THE GEOLOGY OF A PART OF THE CALIFORNIA LAKE AREA, MANITOBA

A THESIS

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by

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Abstract

The location, topographic character, and general geology of the California Lake Area are described. Five types of granitic rocks are recognized, petrographic details are described, and age relations postulated.

The name "Semple Lake series" is given to a belt of sedimentary and volcanic rocks found in the southern part of the area. Rock types found in the series include acidic and basic lavas, greywacke, tuff, agglomerate, and conglomerate. Petrographic descriptions are given and the rocks are found to be in the epidote-amphibolite facies of regional metamorphism. The significance of the conglomerates is discussed, and an attempt is made to correlate the Semple Lake series with similar rocks found outside the map area.

The Baker Lake series lying in the east-central part of the area is described. Rock types present are altered basic lavas and greywackes, which are in the plagioclase-amphibolite facies of regional metamorphism. The mineral assemblage "pinite", found to be replacing

cordierite indicates that some of the rocks have undergone retrograde thermal metamorphism.

CHAPTER 1

INTRODUCTION

During the field season of 1953, the author studied and mapped the Precambrian rocks of the California Lake Area, Northern Manitoba, while in the employ of the Manitoba Mines Branch. The author was accompanied by Mr. Jackson H. Shepherd, who shared equally in the leadership of a field party consisting of five men. This survey represents the trial of a scheme whereby graduate students in geology at the University of Manitoba would conduct field mapping as a part of post graduate studies at the Master's level. It is hoped that at some future time, a suitable section of the Province of Manitoba will be set aside to provide mapping problems for students undertaking post graduate work.

Location and Access.

The California Lake Area lies across the boundary between the Cross Lake and Oxford Lake mining divisions. The area comprises approximately two hundred and thirty square miles, and lies between 55°00' and 55°20' north latitude, and between 95°30' and 95°45' west longitude.

The most convenient mode of access to the area is by aircraft from Norway House, at the head of Lake Winnipeg navigation, or from Ilford, on the Hudson Bay Railway; the distances being one hundred and twenty, and sixty miles, respectively. The best canoe route originates at Oxford House, Manitoba. From Semple (Sucker) Bay, on Oxford Lake, the route follows the Semple River, with three short portages, to Semple Lake, in the extreme southern part of the area. From the north shore of Semple Lake, a stream, with two short portages, gives access to Powstick Lake. From the north shore of Powstick Lake, a one mile portage leads to California Lake, and from the north shore of California Lake, a three-quarter mile portage terminates on the south shore of Bear Lake. Access to the northern part of the area may be gained by following the Bigstone River, from its point of origin on Bear Lake, over one short portage, to Bigstone Lake. Utik Lake, in the north-west corner of the area, may be reached by a half mile portage from the north shore of Bigstone Lake.

General Character of the Area.

The topography of the California Lake Area, like that found everywhere in this part of Manitoba, is characterized by wide areas of swamp and muskeg, separated by gently sloping belts of clay and sand. Deposits of clay, sand, gravel, and boulders, resulting from

Pleistocene glaciation, cover large parts of the area. The ice sheets crossed the area in a generally north-east to south-west direction, and many of the topographic features of the area have their long axes in that direction.

Bedrock exposures are not widespread, and for the most part are limited to the lake shores. Large tracts of the area contain few, if any, outcrops. The most extensively exposed portion of the area lies between Bear Lake and the Bigstone River. This region has the greatest relief in the area, but the highest hills probably have elevations less than one hundred and twenty-five feet above the surrounding lowlands.

In the past, fires have swept much of the region. Sand and boulder ridges are covered with jack pine, intermingled with second growth spruce and deadfall. The muskegs and clay belts are sparsely dotted with spruce. Tamarack grows extensively in some of the swamps. Other trees, of minor occurrence, are birch, poplar, and balsam fir. The average diameter of living trees is from four to six inches. Timber for mining operations, or extensive construction could not be obtained in the area.

Previous Work.

Merritt (1925), made a track survey of the Bigstone and Fox rivers, during which he passed through the

California Lake area from south to north. This survey is the only previous work done within the boundaries of the area.

Present Work.

The California Lake Area is the easternmost map area in a mapping project begun in 1951 by the Manitoba Mines Branch. The territory mapped extends westward from the present map area to the Nelson River, and is described in reports by J. H. Shepherd and M. D. Moorhouse (1954), G. C. Milligan (1952, 1954), and C. M. Allen (1953, 1954).

During the field season of 1953, traverses were run, where feasible, at intervals of fifteen hundred to two thousand feet. Outcrops were located by pace and compass, and by vertical aerial photographs. Geological data were recorded on a base map compiled by the Manitoba Surveys Branch from vertical aerial photographs.

A strictly geographical subdivision of the map area for the purpose of providing two suitable thesis problems would have resulted in some duplication of work; consequently, it was decided that Mr. Shepherd would study the northern sedimentary-volcanic complex and that the author would study the southern one, herein called the Semple Lake series. Later the author expanded this study to include a discussion of the granitic rocks, and also a description of the Baker Lake series, which is a geographically isolated portion of the northern sedimentary-volcanic belt.

Acknowledgments.

The writer wishes to thank Mr. Jackson H. Shepherd of the University of Manitoba, who worked alongside the author in the field with diligence and spirit, and who is responsible for much of the geological data recorded on the accompanying map. Additional field assistance was capably provided by Messrs. Gordon Johnston, Hugh Harries and Dudley Brett, all of the University of Manitoba.

The author is deeply indebted to Dr. H. B. D. Wilson of the University of Manitoba for the constructive criticism and helpful advice given during the preparation of this report, and to Dr. G. H. Charlewood, Chief Geologist, Manitoba Mines Branch, and Dr. G. M. Brownell, Chairman, Department of Geology, University of Manitoba, for their helpful advice, and their critical reading of the manuscript.

The writer is grateful for the services rendered by Mr. G. C. Milligan of the Manitoba Mines Branch, who, together with his assistants, mapped much of the area surrounding Semple Lake in the southern part of the area.

The many courtesies extended by Mr. T. McEwan, of the Hudson's Bay Company, Norway House, and Mr. N. C. McCoy, of the Manitoba Government Air Service, are greatly appreciated.

Permission to reproduce the map of the California Lake Area was obtained from the Mines Branch, Department of Mines and Natural Resources, Province of Manitoba.

General Geology.

