted in the area. They are defined, described, and discussed here because they are an important key to the interpretation of the depositional history of the rocks.

Scour Channels

Potter and Pettijohn (1963, p. 123) define channels (or channel fills) as:

> "Unlike other sole markings which exhibit such slight relief that some are seen only with strong, low angle illumination, channels are characterized by their broad width and their marked depth. They may be up to several meters wide and have a depth of several centimeters."

Scour channels in the Rice Lake Group cannot be traced for great distances. The maximum exposed length is only some 300 meters. Generally, the channels either pinch out between exposures, or the attitude of the strata and the position of the exposures do not coincide. Most frequently, the problem is one of insufficient exposure. Clasts in the channels are similar to those sediments truncated by the channel, indicating that filling was contemporaneous with erosion. Nowhere was one channel found to truncate another. Each is in turn overlain by "normal" sediments — laminated chert, greywacke and siltstone.

Sediments near the top of the Dove Lake Formation frequently show large, conglomerate-filled channels truncating the bedding of underlying units. These channels range in width from 10 cms. to over 5 meters. They are commonly less than two meters deep and with irregular lower surfaces. They may vary markedly in thickness along their exposed cross-section (see figures 29 and 30). The contacts along the flanks of these channels are always sharp. No post-erosional slumping is evident.

The large scour channel at the base of the Dove Lake west of Beresford Lake contains large chert clasts as part of the polymictic conglomerate filling. Near the small creek which drains Wentworth Lake, this same scour channel truncates interbedded greywackes, siltstone and chert.

The material filling these channels is composed predominantly of poorly rounded and unsorted basic volcanic fragments, in a feldspathic greywacke matrix.

Scour and fill channels are not restricted to contact zones of the Dove Lake Formation. Very small scour channels occur in the central part of the Dove Lake (see figure 31) and in the Stovel Lake Formation in the vicinity of Cliff Lake. Infrequently, a bedding plane is exposed which shows very small scours filled with sand-sized material (see figure 32).

Interpretation

Scour and fill channels are typical of sediments deposited

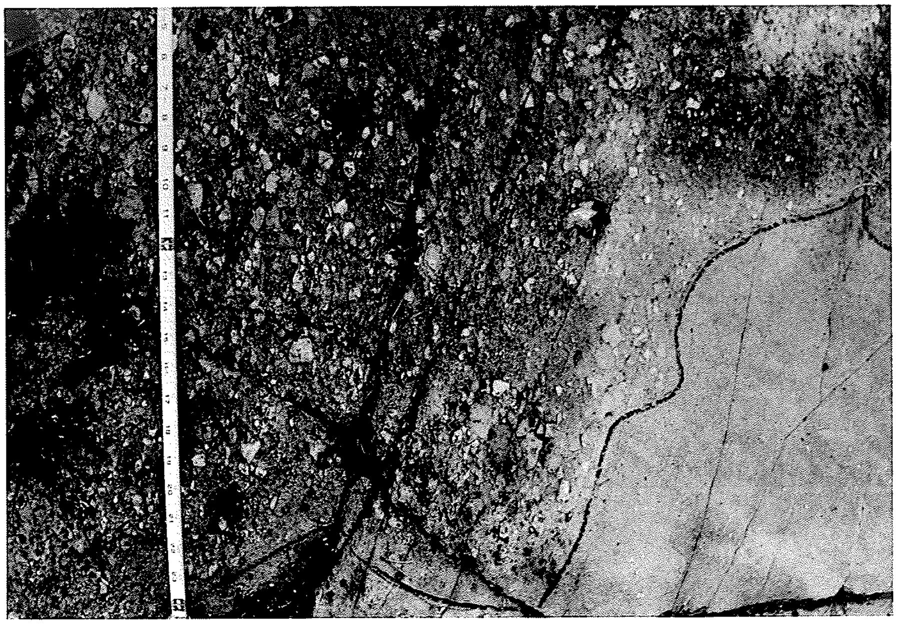


Figure 29: Part of a large scour channel near the base of the Dove Lake Formation.

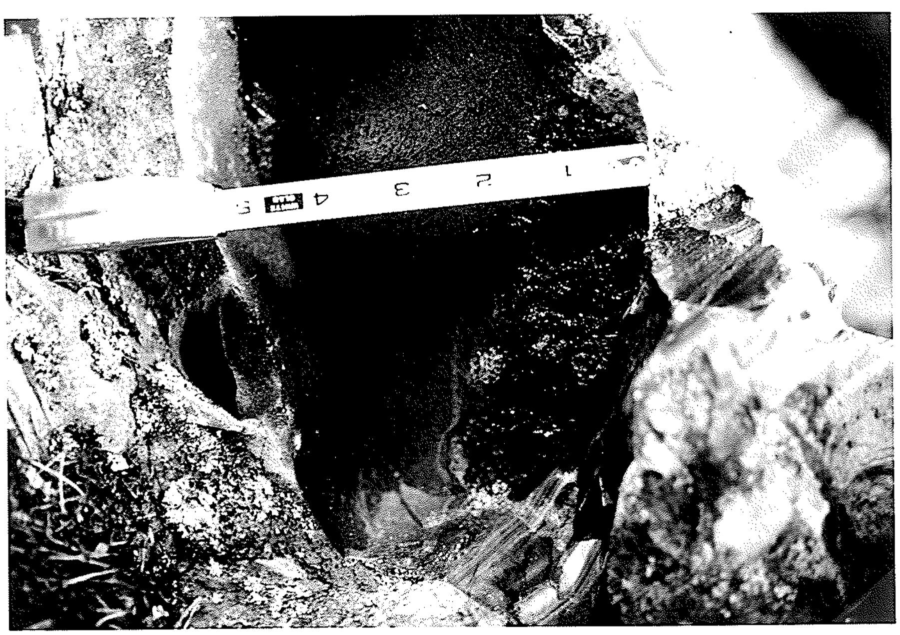


Figure 30: Small scour channel near the top of the Dove Lake Formation.

Figure 31: Very small scours in the central part of the Dove Lake.

Figure 32: Possible scour pits, exposed in plan view.

by turbidity currents. The shape of the channels, contemporaneous erosion and deposition, grain size, and stratigraphic position, strongly indicate that a turbidity current mechanism was responsible for their formation.

Ripple Marks

The rocks of the area have a pronounced tendency to fracture along the well-developed axial plane cleavage. Induration is such that the rocks will not part along the bedding planes. Consequently, ripple marks are extremely rare in the rocks of the Rice Lake Group. They were found at only one locality (see figure 33).

The ripple marks are exposed on the upper surface, approximately 1.5 meters square, of a sand-sized feldspathic greywacke bed in the Stovel Lake Formation (see figure 34). The same bedding plane crops out approximately 2 meters from the first exposure and, though smaller, also shows good ripple marks. The crests are straight, non-bifurcating and the wave length of the ripples is approximately 20 cms. The amplitude is approximately 2.5 cms. No internal lamination is visible either above or below the ripples and the ripples are classified as oscillation type.

Structures which may be interpreted as ripple marks were infrequently observed in vertical section (see figure 35). These occur at the top of a fine sand and silt layer, and directly overlie a bed which shows convolute bedding. The structure may have developed at the same time as the convolute bedding, or may have

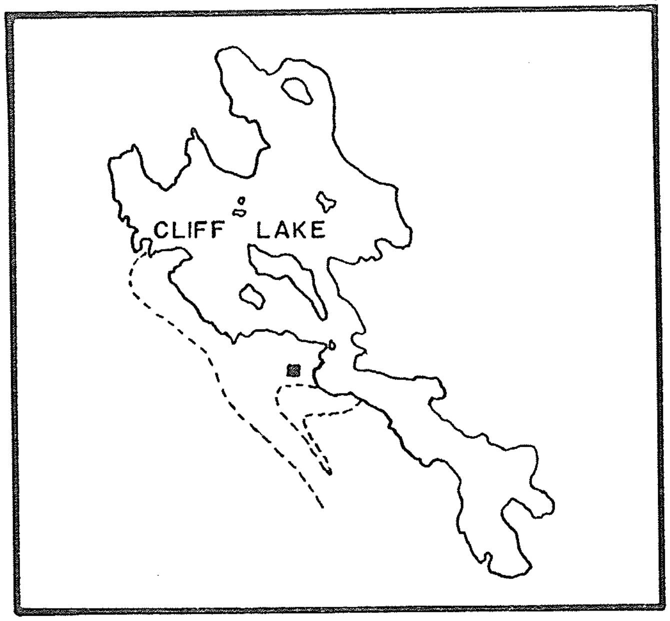


Figure 33 Ripple mark location in the Stovel Lake Formation.

Figure 34 Ripple marks on a bedding plane in the Stovel Lake Formation.

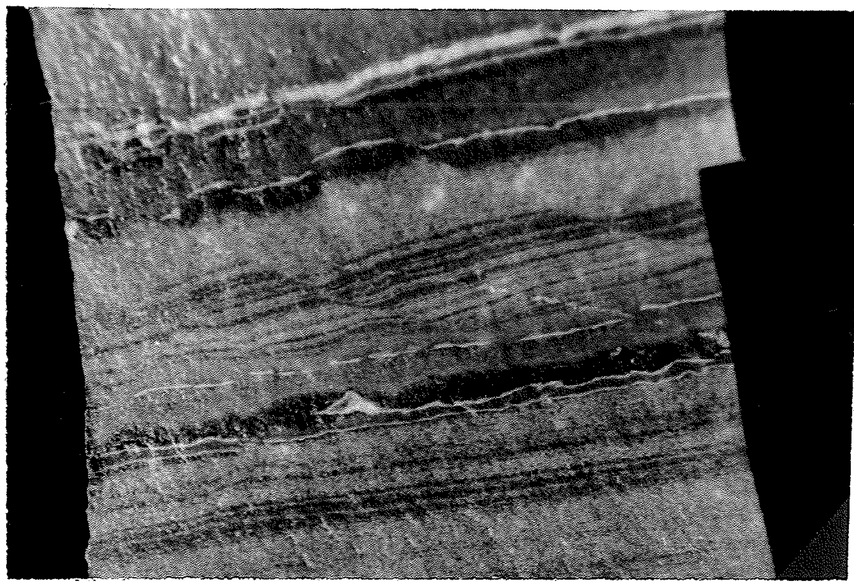


Figure 35: Possible ripple marks in vertical section, Dove Lake Formation.

been produced by bottom currents. If the latter, then the wavy structure is actually a vertical section of a rippled surface.

Interpretation

Pettijohn attributes oscillation ripples to wave action, and considers them indicative of a shallow water environment. However, they have been reported in depths up to 1500 meters (Menard, 1952). Where they are abundant, though, it is unlikely that the water was very deep (Pettijohn, 1957, p. 186).

The presence of ripple marks on the upper surfaces of beds indicates that bottom currents were active at the time of, or shortly following, deposition of the sediment. The type of ripple marks present may be indicative of shallow water. However, an isolated occurrence lends little support to a shallow water hypothesis for the basin of deposition.

The main conclusion that may be drawn from the presence of ripple marks is that bottom currents were active during part of the depositional history of the basin.

Graded Bedding

Graded bedding is ubiquitous throughout the sedimentary formations in the area mapped. It is the single most useful indicator of upward sequence in these rocks.

Bouma (1962, p. 139) defines the graded bedding as:

> "If both the maximum and/or the average grain sizes of a layer decrease from bottom to the top, the phenomenon is called graded bedding. In each horizon all grain sizes are present and smaller than the maximum in the lower part of the layer. Negative graded bedding: the maximum and average grain sizes increase from the original bottom to top."

Two types of graded beds are presently distinguished:

(1) Grading produced by a waning current.

(2) Grading produced by differential settling from a turbidity flow.

In both types, the clasts decrease in size towards the original top of the bed. In the first, the mean size of the clasts would decrease upward, but the sorting would remain constant; in the second, the size would also decrease, but the sorting would improve.

Walton (1956) proposed the terms "delayed grading" and "interrupted grading" as two types of graded sedimentation units. He (p. 263) defined these as:

> "Delayed grading: In some beds coarse grains are present at the base; the main part of the bed is uniformly medium-grained; and the upper portion grades rapidly into siltstone or shale.
>
> "Interrupted grading: In this case, the upper, fine-grained, portion of the bed is missing, and the shale lies directly, with sharp contact, on medium-grained greywacke."

Bouma (1962) expanded the study of individual sedimentation units, and proposed a fivefold subdivision of the complete turbidite sedimentation unit.

The complete cycle of Bouma was not observed in the rocks of the area. Frequently, however, variations of the cycle are present. The most complete cycles (from the base to the top) present can be represented as follows:

(1) Coarse-grained, feldspathic greywacke, which may contain small, intraformational shale chips or pebbles of chert, and have small scours at the base, grading upwards into —

(2) Coarse-grained, sandy siltstone, laminated near the top in many beds (this division often forms the main part of the unit), grading upward into —

(3) Fine-grained siltstone, often with an abrupt contact with the underlying siltstone, grading upward into —

(4) Finely laminated chert.

These all may be present in a single sedimentation unit. Most frequently, unit 4 is missing. It may have been removed by erosion, or may not have been deposited.

Graded beds in the Dove Lake and Stovel Lake Formations are, in general, less than 25 cms thick. Typically, the base of the unit consists of medium to coarse sand-size material, grading upward into fine sand, silt, and chert.

Flame structures and possible load structures may be present at the bases of these graded units. The load structures show internal grading on a small scale (see figure 36).

Graded bedding also occurs at the bases of the beds which

Figure 36: Cross-section of load casts showing graded bedding, Dove Lake Formation.

Figure 37: Rip-ups and graded bedding, Dove Lake Formation.

contain large, randomly oriented, rip-up clasts (see figure 37). If internal laminar flow or shearing continued following deposition, the ripped-up fragments would have acquired a preferred orientation, and the graded part of the bed would have developed parallel lamination. Neither of these structures is present. This type of graded bedding indicates that the entire mass "froze" in its present orientation following deposition.

Graded bedding is not restricted to the sand-sized sediments of the Rice Lake Group. Rare graded bedding occurs in the conglomerates common to the upper part of the Dove Lake Formation. The maximum clast size near the base of these units is not markedly different from that at the top. However, the percentage of matrix present at the top of the unit is greater than that at the base. Lateral grading in these conglomerates was not noted. Near Tinney Lake, grading also occurs in the volcanic agglomerates of the Stovel Lake Formation, (see figure 38).

Grading also occurs in the thin chert and siltstone beds at the tops of the sedimentation units consisting predominantly of coarser sediment.

Zwanzig (1969) noted numerous occurrences of graded bedding in the Edmunds Lake Formation. No graded bedding was found in either the Stormy Lake or The Narrows Formation.

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Figure 38: Graded bedding in volcanic agglomerate, Stovel Lake Formation.

Interpretation

The graded sedimentation units present in the rocks of the area, together with the gross lithology and other sedimentary structures, strongly suggests that the majority of the sediments were deposited by turbidity currents.

Cross-stratification

Cross-stratification is relatively common throughout the sedimentary rocks of the lower part of the Rice Lake Group. However, it was not always possible to measure the orientation of foreset laminae for use as paleocurrent indicators. The Dove Lake Formation contains the largest number of cross-stratified units.

Several types of cross-stratification occur in the rocks of the Rice Lake Group. The cross-beds are mainly of the planar type (McKee & Weir, 1953, p. 387); minor, small, festoon-type cross-lamination also occurs. Planar foreset beds are essentially parallel planes which intersect the bounding bedding planes at a sharp angle. Some are slightly curved, with the concave side upward. Occasionally, small channels are filled with cross-laminated sediment. Cross-bedding commonly occurs in closely-spaced sets, with 3 or 4 units in a sequence less than 0.8 meters thick. Foreset laminations are most common in the uppermost few centimeters of an individual sedimentation unit. These typically intersect the bedding plane of the underlying stratum at an acute angle (see

Top ↑

Figure 39: Cross-bedded greywacke, Dove Lake Formation.

figure 39). High angles of intersection were sometimes noted. Angles of foreset bedding vary considerably, from less than 15° to greater than 40°. Foresets in fine-grained sediments are not traceable to the base of the unit in many cases.

Occasionally, the bases of some cross-bedded units are graded, but no correlation between cross-bedding and grading was noted.

Cross-bedding and cross-lamination are less abundant where the Dove Lake Formation is thin. Cross-stratification is not well-exposed in the conglomeratic parts of the sedimentary formations. Only two cross-laminated units were recorded in the uppermost part of the Dove Lake Formation west of the Dove Lake Shear. The Stovel Lake Formation contains poorly cross-laminated units in the vicinity of Tinney Lake.

The Rathall Lake Formation contains few cross-bedded units. One large channel scour filled by cross-bedded sandstone was noted (see figure 40).

The Narrows Formation does not show any cross-bedding. It is also extremely rare in the Stormy Lake Formation. Zwanzig (1969) reported that the structure is rare in the Edmunds Lake Formation.

At all locations, the cross-stratified unit, or "set", is over and underlain by normally-bedded units. The attitude of both the normally-bedded strata and the attitude of the foreset beds was recorded wherever possible. Foreset beds are most often

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Figure 40: Cross-bedded channel in the Rathall Lake Formation.

exposed on joint or fracture planes. It was possible to align an aluminum clip-board with the traces of individual foresets on two such planes. The attitudes of the majority of the cross-beds were determined in this manner. Where two surfaces were not exposed, the sense of the paleocurrent direction was recorded. However, this method is vary inaccurate, as the foreset could lie at any angle to the plane of exposure.

Interpretation

Recent studies by other workers (Casshyap, 1968; Lindsey, 1969) of the sedimentology of other Precambrian rocks have shown that cross-stratification may be used as a paleocurrent indicator in low-metamorphic grade rocks. However, where folding and metamorphism are intense, deformation of the structures renders such attempts relatively useless.

Any cross-laminated stratum which may have undergone internal deformation by flow parallel to the bedding planes will show either steepening or shallowing of the foreset laminae. The orientation of the line of intersection of the foreset and bedding planes will not change, as the amount of deformation on any plane parallel to the bedding is constant (see figure 41). Internal flow parallel to the bedding planes will produce an incorrect paleocurrent measurement only when the amount of flow is sufficient to produce a dip on the foresets with an opposite sense of direction (see figure 42).

Natland and Kuenen (1951) believed that the absence of cross-bedded sandstones, together with sorting and lithology, indicated deposition by turbidity currents. Kuenen and Sanders (1956, p. 665), on the other hand, favour turbidity currents as the agent of deposition of cross-laminated beds. They attribute the ripples developed in the uppermost part of a sole marked bed to have been produced by the same current which deposited the lower portion. In general, sandstones characterized by graded bedding do not show thick cross-bedding. However, thin cross-laminated units are common, as in the Pliocene of the Ventura Basin (Hsu, 1964, p. 380).

Hsu, (1964, p. 380), suggested that many of the cross-beds which occur in graded strata could have been produced by ocean bottom currents. Shepard, et. al., (1939) studied bottom currents in the ocean and found no preferred flow direction.

Where two or more sedimentary processes act on the same detrital material in a basin, the resulting admixture of textures and sedimentary structures could result in confusion of interpretation. "Normal" pelagic sediment deposited in a basin adds material to any turbidite sequence. The action of bottom currents, together with eddies set up by successive turbidity currents, would produce divergent paleocurrent patterns, indicated by cross-bedding.

Lack of a preferred paleocurrent direction is one indication that both processes were active during the deposition of the Dove Lake and the Stovel Lake Formations.

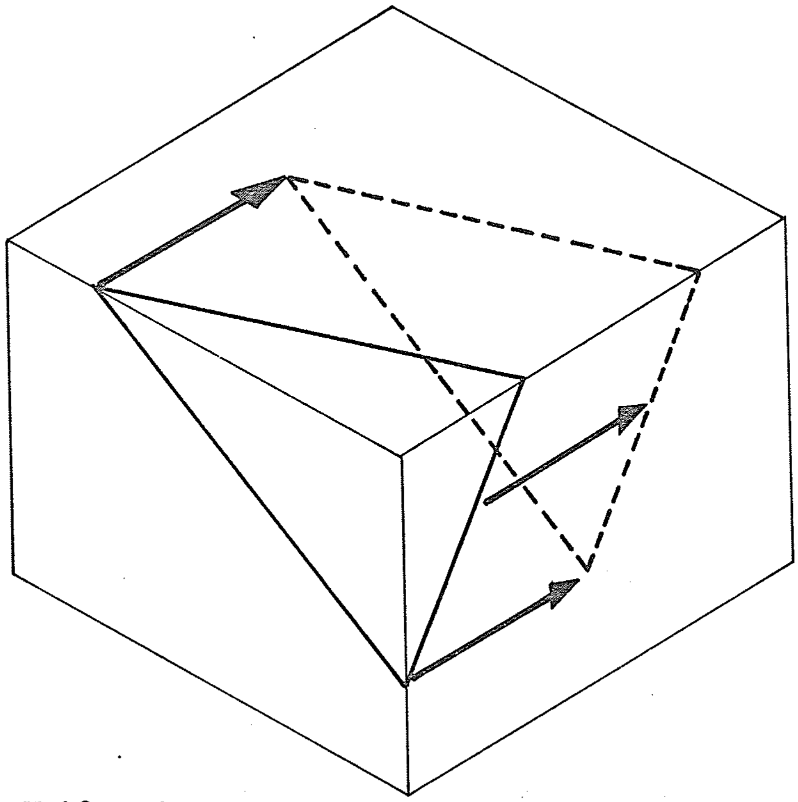

Figure 41: Uniform internal flow parallel to the bedding planes, deforming the foreset laminae. Note no change in the paleocurrent direction.

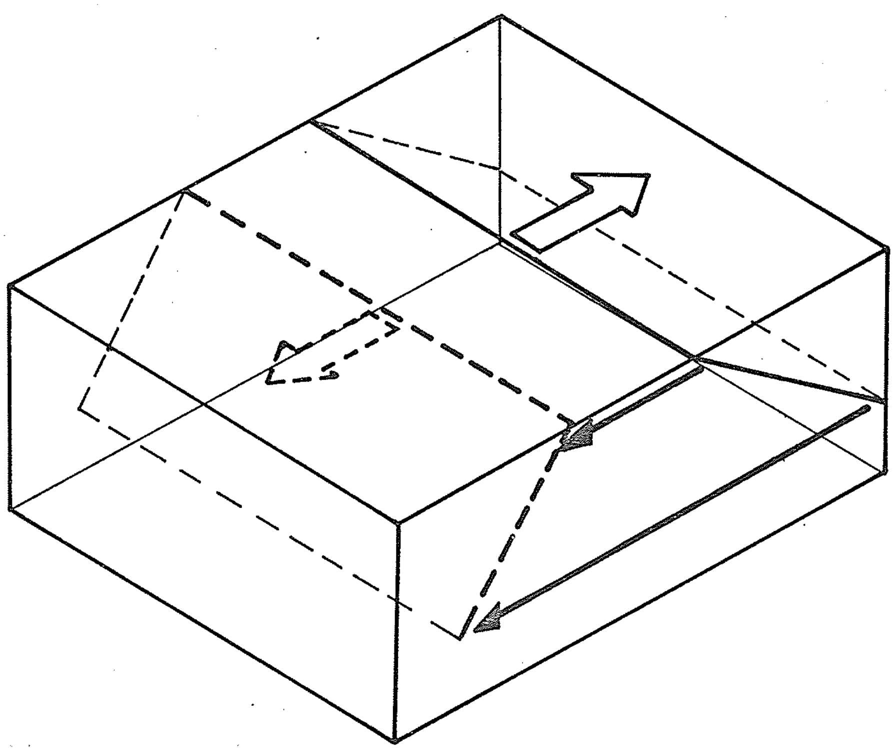

Figure 42: Non-uniform internal flow parallel to the bedding planes producing an opposite paleocurrent "sense" of direction by overturning the foreset laminae.

Convolute Bedding

Kuenen (1953, p. 1056) proposed the term "convolute bedding" and stated:

> "In the most typical form, the distortion, indicated by lamination within a single bed, gradually increases upward to intensive but rather regular folds and then dies out gradually. There is no pulling-apart or piling-up and in some beds the undulations can be followed along the strike without any change in intensity...."

Other authors have used a variety of terms to describe the phenomenon: "convolute lamination" (ten Haaf, 1959, p. 190); "intrastratal contortions" (Rich, 1959)' "antidunes", (Lamont, 1957).

Convolute bedding or convolute lamination occurs in all sedimentary environments (Dzulynski and Smith, 1963; Wood and Smith, 1959; Hubert, 1966; Prentice, 1956; Dott and Menard, 1962). It may be associated with flutes, grooves and other features considered indicative of a turbidite sequence.

In the rocks of the Rice Lake Group, convolute bedding is not common. It occurs most frequently in the Dove Lake Formation. It does not appear restricted to any particular part of the formation, but is definitely more abundant near the top.

In the Dove Lake Formation, distortion commences very rapidly from the base of a unit, and dies out over an equal distance above the uppermost anticlinal crest level. The overlying strata are undeformed. The lowermost part of the superposed unit is typically finer-grained than the distorted unit, and is generally massive. There appears to be no correlation between the thickness of the underlying bed and the deformed strata. The convoluted beds do not occur in sets, and most commonly occur singly near the center of a fine-grained unit.

Convolute bedding is best developed in the fine-grained sediments of the area. Individual folds may be traced along their axes for more than ten times their relief (see figure 43). The anticlines are typically broad, flat-crested and frequently recumbant. Synclines are typically small, tight, with shortened limbs. Considerable internal flow has occurred along the flanks of the folds, producing enlarged crestal cross-sections. Reclined, conjugate, and similar folds are all developed in the same deformed strata. Typically, the deformed beds are less than 3 cms. thick.

Individual laminae, less than 0.5 mm. thick may easily be followed through the folds. Minor faulting on a microscopic scale is present. Shearing parallel to the bedding planes has locally caused displacement of the crests and troughs of the folds; and the broken laminae show abrupt terminations, one against the other.

Convolute bedding is not restricted, however, to fine-grained sediments. Fine sand and coarse silt-sized sediment, interbedded with conglomerates, also locally show convolutions. Their position relative to other sediments above and below does not appear systematic (see figure 44).

However, this structure could be seen at only one place in each outcrop and could not be traced laterally. This structure may have been produced by gravity sliding or slumping.

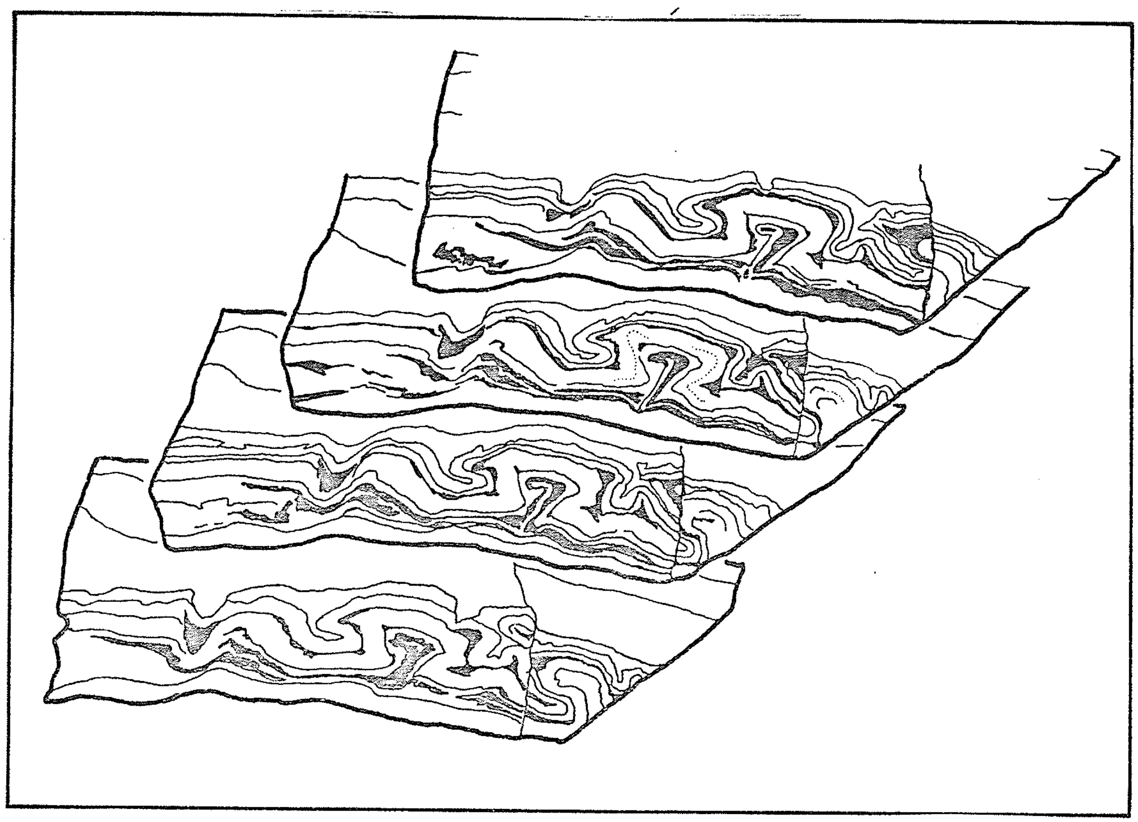

Figure 43: Convolute bedding, drawn from serial sections, Dove Lake Formation.

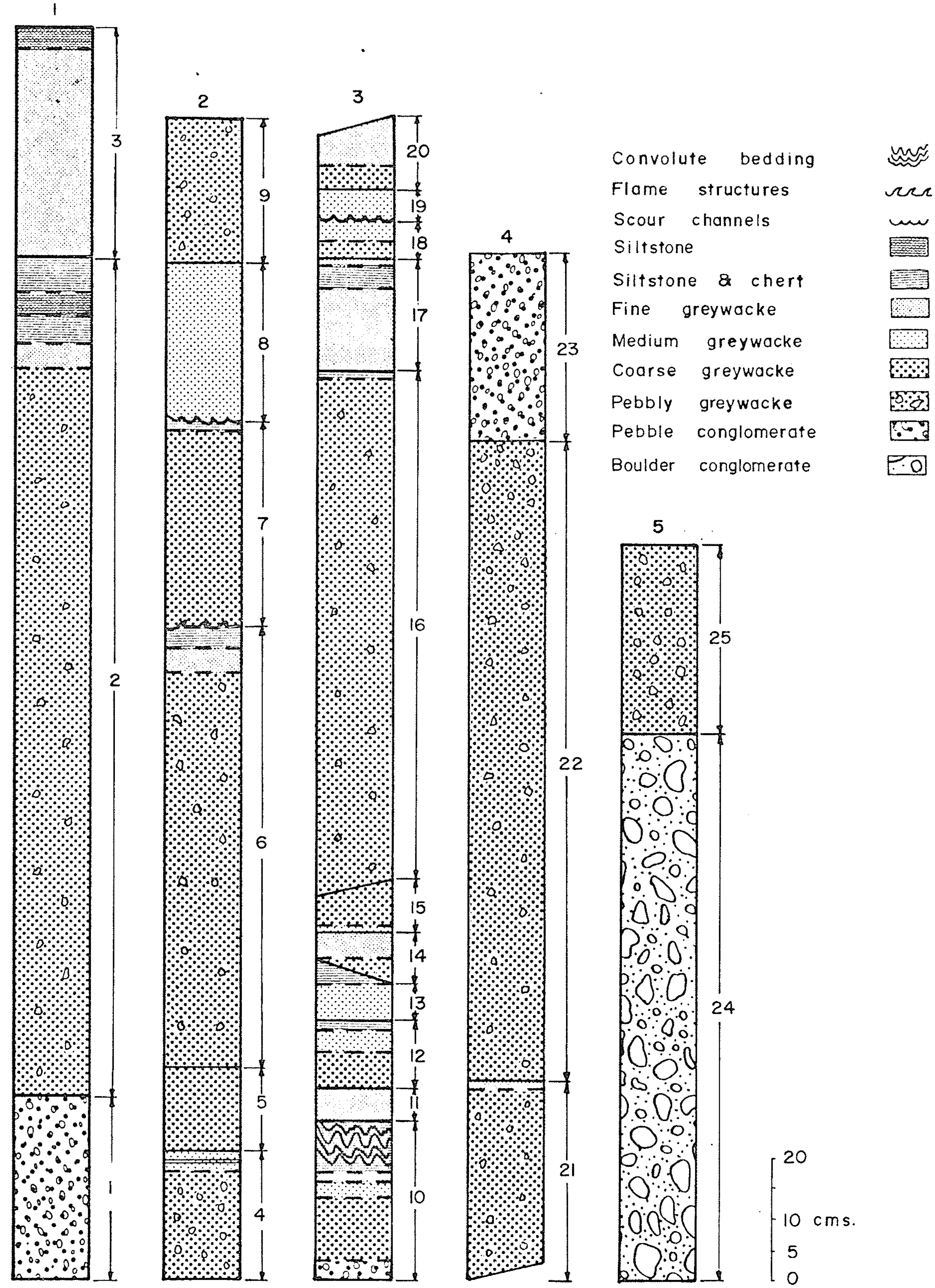

Figure 44 Measured section and lithologies in the upper part of the Dove Lake Formation. Individual sedimentation units as numbered, from the base (1), to the top (25).

Individual sedimentation units are easily delineated in the outcrops. Figure 44 illustrates a series of sedimentation units within the Dove Lake Formation. The overall sense of grading in individual units, for example, is shown in units 2, 6 and 10. The position of the convolute bedding at the top of unit 18 is typical of much of the Dove Lake Formation.

The individual units are subdivided into segment bands on grain size, and presence or absence of internal properties. Where a fine-grained subunit is either thin or absent, one must assume that part of it has been removed by successive turbidity currents.

The subdivision into subunits assumes that the entire unit was deposited by successive parts of the turbidity current. The finely-laminated chert and siltstone may be the products of "normal" pelagic sedimentation. How much of the uppermost "pelagic" unit has been removed cannot be calculated. In some cases, the entire subunit may have been incorporated into the overlying unit. The uppermost conglomerate (unit 24, figure 44) contains large chert rip-ups derived from one of the underlying units.

The repetitive nature of this measured section is characteristic of the entire Dove Lake and Stovel Lake Formations. The stratigraphic position of the sequence determines the maximum grain size present. For example, at Cliff Lake, the sequences are repetitive models of this type, except that the chert, siltstone and fine-grained greywacke predominate as opposed to coarse greywacke and conglomerate.

Interpretation

The formation of convolute bedding is attributed by Sanders (1960) to the development of shearing stresses in semi-consolidated sediment at certain flow intensities. Sanders (p. 416) explained the development of convolution in fine sand as follows:

> "An increase in shearing stress is placed on the bottom, where slight cohesion has already resulted between the grains...Once cohesion becomes important, the bottom is no longer able to react by forming current ripple-marks, as it would normally do if the grains were cohesionless. Instead, the bottom responds by developing a series of "anticlines" that are analagous to the streaked out "ripples" of lutite discussed previously."

Williams (1960) attributed the development of convolute bedding to the result of complete loss of shearing strength of the material. This applies to all fine-grained sediments up to fine sand size. Intrastratal flow within liquified layers may result in the intrusion of small amounts of material into crests and troughs during the folding of the laminae. Internal flow obeys the laws of fluid flow, and must cause internal deformation of the viscous layers over a considerable lateral extent (Williams, 1960, p. 211).

McKee and Goldberg (1969) experimentally produced convolute structures. They have shown that convolutions may develop under a variety of different conditions and that differential loading is the dominant factor in their development.

Flame Structures

Flame structures are closely related to the development of load structures. They have been variously termed "antidunes" (Lamont, 1938); "load waves" (Sullwold, 1960); and "flame structures" (Walton, 1956). Of these, the latter is the most widely used term at present. Flame structures are small, pointed, intrusions of fine-grained sediment into the base of the overlying, generally coarser, stratum. They are best developed when the grain and density size contrast is marked between the two sedimentation units.

Flame structures may occur singly, or in "sets". The largest observed in the rocks of this area, is less than three centimeters; the smallest less than 0.5 cm., (see figures 45 and 46).

Frequently, the "axial plane" of the flame structures is curved. These are termed "overturned flame structures". The tops of these sometimes become detached from the flames and may be transported any distance from the site of flame development and incorporated into the overlying stratum. Infrequently, these are severely distorted in the planes of movement and occur in closely-spaced groups. Figure 46 illustrates this structure in fine-grained siliceous siltstone, overlain by medium-grained sandstone. The peculiar, "tear-drop" shape of the disrupted clasts derived from the flames may be a result of the amount of relative movement of the overlying stratum prior to consolidation. "Tear-drops"

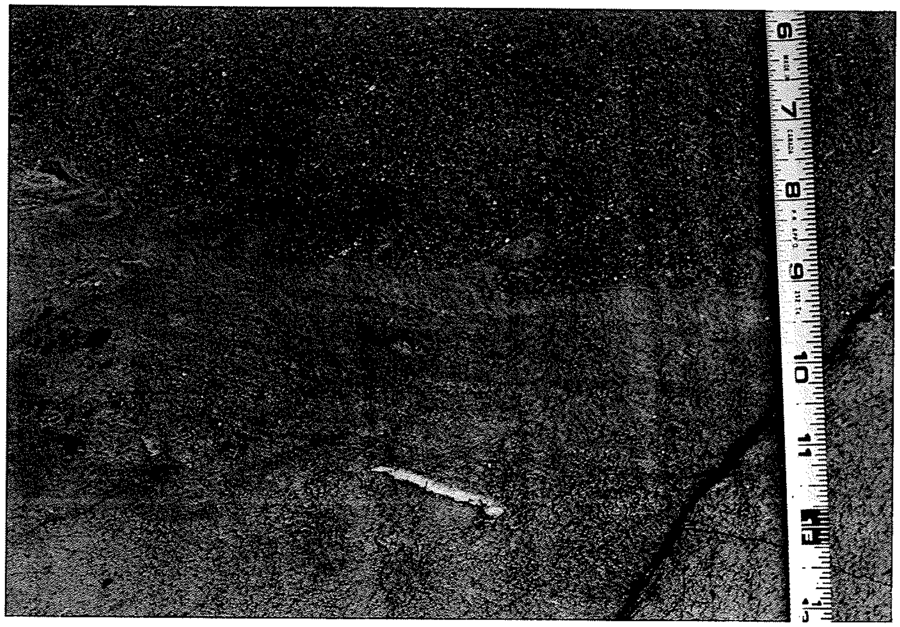

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Figure 45: Flame structures developed at a shale-greywacke interface, Stovel Lake Formation.

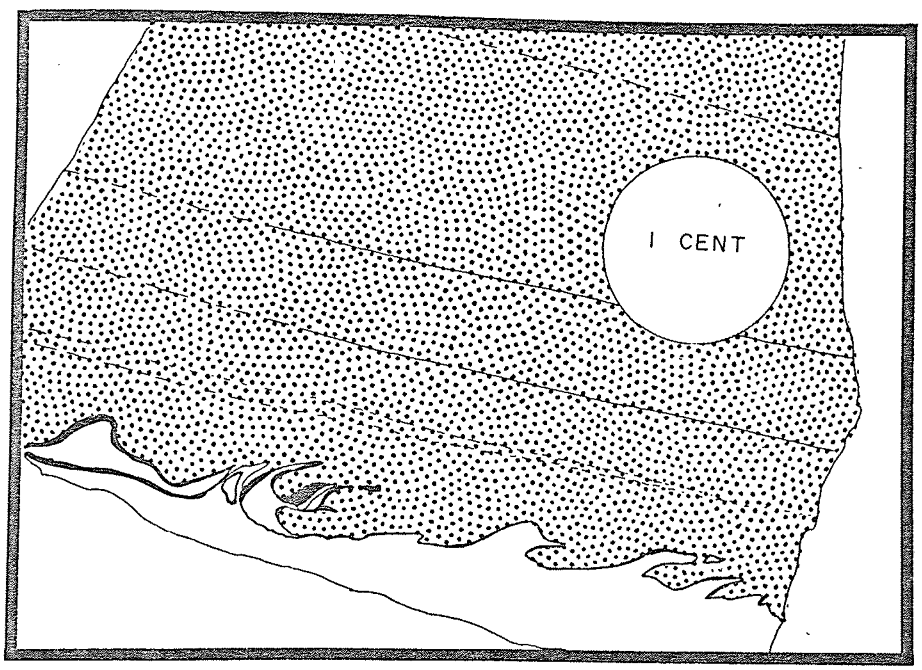

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Figure 46: Flame structures with "tear-drops", Dove Lake Formation. Sand - stippled pattern. Drawn from a photograph.

in the process of formation are illustrated in figure 48.

The development of these peculiar clasts is convincing evidence of an intraformational source for the small siltstone clasts in the feldspathic greywacke.

These particular flames, together with their detached tops, closely resemble structures produced experimentally by Kuenen and Menard (1952), and by McKee and Goldberg (1969).

Flame structures are not common in the sediments of the Rice Lake Group in the area. Where present, they have developed at the contact between fine to medium-grained feldspathic greywacke and fine siliceous siltstone and chert. No flames were found at the soles of conglomerate beds.

The structures occur apparently at random throughout the lower part of the stratigraphic column, from the lowermost Stovel Lake to the uppermost Dove Lake. They were not recorded in the higher formations.

Nowhere was any current ripple lamination found between or beneath flame crests. The overlying stratum is characteristically poorly sorted, and showed a faint sense of positive grading. Infrequently, these strata showed faint parallel lamination.

Individual flame crests may be traced along the flame axis for distances approximately ten times the relief of the flame. The relief of the flame above the "normal" upper surface of the underlying bed does not show any relation to the original thickness of either the underlying or overlying unit.

Interpretation

Flame structures are the result of internal flow within a unit, followed by rupture, and intrusion of some of the substratum into the overlying sediment. This may occur during or following deposition of the overlying sediments. When the overlying sediment is still moving at the time of rupture of the upper surface, overturned flame structures can develop. Continued movement can result in the formation of flaser bedding — flame structures which become completely detached from their source.

Flame structures in the Rice Lake Group are indicative of deposition by turbidity currents, for the following reasons:

1) The sedimentation unit underlying the flame structures is invariably graded, with the flames developed only in the uppermost part.
2) The flames are always overturned, and frequently detached.
3) Flaser bedding is frequently developed at the bases of the coarse sandstone units.
4) "Wisps" of fine-grained sediment are common rock fragments in the feldspathic and lithic greywackes.

The flame structures are not restricted to any one part of a formation. They occur in both the Dove Lake and the Stovel Lake Formations. They are most frequently developed at the top of the Dove Lake, near the contact with the Gunnar Formation. No flame structures were found in The Narrows, Stormy Lake, Edmunds Lake, or Rathall Lake Formations.

Prior to the experimental work by McKee and Goldberg (1969), it was generally believed that the crests of overturned flame structures pointed down current. However, in the light of this new experimental evidence, they were considered unreliable paleocurrent indicators and not used in this study.

Load Structures

Load casts is the term proposed by Kuenen (1953, p. 1048) for the flow casts of Shrock (1948). Kuenen describes load casts as:

> "The base of the graded beds* is sharply cut and flat or forms pockets in its substratum..."

(* this authors underlining)

Potter and Pettijohn (1963, p. 145) offered a more complete description which precludes any possibility of error in identification of the structure:

> "Load casts occur on the base of sandstone beds that overlie shales or other sediments that were in a plastic condition at the time of deposition (*of the sandstone*)+. They appear as swellings varying from bulges, deep or shallow rounded sacks, knobby excressences, or highly irregular protrubances... In some cases, they are much flattened; in others they exhibit a striking mammiliary or papilliform appearance."

The substitution of "structures" for "casts" proposed by Dzulynski and Walton (1965) is used here.

Load structures are not common in the rocks of the area. They were seen only in vertical section. The features interpreted as load structures are not large. Relief is always less than 5 cms. The structures are always filled with sand-sized material. Nowhere were load structures seen on the base of a conglomerate bed. Locally, fine lamination can be seen in the sediments beneath the loaded surface.

+ This author's italics.

At one locality, sub-rounded, sand-filled depressions were observed on the upper surface of a siltstone bed. These may be interpreted either as load structures, or as small scour pits, (see figures 47 and 48).

The best-developed load structures observed occur in the Dove Lake Formation, where interbedded sand and fine-silt-sized sediments are common. These are illustrated in figure 49. The load structures are typically rounded, with steep, curved sides. In vertical section, the sand-filled depressions often deform the underlying, laminated sediments.

Sometimes, the structures are asymmetrical, and show an overturned shape (see figure 50). These occur on the same basal plane as the "normal", symmetrical structures. The structures were not continuous to the opposite surface of the sample, as would be expected if they were groove or flute structures.

Interpretation

Shrock (1948) attributed load structures to the deformation of soft, hydroplastic sediment reacting to a superincumbent load by flow. This explanation has been accepted by other workers, and the structures have been produced experimentally by Kuenen and Menard (1952) and others.

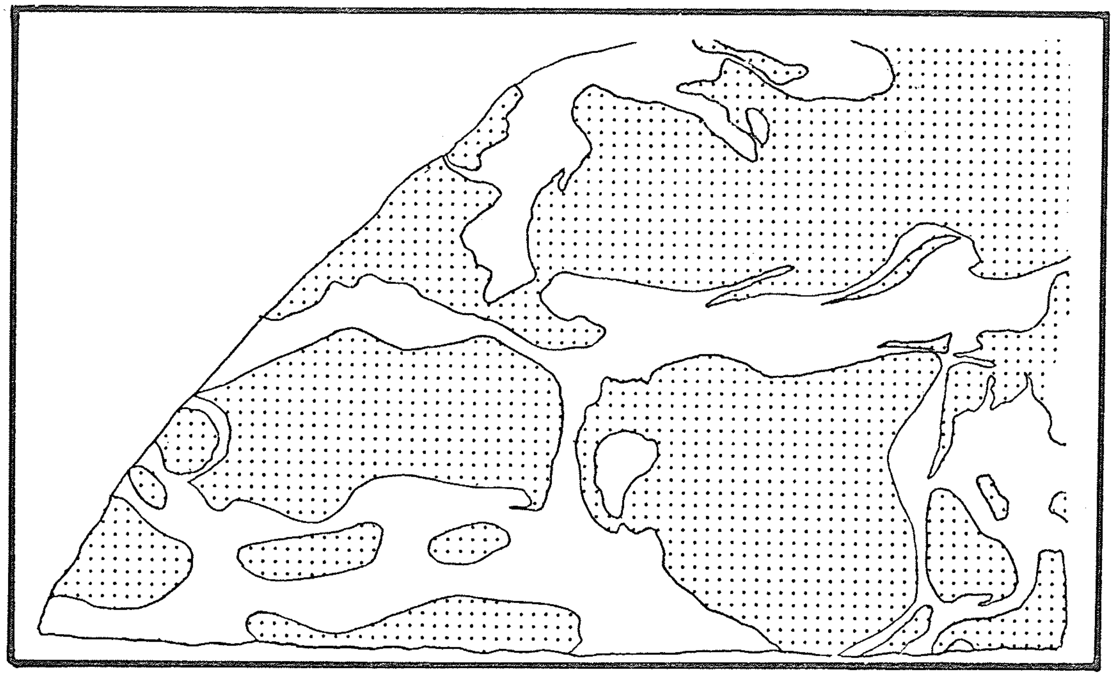


Figure 47 "Streaked-out mud ripples", plan view. Drawn from Ballance, 1964, Figure 2.

Figure 48 Possible scour pits or flame structures, plan view, Dove Lake Formation.

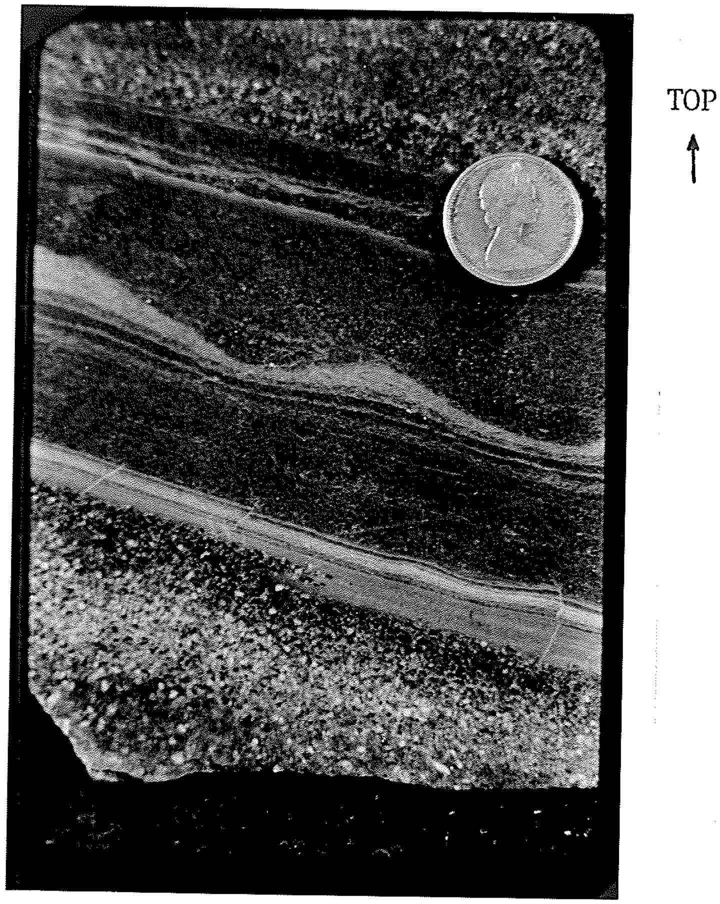


Figure 49 Load structures, Dove Lake Formation.

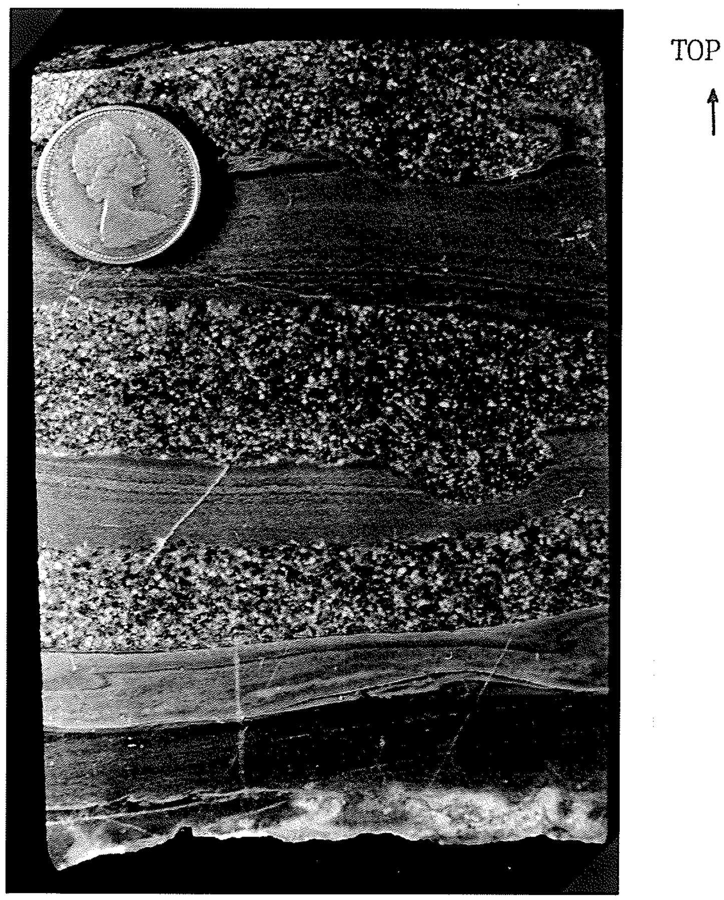


Figure 50 Asymmetrical load structures, Dove Lake Formation.

The features interpreted as load structures are interpreted as indicative of the unconsolidated nature of the underlying stratum. The graded beds overlying the load casts are characteristic of turbidites. The rapid influx of sediment necessary to apply a load over a large surface area could easily be accomplished by turbidity currents.

<u>Flaser Bedding</u>

A similar term has been used by other authors, (Bouma, 1962, p. 138):

> "Flaser structures: an indistinct structure which has ripple characteristics and lenticular forms. They may belong to the group of current ripples."

Flaser bedding described here is a type of bedding characterized by lenticular clasts of fine-grained siliceous siltstone and shale parallel and sub-parallel to the bedding. The enclosing sediments may or may not be graded, and may frequently intrude along the bedding planes of the clasts. The clasts may be of varying sizes and shapes, and commonly show a wavy form in vertical section. The terminal contacts of the fragments are often tenuous, but may be abrupt. Single lamina may be detached from the main mass of the fragment, and distorted within the matrix, (see figures 51 and 52).

The structure is common to the rocks of the Dove Lake, and less so to the Stovel Lake Formation. Figures 51 and 52 show flaser bedding typical of the Dove Lake Formation. Most commonly, it occurs in the uppermost part of the formation, where conglomerates are common. The flaser bedding in the Stovel Lake is restricted to the vicinity of Cliff Lake. No flaser bedding was recorded in the rocks higher in the stratigraphic sequence.

Figure 52 shows the wispy nature of some of the clasts, and the characteristic undulatory nature of the upper and lower boundaries. Some fragments show abrupt terminations, indicating that they have ruptured during, or shortly following, transportation and deposition. Some fragments show small "sills" of matrix which has "intruded" the clast along the bedding planes. These small "intrusives" indicate the hydroplastic nature of the clast.

Interpretation

The structure is believed to form when a fine-grained bed is disrupted by a turbidity current and its fragments incorporated into the overlying bed. Post-depositional internal shear and/or plastic flow produces a preferred orientation of the fragments. Post-depositional differential compaction may produce the distorted "wavy" form characteristic of the fragment.

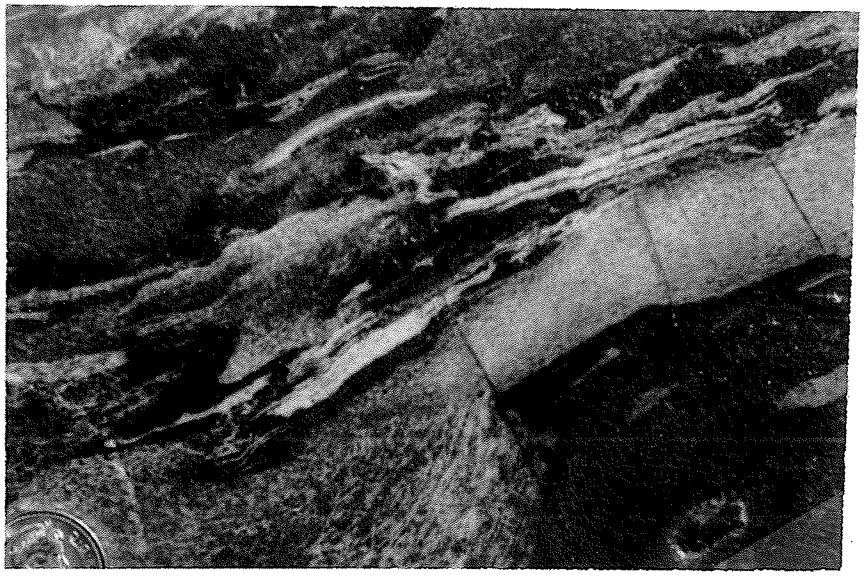


Figure 51: Flaser bedding, upper part of the Dove Lake Formation.

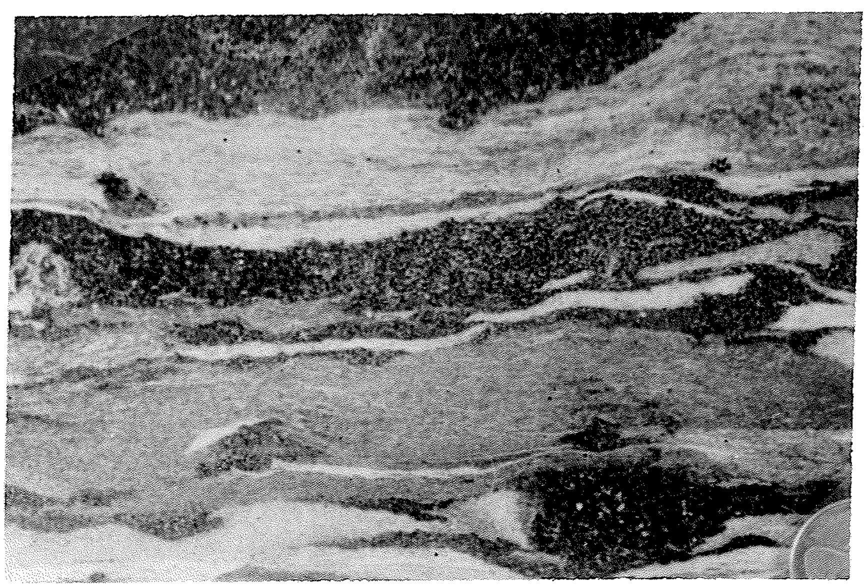


Figure 52: Flaser bedding, upper part of the Dove Lake Formation.

The fragments are obviously derived from pre-existing, unconsolidated, sediments, and their presence is an indication of a short time of transport. Their presence within a typically coarser matrix is indicative of turbidity current action.

The flaser bedding described here is considered to be a strong indicator of the action of turbidity currents as a major transportation mechanism.

Rip-Up Structures

Rip-ups are large clasts of sediment, generally very angular, in a matrix of much coarser or finer sediment. In outcrop, they are recognized by their characteristic colour, size and shape (see figure 53).

The rip-ups represent the very top of the underlying sedimentation unit from which they had been eroded. All the clasts in the Rice Lake Group which occur as rip-up fragments are extremely fine-grained. The majority are chert, but fine-grained siltstone, and possibly silicified shale are also present. No coarse-grained clasts occur as rip-ups. Clasts range in size from less than 2 cm. to over 2 meters. Typically, they are lath-shaped, or blocky in plan view, and may be rod-like or blocky in three dimensions.

Large (0.5-1.0 meter) blocks of bedded sediment similar to the large ripped-up chert blocks occur in other conglomerate mudflows (Lindsay, 1966).

Figure 53: Chert rip-ups in coarse greywacke, Dove Lake Formation.

In the Dove Lake Formation, rip-ups are generally associated with either thick beds of feldspathic greywacke, or channel fill conglomerates. Large chert rip-ups occur close to the upper contacts of the Dove Lake and the Gunnar Formations (see figure 54). Similar chert clasts occur near the contact of the Dove Lake and the Tinney Lake Formation.

The Dove Lake contains thick "lahar-type" units near the contact with the Gunnar Formation. These are typically exposed near the contact of the Dove Lake with the quartz diorite to the west. The units consist of large blocks of dark grey vesicular and non vesicular basalt, in a fine-grained, feldspathic greywacke, matrix. The units are unique, however, in that they contain extremely large chert fragments. These fragments range in size from 20 cms., to approximately 2 meters. The largest of these is approximately 2 meters long, and 30 cms. thick. It is completely detached at both ends, and undulatory along its exposed length. The third dimension was not exposed, and the clast may be resting near the upper part of the flow. Shale clasts of similar size have been reported in a turbidite-conglomerate by Fisher and Mattinson, (1968, p. 1014).

Clasts of this size indicate a very short distance of transport, as it seems highly improbable that a fragment of this size, lithology, and shape could be transported any distance in contact with irregular blocks of basalt and not be broken up, or more highly distorted.

Rip-ups are generally confined to one sedimentation unit, or a closely-spaced series of units. The thickness of the strata containing these clasts varies, but the minimum appears to be at least 2 meters. The maximum thickness observed was greater than 5 meters, in a scour channel. These strata appear restricted to the contact zones between the sediments and basalts. Rip-ups were not observed in the central part of the sedimentary formations.

Higher in the stratigraphic column, rip-up structures have not been noted, except in the Rathall Lake Formation (see figure 55). Rip-up structure is rare in this formation. Chert or siltstone, however, is not common. Siltstone rip-ups were observed at one locality (see figure 56).

The absence of fine-grained sediments elsewhere in the stratigraphic sequence may explain why rip-ups are not found. A second possibility is that turbidity currents may have ceased to be an active mechanism of sediment deposition at the end of the deposition of the Dove Lake Formation.

Some rip-up clasts show internal deformation which is not reflected in the exterior shape (see figure 56). The interiors of these are contorted, indicating plastic deformation occurred prior to rupture and incorporation into the overlying sediment. Occasionally, re-entrant angles are present on the exterior (see figure 57).

Figure 54: Large chert rip-ups, lower part of the Dove Lake Formation.

Figure 55: Siltstone rip-ups beneath graded greywacke, Rathall Lake Formation.

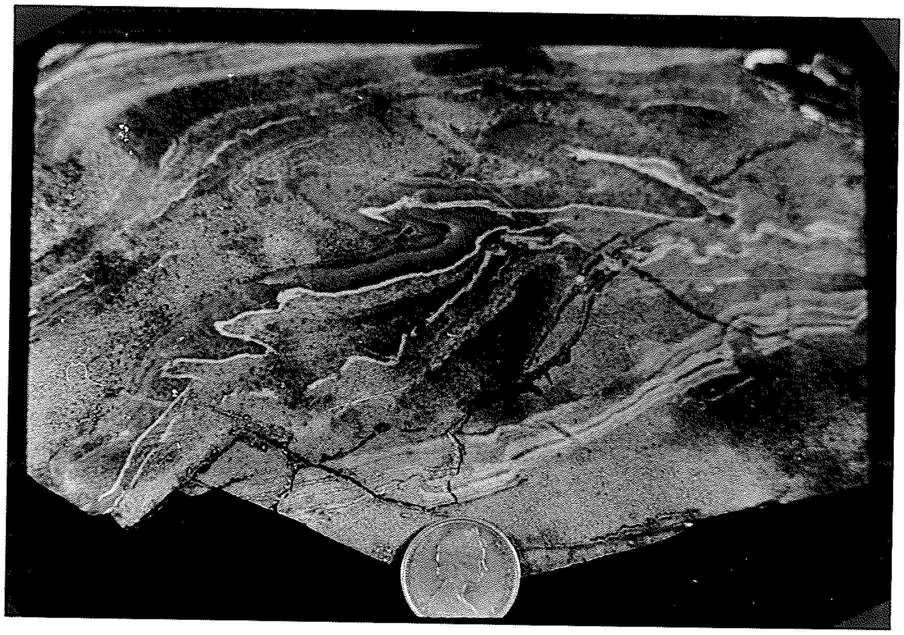


Figure 56: Rip-up fragments showing internal deformation.

Figure 57: Re-entrant angles on the exterior of a ripped-up clast, shown by arrows.

Interpretation

Field evidence documents the ability of these sediments to undergo plastic deformation when small stresses were applied. If the load was large, moving, and increasing at the same time, fragments could be literally "plucked" from their original site of deposition. Shale fragments in the Goldenville Formation of Nova Scotia behaved in a similar manner, (Campbell, 1966).

It is significant that rip-ups are restricted to the upper and lower parts of the sedimentary formations. Since they must have been derived from pre-existing sediments, and are now incorporated as a part of much coarser units, a turbidity current appears to be the most plausible mechanism of formation.

Microbrecciation

Microbrecciation is a type of bedding characterized by small, micro-faulted blocks slightly displaced from the original site of deposition. Care must be exercised that microbrecciation is not confused with "microbreccia" - a fine-grained breccia. The latter is present in small quantities in the Dove Lake Formation. Normally, these blocks, and the location from which they were removed, may be seen in vertical section. The sediments which show microbrecciation are all very fine-grained. They consist of fine siltstones and chert. Characteristically, they are well-laminated.

Individual laminae are continuous through the length of the block, and "sets" of laminae may be traced to the site of disruption.

The structure occurs, but is not abundant, in the Dove Lake, Stovel Lake and Rathall Lake Formations. It was not recorded in the other formations.

Normally, the blocks have moved less than 3 cms., although distances up to 5 cms. have been noted. The clasts are not large, rarely exceeding 5 cms. in length, and usually less than 2 cms. in thickness. The third dimension could not be measured precisely, though it was always greater than the thickness of the sample. The fragments, therefore, have a tabulate form, and appear to have behaved as "rafts" in the enclosing matrix.

The surrounding sediment is always fine-grained. Nowhere did microbrecciation occur in sediments coarser than fine-sand size. Generally, the "matrix" is coarse-silt to fine-sand.

The thickness of the microbrecciated units is relatively constant. No brecciated unit was found to exceed 10 cms. Most are less than 7 cms.

Figure 58 illustrates the microbreccia of the Dove Lake Formation.

Interpretation

The proximity of the fragments to the source is similar to the disrupted tops of the flame structures. This indicates that

TOP

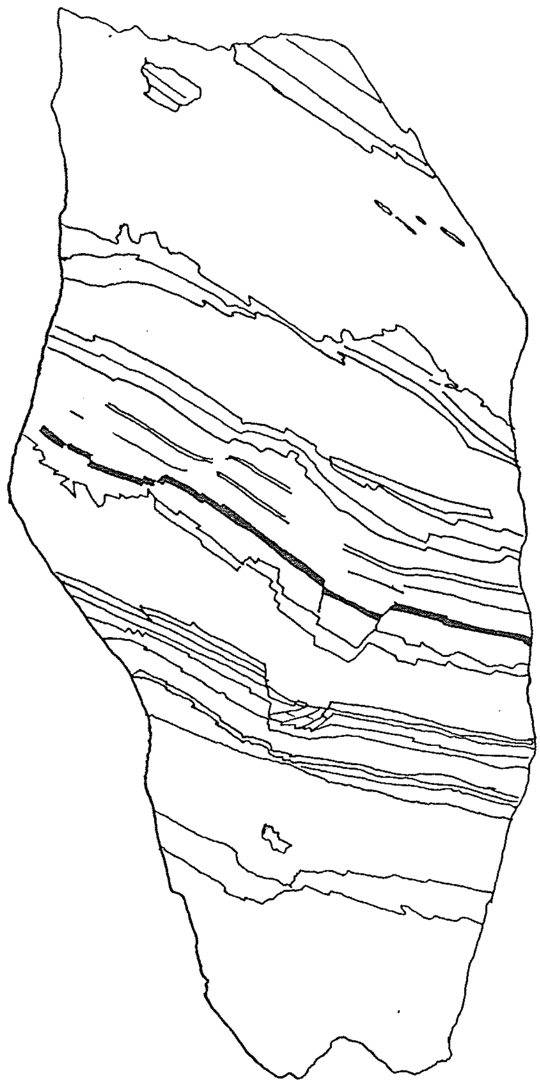


Figure 58: Microbreccia of the Dove Lake Formation. Drawn from slab, true size.

the rupture strength of the material was exceeded just prior to the "freezing" of the overlying mass of sediment (Middleton, 1967). The cohesion of the sediment is not conducive to internal plastic flow. When the rupture strength of the sediment was exceeded, the material behaved as a brittle solid, without first undergoing internal shear, as was noted with some of the rip-ups.

If the mass of the turbidity current was large, the disrupted fragments would most likely be incorporated into the overlying bed as rip-ups. However, as the clasts are close to their original site of deposition, the initial current must have been either relatively small, or the shear strength of the sediment must have been high. The latter possibility does not seem too likely, as the overlying stratum is always less than 20 cms. thick, and is always fine-grained. The initial water content of the sediment also must have been low, since the beds have deformed as a brittle, rather than plastic, material.

The consolidated nature of the microbrecciated strata, indicated by the brittle deformation, together with the thin overlying strata and its fine grain size, indicate a pulsating type of sedimentation, typical of turbidity currents. The interval between "pulses" would permit "normal" pelagic sedimentation, and a time period long enough for the finely-laminated sediments to accumulate. These may have in part accumulated as the "tail" of the previous turbidity current, but their characteristically laminated nature indicates more than one time of deposition.

Deformed Bedding

Primary sedimentary structures are not exclusively of sedimentary origin. Infrequently, as in the Stovel Lake Formation, basalt in contact with fine-grained sediments has "squeezed" the sediments into the intersticies between the pillows, and the form of the "folds" thus produced are outlined by the laminae within the sediment. Minor faulting, rupture, and flow accompany the intrusion of the sediment.

Figures 59 and 60 illustrate the forms of the structure. The basalt was extruded directly onto unconsolidated, hydroplastic sediment, and the resulting structure shows that no deposition of coarse clastics occurred in the area prior to extrusion of the basalt. The basalt-sediment contact is unique in that the eruption of the basalt is not preceded by coarse-grained effusive clastic material.

Minor sediments intercalated with the basalt of the Tinney Lake Formation locally show well-preserved soft-sediment deformation structures. These have been produced by the compaction of the finely-laminated sediment over blocks and bombs, (see figure 61). These "bombs" range in size from 4 mm. to approximately 200 mm. Characteristically, the laminae are fractured across the tops of the clasts, and show some flowage along the flanks. Graded bedding shows the top direction of the sediments in the area.

Coarse-grained pyroclastics are interlayered with the chert and fine-grained greywacke at only one locality (see figure 62),

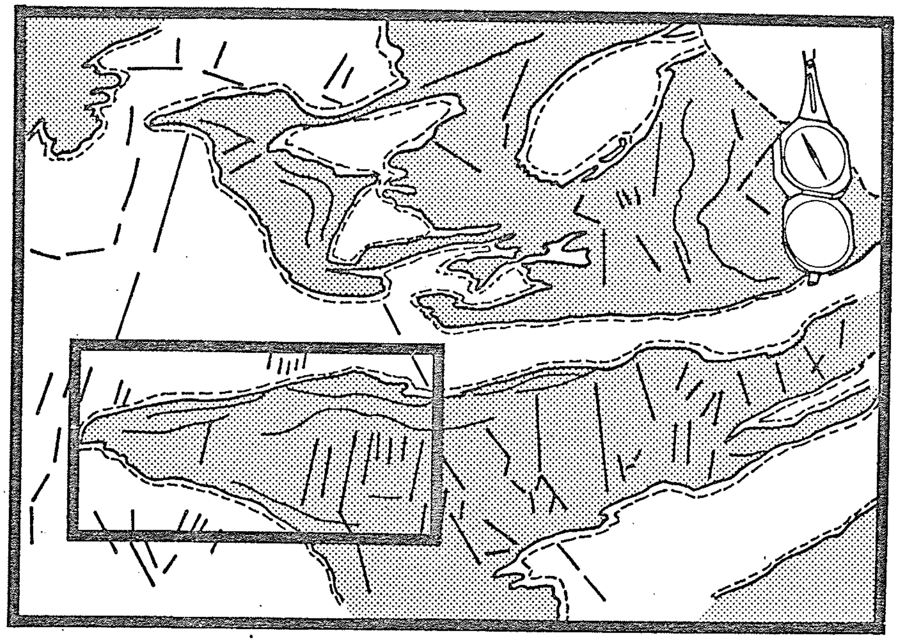


Figure 59: Plan view of deformed bedding in chert (stippled) produced by basalt (no pattern). Drawn from a photograph. Outlined area enlarged below.

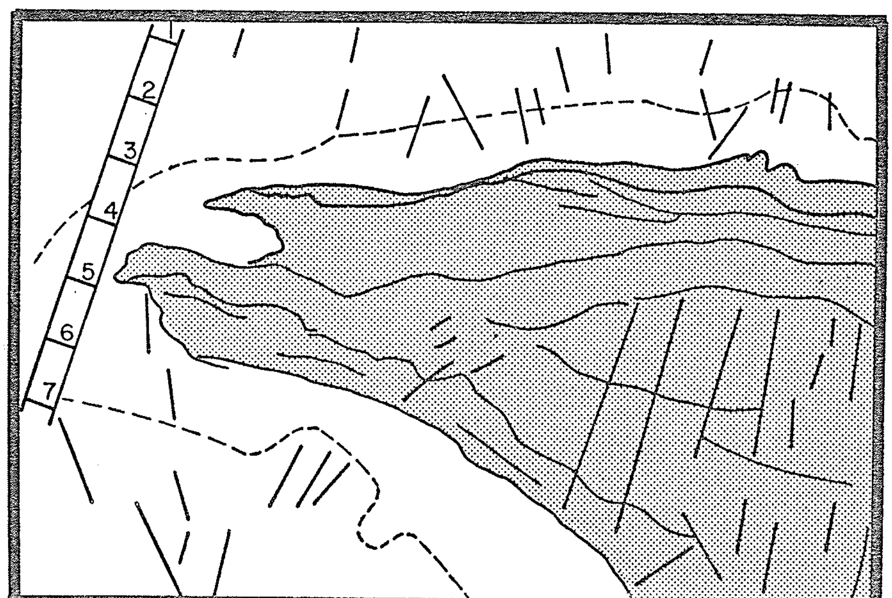


Figure 60: Enlarged area of Figure .
Drawn from a photograph. Scale in inches.

Figure 61: Chert and siltstone deformed over the tops of bombs. Intraformational sediments of the Tinney Lake Formation.

Figure 62: Tephra interbedded with chert and siltstone. Intraformational sediments of the Tinney Lake Formation.

in the vicinity of the Central Manitoba mine. This unit attains a maximum exposed thickness of only 30 meters. It can be traced laterally in both directions for some 800 meters. The clasts do not appear to increase in abundance or size in either direction along the strike of the unit.

The stratigraphic position of the interlayered pyroclastics and sediments in this area is unique, in that the pyroclastics are the only recognizable extrusive fragmental volcanics in the lower part of the stratigraphic column. They are closely associated with brecciated flow tops (?), and directly overlie the vesicular flow tops of the upper part of the Tinney Lake Formation.

These coarse-grained pyroclastics commonly show chilled margins similar to the mini-pillows reported by Carlisle in the pillow basalts of British Columbia.

CHAPTER V

STRUCTURAL GEOLOGY

Regional Structure

The dominant structure in this area is a doubly-plunging anticline, with an inclined, northwest-trending axial plane, (see figure 63). Subsidiary folds are developed in the crestal area, and a complimentary syncline is developed on the southwestern flank of the dome. The southern part of this doubly-plunging anticline has been termed the Beresford Anticline by Church (1968). The fold elements at the extremities of this doubly-plunging anticline are shown in figures 64 and 65.

The southwestern side of the anticline is truncated by a northwesterly trending strike-slip fault, with an apparent right lateral displacement of approximately 1000 meters. The fault is continuous from Stormy Lake to Halfway Lake, and has been termed the "Dove Lake Shear" by Stockwell (1934).

A shallowly-plunging syncline is developed on the southwestern flank of the Beresford Anticline, east of the Dove Lake Shear. This fold has been termed the "Beresford Syncline" by Church (1968). The axial plane attitude and plunge direction of this syncline have the same trend as the adjoining Beresford Anticline. The plunge, however, is considerably less. Figure 66 shows the fold elements of this syncline.

The Dove Lake Formation is folded into an open anticline, with a near-horizontal axis, west of the Dove Lake Shear. The formation is characterized by unusually shallow dips in this area. However, near the contact of the Dove Lake Formation with the overlying Gunnar Formation, the sediments are near-vertical. Figure 67 shows a

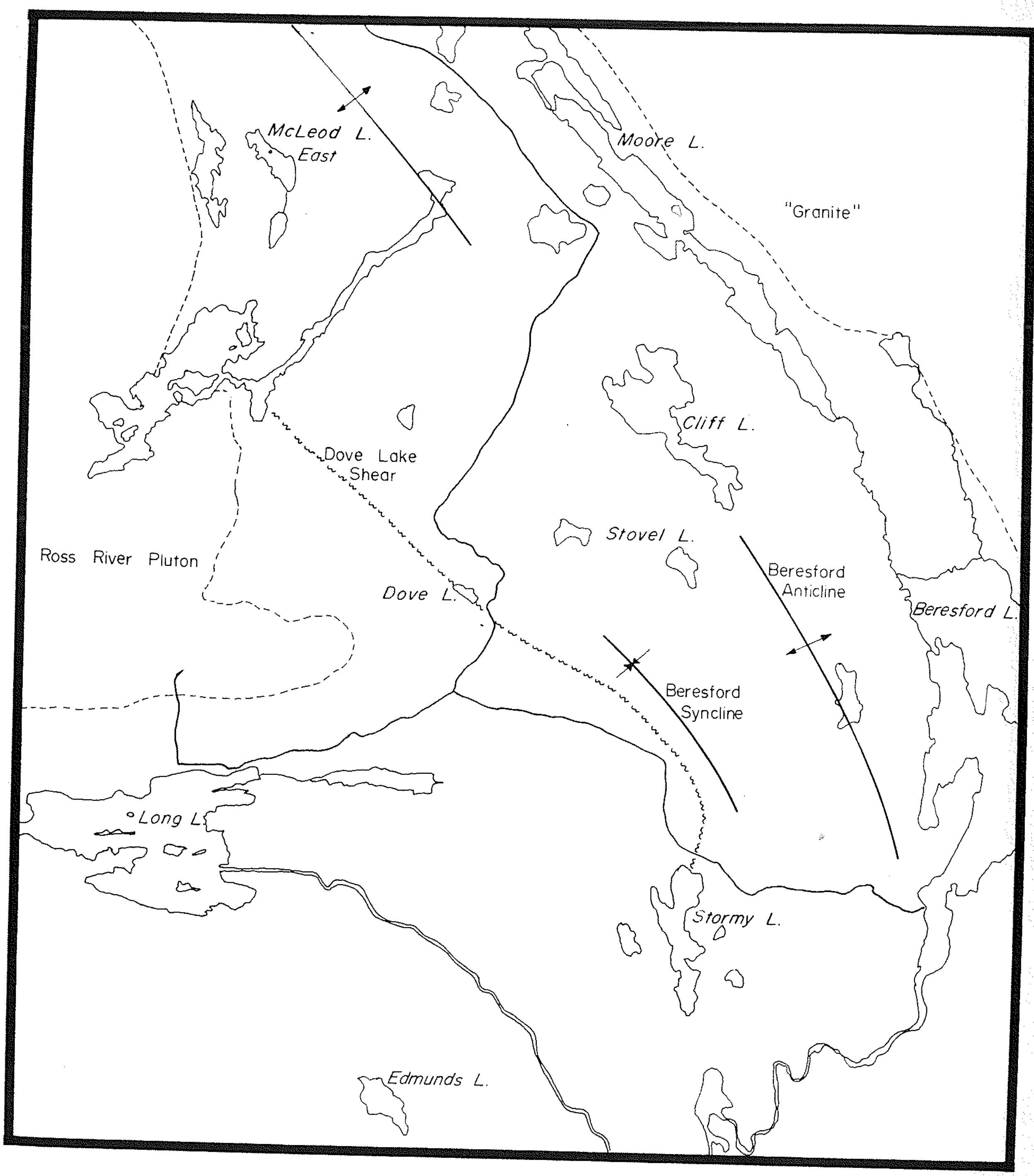


Figure 63 Regional Structural Geology, Dove Lake—Beresford Lake Area.