All consolidated rocks in the area are of Precambrian age. The main geologic features of the area are two belts of volcanic and sedimentary rocks. One of these belts outcrops around Bigstone Lake, and has been described by Shepherd (1954). The second belt lies in the southern part of the area, and is exposed around Powstick and Semple lakes. The rocks making up the second belt have been named the Semple Lake series, and are described in this thesis.

The volcanic and sedimentary belts have been intruded by granitic rocks, whose composition ranges from quartz monzonite to quartz diorite. Five different types of granitic rocks are recognized, but age relations among them are obscure. The northern sedimentary-volcanic belt has been subjected to medium and high grades of regional metamorphism, whereas the Semple Lake series has suffered only low grade regional metamorphism.

Large scale folding is not recognized in the area. Major faults occur in the Semple Lake series, and late faulting has affected diabase dykes within the area.

The rock types found, and their postulated age relations are shown in Table I.

TABLE I

TABLE OF FORMATIONS

P R E C A M B R I A N	Basic Dykes
	Intrusive Contact
	Alaskite Northern quartz monzonite and granodiorite; marginal phases Porphyritic granodiorite Pink massive quartz monzonite Grey and buff quartz monzonite, granodiorite, and quartz diorite
	Intrusive Contact
	Sedimentary and volcanic rocks: Andesites and basalts, and derived schists Tuff, agglomerate, greywacke, conglomerate, and derived schists Cordierite schist

CHAPTER II

GRANITIC ROCKS

Introduction.

Granitic rocks are of widespread occurrence in the California Lake Area. Rock types mapped are:

(1) Grey and buff quartz monzonites, granodiorites, and quartz diorites.

(2) Pink massive quartz monzonite.

(3) Porphyritic granodiorite.

(4) Northern quartz monzonite and granodiorite, plus marginal phases.

(5) Alaskite.

No true granites occur within the area, although the alaskite probably has the composition of a granite. All rock names in the discussion and description of granitic rocks are based upon the classification used by Grout. (1932)

Grey and Buff Quartz Monzonite, Granodiorite, and Quartz Diorite.

Distribution. Greyish granitic rocks of intermediate composition comprise the most extensive igneous intrusives in the area. Quartz monzonites, granodiorites, and quartz diorites outcrop chiefly in the area between Bigstone and Bear lakes in a belt extending across the map area, and are best exposed in the region to the north of Bear Lake. Scattered outcrops of the same rock types are also found around the southern and eastern portions of Semple Lake. To the west of the California Lake Area, similar intrusive rocks have been mapped by Milligan (1952, 1954), and Allen (1953). The belt extends for an unknown distance east of the present map area.

Lithology. The color of the weathered surfaces of most of the rocks in this unit ranges with exceptions, from grey to greyish white. The rocks may locally assume a pink color, due to the presence of pink feldspar. Where this pink feldspar is dominant, the rocks have been mapped as pink massive quartz monzonites. Bodies of this pink massive quartz monzonite are surrounded by greyer granitic rocks which contain moderate amounts of pink feldspar. Near Semple Lake, and in the region south of Bigstone Lake, west of the Bigstone River, the rocks have a buff color.

The color of the fresh surface is similar to that of the weathered surface. On most specimens, a bleached zone extends to a depth of about one-eighth of an inch below the weathered surface. Below this zone, a brownish band, which may attain a maximum thickness of one-half an inch, grades imperceptibly into the fresh rock.

The fresh surface shows grey to greyish-white feldspar grains, closely intermingled with darker grey, anhedral quartz. Twinning striations can be seen on the cleavage surfaces of some plagioclase grains. Ferromagnesian minerals, usually biotite, make up five to ten per cent of the rock. Hornblende may accompany, or replace biotite in areas of much contamination, and in the vicinity of greenstone contacts.

Rocks of this unit display a primary alignment of biotite over most of the area. The most notable exception is a greyish-white weathering, massive granodiorite which has intruded parts of the Baker Lake series in the eastern part of the map area. In addition to the alignment of biotite, the greyer rocks commonly have a distinct primary foliation, caused by the concentration of biotite into sinuous bands, ranging from less than one inch to more than one foot in width. Rocks having this foliation are best exposed on the extreme western shore of Bigstone Lake.

Microscopically, this rock unit exhibits a similar texture throughout the area, but has considerable variation in composition. A xenomorphic-granular texture was found in all specimens examined. The grain size of the major constituents ranges from 1.5 millimetres to 5 millimetres, and averages from 2 millimetres to 4 millimetres.

Quartz grains are always anhedral, and except where recrystallized, show strain shadows. Plagioclases are anhedral, and are corroded where they come in contact with quartz. They are slightly sericitized. This alteration has attacked the plagioclase twins differentially. Commonly, only alterate twin lamellae are affected. Where twinning is absent, sericitization sometimes affects certain concentric zones within a single grain. This indicates that alternate twins have different composition, and also that there are concentric zones of composition which do not have differing optical extinction angles. Saussuritization of plagioclase grains is locally extensive. Potash feldspars are interstitial, clear and unaltered, and are mostly microcline, although in some specimens orthoclase is dominant.

The biotite of the granitic rocks is mostly of a greenish-brown color. Partial alteration of biotite to chlorite and/or epidote is extensive. The massive granodiorite which intrudes the Baker Lake series contains deep brown biotite which has developed inclusions of magnetite or rutile. These inclusions form a sagenitic type structure in the biotite. The occurrence of this type of biotite is believed to be the result of the assimilation of sedimentary rocks by the granodiorite.

Accessory minerals found in the unit as a whole show very little variation throughout the area. Common accessories include magnetite, apatite, and zircon. Muscovite is a less common accessory.

Most thin sections show a few grains of myrmekitic quartz-plagioclase intergrowths. Williams et al.[1] state that myrmekite is the result of solid state reactions, and that some of it results from crystallographic development of biotite from potash feldspar, with the consequent liberation of quartz and plagioclase.

The mineralogical composition of the unit was determined by means of rosiwal analyses of thin sections, using specimens obtained from different parts of the area. Prior to making a rosiwal analyses, thin sections were subjected to a special staining technique, which enabled the author to distinguish between potash and plagioclase feldspars. This technique is described in Appendix A.

Buff colored rocks are mostly quartz monzonites. The results of three rosiwal analyses of specimens from the large mass of buff quartz monzonite which outcrops extensively south of Bigstone Lake are shown in Table II.

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[1] Howell Williams, Francis J. Turner, and Charles M. Gilbert, Petrography, An Introduction to the Study of Rocks In Thin Section (San Francisco, W. H. Freeman and Company, 1954), pp. 134-5.