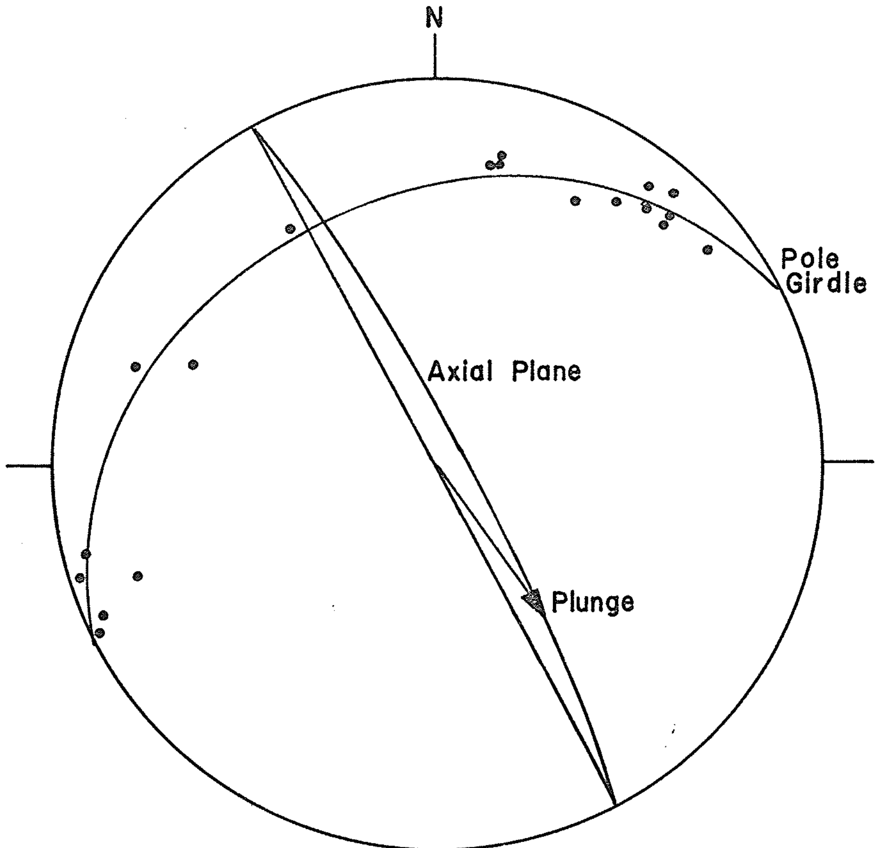


Figure 64 Fold elements of the Beresford Anticline. Drawn from 19 poles to bedding, Dove Lake Formation.

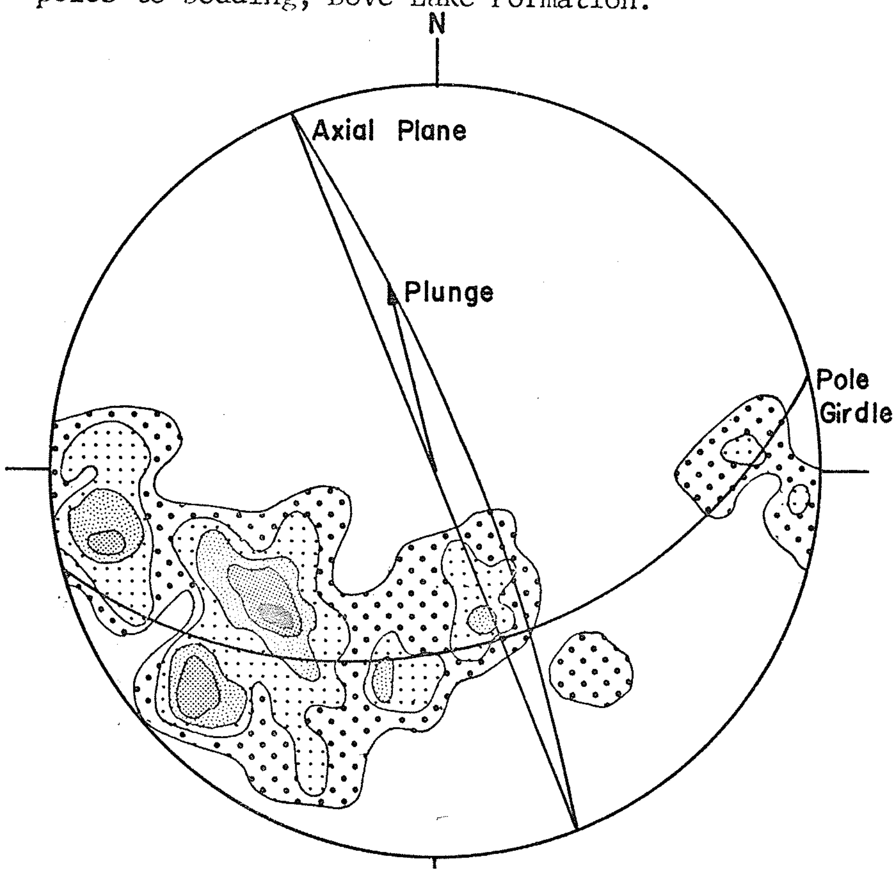


Figure 65 Fold elements of the anticline in the MacLeod Lake East Area. Drawn from 45 poles to bedding, Dove Lake Formation. Contours at: 0.5%; 1.0%; 2.0%; 3.0%; 4.0%.

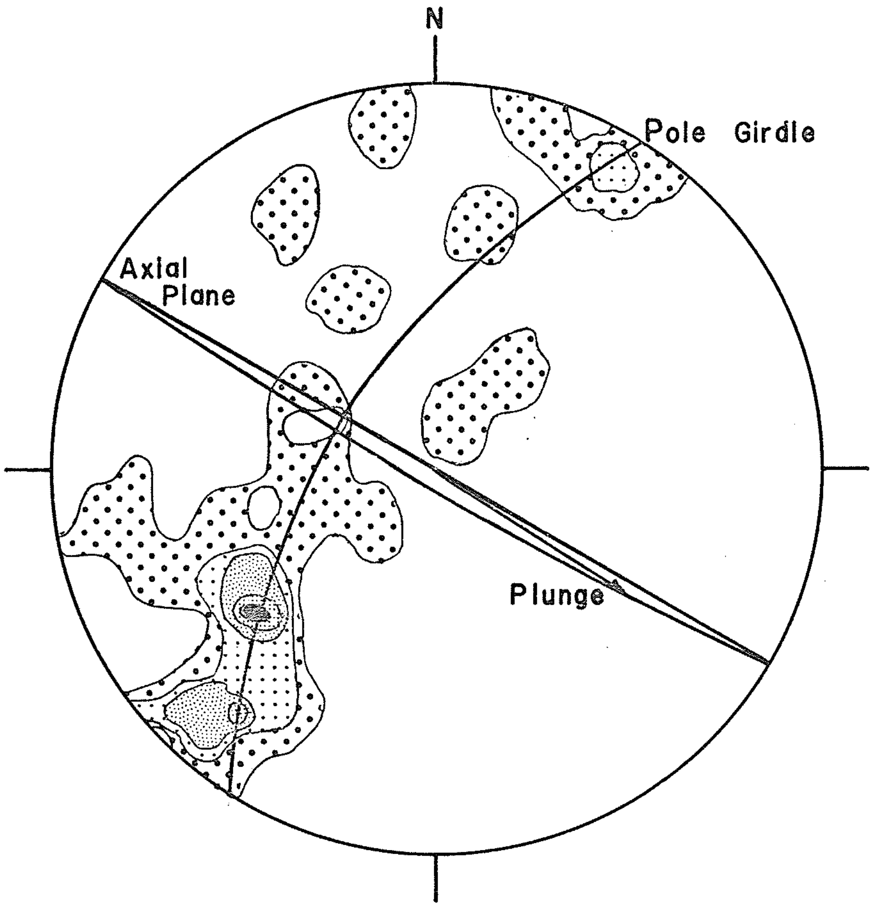


Figure 66 Fold elements of the Beresford Syncline. Drawn from 31 poles to bedding, Dove Lake Formation.
Contours at: 0.5%; 1.0%; 2.0%; 3.0%; 4.0%.

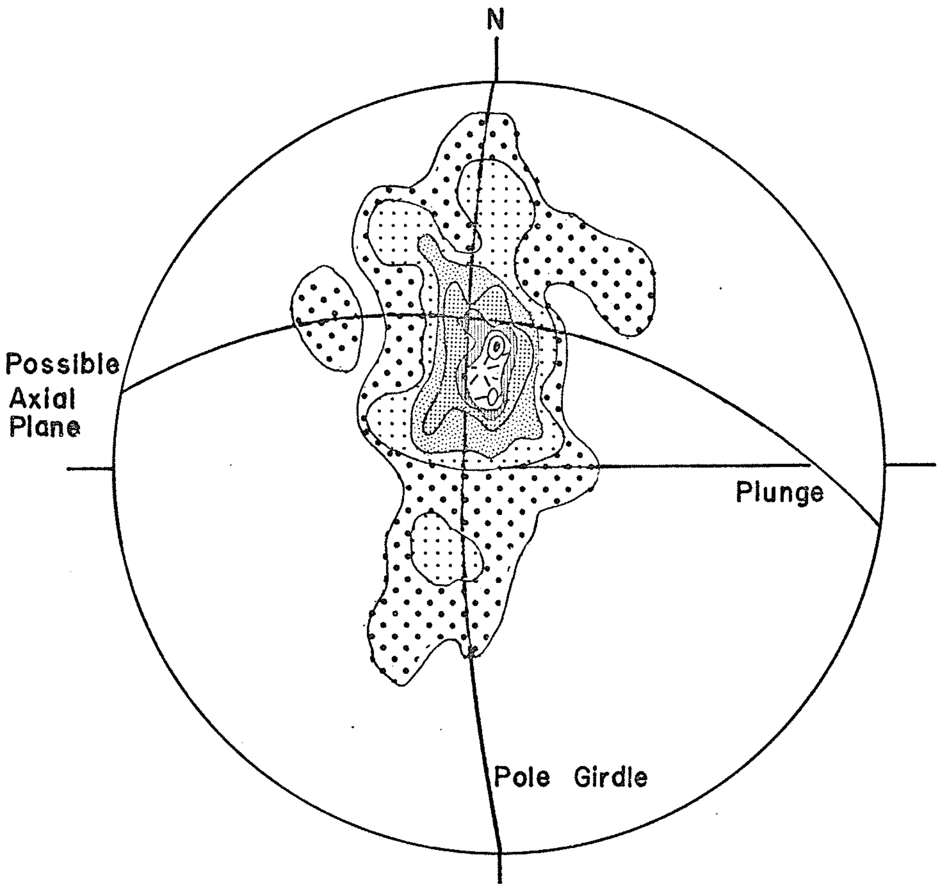


Figure 67 Fold elements of the fold west of the Dove Lake Shear. Drawn from 31 poles to bedding, Dove Lake Formation.
Contours at: 0.5%; 1.0%; 2.0%; 3.0%; 4.0%; 5.0%.

contoured plot of the poles to bedding in the Dove Lake area.

The Dove Lake Shear displaces this anticline from the Beresford Syncline along their common limb. However, the Dove Lake Formation may be correlated across the shear, by lithology and stratigraphic position.

The stratigraphic succession present in the Dove Lake Formation indicates it was deposited as a clastic wedge, thinning to the northeast. This interpretation could explain the apparent thickening of the formation at the trough of the Beresford Syncline. The increase in apparent thickness of the formation may also be attributed to a change in the attitude of the beds.

The outcrop pattern of the Stovel Lake Formation defines the more complicated structure in the crestal area of the doubly-plunging anticline. The formation is folded into a tight, shallowly-plunging anticline with a shallowly-plunging syncline developed at the crest of the anticline between Stovel Lake and Cliff Lake. The north limb of this syncline is defined by a one meter band of laminated chert just south of Cliff Lake. The axial planes of minor folds, which occur close to Stovel Lake, have orientations similar to that of the crestal syncline. Figure 68 shows the attitudes of these folds, calculated from the fold elements.

The Stovel Lake Formation appears to increase in thickness near the crest of the anticline at Tinney Lake. This is caused, in part, by a change in the dip of the strata.

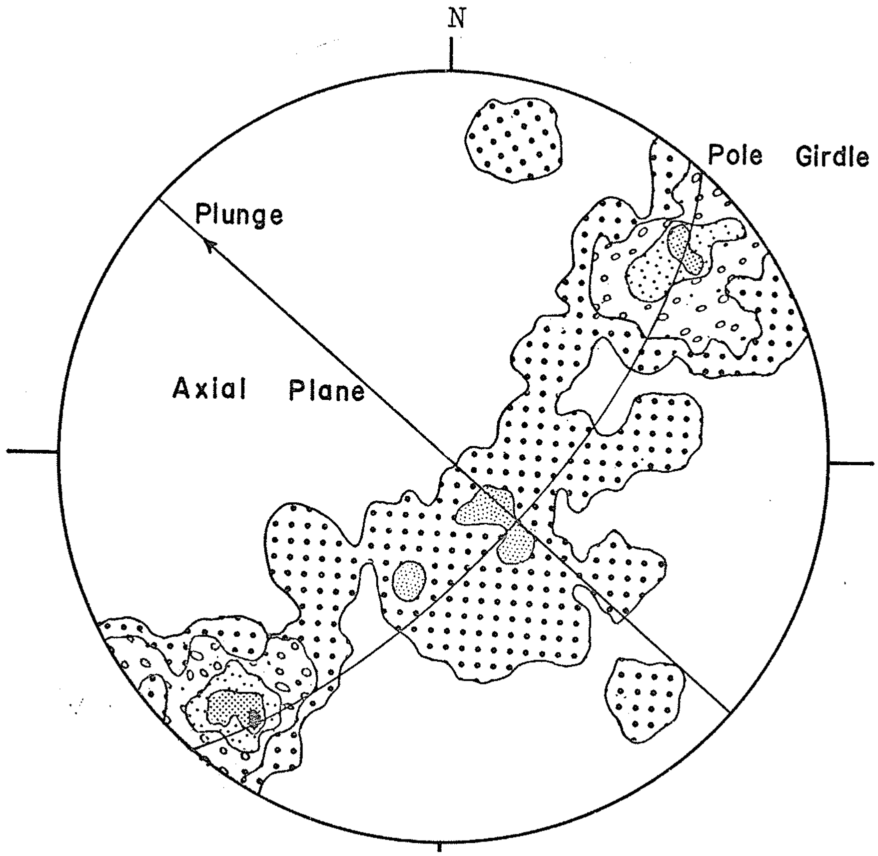


Figure 68 Fold elements in the Cliff Lake Area. Drawn from 65 poles to bedding, Stovel Lake Formation. Contours at: 0.5%; 1.0%; 2.0%; 3.0%.

Interpretation

The mechanism of folding of the Rice Lake Group in this area is interpreted as flexure-slip, for the following reasons:

(1) Bedding is the most pronounced planar feature in the sediments.

(2) There is no regional foliation.

(3) A weak joint set is developed sub-parallel to the axial planes of the folds.

(4) Sand and grit-sized clasts in the sediments show no preferential alignment, except near shear zones.

(5) Clasts in the channel-fill conglomerates are randomly oriented, except near shear zones.

(6) Pillows in the basalts are relatively undeformed, and their contained vesicles show no preferential orientation.

Correction for tectonic deformation

In regions of tilted and folded strata, paleocurrent indicators no longer retain their original orientation. Correction for the degree and style of deformation must therefore be applied to restore the strata to their original orientations.

The effects of folding upon the orientation of primary sedimentary structures has been thoroughly discussed by many authors (ten Haaf, 1959; Ramsay, 1960; Potter and Pettijohn, 1963).

Paleocurrent indicators within beds are most easily restored to their original orientation if they are expressed as a linear structure, which may be plotted on a stereonet. Cross-stratification may be expressed as a lineation by plotting the line of intersection between the foreset beds and the bedding planes.

The style of folding in the area has been interpreted as flexure-slip. Ramsay, (1960) has shown that strata folded by flexure-slip may be restored to their original orientations by using a stereonet. This may be accomplished by one of two methods, outlined below:

(1) The plunge of the fold is removed by rotating the plunge to the horizontal, about a horizontal axis. The beds are then rotated to the horizontal about their new strike lines.

(2) In the second method, the beds are rotated about the axis of the fold to a dip equal to the plunge. The bed in this position is then rotated to the horizontal about its new strike line.

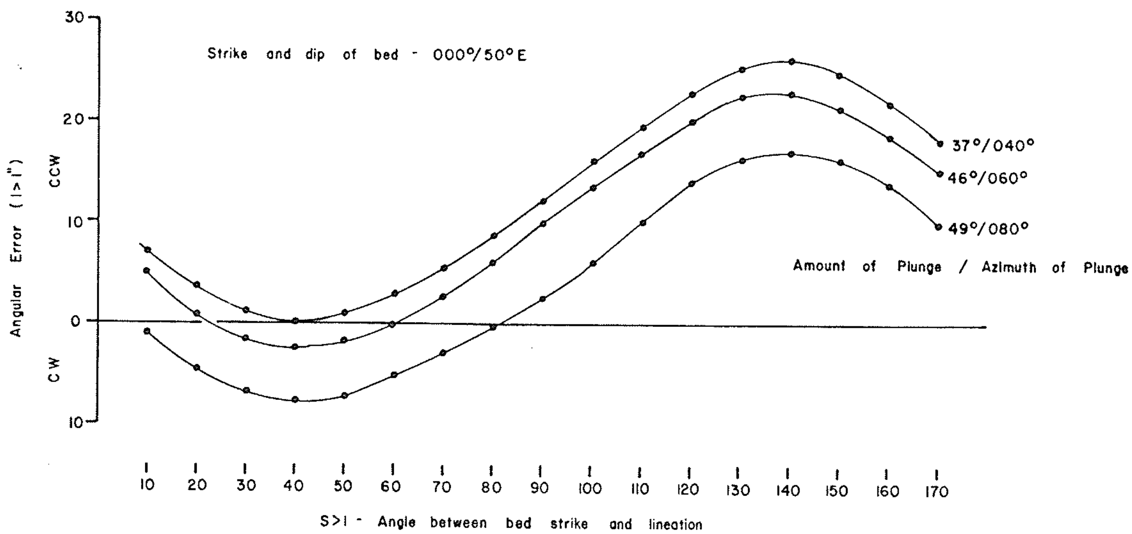
Theoretically, these procedures should produce the same results. However, when each is done graphically, slight differences are apparent.

Figure 69 shows the error calculated by each method which is introduced into the paleocurrent measurements when strata are not restored to their original attitudes. The figure is constructed for a unique situation, and cannot be universally applied to other areas. The terms used in the graphs are factors which cause variation in the amount of error. The terms are defined below:

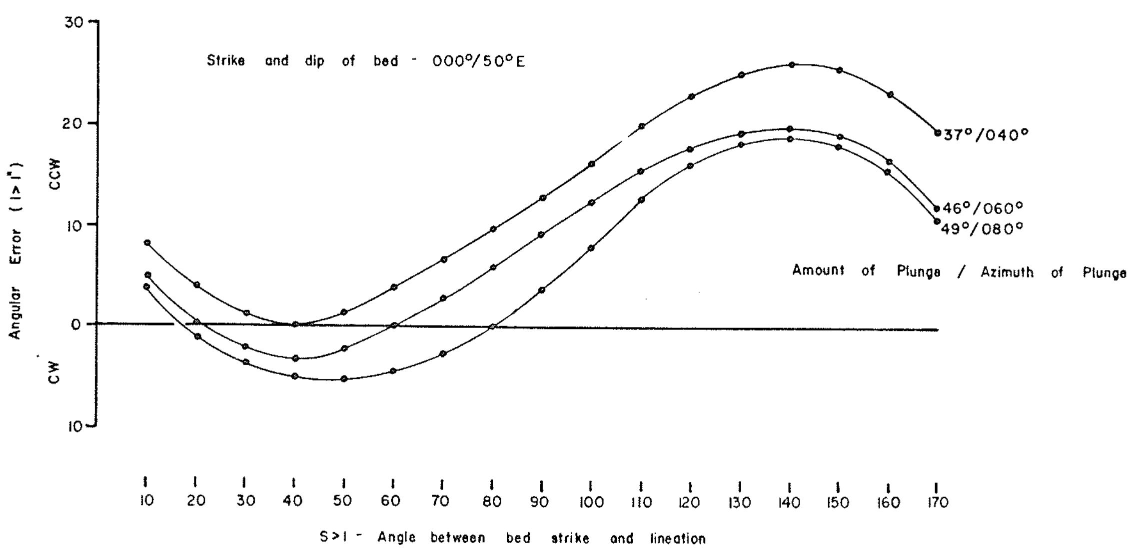
(1) 1 < s: angle between the azimuth of the lineation and the plunge of the fold.

(2) cw - clockwise correction,
ccw - counterclockwise correction.

The variation in results between the two methods appears within the limits of error of the original measurement, and is not considered sufficiently significant. The cross-stratification data were corrected by method 2 in this study.



Angular error calculated by method I.



Angular error calculated by method 2. Data the same as for method I.

Figure 69: Angular error in paleocurrent directions when the dip of the bed and the plunge of the fold are ignored. Direction of the error (ccw or cw) from the line of intersection of the foreset beds and the bedding plane.

CHAPTER VI

CROSS-STRATIFICATION

Cross-stratification paleocurrent data were corrected for deformation by rotating the bed about the axis of the fold, to an amount of dip equal to the plunge, and then rotating the bed to the horizontal about this new strike line.

Figure 70 illustrates the resulting paleocurrent rose diagram. The azimuth direction of the "arms" point in the direction in which the current flowed.

Figure 71 illustrates the paleocurrent pattern by locality. The single occurrence of ripple marks is shown as a double-headed arrow south of Cliff Lake.

Interpretation

The restored cross-stratification paleocurrent pattern is not indicative of any single source area. Rather, it may be considered as indicative of either a multiple source or a "reworked" pattern.

Stanley (1964) and Scott (1966) both have shown that divergent paleocurrent patterns could be formed by a series of turbidity currents from the same source (see figure 72). If such an initial paleocurrent pattern is further complicated by reworking of the sediment by bottom currents, a random paleocurrent pattern

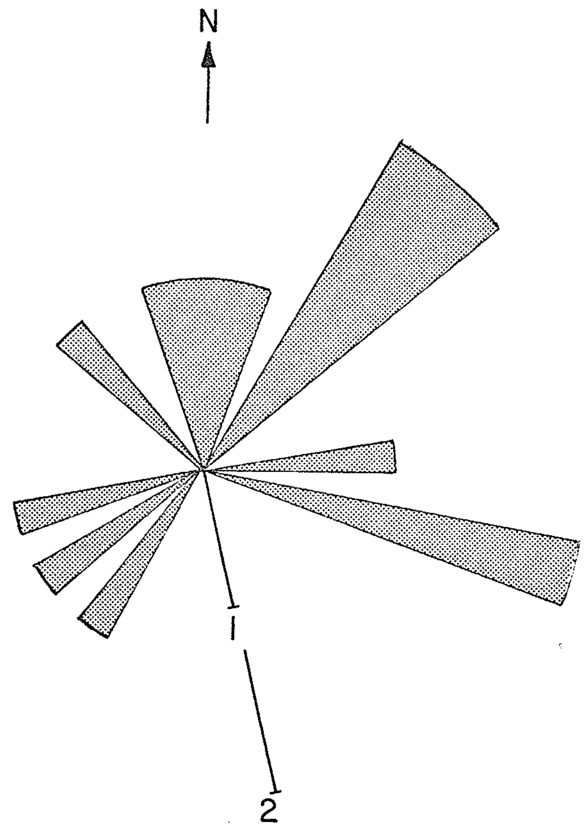
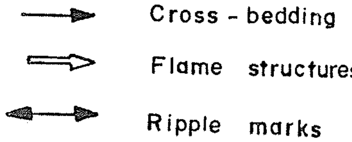


Figure 70 : 10° rose diagram of restored cross-bedding in the Dove Lake Formation. Number of readings per section shown on scale. Based on 14 readings.

FIGURE 71 : Restored paleocurrent pattern by location.



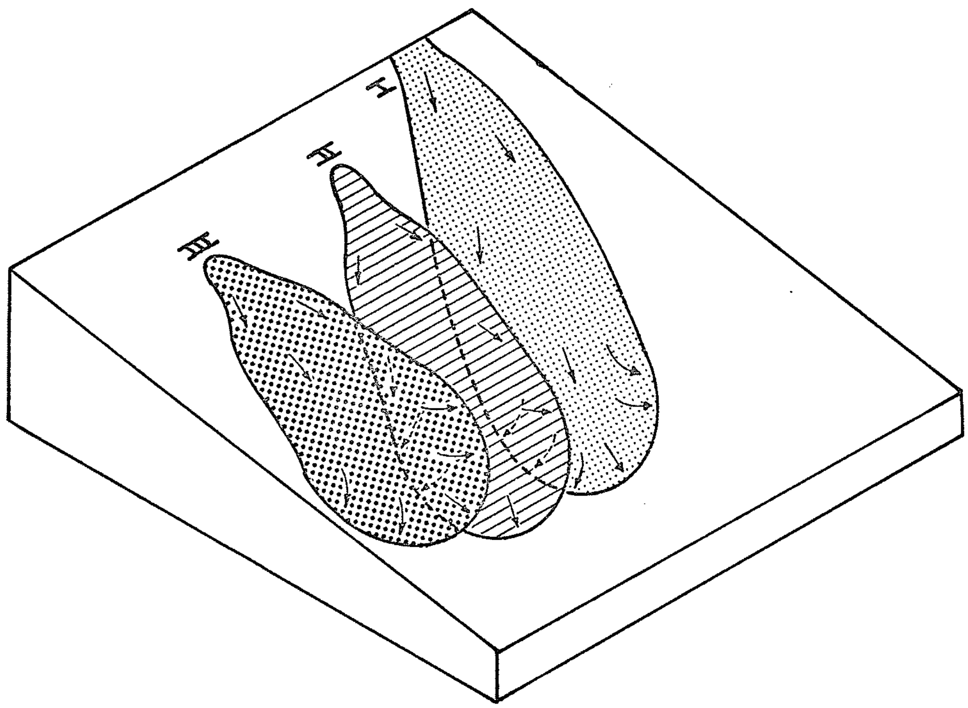


FIGURE 72: Diagrammatic sketch of variations in Paleocurrent patterns produced by successive turbidity currents. Dashed arrows show current direction produced by earlier flow.

would emerge. It is not possible to discriminate between cross-bedding produced by turbidity currents and cross-bedding produced by bottom currents.

Kuenen (1959) has shown that the source of detritus may not necessarily parallel the paleocurrent direction. Scott (1964) has shown that slide conglomerates typically occur along the flanks of the basin. Their "flow pattern" may be controlled by the slope of the basin of deposition.

Localized, closely spaced, sources can produce divergent paleocurrent patterns. If the slope of the basin of deposition is negligible, the paleocurrent pattern may show discrepancies up to 180° (see figure 72). The fan-like nature of any small turbidity current, or slump deposit, will produce a diverging paleocurrent pattern at its base. Successive slumps, or turbidity currents, could produce similar patterns, but stratigraphically superimposed over the first. Individual sequences or formations may, in this manner, show a multiple or composite paleocurrent pattern.

Because of the scarcity of cross-stratification within the Rice Lake Group, it is concluded that they cannot be used as reliable indicators of the source areas.

CHAPTER VII

ANALYSES OF THE DOVE LAKE FORMATION CONGLOMERATES AND THEIR DEPOSITIONAL ENVIRONMENT

Conglomerates which could be traced continuously were sampled along their length, in order to delineate possible source areas and outline the paleocurrent pattern. All the beds sampled are within the uppermost 200 meters of the Dove Lake Formation where conglomerates are abundant. The samples were examined to determine:

(1) If there is any preferred orientation or imbrication of clasts within the conglomerate.

(2) The variation, if any, in the clast/matrix ratio.

(3) The mean size and lateral size distribution of the clasts within the conglomerate bed.

(4) The lateral lithologic variations, if any, within a single bed, and between beds at different stratigraphic positions.

(5) To delineate any variations in clast shape with stratigraphic position.

These attributes are extremely difficult to measure in a consolidated rock. A method devised by this author, described below, was utilized:

When a conglomerate bed was located, it was mapped as closely as possible on vertical air photographs at a acale of 16 inches to 1 mile. The exposed thickness of the conglomerate beds is often sufficient to map many of the units at this scale. The out-

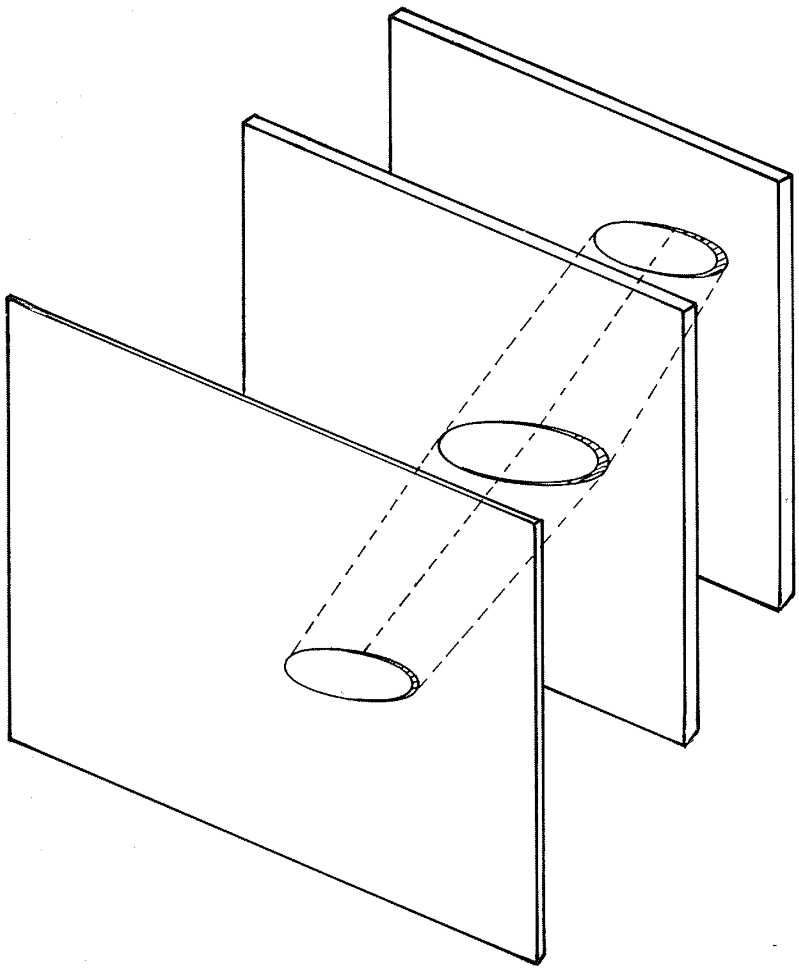


FIGURE 73 Expanded view of conglomerate slabs traced on glass plates. NOT TO SCALE.

crop pattern controlled the sampling of the beds. None of the conglomerates could be traced more than 300 meters. Where possible, samples were taken from the same stratigraphic positions within the individual units, most often at or near the base. No samples were taken less than 50 meters apart.

Individual samples were first cut into serial sections. Each slab had a constant thickness of 2.5 mm. Both sides of the slabs were etched with HF and stained with sodium cobaltintrate to determine the amount of K-feldspar present. The sample was dried and sprayed with a high gloss, clear, plastic to preserve the surface texture, and render the clasts more visible. Each slab was then examined with a binocular microscope. Each clast was outlined with india ink, given an identification number, and a brief description. The outline of the clasts on each surface of the slabs was traced onto clear acetate, and the acetate mounted on a glass plate of the same thickness as the original slab. The glass plates were separated by part of a glass plate with the same thickness as that section of rock removed by the saw. A "transparent model" of the original sample was produced when these plates were aligned and clamped in a small vise. Figure 73 illustrates a clast within a sample after construction of the "transparent" serial section.

The orientation and lengths of the clast axes can be measured from the resulting model. The roundness and sphericity of each fragment can be calculated from these data. The long and intermediate axes were always measured, and the short axis wherever possible. However, due to the nature of the glass, it was extremely difficult, and in some cases impossible, to measure all three axes. Plexiglass might be more suitable for future studies.

The percentage of matrix in individual samples was estimated visually. Three slabs were used to eliminate the effect of one large fragment on the distribution. The percentage of matrix varied from 20 per cent to 40 per cent. The cumulative distribution curves are drawn only for those clasts greater than four millimeters (-2Ø). In most cases, clasts less than 4 mm. do not occur on more than one surface of the 2.5 mm. slab.

The conglomerate clast date is given in Appendix I. The diagrams were constructed for each of the samples taken in each bed. The cumulative distribution curves are constructed on arithmetic-probability paper.

Histograms and cumulative curves of the clasts measured in the Rathall Lake Formation are also shown in Appendix I. These fragments are much larger than any of those which occur in the Dove Lake Formation. The histograms do not include the matrix fraction of the rock. The clasts are completely unsorted (see figure 74).

Clast Identification

The fragments were identified in hand speciman and thin

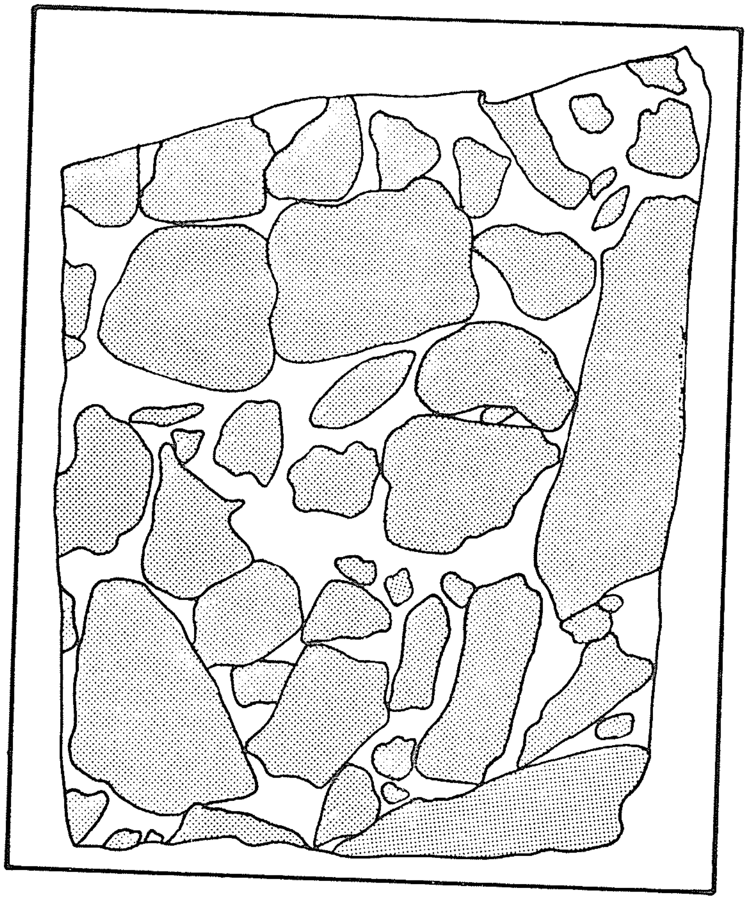


Figure 74 Unsorted clasts shown on a typical conglomerate slab.

section. Correlation of clast types between samples was conducted by binocular examination of the sprayed slab surfaces. The clasts were divided into four groups, as it was believed that a multitude of lithologies would confuse attempts at correlation. A more detailed subdivision of the types of fragments present would not have significantly altered the lithologic distribution. These four groups are described below:

Type A - Fine laths of plagioclase in a dark, fine-grained matrix. Frequently shows trachytic flow texture.

Type B - Large, well-twinned, occasionally zoned, plagioclase crystals, in a matrix of sericite, chlorite and fine plagioclase.

Type C - Small, twinned plagioclase crystals in a matrix of disoriented plagioclase laths; both in a chlorite-sericite matrix.

Type D - Very fine-grained wacke and siltstone; possibly reworked metasediment or volcanic ash.

This general classification is illustrated in photomicrographs in figures 75, 76, 77 and 78.