TABLE II

RANGE OF MINERALOGICAL COMPOSITION OF THE BUFF QUARTZ MONZONITE

Quartz	25-30 weight per cent
Plagioclase.	45-50 weight per cent
Potash feldspar.	15-20 weight per cent
Biotite.	4- 9 weight per cent

The grey phases are quartz diorites and granodiorites, the distinction being based upon the ratio of potash feldspar to total feldspar. Table III shows the results of twelve analyses of these rock types.

TABLE III

RANGE OF MINERALOGICAL COMPOSITION OF THE GREY QUARTZ DIORITES AND GRANODIORITES

Quartz	20-32 weight per cent
Plagioclase (An27-An37). . .	50-65 weight per cent
Potash feldspar.	0- 8 weight per cent
Biotite.	2-10 weight per cent

It is suggested that the buff quartz monzonite represents the original intrusive, and that the grey granitic rocks have become more basic by reaction with the greenstones which they have intruded. This is borne out by the presence of many basic xenoliths in the rocks north of Bear Lake. Here the rock is predominantly grey. To the north, south of Bigstone Lake, the buff quartz monzonite contains few xenoliths, and these are mostly of siliceous sedimentary material, which could easily be digested by the magma, without rendering it more basic.

Pink Massive Quartz Monzonite.

Introduction. An attempt has been made to separate rocks of this type on the map as a separate unit. In the field, it was difficult to decide where the rock ceased to be a grey "granite" cut by numerous pink stringers, and became a pink "granite". The boundaries shown on the map should therefore by regarded as indefinite. As has been mentioned before, it was noted that in the outcrop belt of the grey granodiorites, the bodies of pink quartz monzonite are surrounded by an aureole of greyer granodiorite which is cut by numerous pink stringers and dykes.

Distribution. Pink massive quartz monzonite outcrops in the region around Bear Lake, near the western border of the area. Minor occurrences are found in the central and eastern portions.

Lithology. Both fresh and weathered surfaces are brownish pink in color. The rock is generally massive, and on the fresh surface, shows a medium grained equigranular aggregate of pink potash feldspar, greyer plagioclase feldspar, and quartz.

In thin section the pink quartz monzonite has a xenomorphic-granular texture. Quartz has corroded the earlier formed sericitized and partially saussuritized plagioclase. Myrmekitic quartz - oligoclase intergrowths are more common than in the grey and buff granodiorites and quartz monzonites. Potash feldspar is mostly microcline. Greenish yellow biotite is partially altered to chlorite. Accessory minerals are magnetite, apatite, and zircon.

Analysis of three specimens from the west-central Bear Lake portion of the map area give the following range of composition:

Quartz	21-31 weight per cent
Plagioclase.	35-51 weight per cent
Potash feldspar.	17-33 weight per cent
Biotite.	4- 5 weight per cent

Porphyritic Granodiorite.

Distribution. Porphyritic granodiorite outcrops at several widely scattered localities between Bear Lake and Powstick Lake. Good exposures are found on the portage from Bear Lake to California Lake. Strongly sheared porphyry outcrops on two islands in Powstick Lake. Outcrop is very scarce in this region.

Lithology. The porphyry weathers to a light reddish pink. On the weathered surface, tabular, subhedral phenocrysts of pink microcline up to one inch long are clearly visible. The phenocrysts rarely show primary alignment. The fresh surface shows grey plagioclase, clear grey quartz, green biotite, and magnetite, in addition to the phenocrysts.

Microscopically, the groundmass of the porphyrtic granodiorite has a hypautomorphic-granular texture, and an average grain size of from 1.5 to 2.5 millimetres. Plagioclase grains are subhedral, and are only slightly corroded by quartz. Potash feldspar is mostly microcline, and, apart from the phenocrysts, is of interstitial occurrence. Greenish-yellow biotite commonly occurs in non-oriented aggregates, intermingled with epidote. Magnetite is a common accessory mineral, and can easily be seen in hand specimens in anhedral grains one or two millimetres in diameter.

Rosiwal analyses of three specimens from different locations give the following range of composition:

Quartz	19-35 weight per cent
Plagioclase.	48-59 weight per cent
Potash feldspar.	11-17 weight per cent
Biotite.	2- 4 weight per cent
Accessories.	1- 3 weight per cent
Alteration products.	1- 4 weight per cent

It should be noted that the presence or absence, by chance, of microcline phenocrysts in thin sections must have its affect on the accuracy of the analyses. It is felt that the analyses give a true value of the composition of the unit as a whole (See Appendix B). However, for those rocks where large phenocrysts are only an inch or two apart, a rosiwal analysis would probably indicate a lower percentage of microcline than is actually present.

The contact between the porphyritic granodiorite and the pink quartz monzonite is exposed for a few feet on the shore of a rapids along a creek flowing from Dobbs Lake to Bear Lake, at the western edge of the area. The contact is sharp, with no apophyses or other criteria to indicate any age relationship.

Northern Quartz Monzonite and Granodiorite.

Distribution. Rocks of this unit outcrop in a belt extending across the extreme northern part of the area. Exposures in this region are very scarce; consequently, all but a few outcrops occur on the lake shores. Some good exposures are located on the shore and on small islands in the northeastern part of Bigstone Lake; others occur on the south shore of the north arm of Utik Lake, and on the shores of the small lake immediately to the south.

Lithology. The weathered surface of the quartz monzonite and granodiorite ranges in color from brownish grey to pink. The average grain size is from one to two millimetres, which is definitely less than that of the grey and buff granodiorites and quartz monzonites. Most outcrops are fairly massive. This is especially true of the exposures along the shores of northeastern Bigstone Lake.

The fresh surfaces of the rocks are usually pinkish, although a decrease in pink feldspar content towards the western part of the area results in a darkening of color. Locally, the presence of hematite in fractures and along grain boundaries adds a reddish tinge. Where exposed on Bigstone Lake, the rock has a medium grained saccharoidal texture. Here, the ferro-magnesian mineral content is very low, and consists mostly of clusters of epidote and biotite, which give the rock a spotted appearance.

In thin section, rocks of this unit have a granitic texture and consist of an equigranular aggregate of irregular quartz, plagioclase (An 27-An 34), and potash feldspar. Small flakes of greenish biotite are partially altered to chlorite and epidote. Muscovite is found in minor amounts in some specimens. A characteristic of this unit is the large variety of accessory minerals, which includes magnetite, limonite, hematite, muscovite, apatite, sphene, and zircon.

Mineralogical composition varies considerably within the unit. Rosiwal analyses of specimens show that, with a few exception, the pink rocks, which are found mostly in the central and eastern portions of the outcrop belt are quartz monzonites having the following range of composition:

Quartz	21-29 weight per cent
Plagioclase	36-51 weight per cent
Potash feldspar	13-20 weight per cent
Biotite	2-10 weight per cent

The greyer phases, which are found mostly near the western edge of the area, are granodiorites, and locally, quartz diorites. A typical quartz diorite has the composition:

Quartz	16 weight per cent
Plagioclase	70 weight per cent
Potash feldspar	2 weight per cent
Biotite	8 weight per cent
Alteration products (epidote, chlorite)	2 weight per cent
Accessories	2 weight per cent

Gneissic Granodiorite.

Distribution. A band of gneissic granodiorite has been mapped as a marginal phase of the northern quartz monzonite and granodiorite, and has been indicated separately on the map. The width and longitudinal extent of this unit are not accurately known. The best exposures are located on the shores of the narrows on the southern arm of Utik Lake.

Lithology. This unit, on the outcrops where it is defined, is a gneissic biotite-hornblende-granodiorite. Both weathered and fresh surfaces are dark grey, and show a strong alignment of mafic minerals. The granulation of some quartz grains indicates that this alignment is probably a metamorphic effect.

Examination under the microscope reveals a granitic texture. Greenish yellow biotite, and green hornblende, with associated epidote are scattered throughout an interlocking aggregate of sericitized plagioclase, potash feldspar, and partially recrystallized quartz. In some specimens, hornblende is absent. Well formed sphene crystals, up to one millimetre long are common. Other accessories are magnetite, apatite, and zircon. A typical specimen has the composition:

Quartz	29 weight per cent
Plagioclase.	46 weight per cent
Potash feldspar.	8 weight per cent
Hornblende and biotite . . .	10 weight per cent
Alteration products	
Accessories.	7 weight per cent

The rock is probably the product of reaction with the basic lavas which lie to the south.

Alaskite.

<u>Distribution</u>. Excellent exposures of alaskite are found on the height of land between Bigstone Lake and Utik Lake at the western edge of the area. Alaskite is also found

on several islands in Bigstone Lake, and again at scattered locations near the eastern boundary of the area.

Lithology. Alaskite weathers grey to light grey, and is extremely coarse grained. Anhedral crystals of alkali feldspar over one foot in diameter were found on several outcrops. The rock consists of quartz and alkali feldspar, the latter commonly showing graphic intergrowths. Muscovite and biotite are present, but rarely exceed five per cent of the total composition. It was possible to examine finer grained phases under the microscope. These specimens contained plagioclase feldspar in amounts ranging from five to fity per cent. However it is felt that such specimens are not representative of the unit as a whole.

The origin of the alaskite presents a problem. It is possible that the rock is a late magmatic differentiate, and is a kind of huge pegmatite. Another possibility, which seems to be in accord with the grade of metamorphism in this region, is that the rock forms as the result of the remelting of those constituents of previously formed granitic rocks which have the lowest melting points.

Age Relations.

Age relations among the granitic rocks are obscure. Probably, all the granitic rocks belong to the same period of igneous activity. As has been mentioned before, no knowledge could be gained from a short exposure of the contact between the porphyritic granodiorite and the pink quartz monzonite. The latter rock shows intrusive relations with the grey and buff granodiorites, etc., and is therefore younger. The northern quartz monzonite and granodiorite may represent finer grained phases of the grey and buff granodiorites, etc., but the former is not seen in contact with other granitic rocks. Alaskite is considered to be the youngest granitic rock in the area, because of its probable formation as a late magmatic differentiate. The postulated age relations are shown in Table I.

CHAPTER III

THE SEMPLE LAKE SERIES

Introduction.

The Semple Lake series is composed of steeply dipping andesites and basalts, with minor interbedded sedimentary rocks and intermediate to acidic flows. Batholiths of granitic rocks border the series on the north-east and south-west. The lavas and sediments are cut by minor dykes composed of intermediate rocks, which are geologically older than the granitic rocks. Three major breaks and numerous small faults have affected the series.

Distribution.

Rocks of the Semple Lake series outcrop in a belt having an average width of two and one-half miles. The belt crosses the western boundary of the map area between Bear Lake and Powstick Lake, and continues in a general southeasterly direction across Powstick and Semple lakes, passing out of the area at its south-east corner. To the south, the series is believed to be continuous with similar rocks mapped by Wright (1926,1931) and Morgan (1940) in the Oxford House area. Rock equivalents of the Semple Lake series continue westward from the California Lake area as a volcanic sedimentary belt extending to near the Nelson River.

Lithology.

General Statement.

Andesitic and basaltic flows and their metamorphased equivalents comprise the bulk of the series. Interbedded with these, at scattered localities, are tuffaceous sediments agglomerates, conglomerates, greywackes, dacites and rhyolites. The general scarcity, or in some places, total absence, of rock exposures away from the lake shores makes the tracing of individual beds into the hinterland virtually impossible.

Basic Flows.

Distribution. Basic lavas composed of andesite and basalt are best exposted on the southern shore of central Semple Lake, and on the shores of western Powstick Lake. Sheared flows outcrop extensively along the topographic lineament that follows the south shore of the small lake in the southeastern corner of the map area.

Lithology and Metamorphism. Andesitic and basaltic flows generally present a green to greenish-black, schistose outcrop surface. Weathering has produced a surface marked by alternating crests and troughs, which have a width of about 0.25 millimetre. This "ribbed" surface, as it was described in field notes, is the result of the differential weathering of fine compositional bands within the rock. Individual bands may be traced for twelve inches or more. The discontinuity of the banding, and also the presence, in some outcrops, of "islands" of more massive rocks, showing an equidimensional texture, led to the conclusion that the rocks are metamorphased lavas, and are not the finely laminated basic sediments which they appeared to be at first glance. The detection of these criteria requires a close examination of outcrop surfaces.

More massive flows have a greenish-black weathered surface, showing fine to medium grain size. The outcrops have a "pepper and salt" appearance, caused by the uniform mixture of medium grained, white-weathering feldspar, and black-weathering hornblende.

Pillow structures are not common in the basic lavas. None were seen on the shores of Powstick Lake, and Milligan has recorded their presence at only a very few scattered localities around Semple Lake.