Clast Orientation

The orientation of grains in turbidite beds has received considerable attention. Results, however, are as variable as the

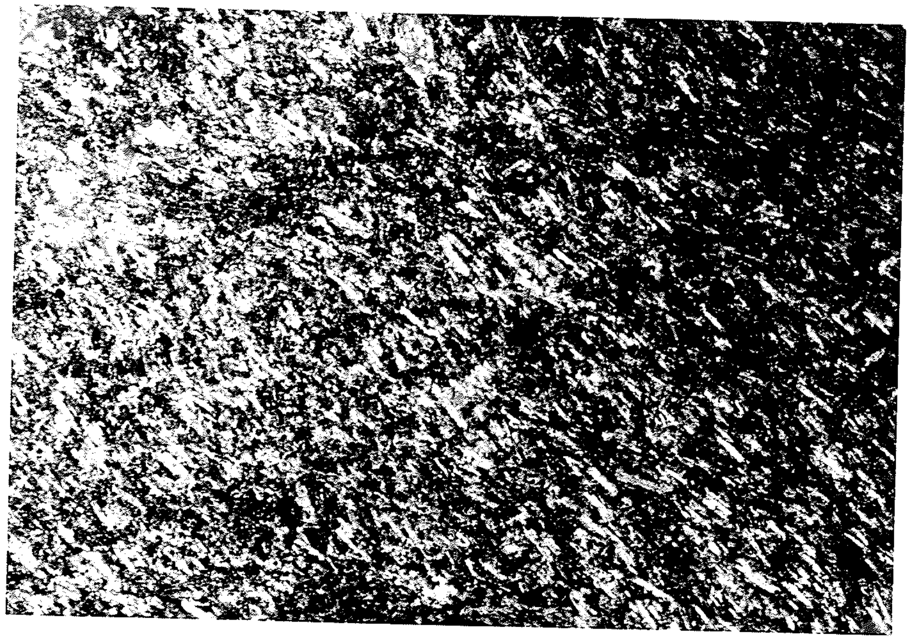


Figure 75: Photomicrograph of a type "A" pebble. Fine laths of plagioclase set in a finer-grained matrix, (x10, crossed nicols)

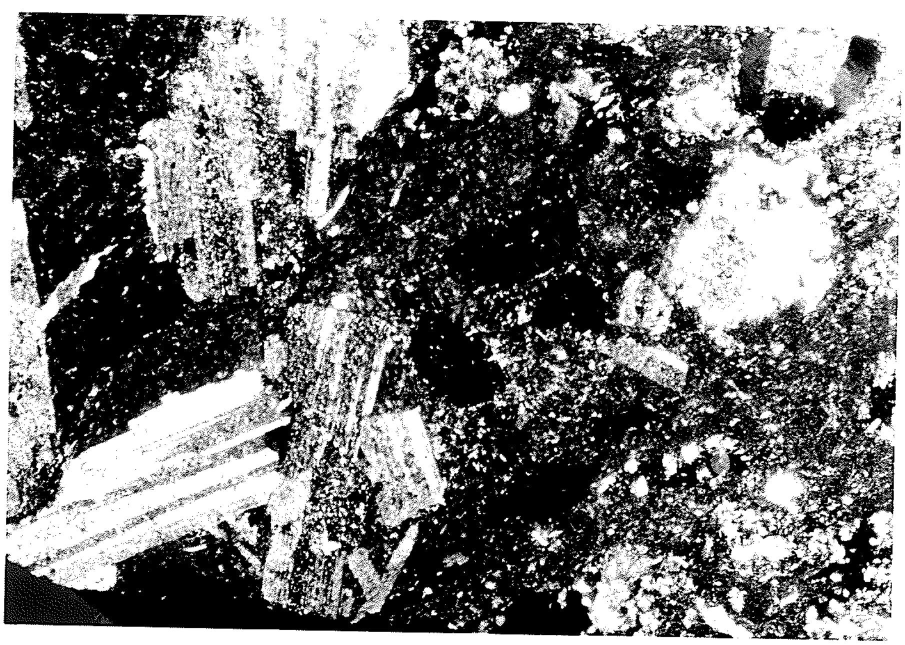


Figure 76: Photomicrograph of a type "B" pebble. Large, well-twinned plagioclase laths in an altered matrix, (x10, crossed nicols)

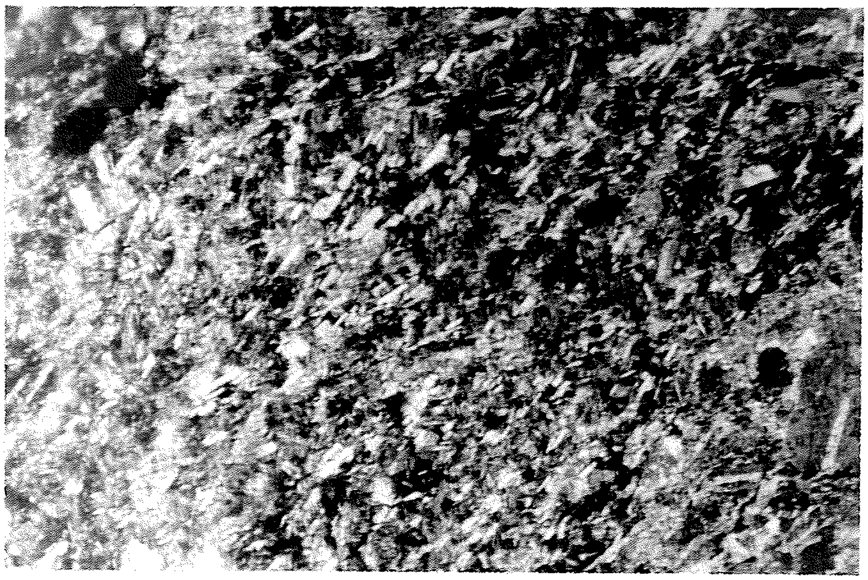


Figure 77: Photomicrograph of a type "C" pebble. Subequal amounts of plagioclase crystals and disoriented plagioclase laths in a fine-grained matrix, (x10, crossed nicols)

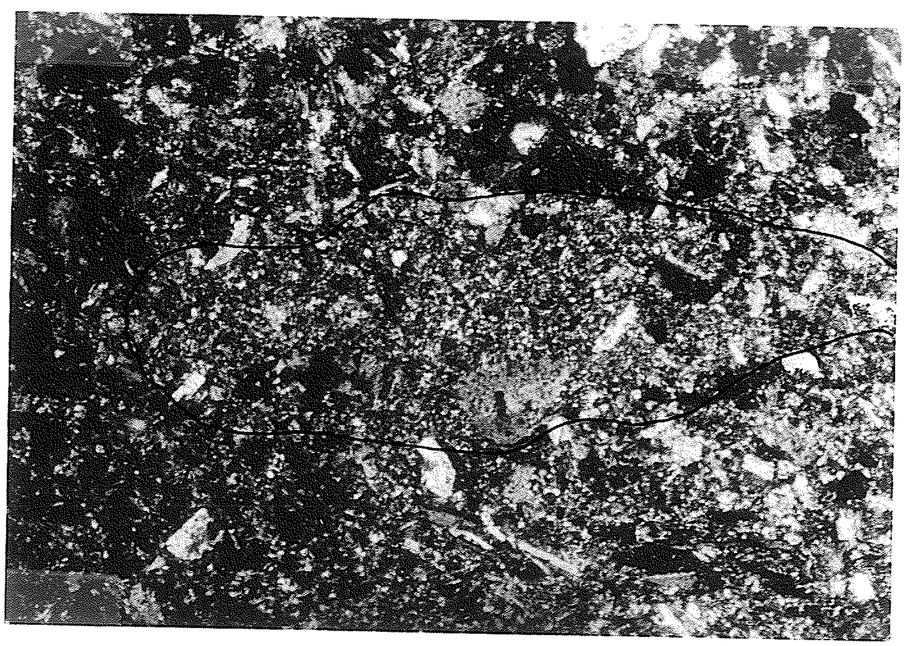


Figure 78: Photomicrographs of a type "D" pebble. Very fine-grained siltstone. Possibly reworked metasediment. Overlay shows the clast outline, (x10, crossed nicols)

number of investigators. Ten Haaf (1959) found the long axes of grains oriented parallel to the direction of current flow indicated by sole marks. Bouma (1962) and Spotts (1964) found long axes to be normal the current flow.

Detailed examination of the scour channel conglomerates, both in the field, and of the slabbed conglomerate samples, showed that the clasts have no preferred orientation, (see figure 74).

Where the conglomerates have been sheared, the clasts have acquired a preferred, tectonically imposed, orientation. This must not be confused, however, with a primary depositional orientation.

Sorting

Sorting coefficients from four different environments are listed below (after Emery, 1955, p. 47), are compared below with the data from the channel conglomerates in the Dove Lake Formation, (Appendicies 1 and 2).

	Sorting Coefficient	Median Diameter in mm.
Marine Beaches	1.25 (1.113-2.14)*	56.0 (10.8-750.0)
Lake Beaches	1.15 (1.09-1.21)	47.0 (13.0-125.0)
Streams	3.18 (1.34-5.49)	19.0 (10.4-355.0)
Alluvial fans	5.33 (2.50-8.95)	16.5 (10.0-64.0)
+ Dove Lake Formation	1.43 (1.31-1.58)	15.5 (14.0-17.5)
+ Rathall Lake Formation	1.58 (1.48-1.65)	115 (110-130)

* Number before parenthesis is median value, and numbers within parenthesis are minimum and maximum values.

\+ Data from this study.

These data calculated where:

Sorting coefficient (Trask): $S_0 = \sqrt{Mm25/Mm75}$

Median diameter: $M_{50} = \emptyset_{50}$

Interpretation

The lenticular conglomerate bodies within the upper part of the Dove Lake Formation are a unique feature within the Rice Lake Group. The proximity of these conglomerates to the Gunnar Formation, plus the volcanic nature of the majority of the clasts, indicates the source of the material.

None of the conglomerate units showed any appreciable change in grain sized along its length. This, however, may be due to three main factors:

(1) The samples were too closely spaced, or,

(2) The maximum variation in grain size is not along the strike, or,

(3) The character of the deposition was such that lateral sorting was not pronounced.

Of these three factors, the evidence cited below indicates the latter is most probable:

(1) The scoured nature of the lower contact shows that the conglomerates were rapidly deposited on unconsolidated sediments.

(2) The steep character of the channel "walls" shows deposition was contemporaneous with erosion.

(3) Examination of the slabs shows the clasts are completely unsorted.

(4) The slabs show that there is no relative increase, or decrease in the percentage of matrix present.

(5) The conglomerates have characteristic short, sinuous forms.

There are five possible sources for near shore gravel deposits.*

(1) Sea cliff erosion,

(2) Stream discharge,

(3) Sea-floor erosion,

(4) Directly-deposited volcanic ejecta,

(5) Longshore transport from one or more of these sources.

Volcanic ejecta deposited in, or close, to, water would be sorted by the wave action and the fines removed to deeper water. Sorting of beach gravels is determined primarily by the clast shape rather than clast size (Fleming, 1964). Any mass subaqueous movement of a near-shore gravel across finer material would produce an unsorted deposit at the site of final deposition.

The conglomerates of the Dove Lake Formation show excellent evidence of subaqueous flow. This evidence is summarized below:

* The term "gravel deposit" is used here not as a size connatation, but as a depositional facies term.

(1) Laminated and bedded wackes and chert both under and overlie the conglomerates;

(2) The conglomerates invariably show scour relationships at the base;

(3) Blocks and small "rafts" of fine-grained, laminated, sediment are incorporated into the conglomerate beds;

(4) The clasts show no preferred orientation;

(5) Graded bedding is either absent or very poorly developed;

(6) Lateral grading was not observed;

(7) None of the beds have any internal structure;

(8) The beds are invariably lensoid;

(9) The beds frequently change markedly in thickness along strike, indicating the development of a number of scour channels of varying depths;

(10) Maximum relief of the channels is greater than 5 meters;

(11) The presence of well-laminated siltstone overlying the channels-fills indicates either quiesence or deep-water deposition immediately following conglomerate deposition;

(12) The large "rafts" of fine-grained sediments which occur near the top of some flows indicates that the mass flowed in a laminar fashion similar to that postulated by Lindsay, (1966, p. 729).

The close similarity of the sorting coefficient of the Dove Lake sediments with those given for marine beach gravels indicates that some sorting has taken place prior to final deposition. If no sorting had occurred, the coefficient would be much lower. This type of initial deposition, erosion, redeposition, and mass movement is shown diagrammatically in figure 79.

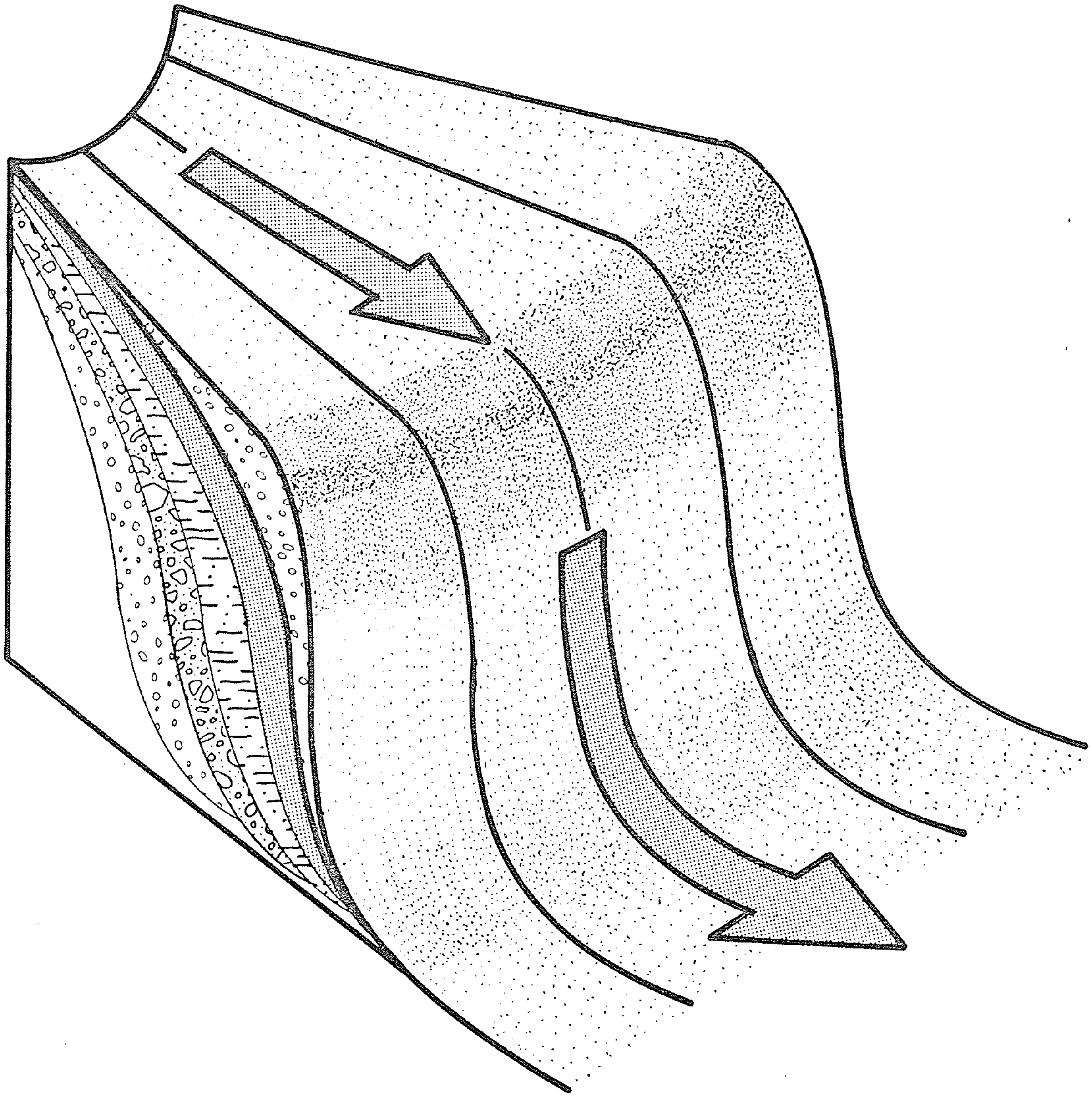


Figure 79 Diagramatic representation of deposition, slumping, and redeposition outward in the basin. Vertical scale highly exaggerated.

CHAPTER VIII

INTERPRETATION OF THE DEPOSITIONAL FACIES OF THE RICE LAKE GROUP

The facies delineated within the Rice Lake Group are utilized as indirect paleocurrent indicators. The rocks were subdivided into facies based upon the classification of Walker (1967, p. 32), who defined characteristics typical of distal and proximal turbidite environments.

The two environments may occur together, and where this occurs the writer proposes to classify the resulting facies as transitional. Characteristics of this proposed transition facies are listed below:

(A) Beds are both thin and thick.

(B) Bed thickness appears grain size dependent.

(C) Sandstone beds are often separated by a thin silt or chert layer.

(D) Beds have uniform thickness, frequently over large distances.

(E) Few, small, scour channels are present.

(F) Beds often show good grading. Thicker beds show poorly developed, or delayed grading.

( ) Bases of sands are always sharp; completely graded sequences (A-E type) not seen.

(h) Laminations commonly only in fine-grained sediments.

The most reliable method, it would appear, would be to record accurately and measure features characteristic of each environment at every locality. Arbitrary limits could then be established, for example:

greater than 70% Type I - proximal
greater than 70% Type III - distal
any combination less than these limits - transitional.

Ideally, a facies should contain approximately 100% of one or two lithologies. Turbidities, though rarely attain this ideal. This style of deposition creates diverse mixtures of lithologies, such as quartz-pebble conglomerate overlying shale. It is proposed, then, that the facies limits be established at 70%, rather than 100%. Utilizing these three divisions, the Dove Lake Formation can be subdivided into three facies: proximal (I); transitional (II); and distal (III).

The Dove Lake, Stovel Lake, Stormy Lake, and the Narrows Formations contain facies which can be utilized as indicators of sources. These facies are shown in figure 80.

Rocks characteristic of the proximal facies are predominant in the uppermost part of the Dove Lake Formation in the western part of the area, (see figure 81). Rocks in this area become progressively coarser to the west. Near the quartz diorite, there are very few fine-grained sediments.

The coarse basalt breccia with intraformational chert clasts occur only near the quartz diorite contact. The unit rapidly pinches out to the east, and does not occur east of the Long Lake-Wadhope road. The clast size, angularity and unsorted nature of these rocks indicates that they have not been transported far.

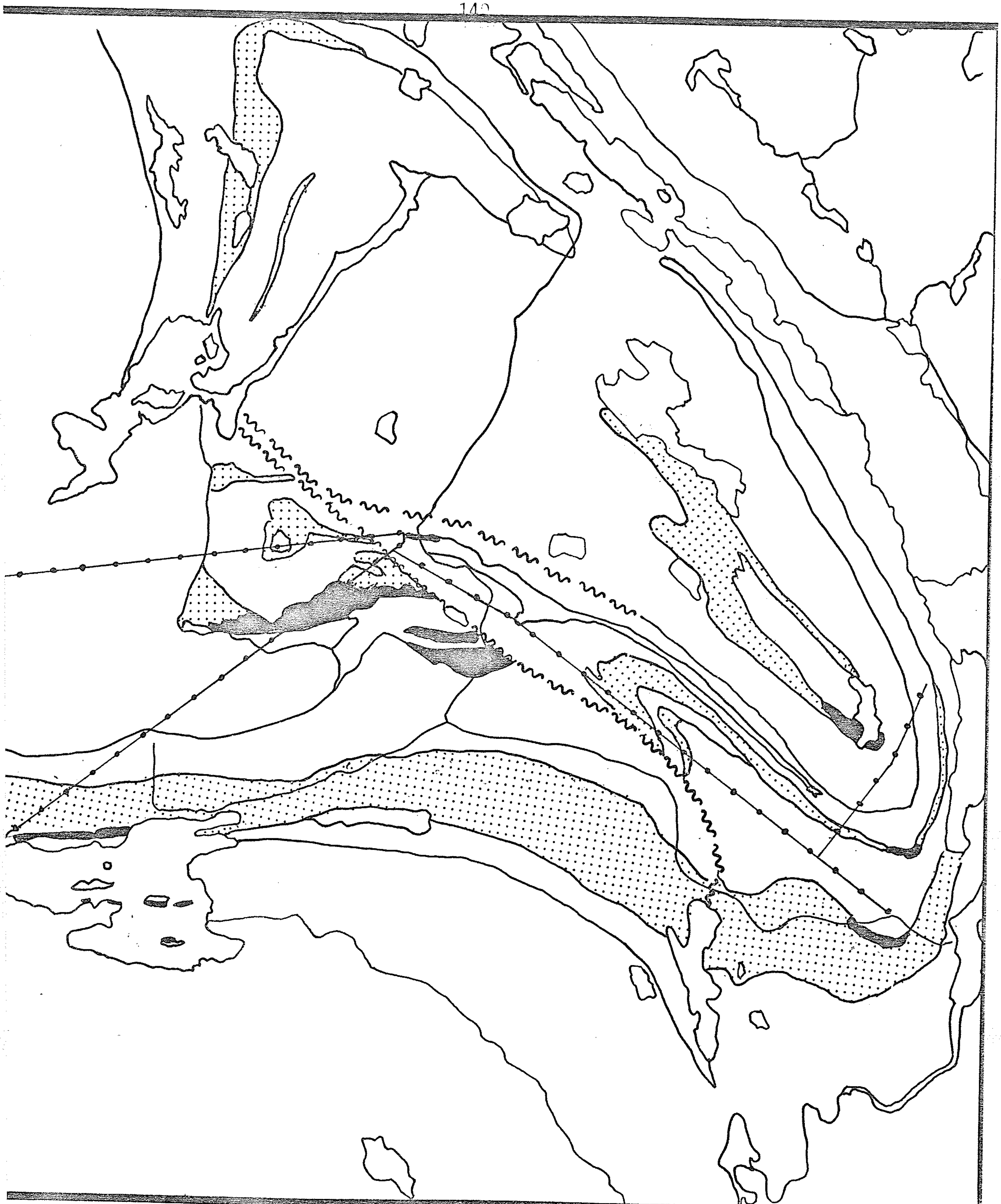


FIGURE 80: Proximal facies(solid pattern), and transitional-distal facies (stippled), within The Rice Lake Group. Geology as shown in Figures 3 to 9.

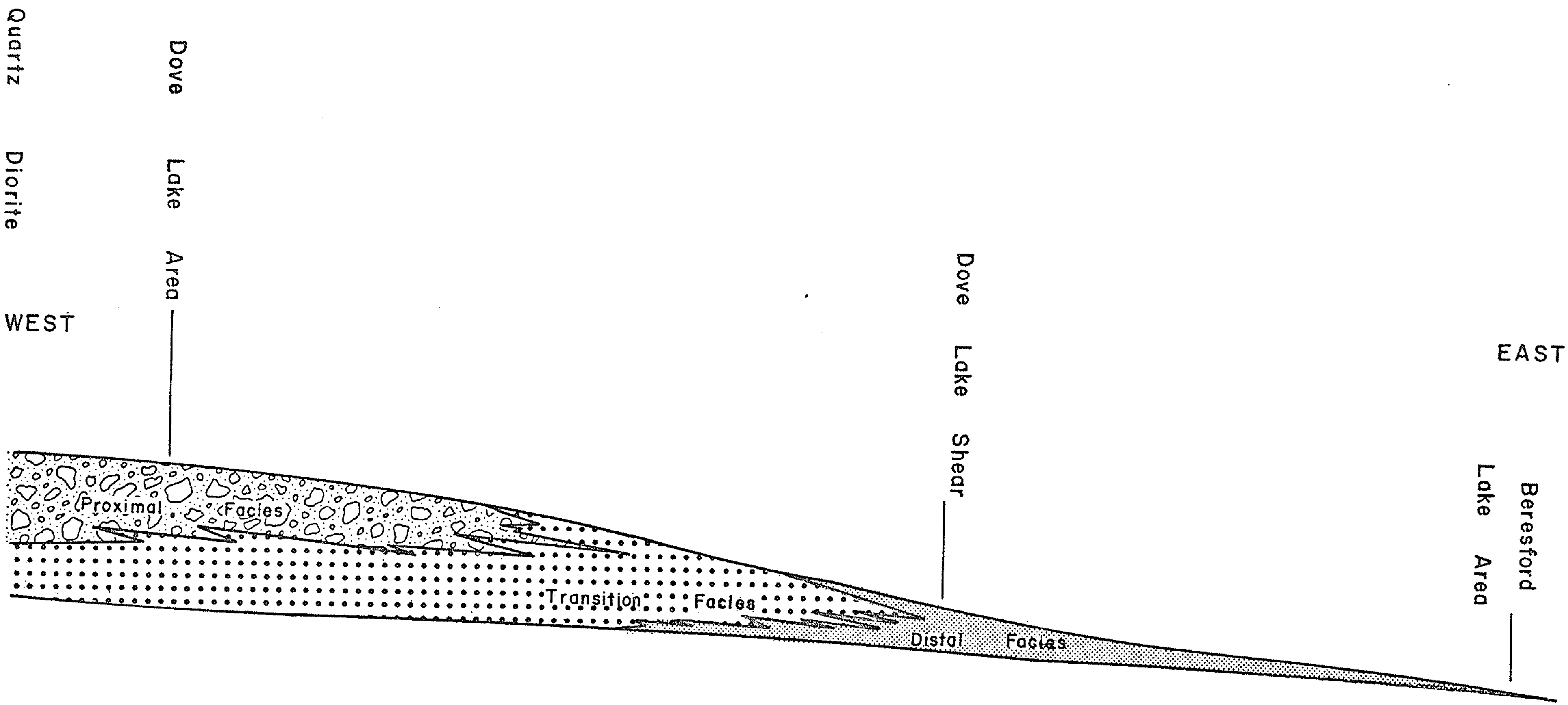


Figure 81 : Diagramatic cross-section through the Dove Lake Formation, showing facies changes and thickness variations. NOT TO SCALE.

A very angular breccia near the contact of the Dove Lake Formation with the Gunnar Formation is a useful source indicator. The blocks are predominantly one lithology, extremely angular, and unsorted. The shape of the clasts is the most distinctive aspect of the breccia. All the clasts have sharp edges, and low angle, acute terminations are common. None of the clasts are rounded and they appear as a broken mosaic on sawed surfaces.

The Stormy Lake Formation contains no appreciable coarse detritus in the western part of the area. The formation is relatively thin, and consists of pillowed and massive basalt, and minor sediments. The formation contain the first "iron formation" within the Rice Lake Group.

The Stormy Lake Formation contains an isolated granitic boulder conglomerate in the east, mapped as proximal facies. The granitic clasts are restricted to the eastern part of the area and indicate a source to the east.

The conglomerate at the base of the Narrows Formation marks a major break in the type of detritus being supplied to the basin of deposition. It marks the first appearance of "acidic" volcanic material in the Rice Lake Group. The conglomerate is thickest at the eastern end of Long Lake, and thins rapidly eastward, where it occurs only as thin, discontinuous lenses.

Upward in the Narrows Formation, basalt and "basic volcanic" wackes are subordinate to crystal tuff, welded "acid" volcanic agglomerate, arkose, and subgreywacke. The coarse, eruptive phase culminated with the deposition of the Edmunds Lake Formation.

The rocks of the Narrows Formation are nearly all of the proximal facies in the vicinity of Long Lake. They are classified as transitional and distal to the east.

The rocks of the Edmunds Lake are relatively well-sorted, compared to underlying sediments. The high quartz content, rounded grains, and lack of matrix is indicative of redeposition from an originally well-sorted sediment.

Lateral lithologic variability is negligible in the Edmunds Lake Formation. The conglomerate within the formation attains a maximum thickness south of Edmunds Lake. It thins in both directions from this location. Coarse grits and thick-bedded sandstones which pinch out to the north and south overlie the conglomerate.

Interpretation

In an area of volcanic activity, any abrupt increase in extrusive activity is immediately reflected in the grain size and internal structures of the derived sediments. Periods of quiesence, followed by rapid violent extrusive activity, followed by quiesence would produce a complex of sediments which would alternately be classified as either proximal facies or distal facies. In these cases, the derived sediments would constitute the transition class proposed by this writer.

The lowermost unit which may be classified as the proximal facies occurs in the Tinney Lake Formation at Wadhope. These rocks are the "tephra" deposits, and represent the most northeasterly extent of proximal facies. The unit is thin and of limited extent, but is very significant in that it represents the northern limit of one of the major facies.

The proximal facies within the uppermost 100 meters of the Dove Lake Formation is the best developed in the entire area.

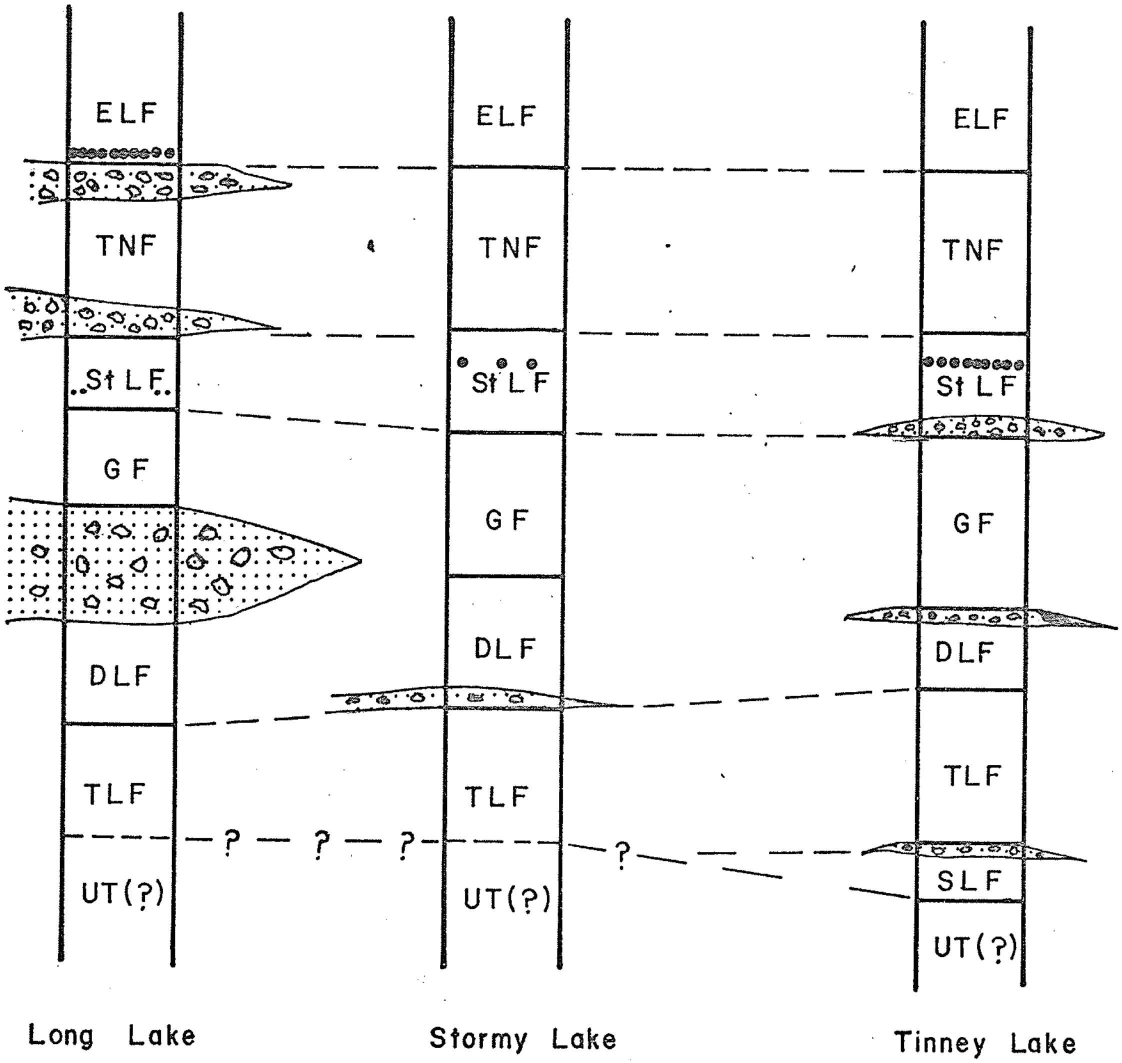
The large scour channels in the Dove Lake Formation have long axes which are oriented approximately normal to the contact of the Dove Lake Formation with the quartz diorite. The absence of any appreciable grain size variation along the channels is attributed to their exposed orientation. If it had been possible to sample down the axis of the channel, grain size variation may have become apparent.

The angularity of the fragments, together with the lack of sorting, and lithologic uniformity, strongly suggest a nearby source. The sharp edges indicate a minimum of transport. W. Weber (personal communication, 1969) has suggested that the breccia may have been formed by a submarine fault, followed by slumping into the basin of deposition. If so, fault activity must immediately have ceased, as the breccia is directly overlain by fine-grained wacke and chert. These wackes are in turn overlain by agglomerate, succeeded by pillow basalt of the Gunnar Formation.

The most notable feature of the formation is the persistence in lateral position of the proximal facies throughout the stratigraphic sequence. The single proximal facies within the Stovel Lake Formation lies stratigraphically beneath the proximal facies within the Dove Lake Formation and Stormy Lake Formation (see figure 82). These three occurrences of the proximal facies are completely surrounded by either distal or transitional facies.

The superposition in sequence, isolated occurrence, and characteristic form of these proximal facies sub-units indicate a nearby source. Weber (1971) has mapped coarse-grained extrusive volcanic rocks in the vicinity of Gem Lake, which he interprets as the remnants of a volcanic neck. These are the only known rocks of this type in the entire area. It is logical, therefore, to consider this volcanic "neck" as the source of the proximal facies rocks in the eastern part of the area.

The persistence of the proximal facies in relatively the same stratigraphic position throughout the early history of the basin indicates that a trough or depression probably existed in the same area. The depression postulated would be necessary to "channel" the coarse clastics into their present position in the sequence. This "depression" may have been produced by localized, relatively rapid, subsidence. Slumping of coarse debris into the basin appears to be the logical transport mechanism.



ELF — Edmunds Lake Formation.
TNF — The Narrows Formation
St L F — Stormy Lake Formation.
G F — Gunnar Formation.
D L F — Dove Lake Formation.
T L F — Tinney Lake Formation.
S L F — Stovel Lake Formation
UT — Unnamed Basalt (Informal name)

Figure 82 Restored stratigraphic sections at three locations.
Coarse stipple pattern - conglomerate;
Dots - iron formation.

Volcanic debris deposited close to the source would be unstable in its initial state, and could easily be thrown into suspension by seismic activity. The material in suspension would flow downslope into the basin of deposition as a thinning lens. The sedimentary clasts in the coarse rocks would have been ripped up during transport. As the mass of material moved further into the basin of deposition, it lost much of its transporting power, and increasing amounts of coarse clastics were deposited. The restricted nature of the proximal facies in the east indicates the flow was reaching the limit of its load-carrying capacity in this part of the basin.

The impersistence, thickness, and lateral relationship of the facies, indicate a very rapid thinning into the basin of deposition. The repeated sequences of proximal rocks represent the western basinward edge of the facies.

The thin conglomeratic facies, detrital quartz, and the iron formation indicate that depositional processes were changing markedly and rapidly with the early deposition of the Stormy Lake.

The fine-grained volcanic wacke which overlies the Gunnar Formation indicates that a volcanic activity was relatively quiescent in the western part of the area. The massive and pillowed basalts near Long Lake show that volcanism was still active during early Stormy Lake time.

Volcanism increased abruptly, commencing with the deposition of the Narrows Formation, especially in the vicinity of Long Lake. The coarse-grained fragmental volcanic agglomerate at the base of the formation represents the beginning of the last major eruptive phase in the lower part of the Rice Lake Group. The conglomeratic phase is thickest at the east end of Long Lake, indicating proximity to the sources. The size of the clasts indicates that they have not been transported far.

The Narrows Formation culminates with a second coarse eruptive phase of fragmental volcanics. These present the uppermost fragmental rocks in the Rice Lake Group. They are restricted entirely to the eastern end of Long Lake.

These rocks may represent a slight westward "migration" of the proximal facies upward in the sequence.

Welded tuff in the Narrows Formation at Long Lake indicates that deposition was at least in part sub-arial prior to Edmunds Lake time. The coarse volcanic agglomerates near the top of the Narrows Formation may represent a subaqueous slump. Insufficient evidence is available to categorically state whether or not this is actually the case.

Welded tuffs and pyroclastics in the upper part of the Narrows Formation indicate more than one hypothesis for the source of the Edmunds Lake Formation.

Subarially deposited clastics would be subject to rapid erosion. With the addition of water, such an unconsolidated mass could flow rapidly downslope (Schminke, 1966). This mass would produce channels and gullies in the unconsolidated sediment over which it passed, and thick, poorly sorted, channel-filled volcanic conglomerates in the basin of deposition. No scour channels are recognized in the Narrows Formation.

Pyroclastic material could undergo both lateral and vertical sorting to produce the alternation typical of the Edmunds Lake Formation. If pyroclastics were the source, rapid variations in the maximum grain size of successive beds should occur. Exotic blocks of coarse pyroclastic material should occur in the lower part of the formation. Neither of these textural features have been recorded.

Lateral and vertical development of graded bedding indicates that turbidity currents were active during the depositional history of the Edmunds Lake Formation. This is a strong indication of source other than the Narrows Formation for the sediments of the Edmunds Lake Formation.

A source area can be inferred from the facies change. It would have lain normal to the regional strike of the formation south of Edmunds Lake. The only recognized volcanic source which may have been active during deposition is at Gem Lake. This is the most probable source area for the following reasons:

(1) The coarse clastics pinch out both north and south along strike from the thickest conglomerate development.

(2) No coarse sandstone or grit occurs either north or south of the maximum conglomerate development.

(3) Lateral facies change, from coarse-grained to fine-grained, is pronounced in a north-south direction from south of Edmunds Lake to the western end of Long Lake.

(4) Rocks mapped as Edmunds Lake at the western end of Long Lake contain increasing amount of argillite, which does not occur to the east and south.

become more abundant, less rounded, and the percentage of matrix is markedly less than in the sediment east of the Dove Lake Shear. Nowhere else in the stratigraphic sequence are such coarse-grained sediments so abundant. Their presence is considered a good indication of the source of the sediments.

Breccias close to the quartz diorite contain blocks of basalt and porphyritic basalt, with minor laminated chert clasts. The chert and other sedimentary fragments indicate the breccias are subaqueous. No breccias of this type occur in the Stovel Lake Formation.

A thin horizon interpreted as an aquagene breccia has been noted within the Tinney Lake Formation, at the Central Manitoba mine. The breccia, with large bomb-shaped clasts, underlies interlayered chert and fine-grained greywacke. The bedding is distorted above and below the fragments. Chert and fine-grained wackes are in direct contact with the basalt at most localities, and are interpreted as the "normal" sediments. Fine-grained wackes interlayered with the chert show good grading on a microscopic scale. These provide the direction of upward sequence.

The wackes and chert represent the only pause in the extrusion of basalt in this area. They further show that deposition of sediment was continuous elsewhere while the basalts of the Tinney Lake Formation were being extruded. The isolated clasts in the fine-grained wacke and chert show the source of the fragments was very close. The breccia indicates that turbidity currents may have been active prior to the deposition of the Dove Lake Formation.

There are no coarse-grained breccias or conglomerates in the Dove Lake Formation north of Halfway Lake. The sediments there vary from coarse sandstones and minor grits to fine sandstone, siltstone and chert. Cross-bedding is not well-developed. Graded bedding was noted at almost all localities. The sedimentation units are thin to medium-bedded. Coarse clastics increase in relative abundance to the southwest in this area. This is similar to the lateral variation in grain size in the uppermost part of the Dove Lake Formation west of the Dove Lake Shear.

If bottom currents were the mechanism of distribution of the sediments, the Dove Lake Formation should maintain a uniform thickness. However, the coarse breccias and channel-fill conglomerates could not have been deposited by bottom currents. They are interpreted as slump deposits. If the entire formation was deposited by turbidity currents, scour channels should be abundant throughout. They are, however, restricted to the proximal facies.

Figure 83 diagrammatically illustrates the deposition, slumping, and redeposition of volcanic-derived sediments in the basin of deposition.

The reconstruction of the depositional history advocated here, may be summarized as follows:

(1) The part of the basin that was investigated was relatively shallow.