The fresh surfaces of the rocks have a much less schistose appearance than do their weathered surfaces. The grain size is so fine in many places as to permit only general conclusions regarding mineralogical content. Those rocks whose grain size is sufficiently great to allow observation of individual minerals with a hand lens, are composed of fibrous to euhedral, greenish-black amphibole, mixed with an equal amount of greenish, granular feldspar. In some specimens a few black grains of magnetite may be seen.

Seen under the microscope thin sections of basic lavas are comprised of about 65 per cent hornblende, 35 per cent plagioclase feldspar, and 5 per cent of epidote, magnetite, chlorite, biotite, and carbonate. The fine compositional banding shown by many of the hand specimens can be seen in detail in thin section. In these rocks, bands of plagioclase alternate with bands of ferromagnesian minerals.

Hornblende generally forms elongate, pleochroic, bluish-green needles. The degree of development of euhedral form varies from place to place. Some sections show bands of hornblende forming interlocking masses in which individual grains have a shredded outline. The appearance of this hornblende suggests that it has replaced chlorite by metamorphism on a volume for volume basis. This conclusion is borne out by the sporadic presence of chlorite in seeming crystallographic continuity with these ragged amphibole grains. Slightly higher grades of metamorphism have caused the hornblende to assume the form of elongate needles, with well developed prism faces. Thin sections of more massive greenstones show hornblende in equidimensional poecilitic porphyroblasts, enclosing abundant plagioclase inclusions.

Plagioclase feldspars commonly occur as uniformly sized granules. Some grains may be elongate, and have their shape determined by the enclosing hornblende crystals, which have a higher form energy. The granular habit of the feldspar is the result of metamorphic recrystallization. The grains show virtually no twinning. Only one thin section showed a few grains of plagioclase have a lath shaped habit. These laths, which show some albite twinning, are apparently the original unrecrystallized feldspar of the rock. The general absence of twinning rendered the identification of the feldspars difficult, except by the use of the universal stage, and this was not attempted. However, the feldspar is assumed to have the composition of albite, or soda-oligoclase, in accordance with the mineral associations found in basic rocks at this grade of regional metamorphism.

Epidote and calcite are intimately associated with the hornblende. Epidote occurs as small granules of high relief and is locally concentrated in lens shaped aggregates, partially enclosing hornblende. Calcite is of interstitial occurrence, and may come from either, or both of two sources, namely introduction via cracks and fissures while the lavas were submerges, or the breakdown of the original calcic plagioclase. Some sections contain a few flakes of brown biotite.

The most common accessory mineral is magnetite, which always occurs in anhedral grains which differ in size from place to place. Magnetite is estimated to comprise approximately 5 per cent of one thin section. In the more schistose rocks, magnetite is distributed as abundant tiny grains, dispersed along planes of schistosity. This peculiar distribution of the mineral leads to the conclusion that part of the magnetite may have been formed from an excess of iron, produced during the metamorphic breakdown of original augite or hypersthene to chlorite. Apatite is another frequent accessory mineral.

The foregoing description has shown that the basic lavas are comprised of the mineral assemblage plagioclase (albite or soda-oligoclase)-epidote-hornblende. This mineralogical association is characteristic of the epidote-amphibolite facies of regional metamorphism. In terms of grade, the presence of biotite in some sections indicates that regional metamorphism has reached the biotite zone. The postulated course of metamorphism is shown in Fig. I.

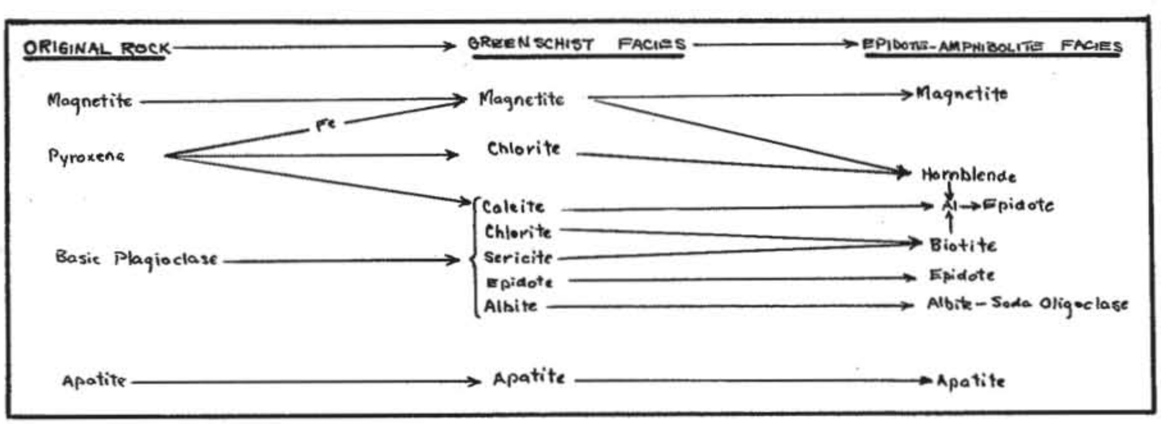

Fig. I. Postulated course of metamorphism in the basic lavas of the Semple Lake series.

Agglomerate.

Distribution. Excellent exposures of agglomerate may be seen on the south shore of Powstick Lake, about 1,000 feet northeast of the large comglomerate outcrop, and again on the south shore of the large island in the narrows at central Semple Lake.

Lithology. The Semple Lake agglomerate weathers to a brownish grey, and is composed of large numbers of volcanic bombs, which are usually less than two inches in diameter, set in a tuffaceous matrix.

Agglomerate outcrops on Powstick Lake have a much more striking appearance. Exposures on the shore weather mostly whitish and consist largely of elongated chert fragments cemented by a fine grained matrix. A few tens of feet south of the shore, the rock weathers a dull green. In addition to the chert fragments described above, the rock contains large blocks of basic material, set in a massive chloritic matrix. The largest of these blocks that was discovered, is an angular fragment, measuring three feet by one foot. The rocks making up these fragments are andesites of various colors and textures, and finely bedded tuffaceous material.

Tuffaceous Sediments.

Distribution. Tuffaceous rocks are of widespread occurrence in the Semple Lake Series as thin beds lying between greenstone flows. Most of these beds are less than 100 feet in width, and it has been impossible to show them on the map. This is expecially true of the southeastern part of the series. Tuffs are well exposed on the south shore of the large island in Semple Lake, and on a small island near the western end of Powstick Lake.