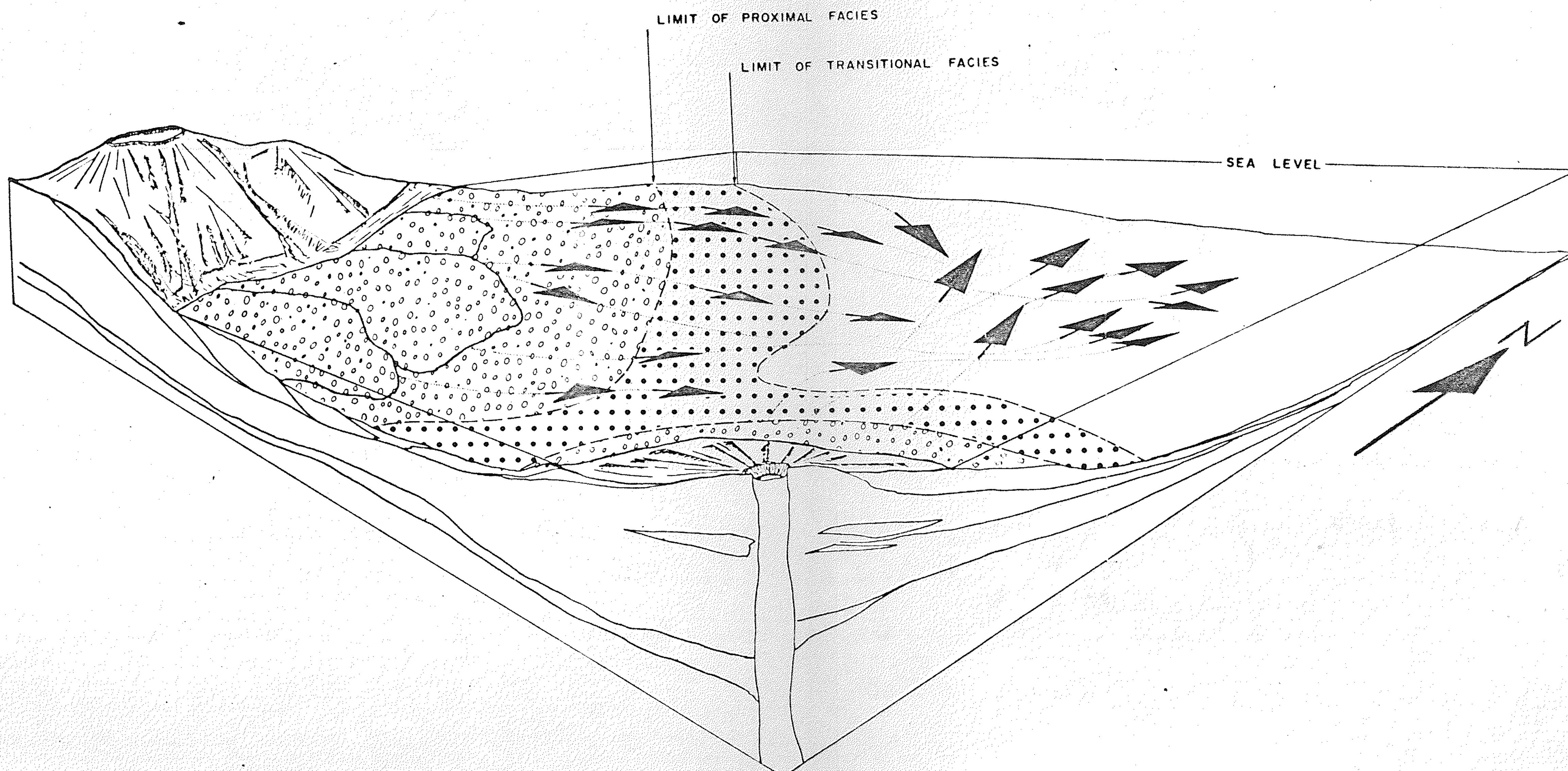


Figure 83 Diagrammatic illustration of the relationship between volcanic sources, turbidity currents, and basinal geometry in part of the Rice Lake Group. Proximal facies — open circles: transitional facies — solid circles. Turbitity current paths shown by dotted lines and arrows.

(2) The main source of the majority of the sediments in the area lay to the west, in the area now defined by the Ross River pluton. The coarse proximal facies rocks near Tinney Lake indicate a second minor source.

(3) Another, isolated, source of volcanic debris was present in the Gem Lake area to the east. This source persisted through much of the history of the basin.

(4) To the east, the basin became progressively deeper, or further removed from the main source of volcanic activity.

(5) As the basin filled with sediments and extrusive volcanics, the volcanism became more acidic, signalling the end of the eruptive cycle.

(6) Marked changes in the chemistry of the basin in its later stages of development are reflected in the development of iron formation. This iron formation is best developed in the eastern part of the area, or the deeper part of the basin.

(7) When, or as, volcanism ceased, uplift of older, possibly granitized, terrain created a new source of detritus which supplied the basin with the quartz-rich sediments of the Edmunds Lake Formation.

(8) An isolated source must have existed for an unknown period of time in the vicinity of Rathall Lake. Sediments derived from this source are now solely represented by the rocks of the Rathall Lake Formation.

(9) Though the top of the sequence is not exposed, one must assume that the conditions which prevailed during the deposition of the Edmunds Lake Formation continued until the entire sequence, continued within the main basin to the south, was buried, granitized and eventually uplifted.

Geometry of the Basin of Deposition

The shape of the basin can be approximately delineated by the facies present in the formation. The shape indicated is outlined as follows:

(1) The absence of rocks characteristic of the proximal facies indicates that the basin was relatively deep in the northeast, in the vicinity of Cliff Lake, Stovel Lake and McLeod Lake East. These are classified as distal parts of the basin.

(2) The precise limits of the basin cannot be established, as the boundaries have been destroyed by large batholiths. However, one source must have lain at, or close to, the present eastern boundary of the Ross River quartz diorite pluton. The abundance of proximal facies rocks, in approximately the same relative stratigraphic position, indicates a persistent and well-developed volcanic area. The source may have been subaqueous but the welded crystal tuffs of the Narrows Formation indicate that it was at least in part

near-surface. This indicates that the basin was shallow west of the Dove Lake area.

(3) The eastern limit of the basin also cannot be defined, as the emplacement of the granite to the east has obscured some of the sediments. The thinning, and fine-grained nature of the Dove Lake Formation shows, however, that this part of the basin was relatively unaffected by volcanism. We must assume, then, that the area was far removed from the affects which produced the rocks of the proximal facies.

CHAPTER X

EVOLUTION AND REGIONAL SETTING OF THE RICE LAKE GROUP

Evolution

The rocks of the Rice Lake Group comprise a sequence dominated by volcanic extrusives and volcanogenic sediments. The quartz-rich sediments of the Edmunds Lake Formation appear to have been deposited only after volcanism ceased to be a major contributor of sedimentary detritus. The source of the quartz in the Edmunds Lake Formation has been attributed to the exposure of quartz-rich granitic rocks, or pre-volcanic granitized paragneiss. The quartzite clasts present in the conglomerate of the Edmunds Lake Formation are indicative of an older, possibly granitized, sedimentary sequence.

McRitchie (1971) recorded the presence of a very coarse granitic boulder conglomerate near the north shore of Wallace Lake (see figure 3). This conglomerate lies within the upper part of the Edmunds Lake Formation, or its lateral equivalent. The unit has been faulted into its present position and, when restored to its original position, lies north of Bissett (McRitchie and Weber, 1971). The conglomerate contains huge clasts, many up to 3 meters in exposed length. The source of these granitic clasts must have been nearby, as they have obviously not been transported far. The granitic boulder conglomerate indicates the following:

(1) The pre-volcanic basement was composed of continental, rather than oceanic, crust.

(2) Uplift which occurred along the flanks of the basin was neither uniform nor continuous, and was extremely rapid during the later stages of basinal development.

(3) Gradual uplift of the granitic terrain is indicated by the upward increase in detrital quartz within the lower part of the Rice Lake Group. This uplift culminated in the deposition of the Edmunds Lake Formation.

(4) The supply of quartz-rich detritus may have been continuous, but the amount increased very rapidly at the <u>end</u> of the volcanic cycle, indicating that uplift of the flanks of the basin was <u>not</u> coincident with volcanism and subsidence.

(5) The rapid uplift indicated by the huge granitic boulders is attributed to the development of ridge(s) on the flank(s) of the basin. These ridges may have been produced by compressional forces which initiated the basin of deposition.

(6) Assuming the pre-volcanic terrain was the source of the Edmunds Lake Formation, then the entire basin was probably ringed with quartz-rich rocks which supplied varying amounts of detritus. The resulting sediments eventually buried the volcanic products as basinal subsidence continued, and volcanism ended.

(7) A similar, but finer-grained, conglomerate occurs in the Bee Lake Area to the southeast, at the top of a possible lateral equivalent of the Edmunds Lake Formation, (Goodwin

and Shklanka, 1967). However, the structural geology of this area is not well understood, and the details of the stratigraphic relationships could not be confirmed.

Regional Setting

The entire Rice Lake Basin, including the Bee Lake Area to the east, is not interpreted as a separate entity, unique unto itself. Rather, it is suggested that the basin represents a single, semi-isolated, volcanic area, set in a much broader "belt" of volcanic activity. The ultramafic rocks of the Bird River Area to the south, though intrusive, may represent that ultramafic suite considered by some, (Anhaeusser et al., 1969), to be an essential part of the greenstone complex, but which is invariably absent in the greenstone belts of the Canadian Shield.

Goodwin (1970) suggested that the Abitibi Orogenic belt was composed of a number of interrelated volcanic complexes and this hypothesis is possibly applicable to the Rice Lake Basin. He states (Goodwin, 1970, p. 13):

> "The regional stratigraphy is dominated by the presence of semi-independent ellipsoidal volcanic-sedimentary domains each of which is termed a volcanic complex. Nine major and two minor volcanic complexes have been delineated in the region (figure 5) each with a mafic to the felsic volcanic sequence, associated intrusions and sediments."

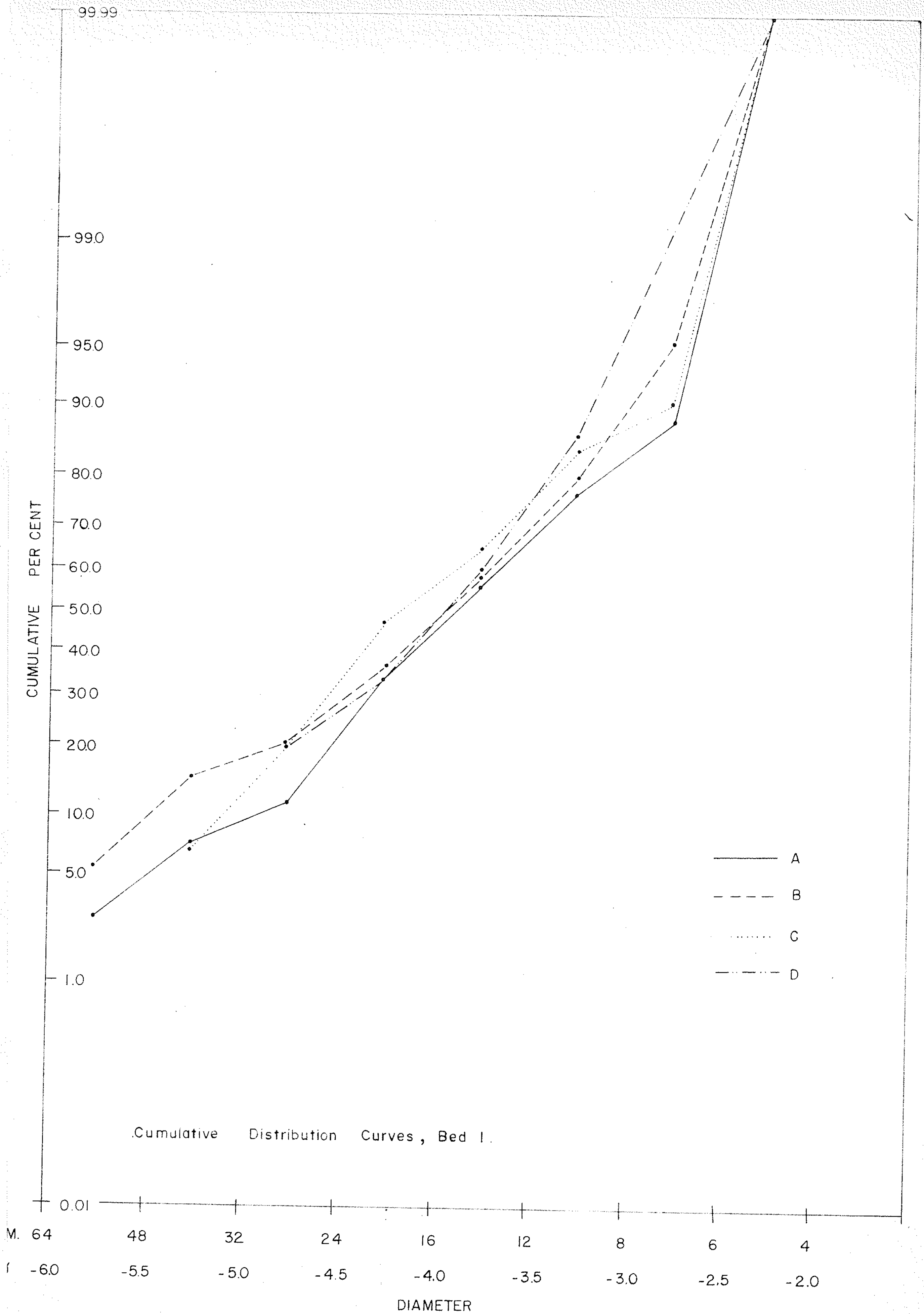
The Rice Lake Group would be one of the semi-independent ellipsoidal volcanic-sedimentary domains. Other volcanic complexes which together may have formed a similar orogen have not been delineated, due to the lack of sufficiently detailed work in similar nearby areas.

Since neither the pre-volcanic basement, nor the flanks of the basin are presently exposed, any hypothesis regarding the relative location of the volcanic sequence within the original basin is predominantly speculative.

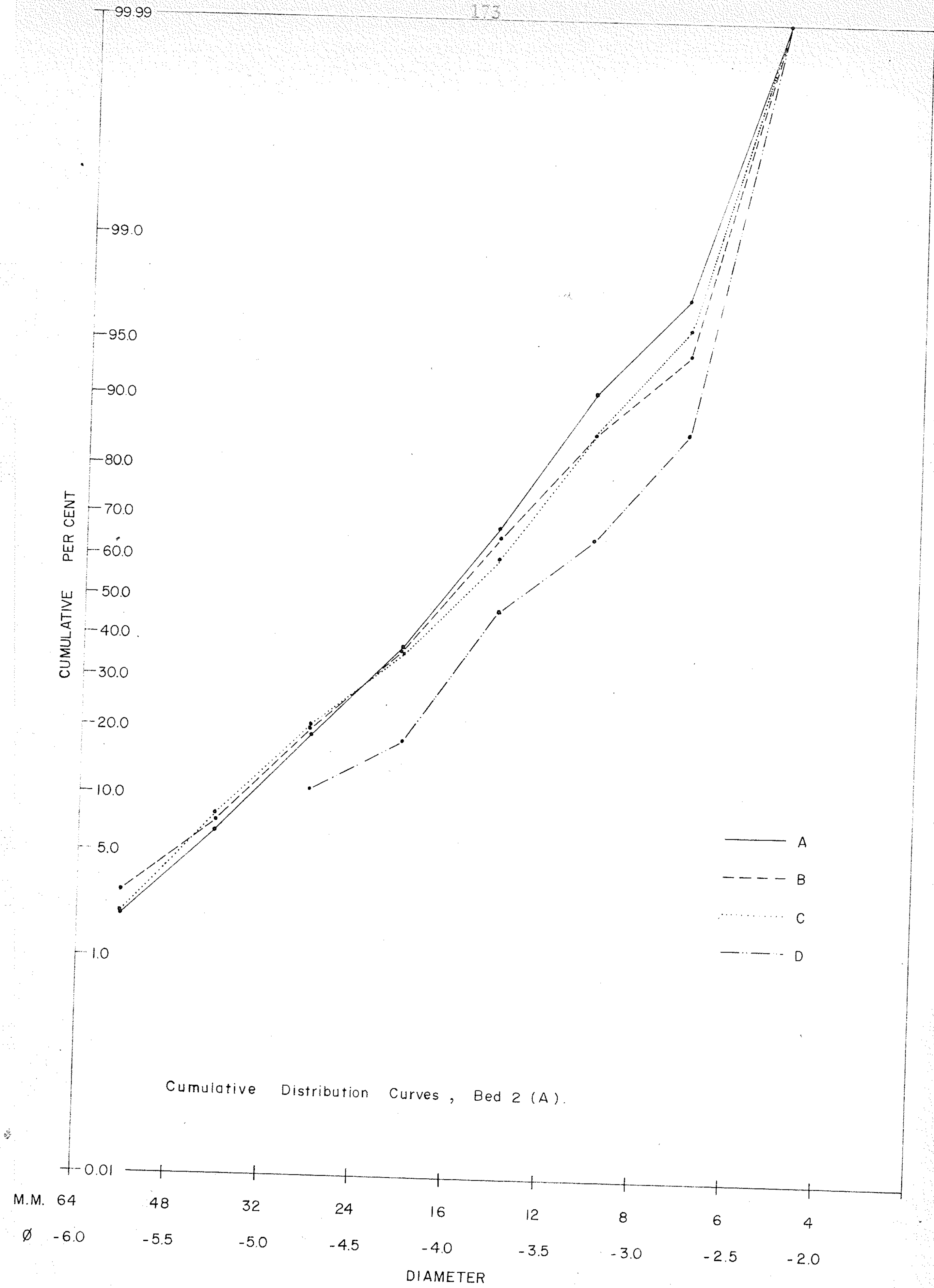
The extrusive volcanic rocks may have been deposited on the flanks of the basin, in the "hinge line" area, between a deeper part of the basin, and the marginal shelf area. The extrusive volcanic rocks, and the derived sediments, could have been derived from magma intruded along fractures developed in this "hinge" area, or the extrusive rocks may have been deposited on either side of a central basin fracture. There is at present no conclusive evidence which favours either hypothesis.

APPENDIX 1

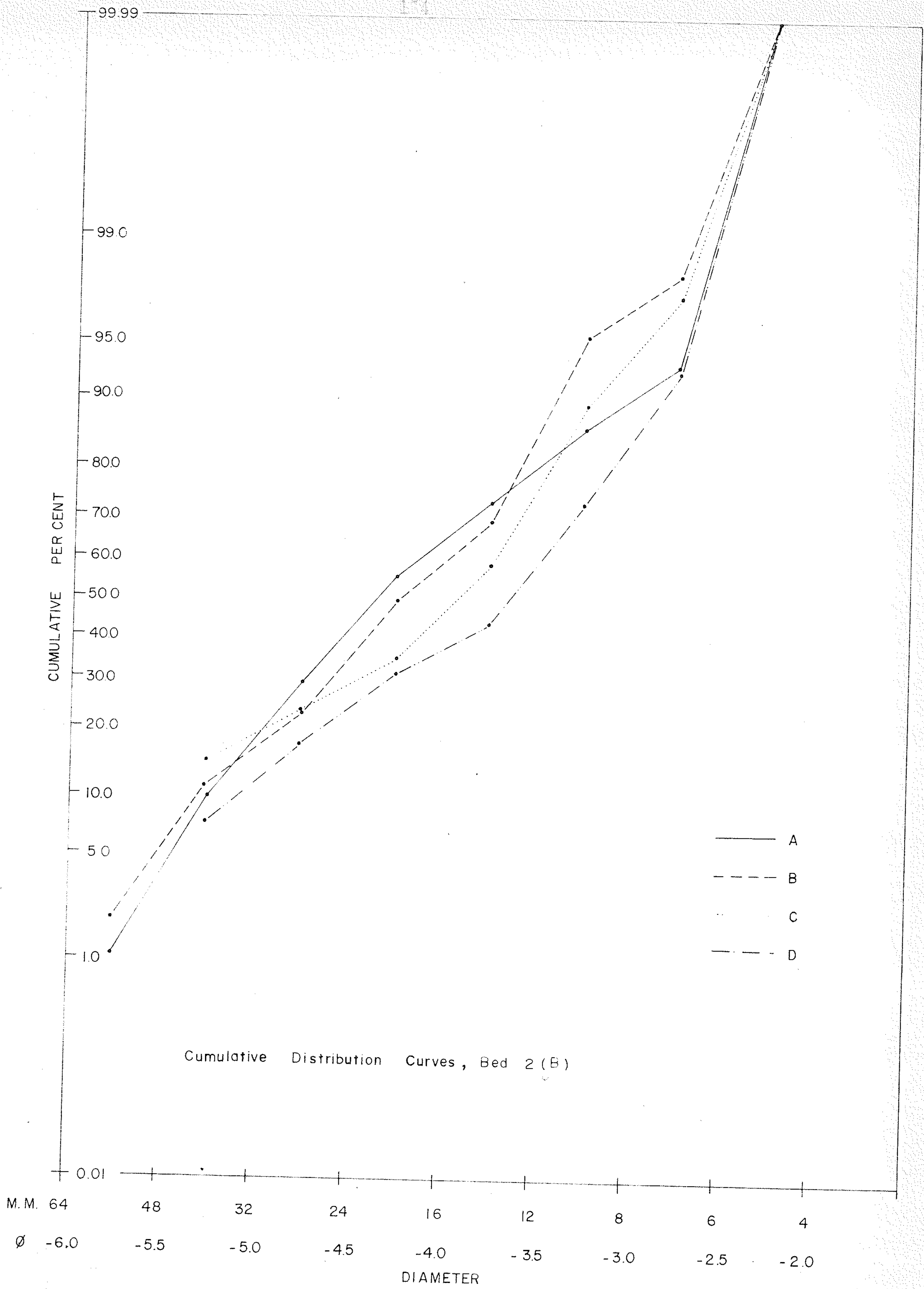
CUMULATIVE DISTRIBUTION CURVES OF CONGLOMERATE SAMPLES



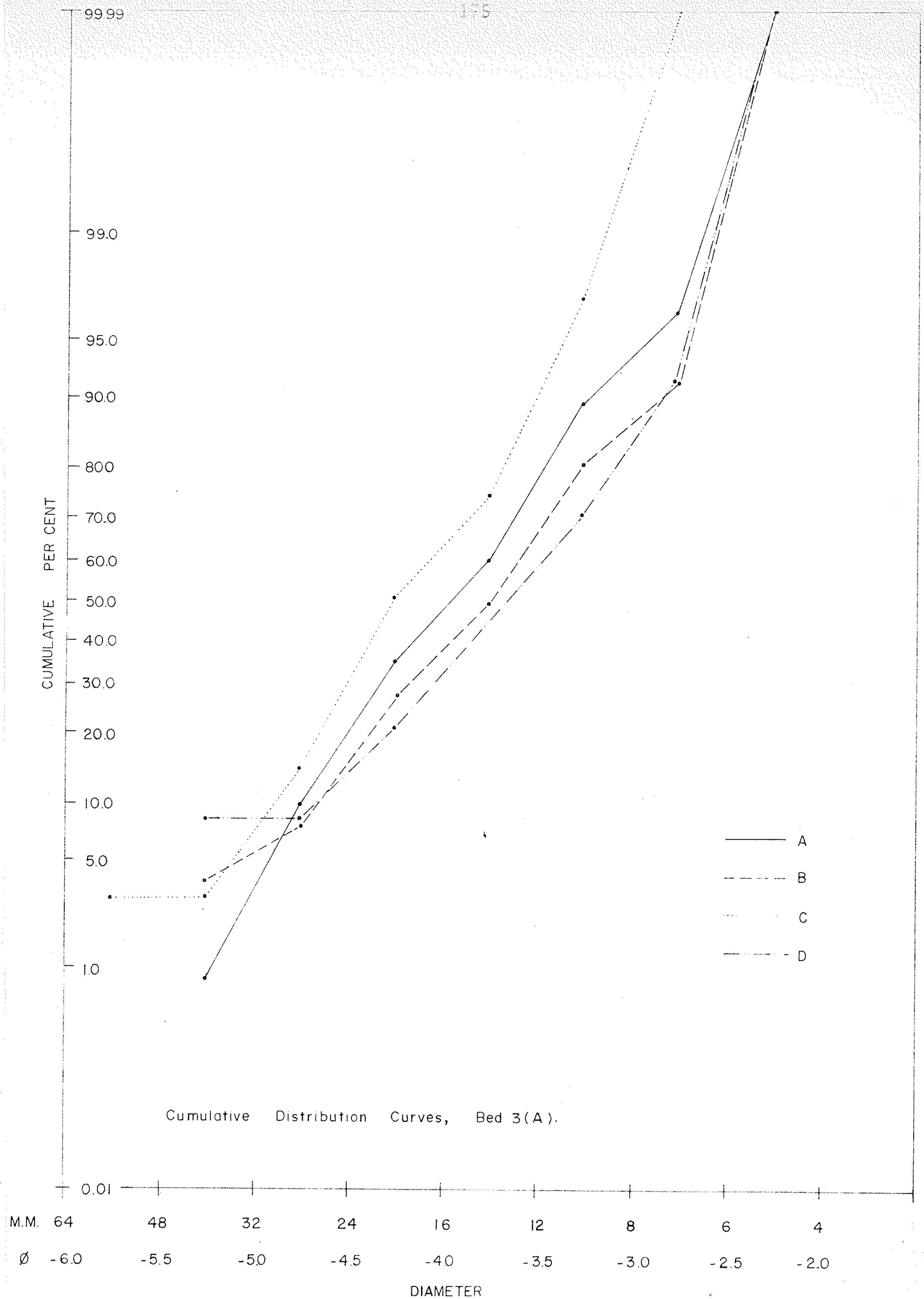
Cumulative Distribution Curves, Bed I.



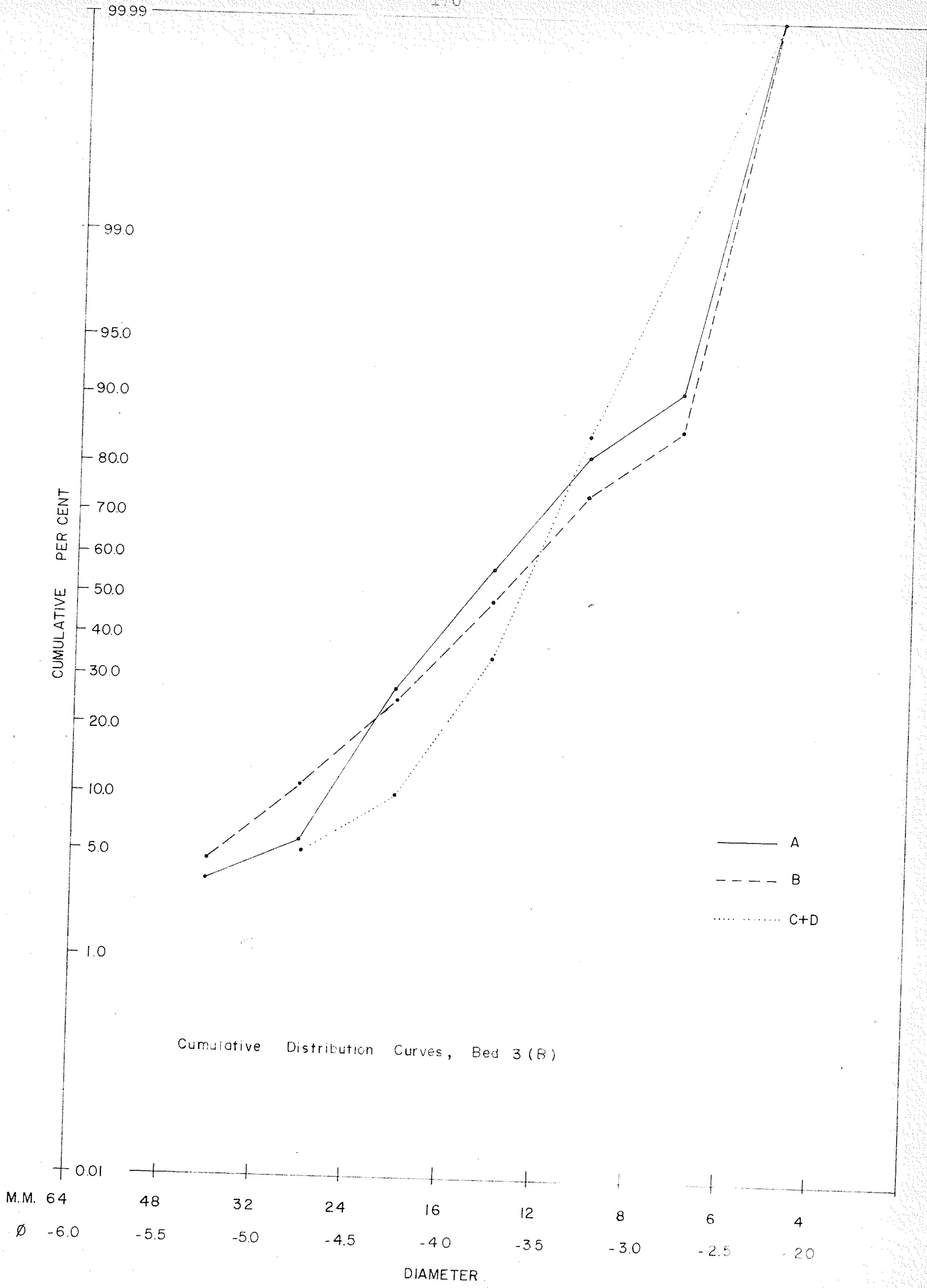
Cumulative Distribution Curves, Bed 2 (A).



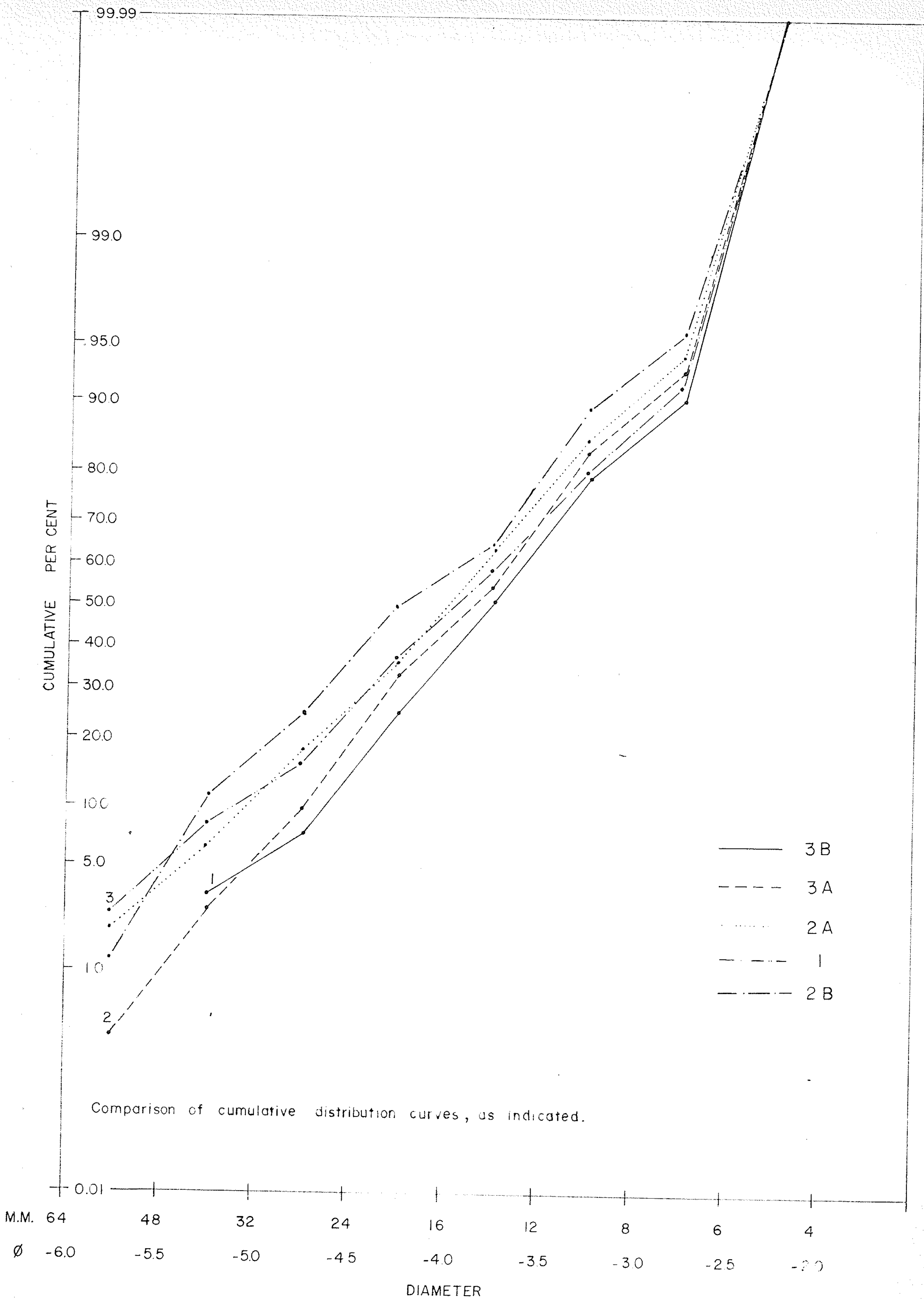
Cumulative Distribution Curves, Bed 2 (B)



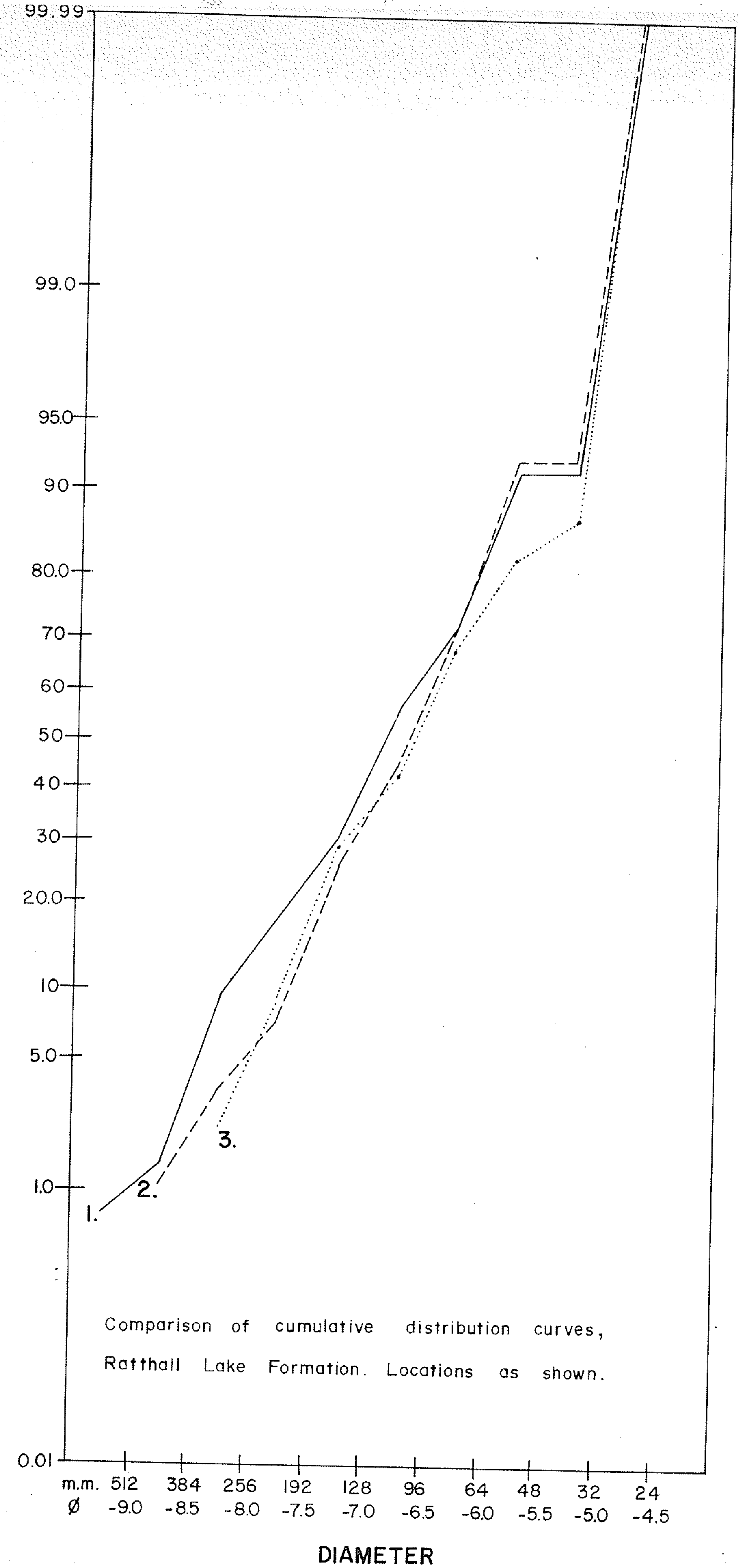
Cumulative Distribution Curves, Bed 3(A).



Cumulative Distribution Curves, Bed 3 (B)



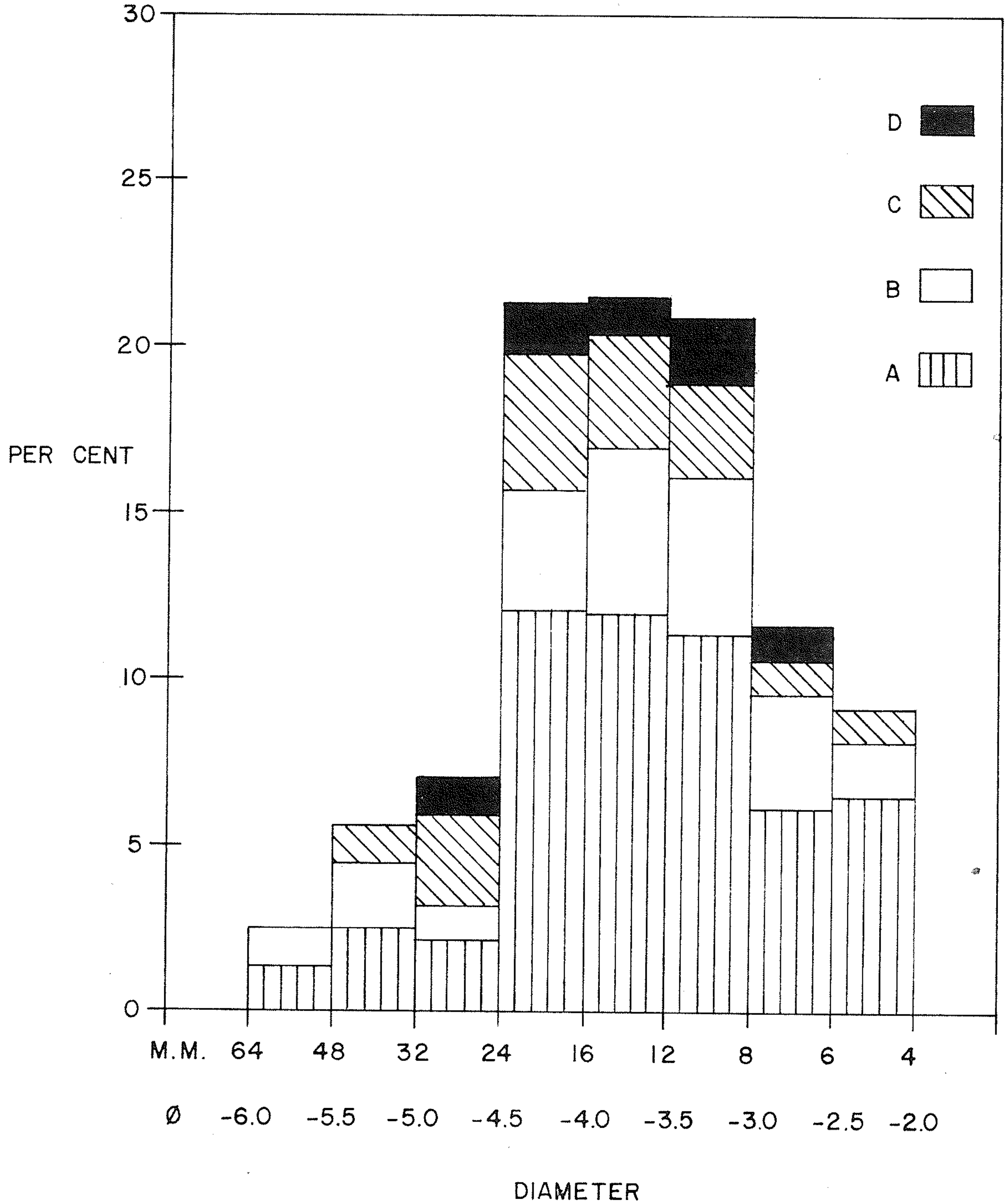
Comparison of cumulative distribution curves, as indicated.



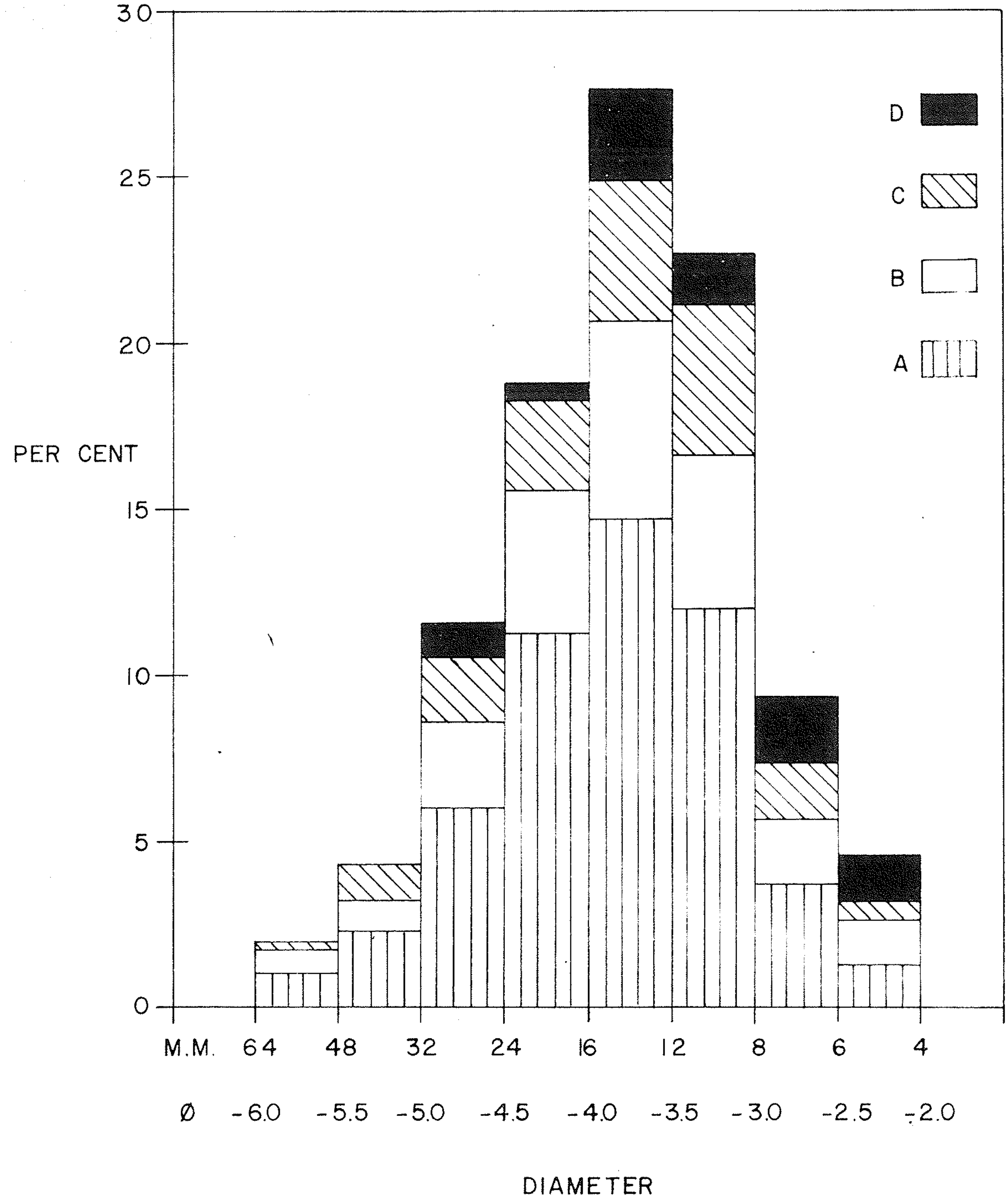
Comparison of cumulative distribution curves, Ratthall Lake Formation. Locations as shown.

APPENDIX 2

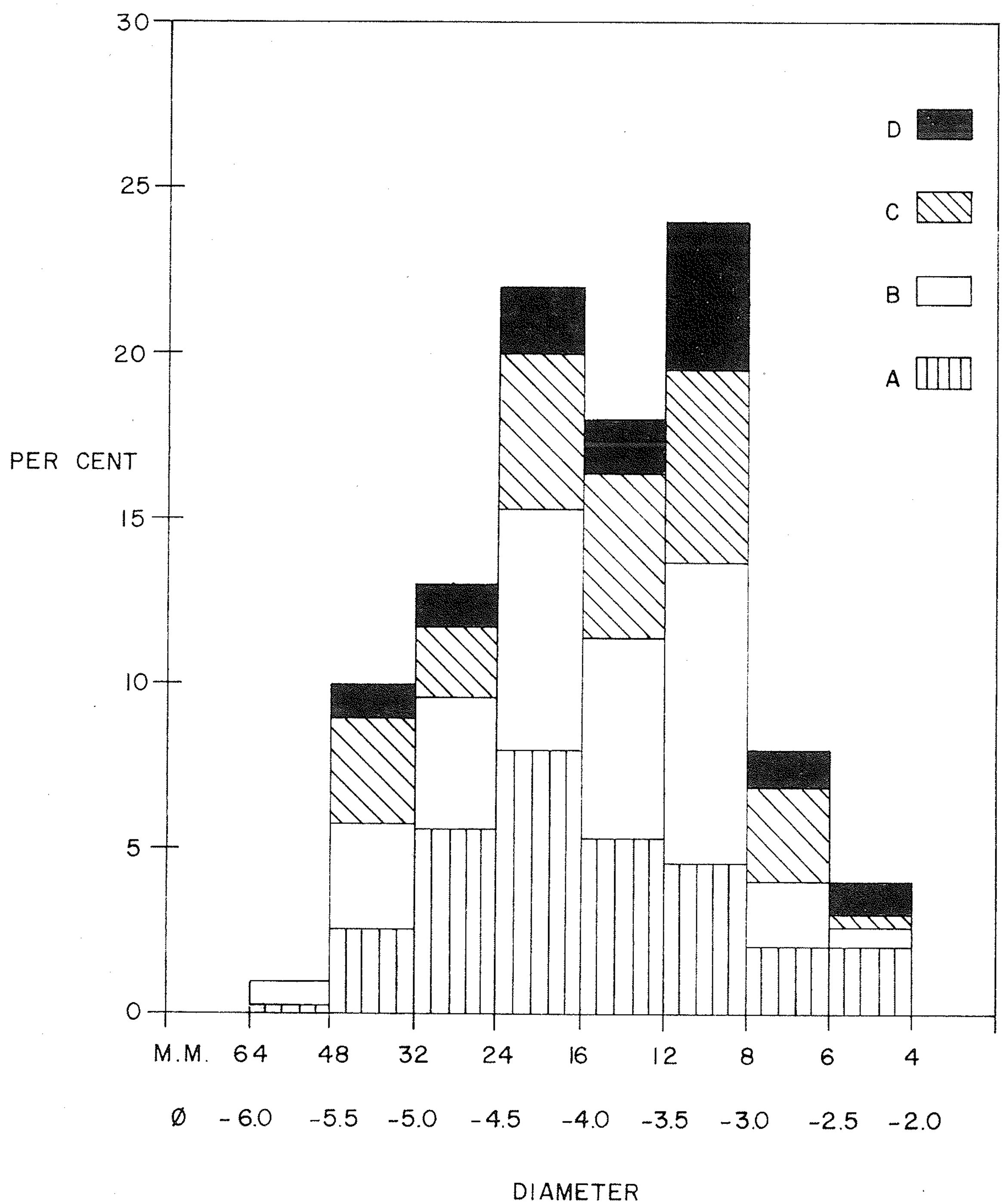
LITHOLOGICALLY DIVIDED HISTOGRAMS OF CONGLOMERATE SAMPLES



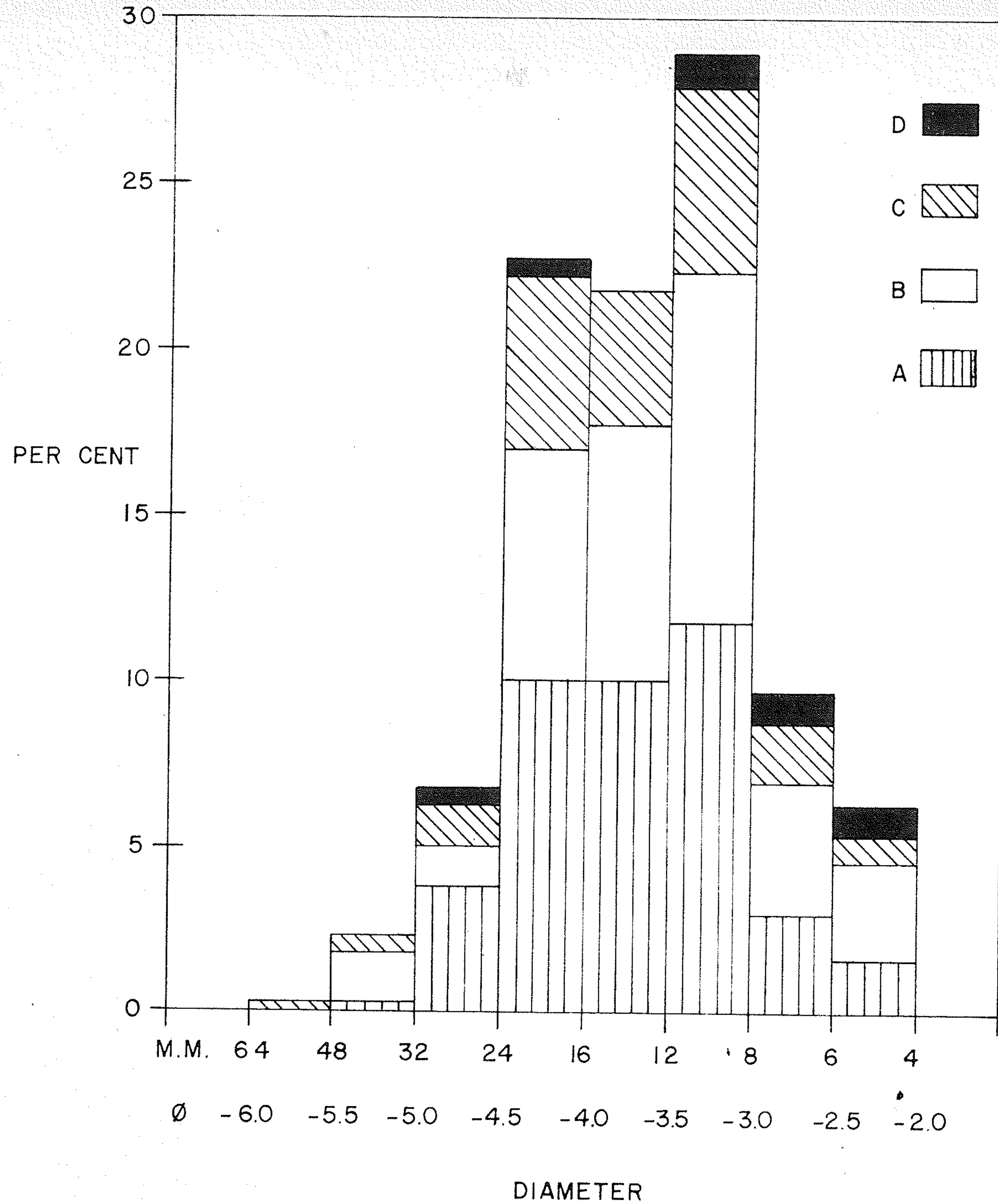
Lithologically Divided Histogram, Bed I.



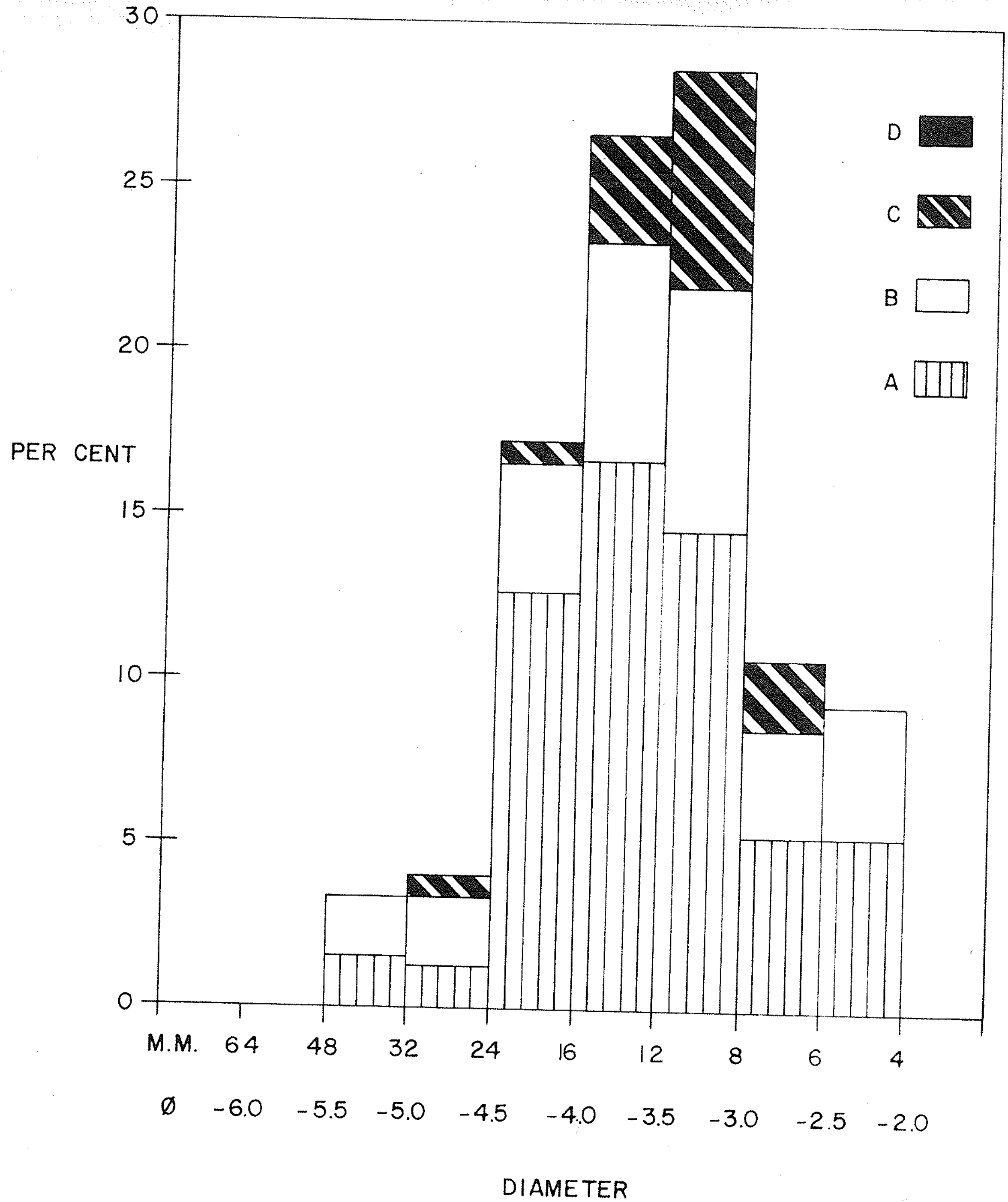
Lithologically Divided Histogram, Bed 2 (A).



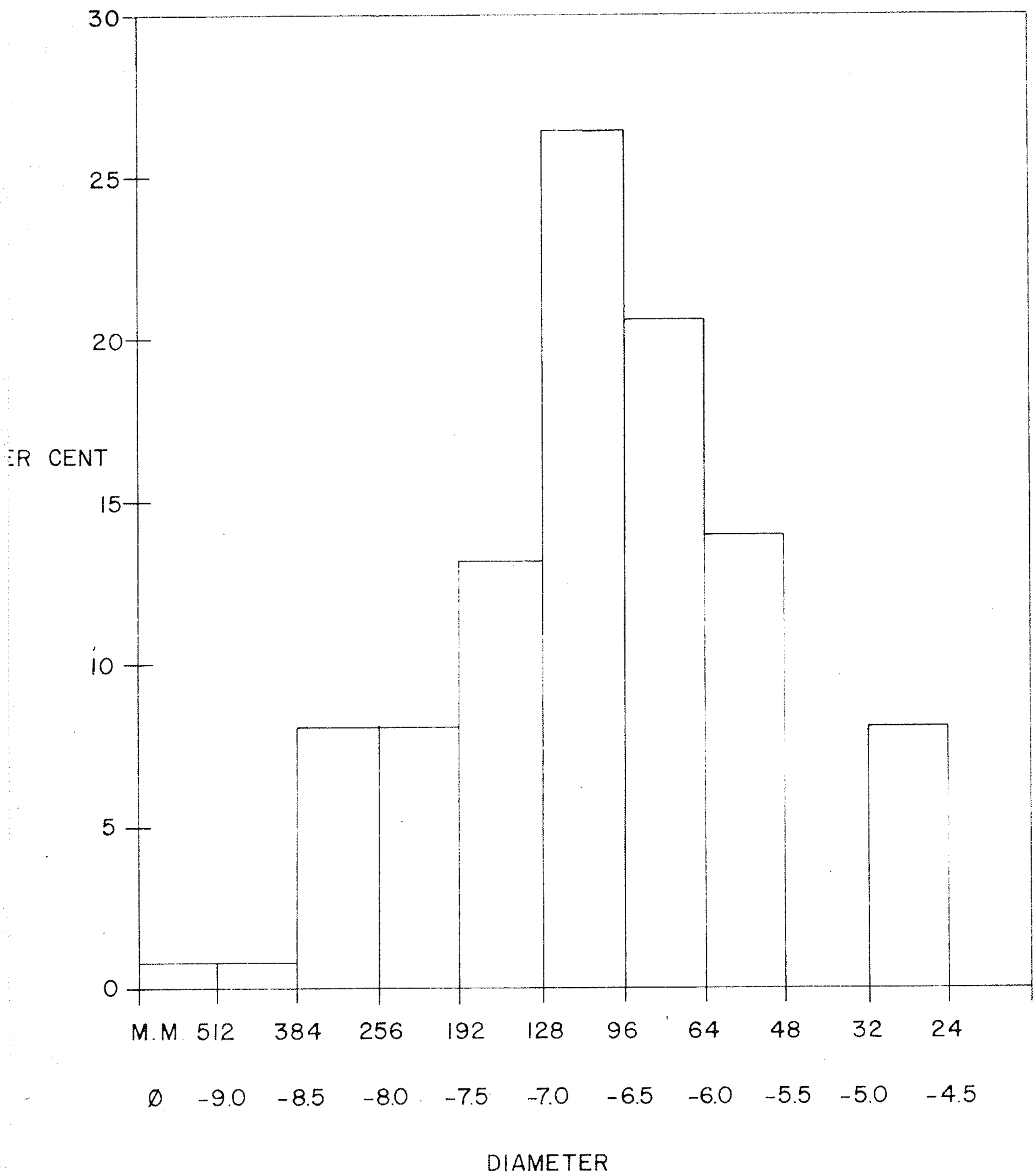
Lithologically Divided Histogram , Bed 2 (B)



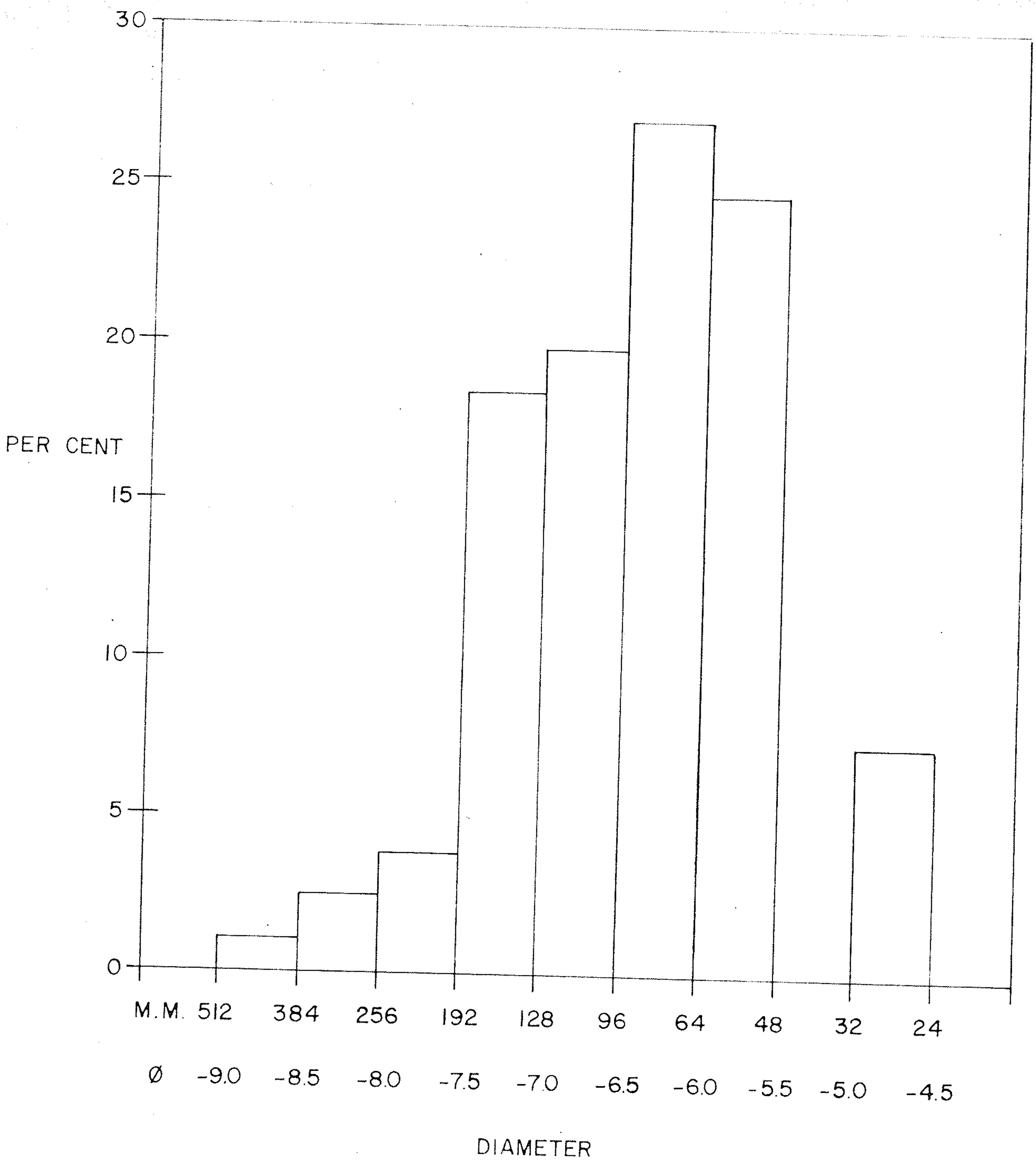
Lithologically Divided Histogram, Bed 3(A).



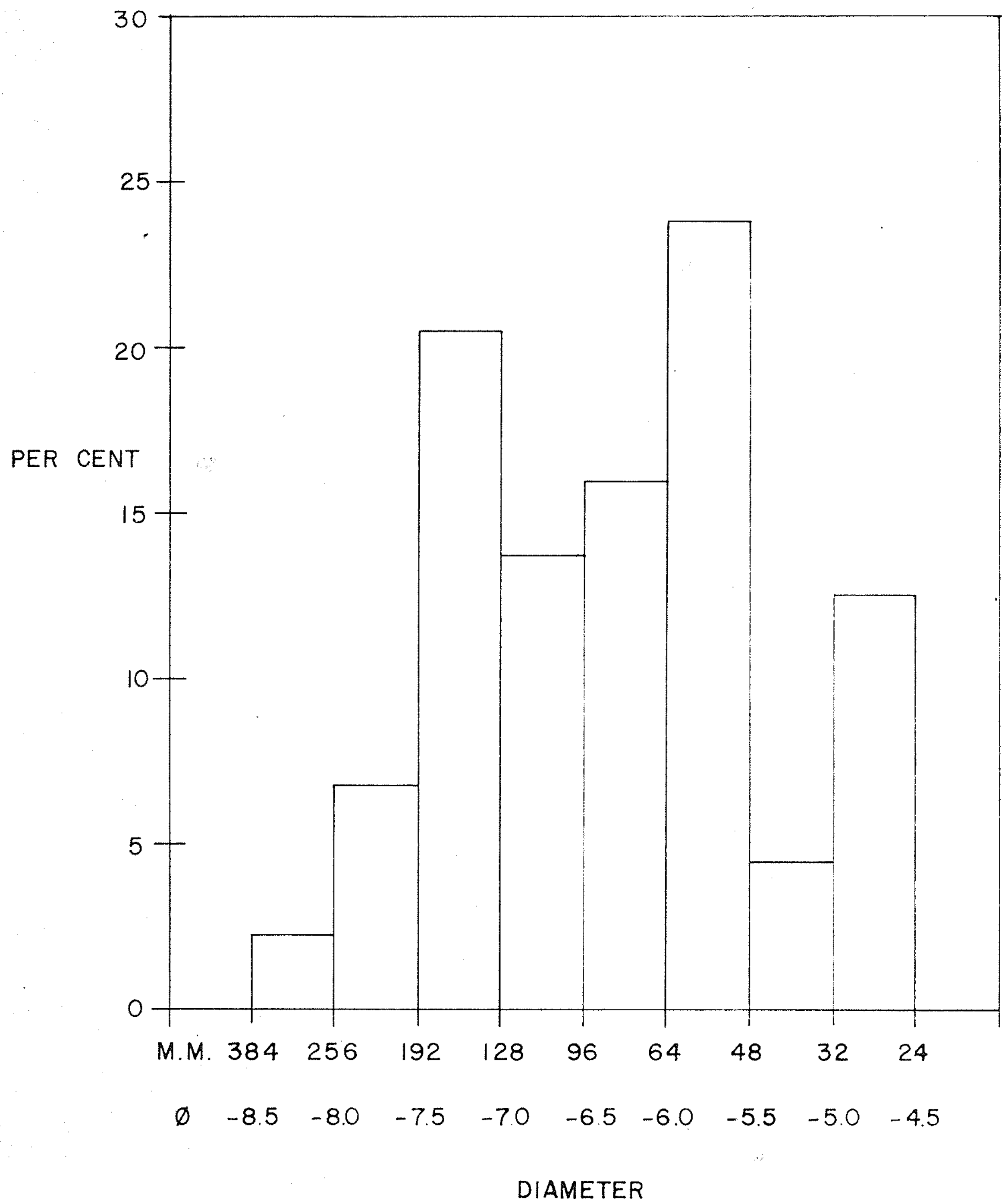
Lithologically Divided Histogram, Bed 3 (B).



Histogram , Location I , Rathall Lake Formation .



Histogram, Location 2 , Rathall Lake Formation.



Histogram, Location 3, Rathall Lake Formation.

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REA .

KE - TINNEY LAKE AR

ND

Glacial till and undifferentiated drift.

nformity

ntrusive Rocks.

orphyry and quartz porphyry dykes.

OGY OF THE DOVE LA

LEGE

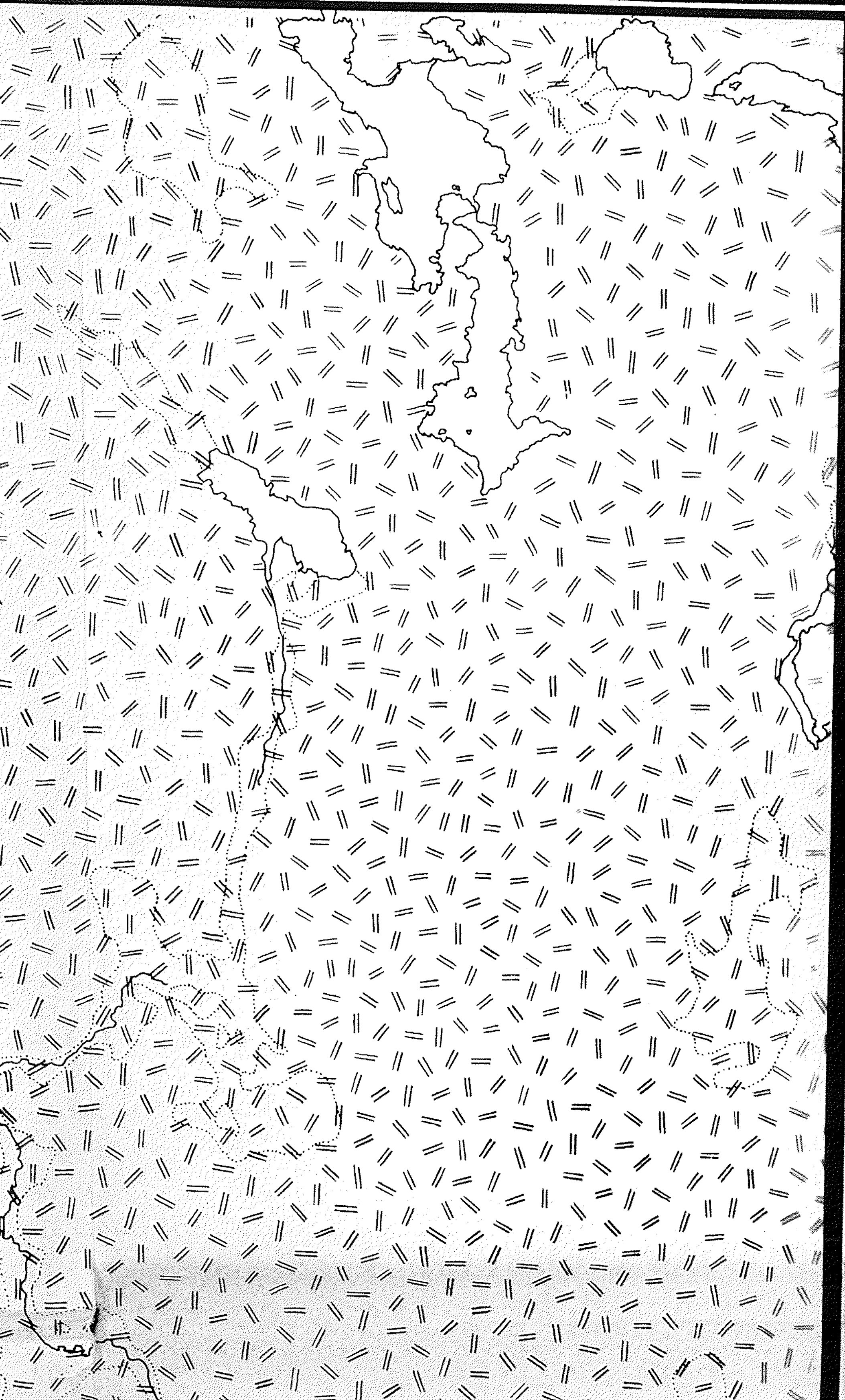
PLEISTOCENE AND RECENT :

Great Unco

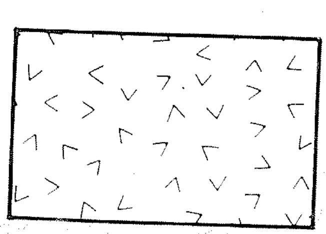
PRECAMBRIAN

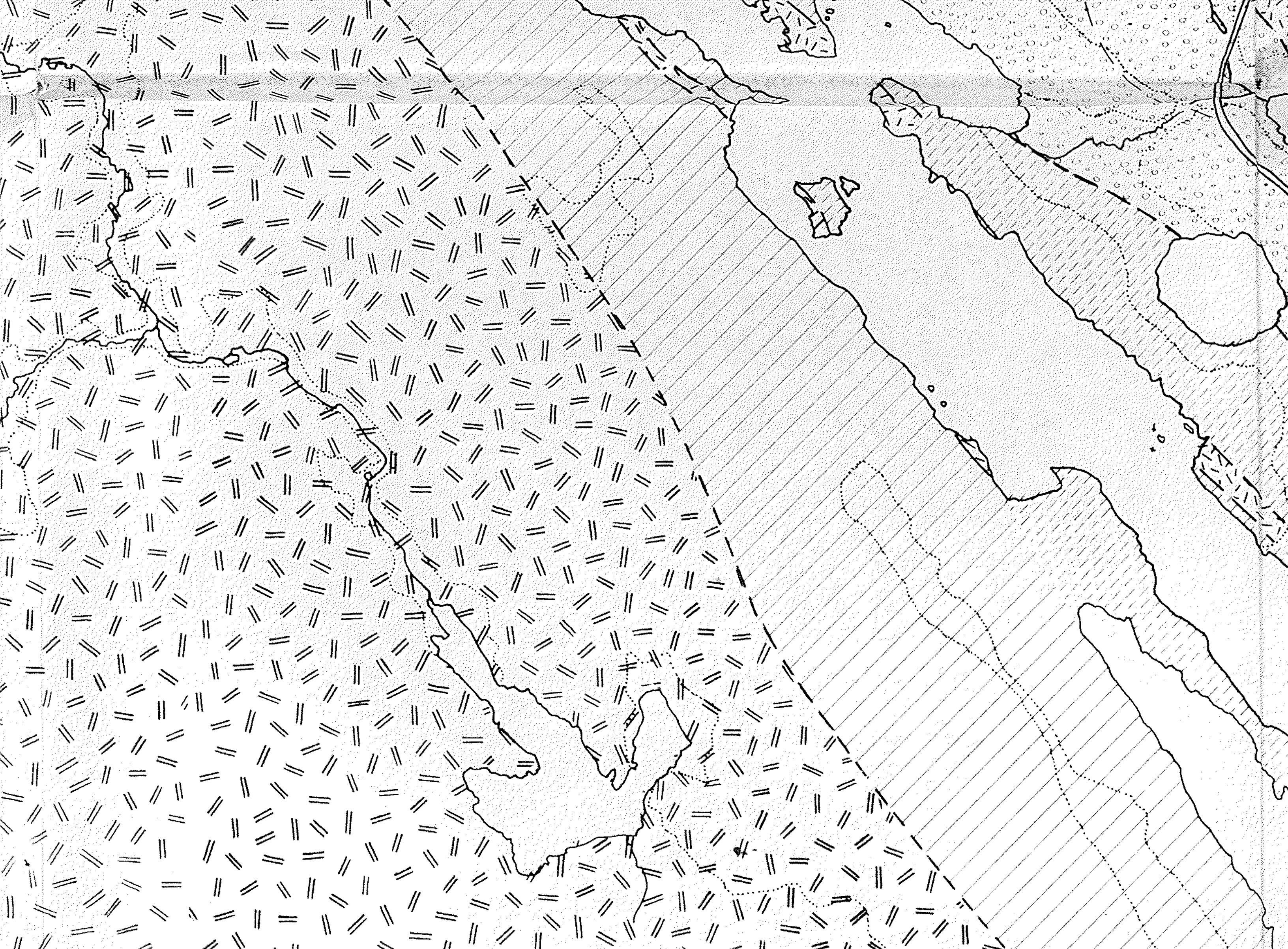
Post - Rice Lake Group I

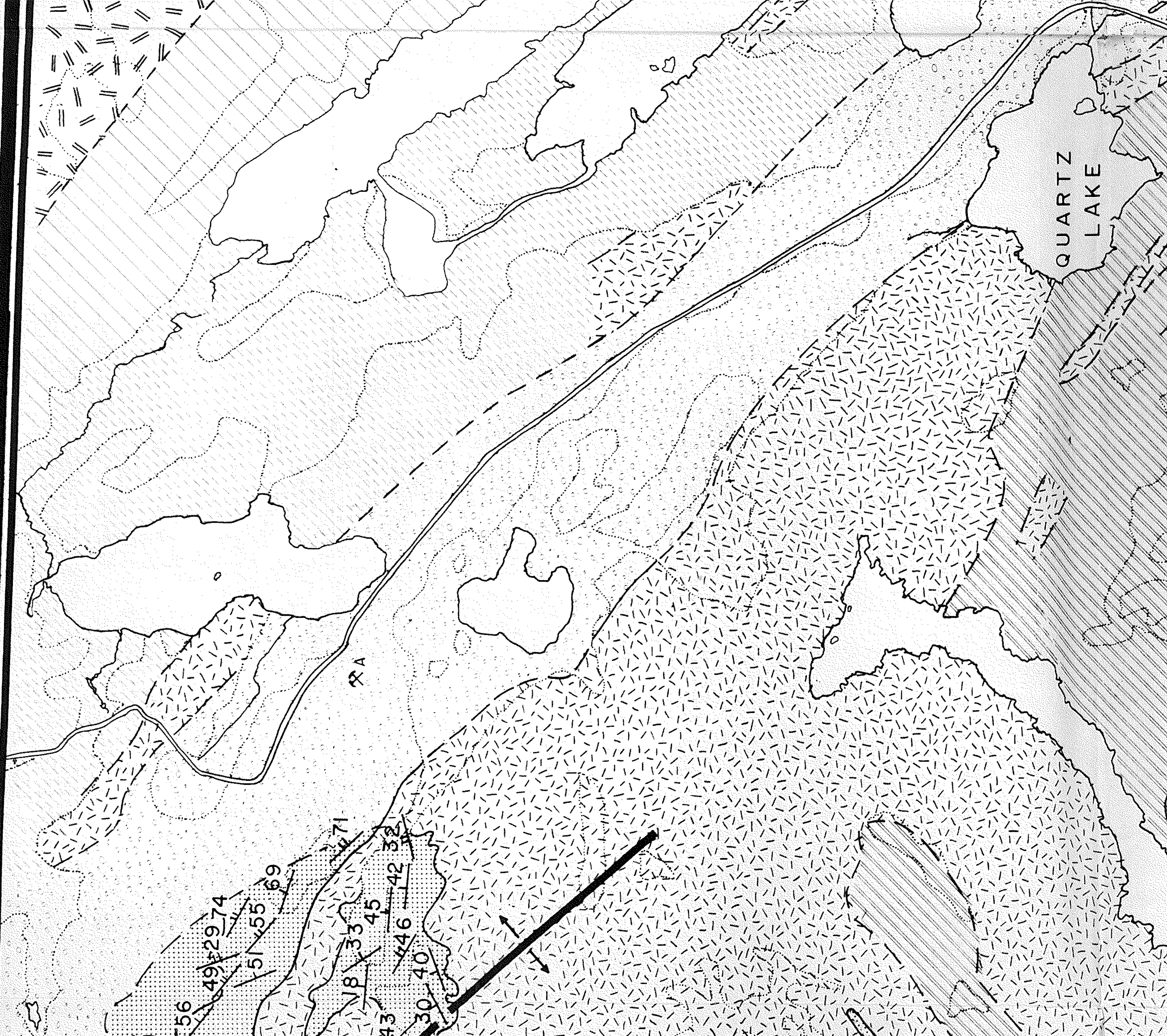
Diorite , quartz diorite , quartz feldspar p



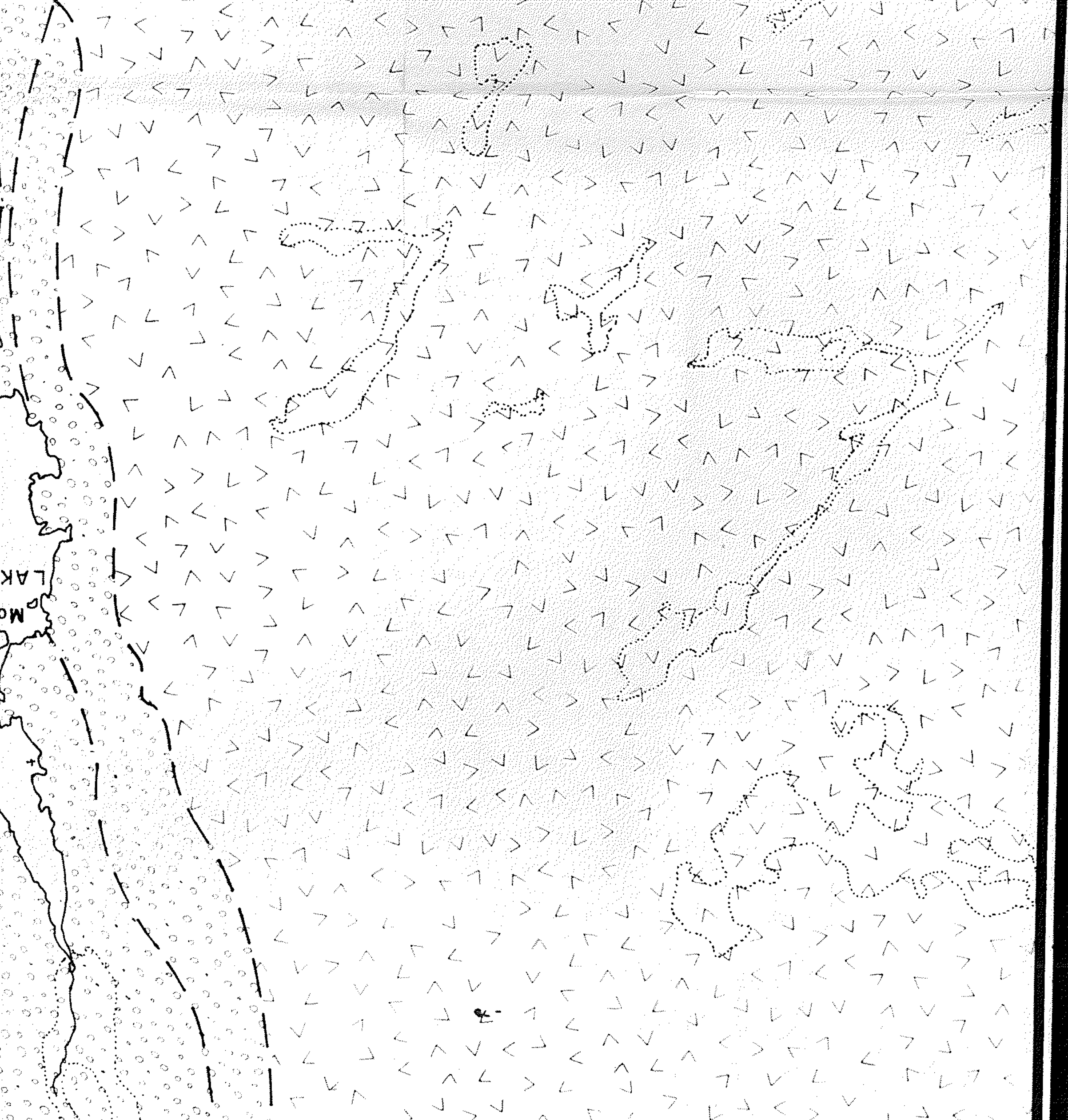
GEOLO






QUARTZ LAKE


McLEOD LAKE
McLEOD LAKE EAST



it , feldspathic greywacke ,

and iron formation .

eldspathic greywacke .

ontrolled .

aphic position unclear). Conglomerate , grit , felds

c greywacke , siltstone , minor conglomerate and

glomerate , welded acidic tuff , minor feldspathi

Granite , granodiorite .