Lithology and Metamorphism. Outcrops of tuffs range in color from black to light grey. All exposures appear well sorted and show a fine sedimentary banding. Individual bands rarely exceed a few millimetres in width. Fresh surfaces are very dense and appear siliceous. Generally, the grain size is so fine that individual minerals cannot be recognized.

No distinct criteria were found for the recognition of tuffs in thin section. The glassy fragments by which these rocks are recognized in an unmetamorphosed state, are no longer present. As a consequence, tuffs are microscopically defined by their extremely fine grain size and excellent sorting, both of which suggest transport by wind. (See plate I).

A typical tuff is composed of 15 to 20 per cent of fine blue-green hornblende needles intermixed with granular plagioclase and angular quartz fragments, whose average size is about 0.02 millimetre. Abundant epidote granules, some brown biotite flakes, and scattered sphene crystals are concentrated in some beds. The high quartz and feldspar content suggests that some of this material became mixed with the ash deposits as a result of normal sedimentary processes.

The rock described above is in the epidote-amphibolite facies of regional metamorphism. Tuffs wherein the metamorphism has not yet reached this facies, and is still in the green schist facies contain chlorite instead of hornblende, and any biotite present is of a drab greenish brown color. The latter is believed to be a metastable mineral, poor in potash, which is replaced by normal brown biotite when the biotite zone is attained. (Harker, 1932; p. 267)

Greywacke.

Distribution. Greywackes are not abundant in the Semple Lake Series. The only bed of mappable dimensions lies about 800 feet northwest of the small lake in the southeast corner of the map area. Elsewhere in this part of the area, beds of greywacke occur as thin deposits interbedded with lava flows. No greywackes occur in the Powstick Lake zone of the series.

Lithology and Metamorphism. Greywackes weather to a brownish grey, and usually present a well laminated outcrop surface. Fresh surfaces of specimens are black and very dense, and show scattered clear quartz grains. The rock is very tough, and, except along planes of bedding or schistosity, is broken only with difficulty.

A microscopic examination of thin sections of greywacke shows four to five per cent of angular, mostly unrecrystallized quartz and feldspar fragments, lying in a fine grained quartz-biotite-chlorite-sericite matrix. Regional metamorphism is at a low grade in this part of the area, and, as a result, the original sedimentary textures of the rock are well preserved. The rock shows very poor sorting under the microscope, in spite of its well laminated outcrop surface. Microscopic bedding tends to be discontinuous, and sporadic lenses of almost pure quartzite may be seen. Greywackes in the map area generally contain some calcareous material.

The well preserved sedimentary textures, and the lack of recrystallization indicate that the greywackes have suffered very little metamorphism. This is borne out by the presence of the greenish biotite mentioned in connection with the metamorphism of tuffaceous sediments. In the thin sections examined, it was clear that metamorphism had not reached the stage where calcite should commence reactions with the aluminous minerals to form hornblende or epidote.

Intermediate and Acid Volcanics.

Distribution. Intermediate and acid flows are not common in the series, and are found mostly in the mideastern and southeastern parts of the belt. A 1200 foot band of dacitic rocks, with interbedded tuffs lies about 2,000 feet north of the small lake in the southeastern corner of the area. Rhyolites are best exposed in a 1,000 foot band which outcrops along the south shore of Semple Lake, south of the large island at the narrows.

Lithology. Dacites weather to a brownish grey color, and have a black, crystalline fresh surface, on which euhedral phenocrysts of feldspar are clearly visible. Rhyolites weather yellowish to pink and are more coarsely porphyritic than the dacites. On their weathered surfaces, rhyolites show square feldspar phenocrysts ranging in size from that of the groundmass, to about three-eighths of an inch. The groundmass has formed flow structures around the phenocrysts.

In thin section, dacites are composed of about fifty per cent phenocrysts, which lie unoriented in a fine grained groundmass. Phenocrysts are mostly plagioclase having the composition of andesine. A few orthoclase, but no quartz phenocrysts are present. Phenocrysts are euhedral to subhedral in outline and have an average mean diameter of about 0.25 millimetre. Exceptional grains have a diameter of 1.5 millimetre. The staining of a thin section revealed that the groundmass is dominantly feldspathic, with abundant greenish brown biotite, plus carbonate and minor quartz.

Thin sections of rhyolites show that the rocks are sheared. This is reflected in the shattering of many of the phenocrysts, and by the development of slip planes composed mainly of sericite. Phenocrysts are anhedral to subhedral in shape, and are composed mainly of acid plagioclase, with a few composed of orthoclase and quartz. The groundmass is almost free from ferro-magnesian minerals, and is composed of a fine grained aggregate of quartz and feldspar, plus a few scattered magnetite grains. Calcite forms isolated pods and veinlets within the groundmass.

Conglomerate.

Introduction. Conglomerates lying within the area will be described in some detail, not because of their thickness or lateral extent, which are small, but because of their fundamental importance in the geology of the whole region. Within the present map area, conglomerates, more than any other rock type give an insight into the petrology of the land surfaces that were being eroded during the period of

Archean sedimentation under discussion. Two conglomerate horizons are mapped and these have been called Powstick Lake conglomerate and the Semple Lake conglomerate.

The Powstick Lake Conglomerate.

Distribution. The Powstick Lake conglomerate occurs as a single large outcrop on the south shore of central Powstick Lake. The bed is truncated by a fault which passes through the centre of the lake, and consequently does not outcrop on the north shore. The conglomerate is bordered on the north-east by agglomerate and massive flows, and disappears under the muskeg to the south.

Lithology and Metamorphism. The outcrop is comprised on the average of about thirty per cent pebbles and cobbles. The percentage of pebbles, etc., is greater near the shore and decreases towards the south. The average mean diameter of the component rock fragments is about three inches. Numerous cobbles have diameters of six or eight inches, and scattered boulders exceed ten inches. The largest boulder noted measured eighteen by twenty-three inches. Practically all of the pebbles are well rounded, which indicates that they are waterworn. Most of the pebbles composed of relatively soft rocks are elongated.

Granitic rocks comprise eighty per cent of the component fragments. Chief among these is a feldspathic quartz diorite. Another common component is a porphyritic quartz diorite. These two rock types constitute virtually all of the large cobbles and boulders.

Pebbles and cobbles of at least three intermediate types of porphyritic rocks were noted. These are probably derived from either surface flows or dyke rocks. Other rock types found are quartz, quartzite, chert, greywacke, sericite schist, and greenstone.