Gabbro , frequently magnetic , fault - contr

Gabbro , as sills and small dykes .

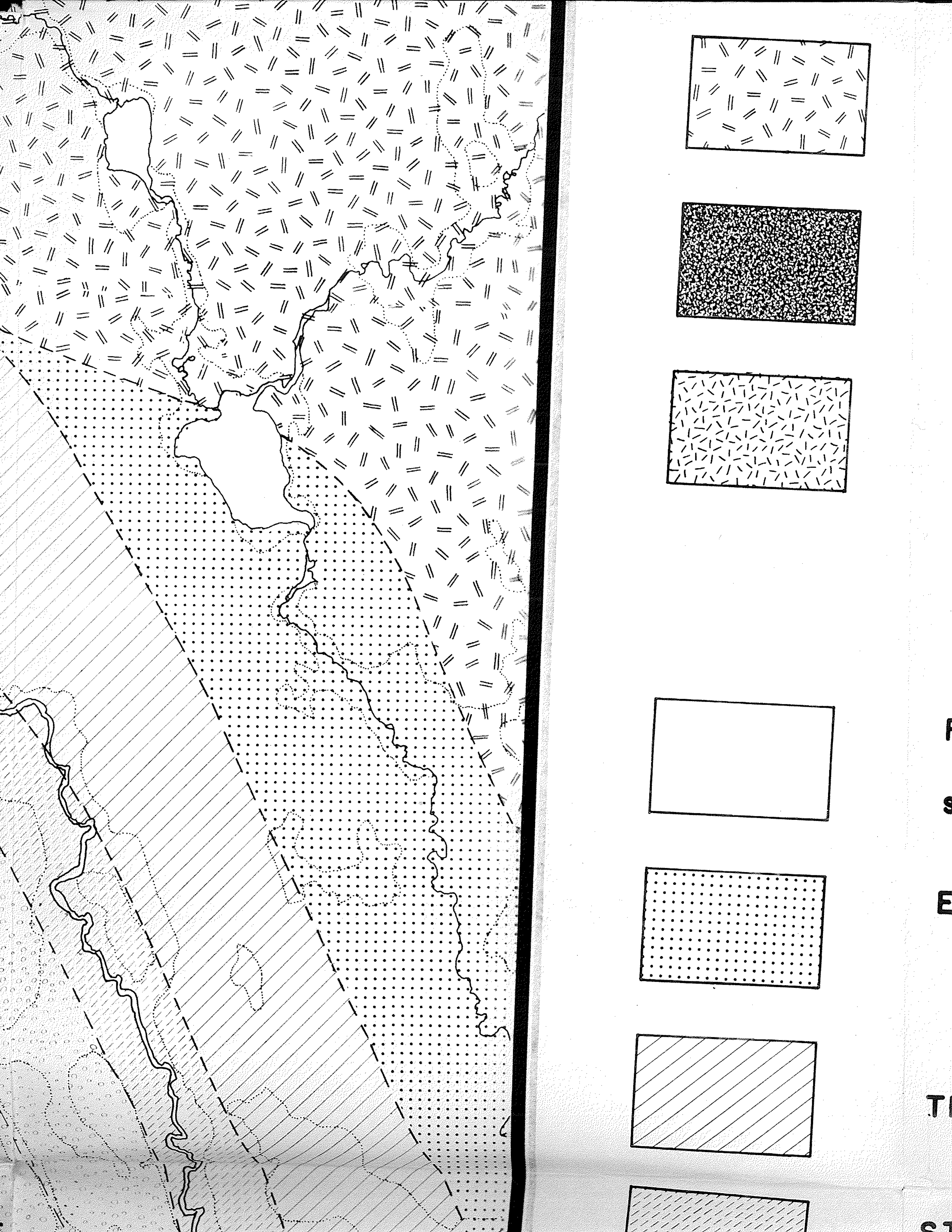
Rice Lake Group

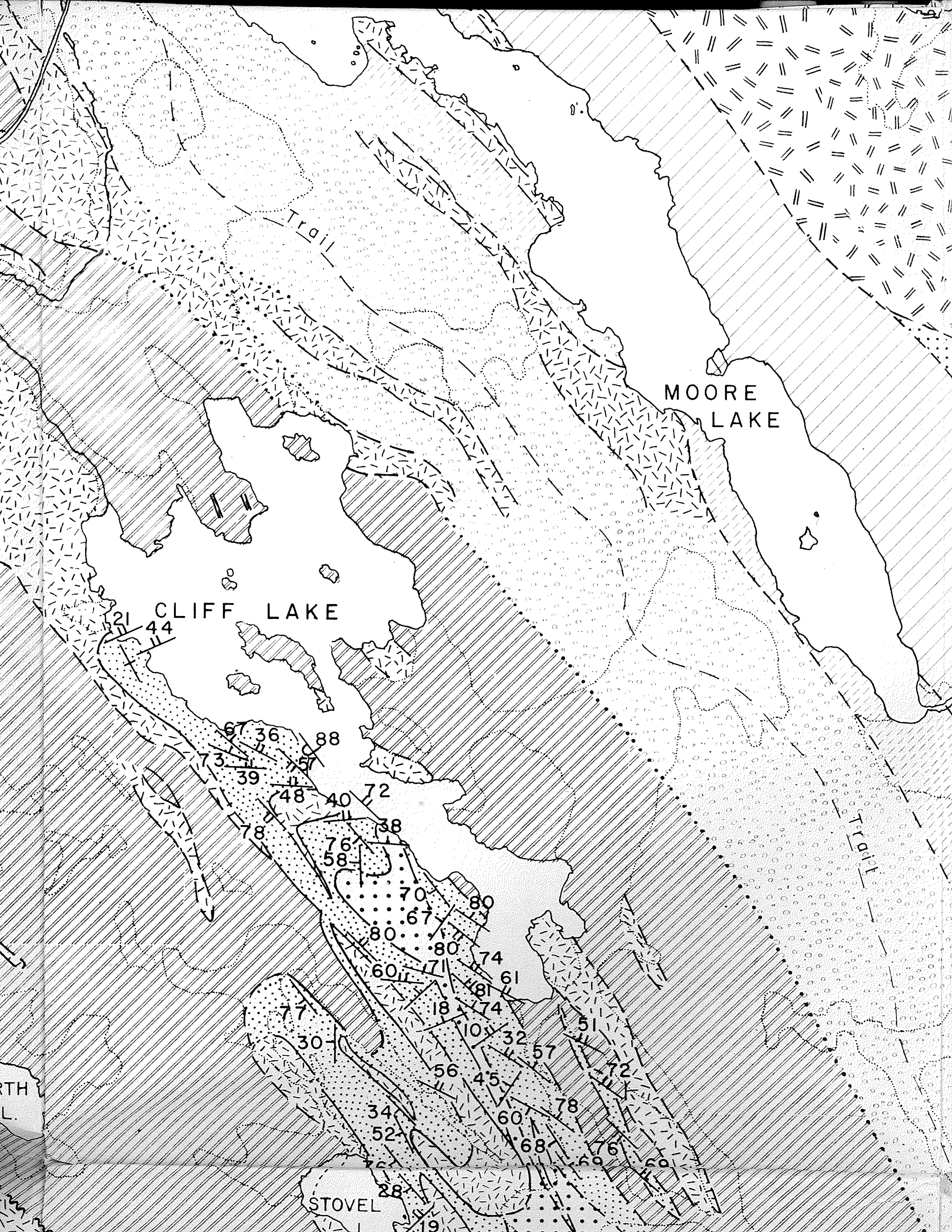
RATHALL LAKE FORMATION : (Stratigraphi
siltstone , chert .

EDMUNDS LAKE FORMATION : Feldspathic g

THE NARROWS FORMATION : Volcanic agglome

STORMY LAKE FORMATION





MOORE
LAKE
CLIFF LAKE
Trail
Trail
STOVEL
RTH
L.
21
44
67
36
88
73
39
57
48
40
72
38
78
76
58
70
80
67
80
80
74
71
60
61
81
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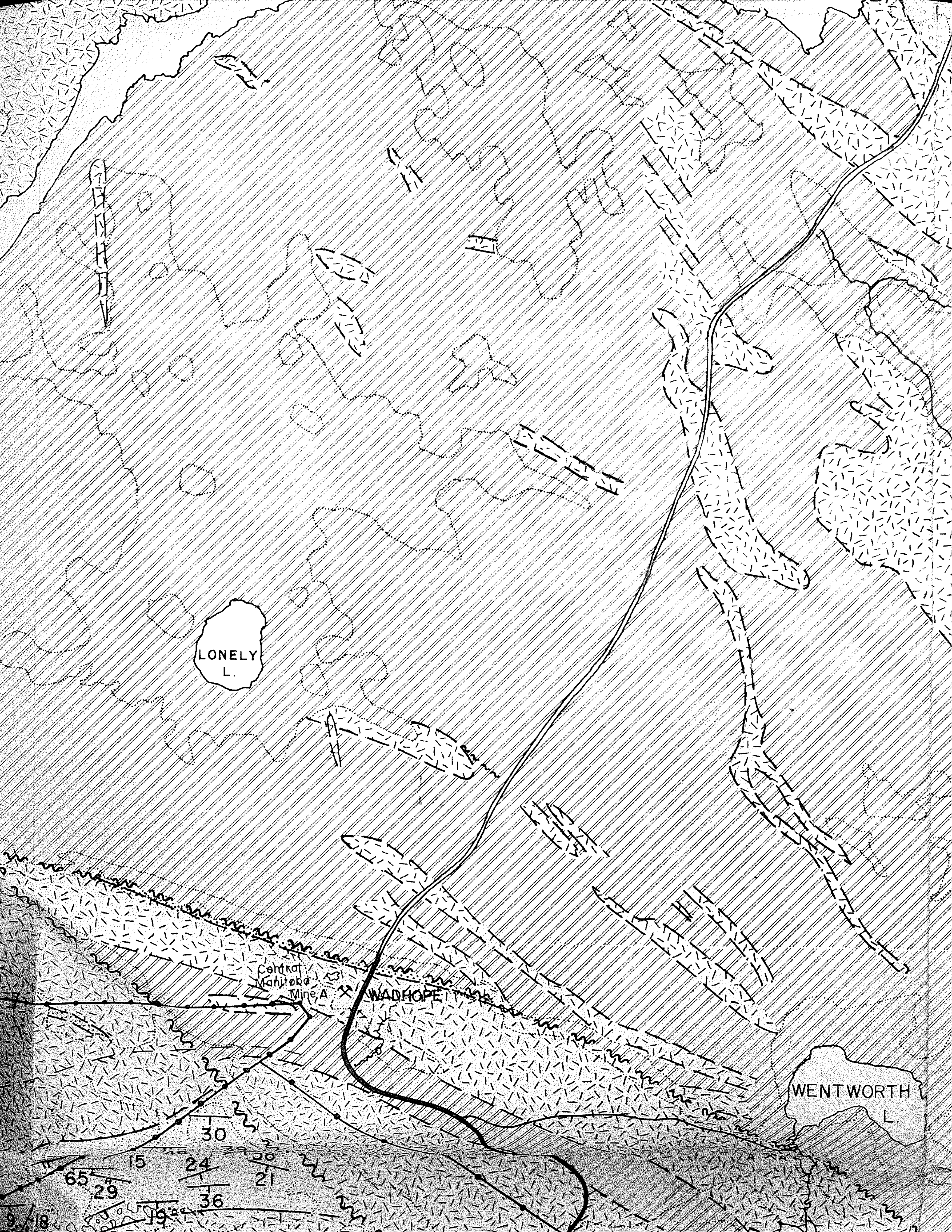
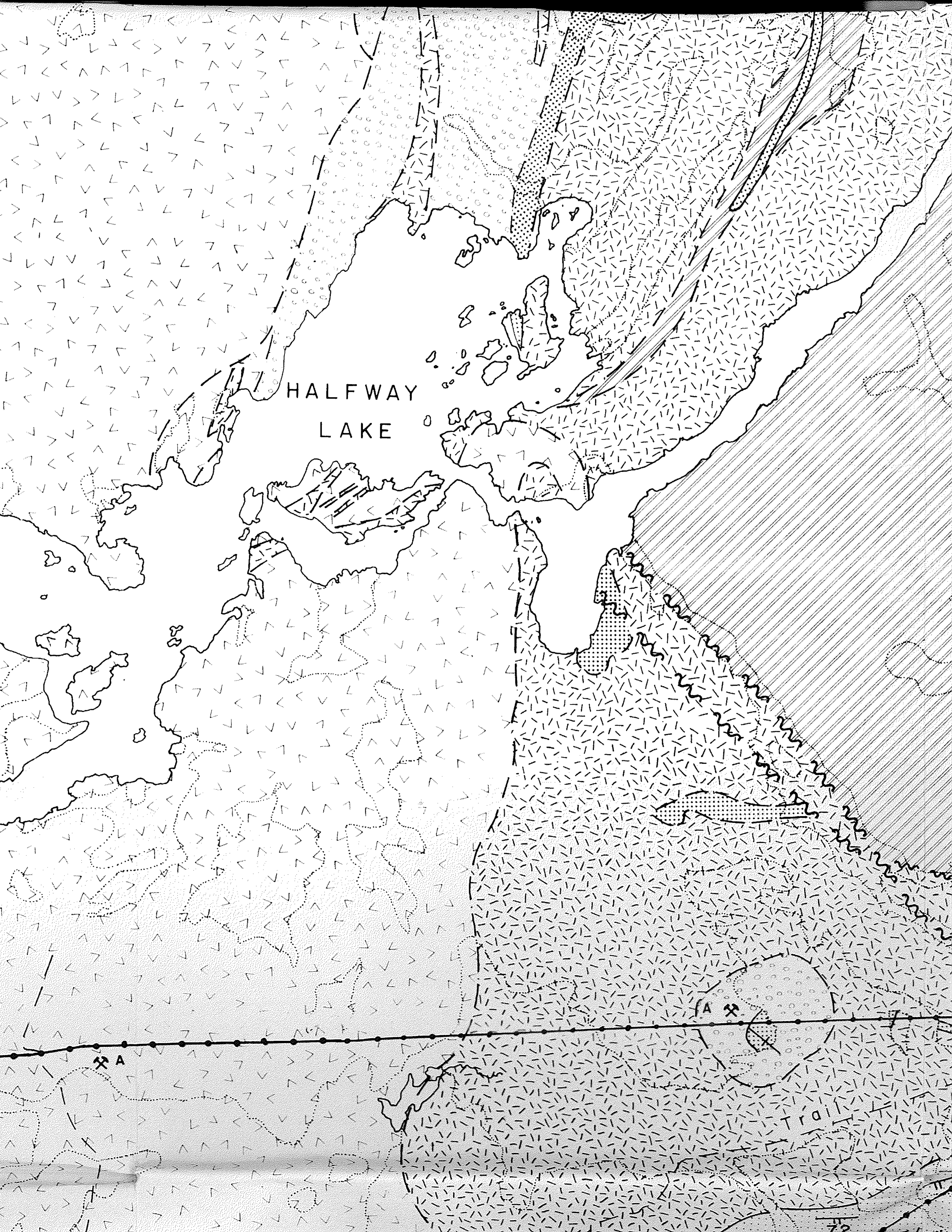
19



LONELY
L.
Central
Manitoba
Mine A
WADHOPE
WENTWORTH
L.
30
15
24
21
36
65
29
19


HALFWAY
LAKE
A
A
Tra


HALFW
LAKE
A

ation. Minor

Coarse greywacke,

cies).

s of feldspathic

liff Lake.

ies); Coarse

al facies).

of feldspathic

c greywacke , siltstone , chert , iron formation .

ive basalt , locally vesicular .

eywacke , siltstone , chert (Distal facies) ; Coarse
nglomerate , breccia , grit (Proximal facies) .

massive basalt . Minor thin intercalations of
amount of unnamed basalt north of Cliff L

c greywacke , siltstone , chert (Distal facies) ;
al facies) ; breccia , agglomerate (Proximal faci

pillowed basalt , includes minor thin horizons of fel

S

STORMY LAKE FORMATION : Feldspatic gr
conglomerate and massive basalt .

GUNNAR FORMATION : Pillowed and massive

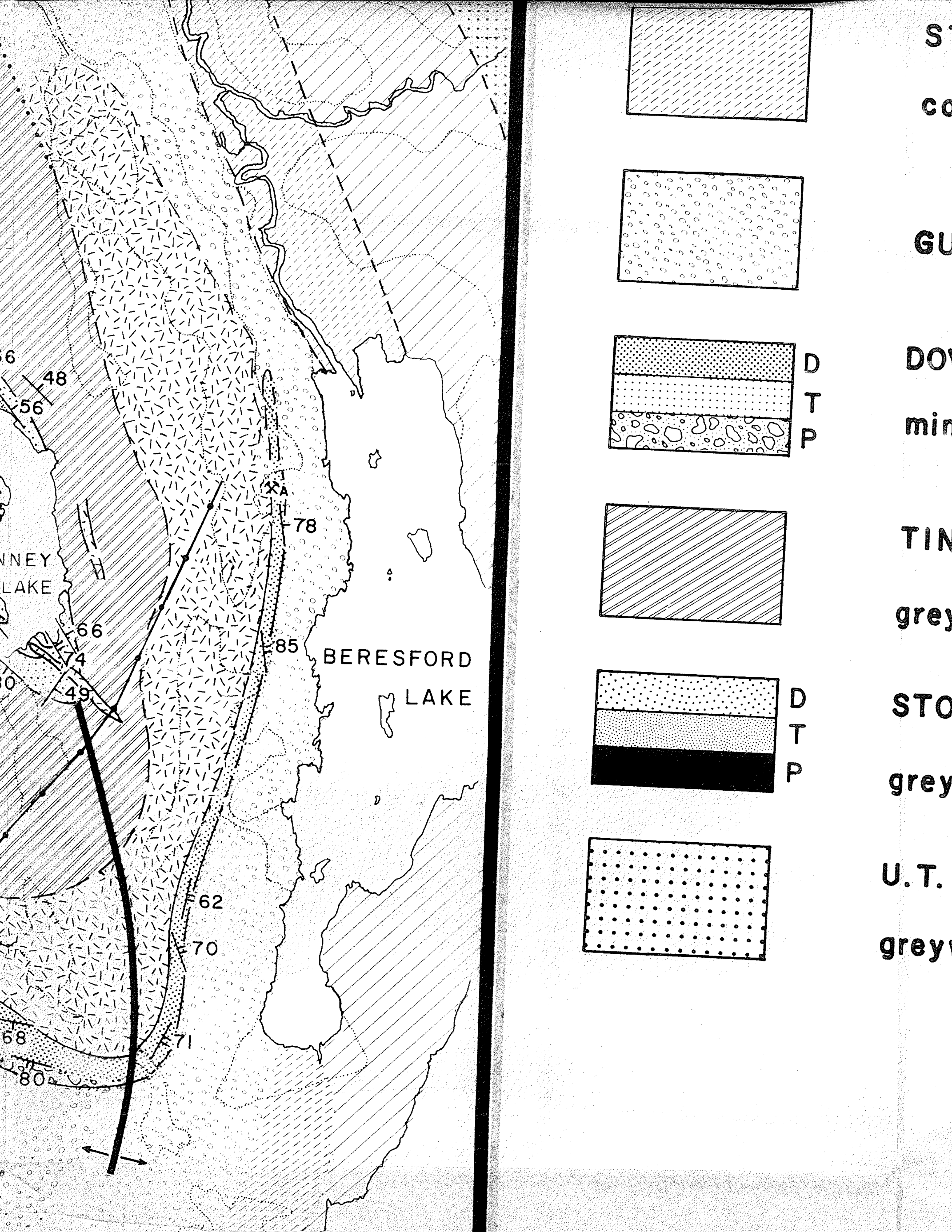
DOVE LAKE FORMATION : Feldspathic greywac
minor siltstone (Transitional facies); Conglom

TINNEY LAKE FORMATION : Pillowed and mas
greywacke and chert . Includes unknown amoun

STOVEL LAKE FORMATION : Feldspathic gr
greywacke , grit , minor siltstone (Transitional f

U.T. BASALT (Informal unit) : Massive and pillow
greywacke and chert.

SYMBOLS



NNEY
LAKE
BERESFORD
LAKE
48
56
78
66
74
49
85
62
70
71
68
80
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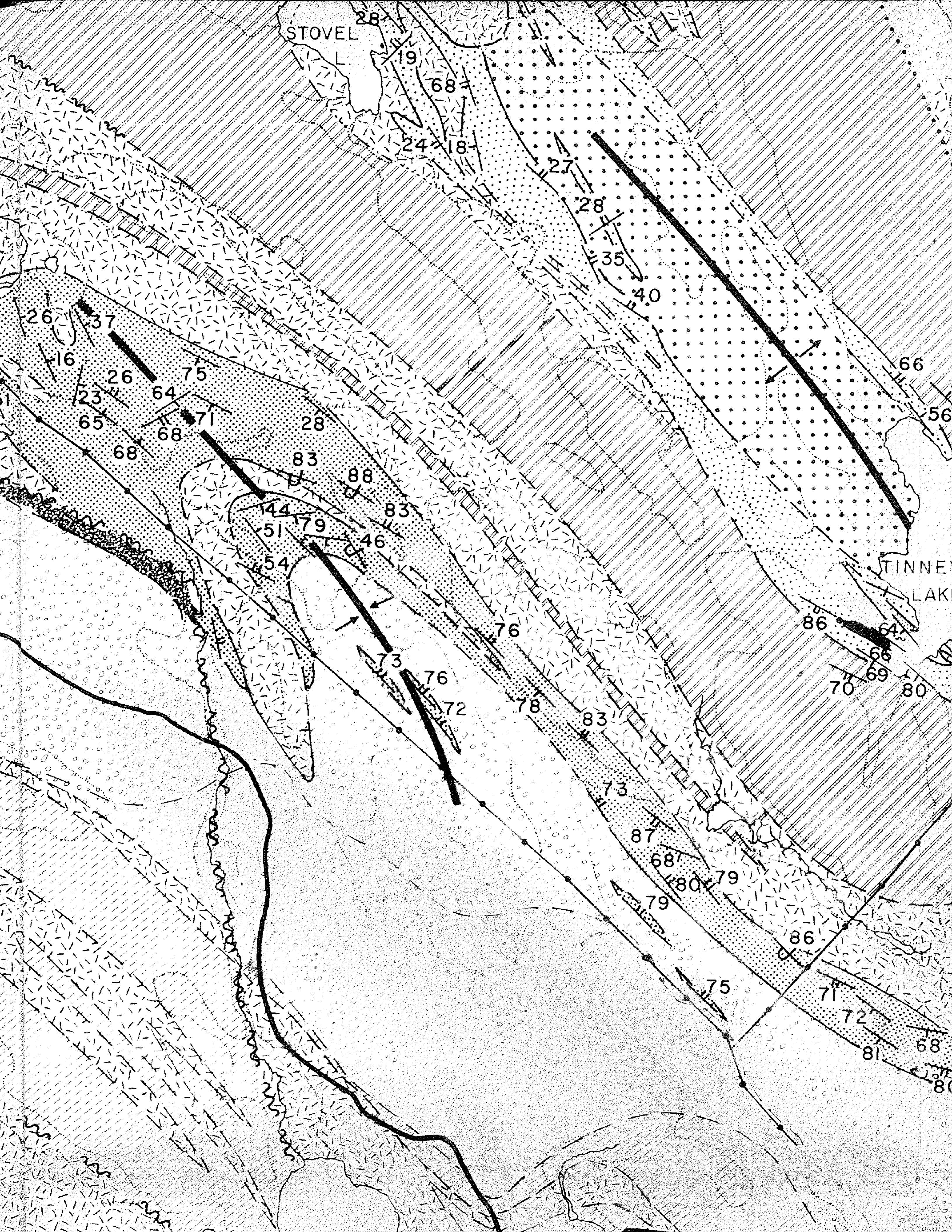
GU
DOV
min
TIN
grey
STO
grey
U.T.
greyw


STOVEL
L

DOVE
BIDOU LAKE
Trail
65
29
21
36
19
9
18
9
10
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51
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87
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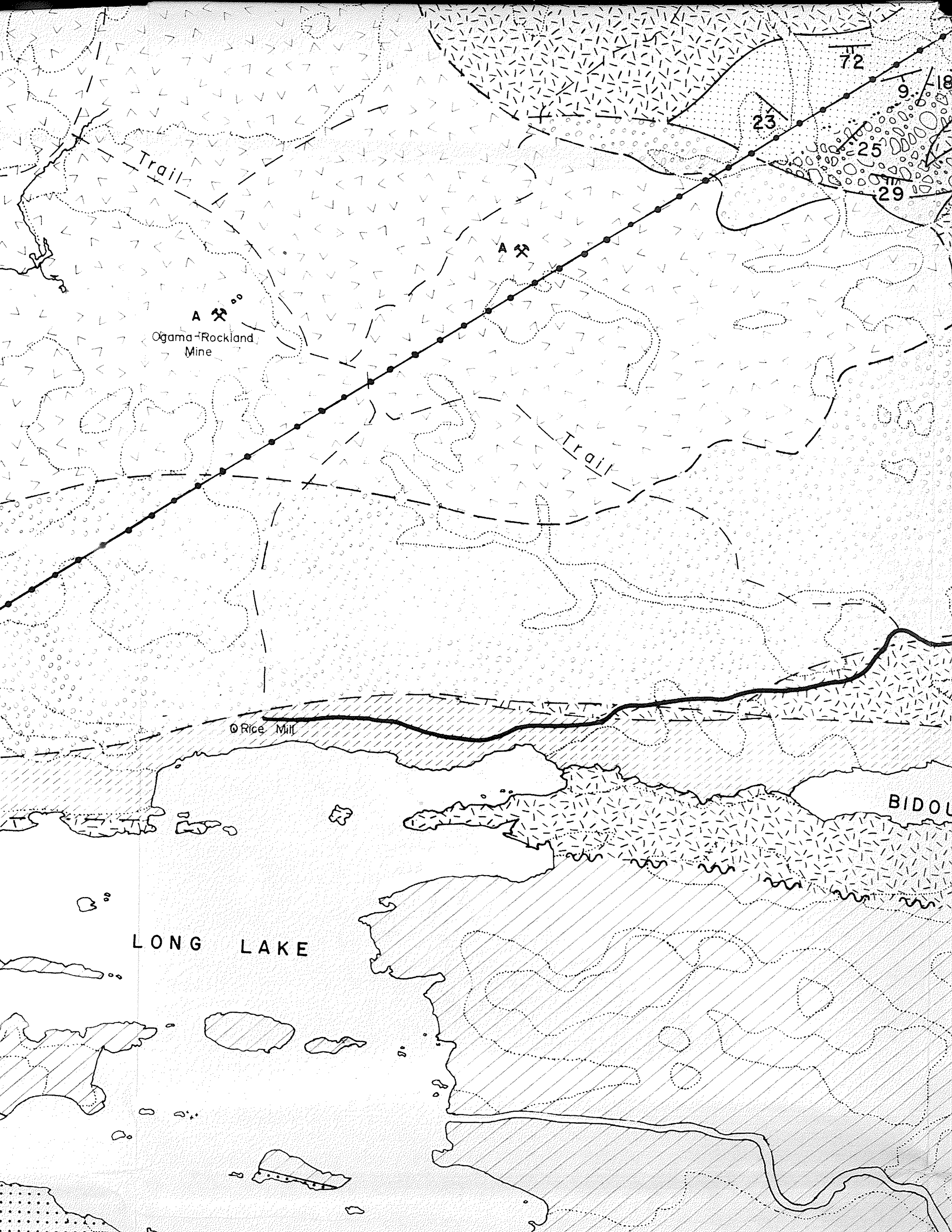
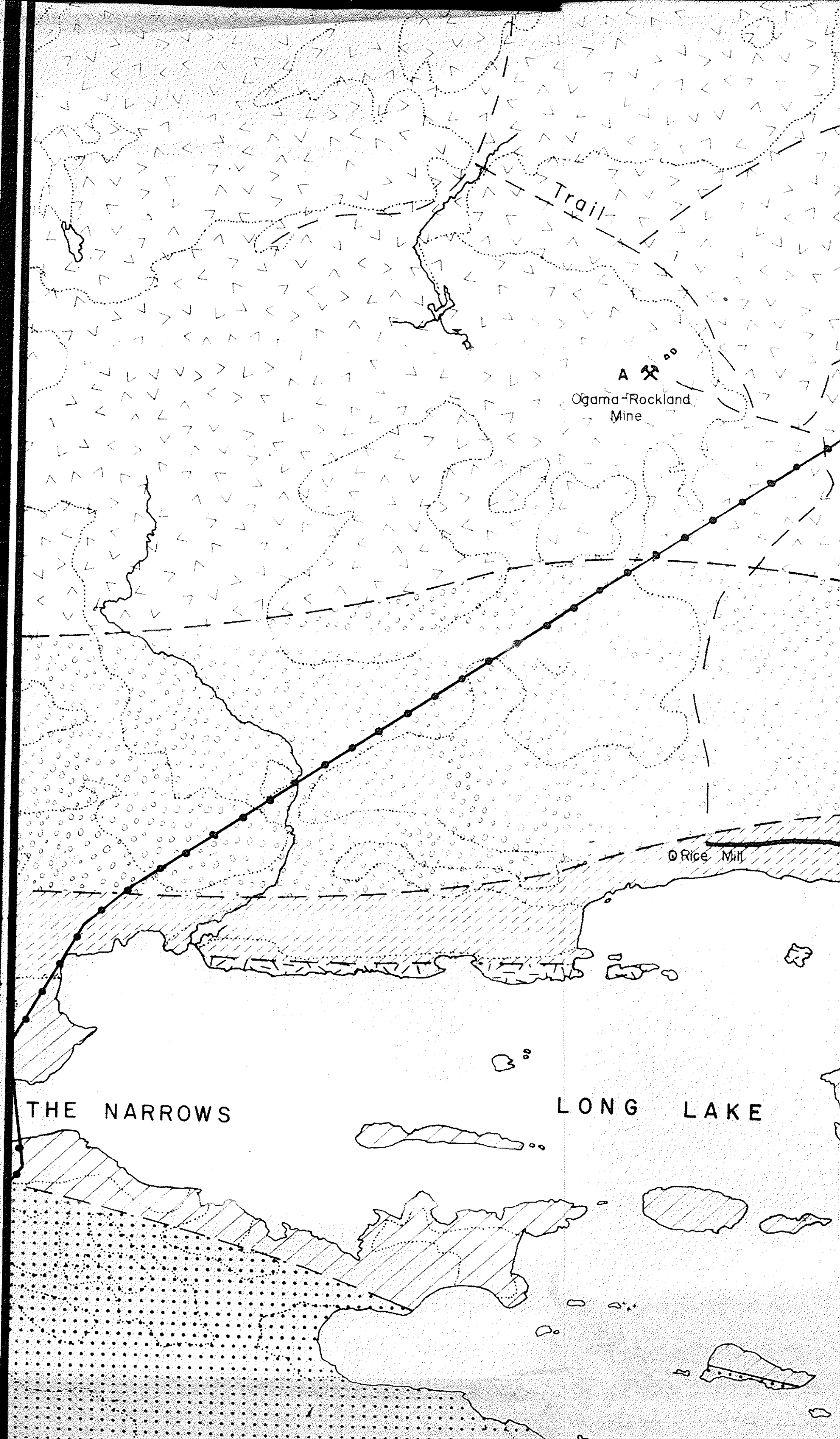
51



Trail
Ogama-Rockland
Mine
Trail
Rice Mill
BIDOU
LONG LAKE
72
9
18
23
25
29


Trail
A
Ogama-Rockland Mine
Rice Mill
THE NARROWS
LONG LAKE

) .

; vertical) .

Geology by: F.H.A. Campbell, R.F.J. Scoates,
W. Weber, 1967-68

ontact (defined , assumed , approximate).

clined - tops known , unknown , overturned ; vertical

ned).

operational , abandoned).

2

G

glomerate , welded acidic tuff , minor feldspath

77° 36° 60° Bedding (inclin

Geological cont

Fault.