Thin sections were made of most of the type fragments in the conglomerate, both to discover their composition, and to discover the effect of a uniform grade of metamorphism on a heterogeneous aggregate of different rock types. Sections of granitic rocks were stained in an attempt to define their composition more closely for purposes of correlation. The results of the staining are disappointing as they serve only to prove that metamorphic recrystallization has impressed such a confused microtexture on the granitic rocks as to render the making of rosiwal analyses impossible.

Granitic Rocks.

Visual estimates give the following composition for the granitic rocks:

(a) Porphyritic quartz diorite.

Quartz	15-20 per cent
Plagioclase.	70-75 per cent
Biotite.	5-10 per cent
Magnetite Chlorite Epidote . . . . . Apatite	1-2 per cent

(b) Grey quartz diorite.

Quartz	10-15 per cent
Plagioclase.	75-80 per cent
Biotite.	4-8 per cent
Magnetite Chlorite Muscovite Epidote . . . . . Zoisite Apatite Carbonate	2-3 per cent

It is interesting to note the total absence of potash feldspars in these rocks.

The original hypautomorphic-granular textures of the granitic rocks have been largely preserved, though in a form modified by low grade regional metamorphism. As has been shown above plagioclase feldspars are the dominant mineral constituent. The once euhedral grain boundaries of the feldspars are now very irregular, and some of the larger crystals have been recrystallized to aggregates of smaller grains. Twinning is generally absent in the feldspars; consequently, the only method of determining their composition from thin sections was by the use of the universal stage, and this was not attempted. Chemical alteration of the plagioclases has been accomplished, either by late deuteric solutions from the magma, or by metamorphism. The products of this alteration - white mica, presumably sericite or muscovite, biotite, chlorite, epidote, and carbonate - are scattered throughout the original crystals as flakes and granules. Commonly, the central parts of feldspar crystals are more altered than the outer parts.

Quartz has two distinct modes of occurrence. Most of the quartz occurs as original interstitial grains. Some of these have been recrystallized to sutured aggregates of smaller grains. Feldspar grains in contact with this primary quartz have usually preserved their euhedral outline. Quartz grains locally enclose aggregates of biotite and chlorite. The second, and less prominent, occurrence of quartz is in the form of very small grains, poecilitically enclosed in the feldspars. These grains are scattered uniformly throughout the rock, and can be distinguished from spots where the yellow precipitate resulting from the staining technique has flaked off the feldspars by their differing optical orientation. It was first thought that these granules were the soda-plagioclase products of a saussuritization process, but their indifference to the staining proceduce proved them to be quartz. The author does not know of any metamorphic or deuteric process which will produce quartz from the breakdown of plagioclase feldspar, and their presence is unexplainable from that fiewpoint. Their presence may be explained as a dispersal, presumably of primary quartz, throughout the feldspars as a result of the increased mobility of quartz at elevated temperatures.

The biotite of the granitic rocks is all of the pleochroic yellow-greenish brown type. Like quartz, biotite has two more or less distinct modes of occurrence. The chief occurrence of the mineral is in the from of aggregates, or as single grains, interstitially dispersed throughout the rock. Magnetite, and locally chlorite, are closely associated with the biotite. This biotite is either primary, or in a modified form thereof. The second occurrence of biotite is as small flakes, occurring as inclusions in the feldspars. This biotite is most probably a metamorphic type, produced by regional metamorphism from the chlorite and sericite alteration products contained in the plagioclase.

The texture of the biotite in these rocks is important in the determination of the metamorphic environment of the granitic components. None of the biotite in the granitic cobbles examined was aligned. In fact, where aggregates of the mineral occur, there is a definite decussate texture. This could only mean that stress was not an important factor in the metamorphism of these cobbles. The fact that the micaceous minerals of the matrix of the conglomerate are all strongly aligned would suggest that the regional stress was absorbed by the matrix and did not affect the larger cobbles and boulders, presumably with the exception of those places where individual cobbles are in contact.

Intermediate Volcanic or Dyke Rocks.

Porphyritic rocks of three different types were found. These may be derived from either flows of intermediate compositon, or from dyke rocks.

One of the porphyries weathers to a light greyish brown. Feldspar phenocrysts do not stand out in relief on the weathered surface. The fresh surface has a general light grey color, relieved by greenish grey feldspar phenocrysts and black biotite clots. The feldspar phenocrysts have a maximum diameter of seven millimetres. A few quartz phenocrysts are also present.

In thin section, the rock is composed of subhedral plagioclase phenocrysts, and a few scattered anhedral quartz phenocrysts set in fine grained quartz-feldspar groundmass. Plagioclase phenocrysts are equidimensional, and are extensively altered, with the production of sericite and calcite, plus some biotite and chlorite. Twinning is rare, and where present, is of a very coarse albite type, not suitable for compositional determination. A zone rich in fine muscovite rims the phenocrysts. This muscovite probably is derived from the metamorphism of clay minerals produced during the Archean weathering of the parent rocks.

Quartz phenocrysts are subordinate, and are usually rounded. Most of them are not recrystallized. Some phenocrysts have a zone of micaceous inclusions, which may indicate that the quartz has experienced a porphyroblastic development.

The groundmass is a fine grained aggregate of quartz and feldspars, with an average grain size of less than 0.1 millimetres. Scattered throughout are abundant, small, unaligned flakes of muscovite. Biotite, probably of metamorphic origin occurs as scattered knots, having a decussate texture. Accessory minerals are apatite and magnetite. There is no flow structure in the groundmass.

A second type of porphyry is more schistose. The weathered surface is a very light grey, with abundant feldspar phenocrysts standing out as rounded knobs. The fresh surface of the rock is a greyish black, and shows elongated grey phenocrysts of feldspar set in a siliceous groundmass. Numerous slip planes developed by stress give the rock a micaceous appearance when viewed from the appropriate angle.

Under the microscope, thin sections of this rock have certain similarities to those of the porphyry described above. The alteration of the phenocrysts is similar, and the groundmass is identical, but for a slightly finer grain size, and the development of aligned biotite. Here, however, the plagioclase phenocrysts are elongated, and have an average size of one millimetre by 0.3 millimetres. A few vestiges of a primary lamellar twinning remain, the rest having been apparently destroyed by metamorphism. The phenocrysts display a tendency towards a preferred orientation at a slight angle to the micaceous slip planes. The phenocrysts contain abundant quartz inclusions similar to those described in the feldspars of the granitic components. No quartz or potash feldspar phenocrysts are present.