Road

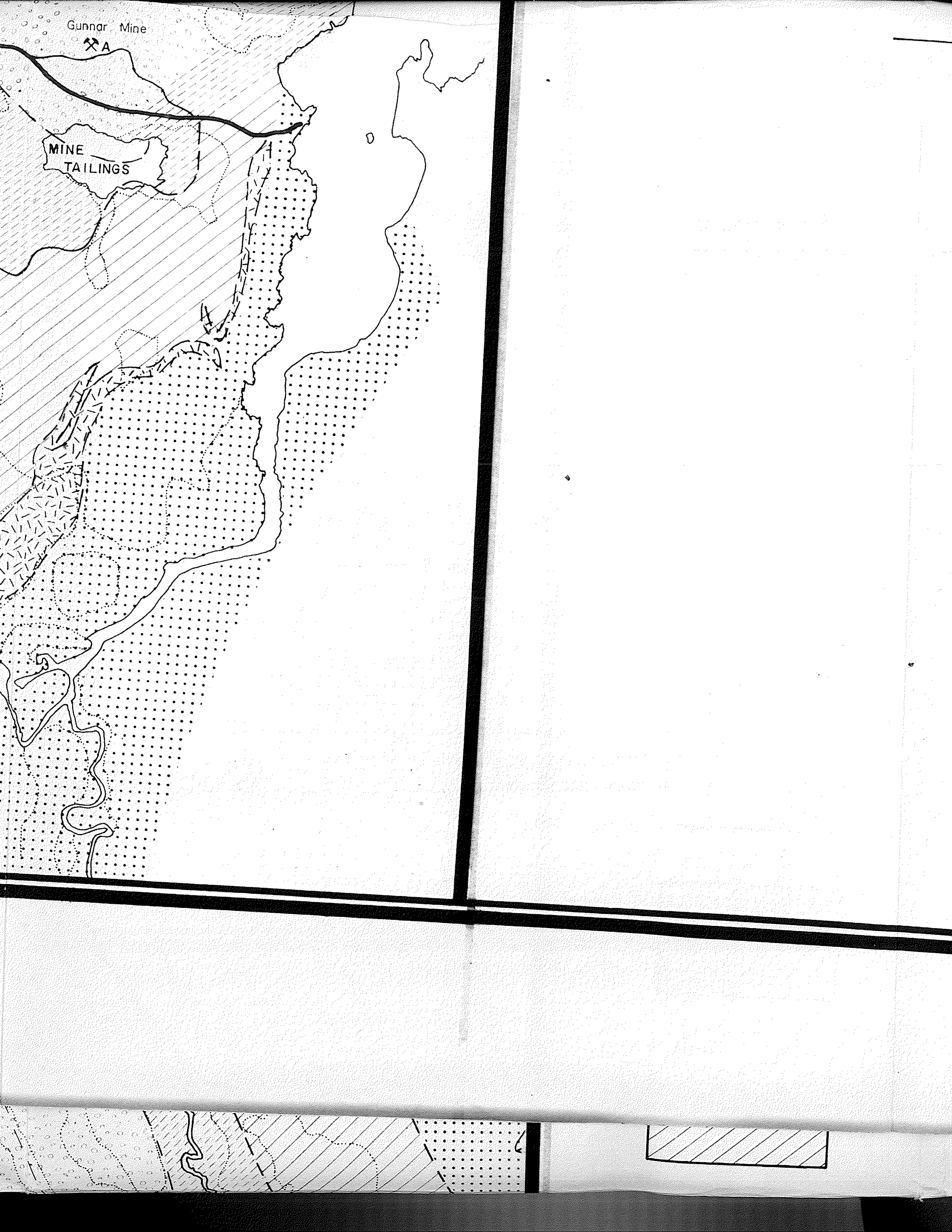
A Mine (abandoned

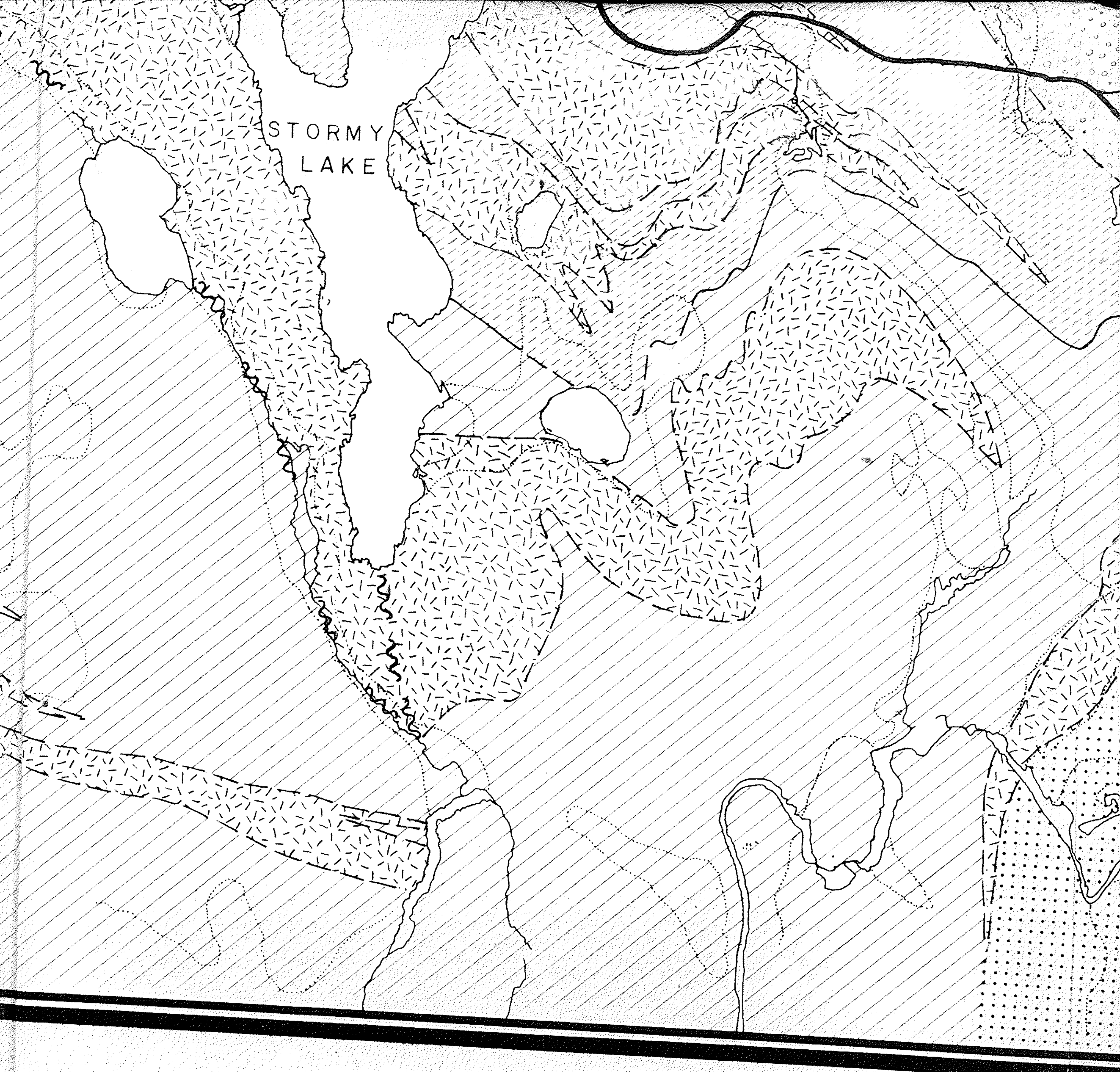
Power line (ope

SCALE

0 1/2 1 1/2 1

MILES


Gunnar Mine
A
MINE
TAILINGS


STORMY
LAKE


45
78
34
60
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76
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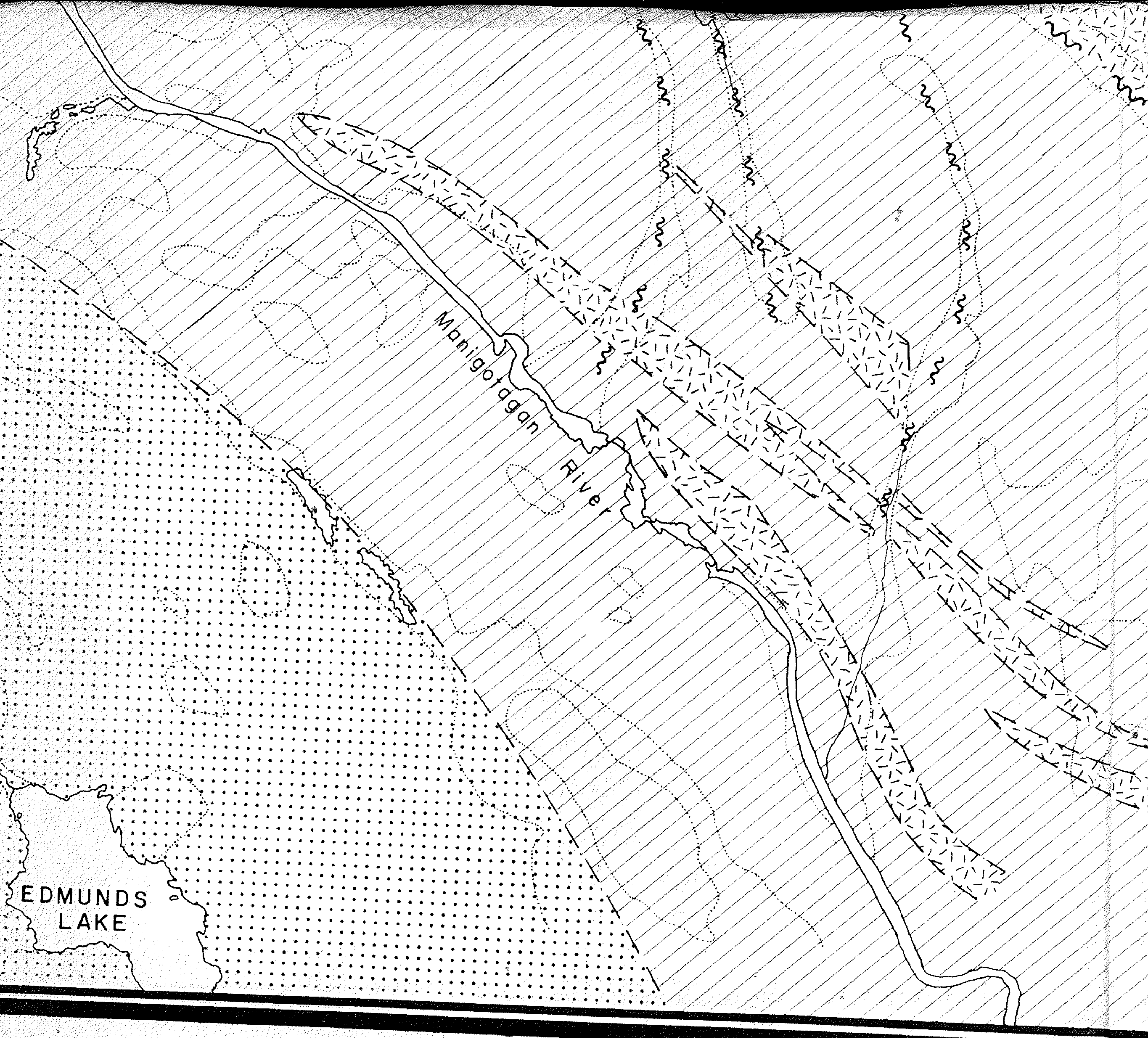
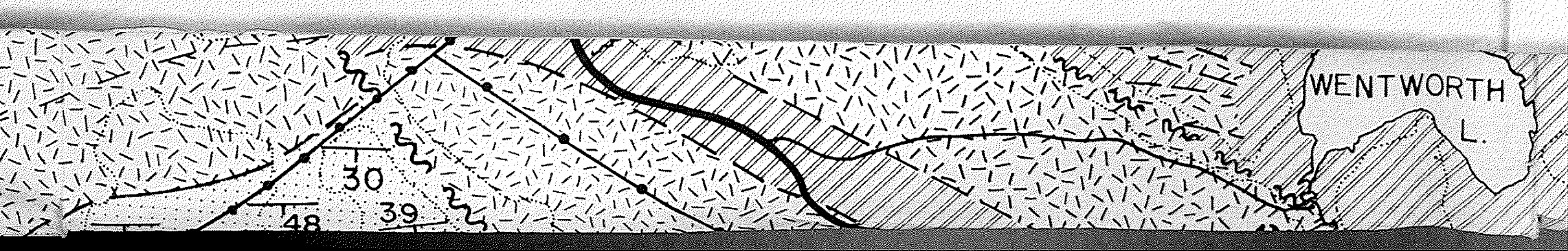
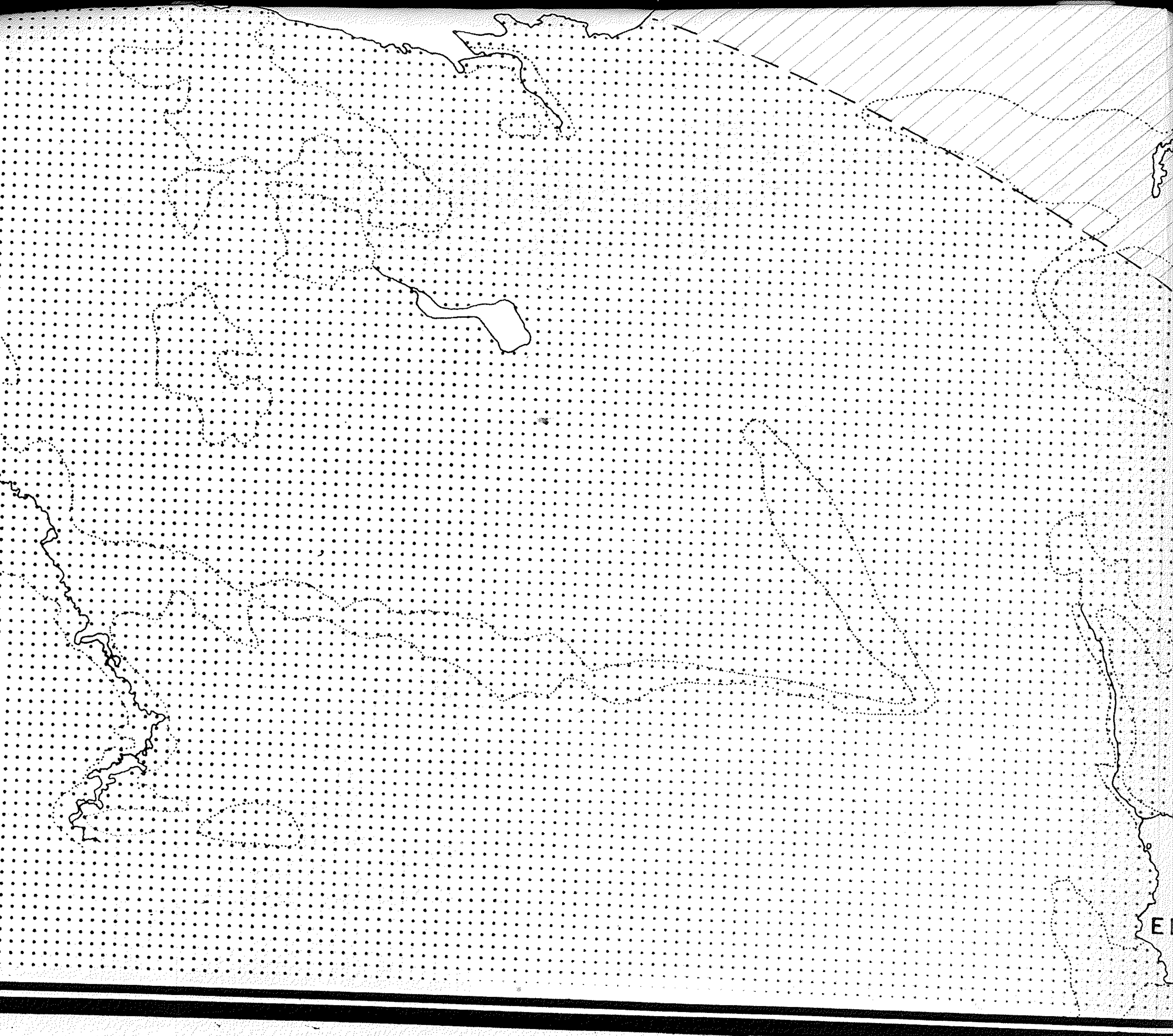
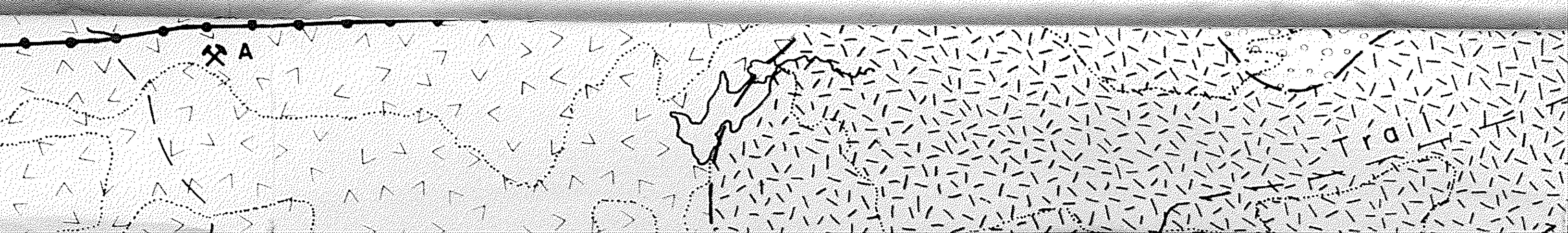

Manigotagan River
EDMUNDS LAKE


WENTWORTH L.
30
48
39

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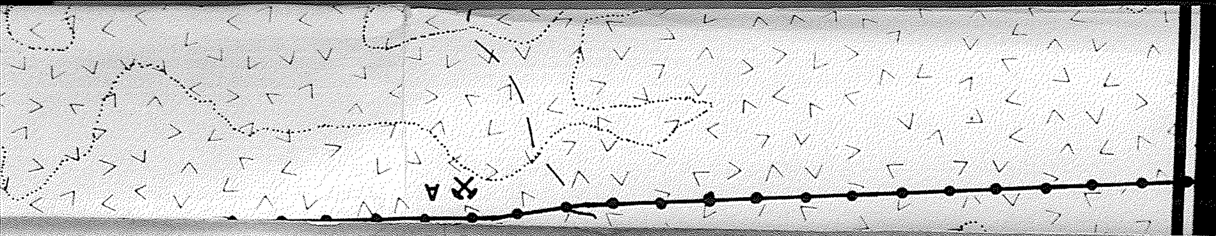


Giesbrecht. K.O.
(2)

LEGEND

POST OXFORD INTRUSIVE ROCKS

5 GABBRO

4 GNEISSIC GRANODIORITE

INTRUSIVE CONTACT

OXFORD LAKE SUBGROUP

3K PARAGNEISS

3J ACID CRYSTAL TUFF

3I VOLCANIC PEBBLE CONGLOMERATE

3H IRON FORMATION

3G FRAGMENTAL HORNBLENDE GREYWACKE

3F GARNETIFEROUS AMPHIBOLITE

3E AMPHIBOLITE

3D BASIC VOLCANIC BRECCIA

3C PILLOW BASALT

3B HORNBLENDE GREYWACKE

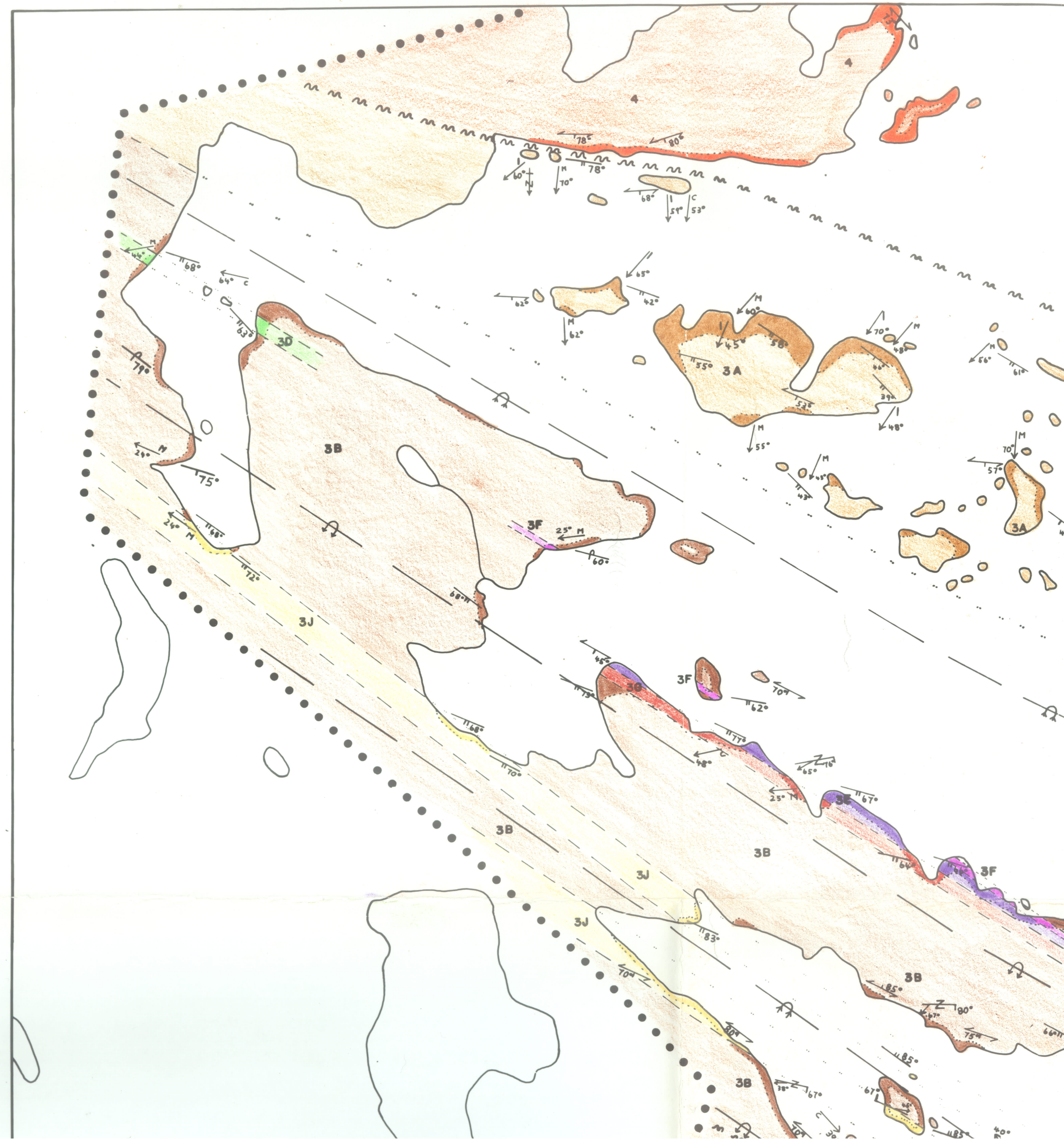
3A VOLCANIC BOULDER CONGLOMERATE

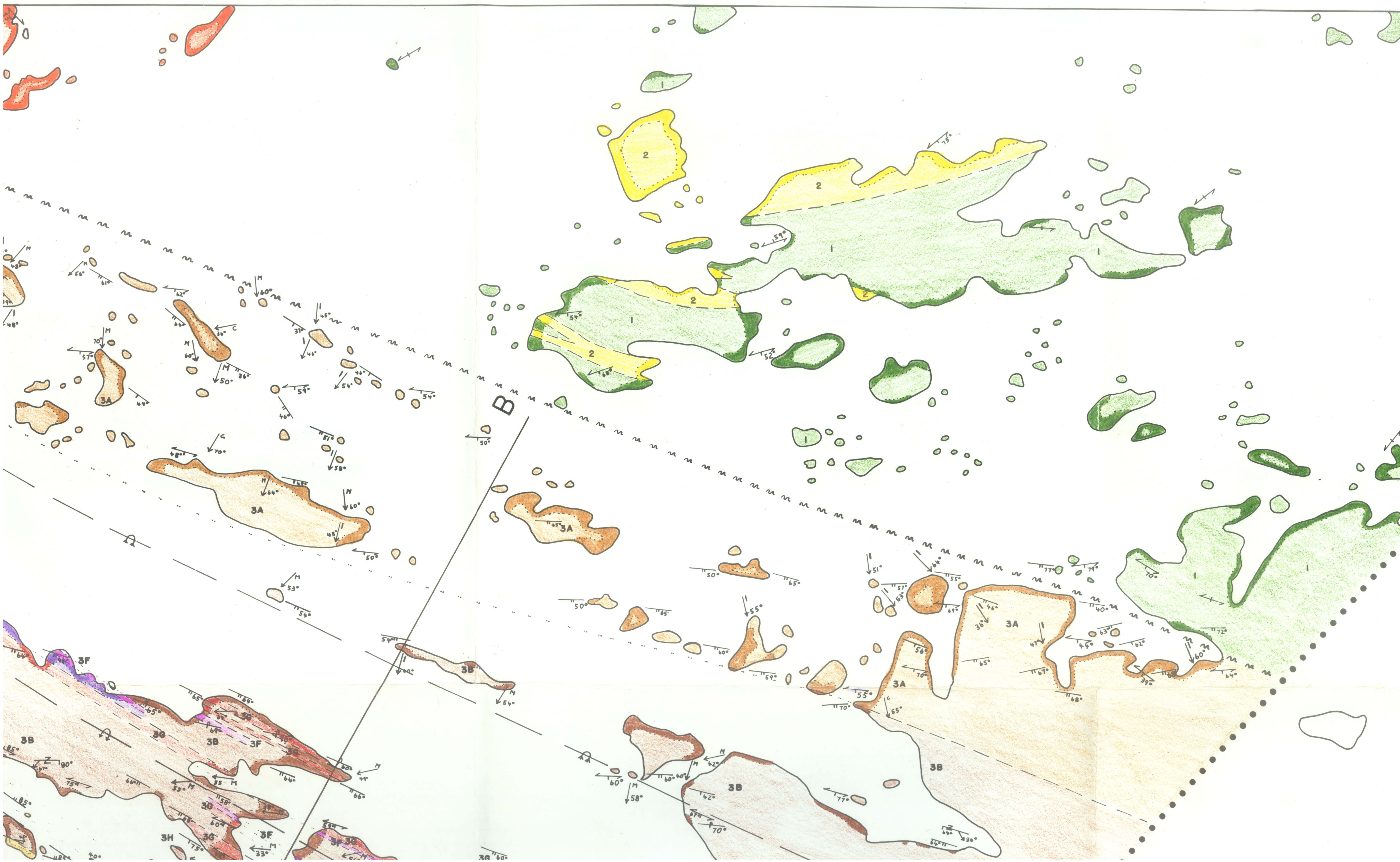
FAULT CONTACT

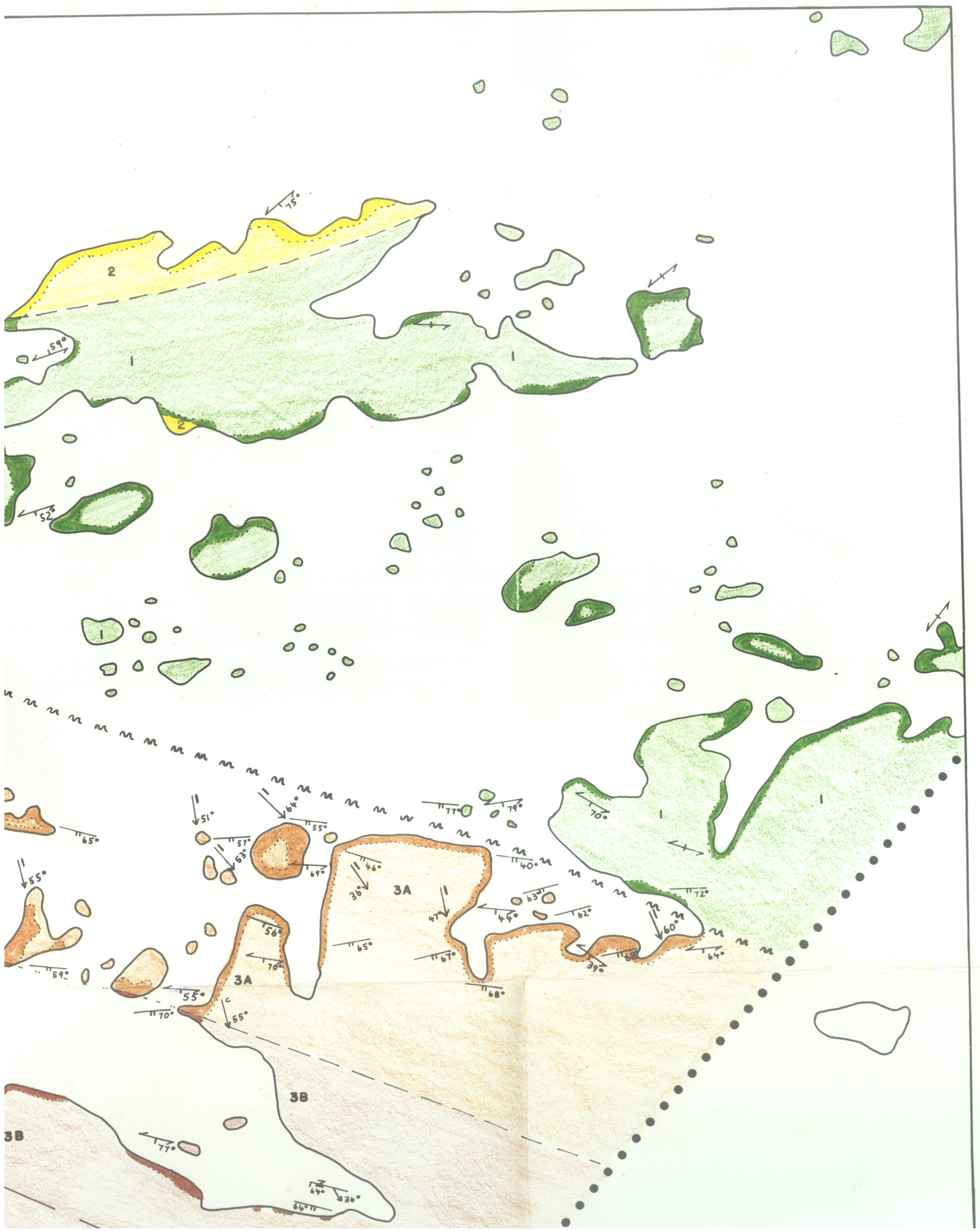
GODS LAKE SUBGROUP

2 QUARTZ CRYSTAL TUFF

1 UNDIFFERENTIATED ANDESITE AND BASALT




B
1
2
3A
3B
3F
3G
3H



SYMBOLS

AREA OF ROCK EXPOSURE

GEOLOGICAL BOUNDARY (DEFINED, APPROXIMATE, UNDERWATER)

LAYERING

60° 90° 60° BEDDING, TOPS KNOWN (INCLINED, VERTICAL, OVERTURNED)

60° BEDDING, TOPS UNKNOWN (INCLINED, VERTICAL)

60° 90° 50° PILLOW TOP DIRECTIONS (INCLINED, VERTICAL, OVERTURNED)

FOLIATION

60° SCHISTOSITY (INCLINED, VERTICAL, DIP UNKNOWN)

MAJOR FOLDS

ANTICLINE, OVERTURNED

SYNCLINE, OVERTURNED

MINOR FOLDS

0° 30° AXES (HORIZONTAL, INCLINED)

AXIAL PLANE (HORIZONTAL, INCLINED, VERTICAL)

SYMMETRY (ASYMMETRICAL Z SHAPED, SYMMETRICAL)

LINEAR STRUCTURES

M M 30° MINERAL LINEATIONS (HORIZONTAL, INCLINED)

C C 30° MICROCRENULATIONS (HORIZONTAL, INCLINED)

I I 30° DEFORMED FRAGMENTS (HORIZONTAL, INCLINED)

FAULTS, SHEARED ZONES

FAULTS, SHEARED ZONES (DEFINED, APPROXIMATE)

CABIN

LIMIT OF MAPPING

3C PILLOW BASALT

3B HORNBLENDE GREYWACKE

3A VOLCANIC BOULDER CONGLOMERATE

FAULT CONTACT

GODS LAKE SUBGROUP

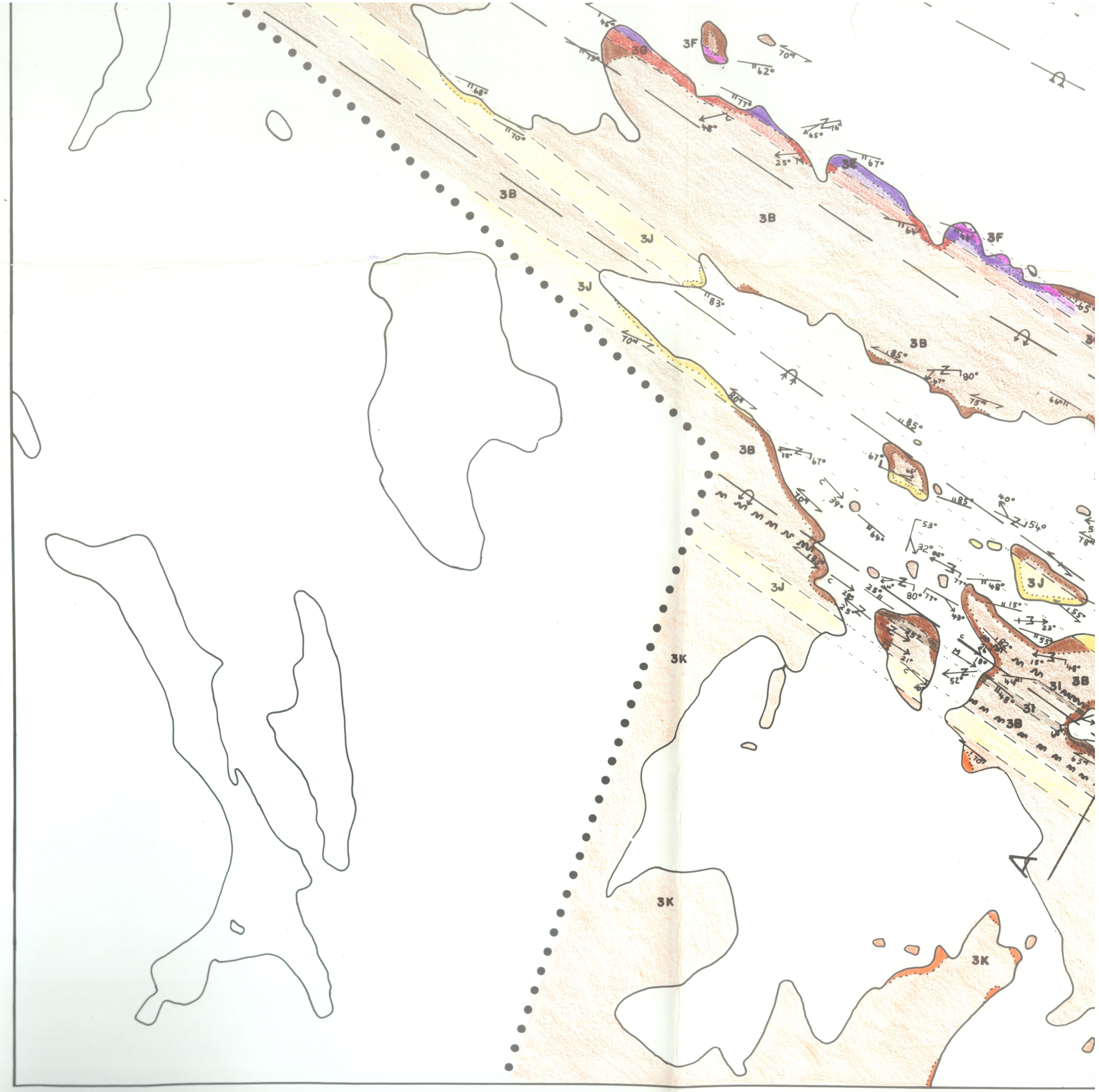
2 QUARTZ CRYSTAL TUFF

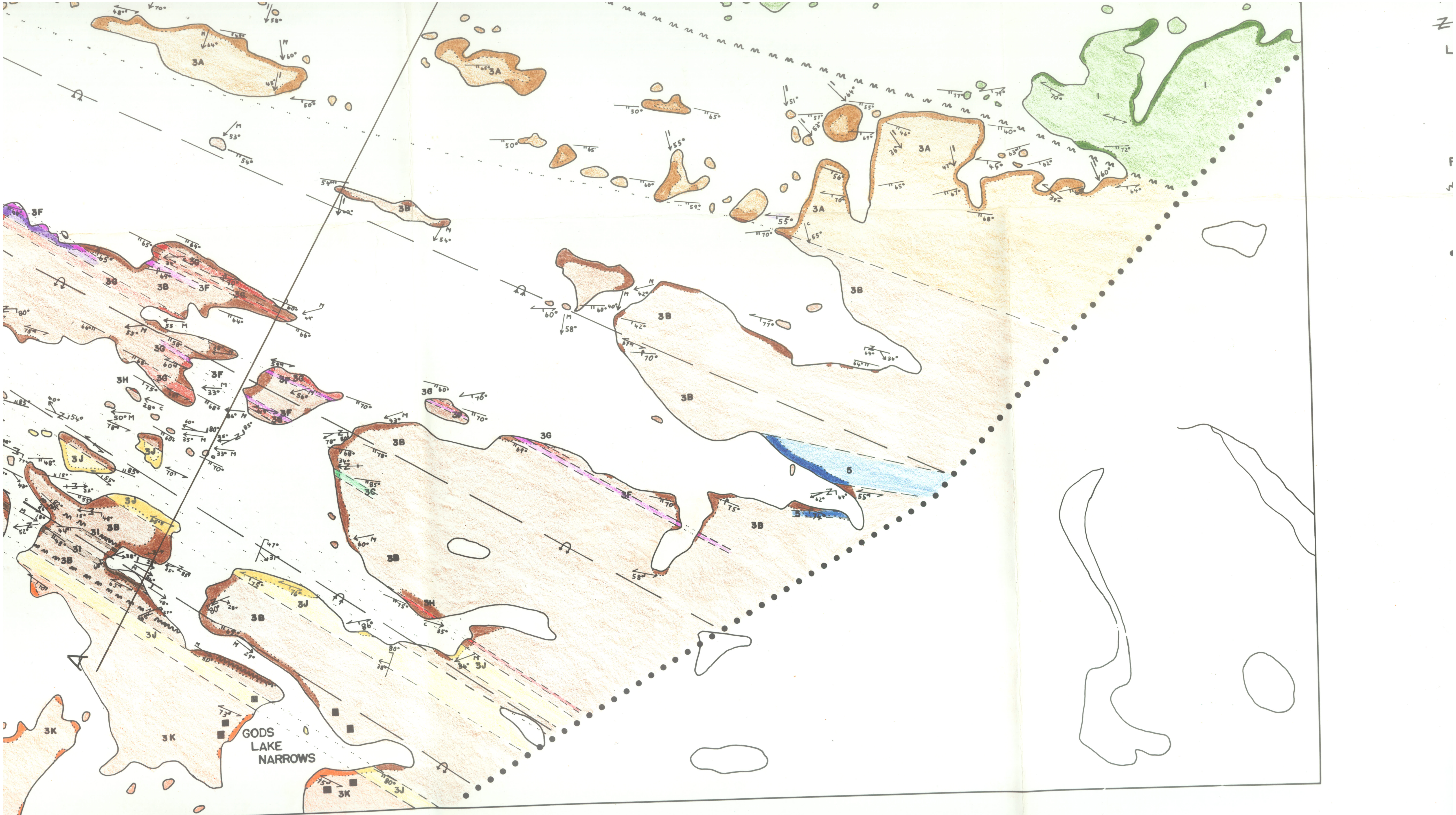
1 UNDIFFERENTIATED ANDESITE AND BASALT

SCALE

MILES 1 1/2 0 1 MILES

METRES 1000 500 0 1000 METRES





GEOLOGY OF THE GODS LAKE NARROWS AREA

SYMMETRY (ASYMMETRICAL Z SHAPED, SYMMETRICAL)

LINEAR STRUCTURES

MINERAL LINEATIONS (HORIZONTAL, INCLINED)

MICROCRENULATIONS (HORIZONTAL, INCLINED)

DEFORMED FRAGMENTS (HORIZONTAL, INCLINED)

FAULTS, SHEARED ZONES

FAULTS, SHEARED ZONES (DEFINED, APPROXIMATE)

CABIN

LIMIT OF MAPPING