The groundmass has an average grain size of 0.05 millimetres. There are a few flakes of muscovite, but the predominant micaceous mineral is biotite, occurring mostly as elongated flakes. A few larger porphyroblastic biotite aggregates are also present. The tendency of the biotite flakes to curve around the phenocrysts gives the latter an "eye-like" appearance.

The third porphyritic rock is black on both weathered and fresh surfaces. Plagioclase feldspars stand out strongly in relief on the weathered surface. The average diameter of these phenocrysts is two millimetres, but a few have a mean diameter of four millimetres. The groundmass appears fine grained, black, and slightly micaceous on the fresh surface.

In thin section, this porphry bears some resemblance to both of the others already described. The plagioclase phenocrysts are subhedral, and the majority have a square cross-section. Feldspar twinning has been retained in this rock on a larger scale than in the others. Some phenocrysts are twinned by the carlsbad law, suggesting that they may be orthosclase. Others have a pseudo grid twinning, the result of twinning by both albite and pericline laws. The latter crystals are probably plagioclase. All the plagioclase phenocrysts are strongly sericitized.

The groundmass is fine grained, with an average grain size of 0.1 millimetres, and consists of a micaceous feldspathic aggregate. Pleochroic yellow-brown biotite is abundant in the form of elongated laths, and muscovite is a minor constituent.

Sedimentary and Basic Igneous Rocks.

A number of specimens having the appearance of chert were collected. These rocks are very fine grained and dense, and weather brownish to black. Their fresh surface show sharp edged conchoidal fractures, and have a siliceous appearance.

A microscopic examination of these rocks shows that they are not true cherts, but are very fine grained impure quartzites, composed of approximately sixty-five per cent angular quartz grains, thirty-five per cent muscovite, and a trace of brown biotite. The quartz grains have a maximum diameter of 0.05 millimetres, and an average diameter of about 0.02 millimetres. The original clastic nature of these sediments is well preserved, but there is no trace of bedding. The fine muscovite flakes are all aligned, and occur between and around the quartz grains. The muscovite is probably developed from clay minerals. Biotite is in its original stages of metamorphic development in these rocks, and occurs as non-oriented flakes up to 0.1 millimetres in diameter.

Unlike the competent granitic components, these sedimentary rocks have not escaped the regional stress. Micaceous minerals are all aligned, with the exception of the newly formed biotite. The pebbles and cobbles themselves commonly have an elongated shape, indicating that they have been squeezed.

Due to an oversight, no specimens of the basic igneous rocks were obtained. Presumably, they would be at the same grade of metamorphism as the enclosing lavas, and would resemble them closely in thin section.

Matrix.

The matrix of the Powstick Lake conglomerate is a mixture of greywacke and grit, of varying grain size, composed of the finer elements of the detrital components already described. Pebbles having a diameter of one inch are common in the conglomerate, but the size range one-quarter inch to one inch is not well represented. The average maximum size of the matrix is about one-quarter inches. These particles consist of rock fragments and locally of individual quartz grains.

The matrix weathers mostly to a brownish grey, but may be greenish where hornblende is present. Good bedding is not developed, but in most places lenses of differing grain size and composition are readily apparent. The fresh surface is generally black, as a consequence of the high mica content. A siliceous appearance is enhanced by scattered clear quartz grains.

In thin section, the matrix is composed essentially of quartz, feldspar, biotite, and muscovite, mixed in various proportions with scattered rock fragments. Micaceous minerals are generally aligned. Where the sediment was highly chloritic, metamorphism has produced hornblende in the form of poeciloblastic porphyroblasts, and where calcareous material was present both epidote or zoisite and hornblende have been formed.

Summary of the Metamorphism of the Powstick Lake Conglomerate.

The Powstick Lake conglomerate affords an excellent opportunity for the study of a heterogeneous assemblage of different rock types under the conditions of low grade regional metamorphism. No evidence was found to suggest that the grade of metamorphism is any higher than the biotite zone. The chief effects of metamorphism are best summarized by the following statements:

(a) Regional metamorphism has rached the biotite zone.

(b) The greater development of biotite in the matrix than in some of the sedimentary pebbles suggests that the latter contained insufficient chloritic material for the extensive production of biotite.

(c) Where calcareous matter was present in the original sediment, it has taken part in two reaction, namely:

  (i) the formation of epidote by reaction with the excess alumina left over from the formation of biotite from chlorite and sericite.

  (ii) the formation of hornblende by reaction with chlorite. Hornblende generally forms porphyroblastic crystals having a sieve texture.

(d) The granitic cobbles, especially the larger ones, have not been subjected to the regional stress which the softer sedimentary components have experienced. The shearing stress has largely been absorbed by the less competent matrix. The large granitic cobbles have therefore been subjected to low grade thermal metamorphism, with high hydrostatic pressure.

(e) Granitic components have suffered extensive recrystallization.

The Semple Lake Conglomerate.

Distribution. The sole occurrence of this rock is as a narrow outcrop on the north-west corner of the first small island south-west of the large island in central Semple Lake. The outcrop is low and shelving and would be mostly submerged during periods of high water. Near the southern edge of the outcrop, three two foot conglomerate beds are separted from the main body by an eighty foot massive basic flow.

Lithology and Metamorphism. The conglomerate is composed of approximately thirty per cent rounded to anglular pebbles and cobbles, ranging in size from one and one-half inches in diameter to four by twelve inches. These fragments are embedded in a schistose quartz-biotite matrix. Sorting is very poor throughout the outcrop. Rock types noted as components of the conglomerate are granitic rocks, porphyritic rocks, and quartzite.

Granitic Rocks.

Two types of granitic pebbles are present. One type is a light grey weathering quartz diorite, similar to that described in the Powstick Lake conglomerate. Rosiwal analyses were not attempted for these rocks, for the same reason as those given in connection with the granitic components of the Powstick Lake conglomerate. A visual estimate of the composition of the grey quartz diorite, made from a thin section shows the following composition:

Quartz	30-35 per cent
Plagioclase (An 30).	60-65 per cent
Biotite	
Magnetite.	2- 3 per cent
Epidote	
Apatite.	tr

A thin section study of this rock at once shows that the granitic pebbles of this conglomerate have not excaped the effects of regional stress as have those of the conglomerate to the north. Here, the quartz grains are strongly recrystallized to sutured aggregates. A few feldspar grains are fractured, and have bands of finely crushed quartz and feldspar extending through them. Plagioclases have retained much of their primarly albite twinning, and a suggestion of their original euhedral shape. Extinction angles measured on the twins indicate a plagioclase composition of oligoclase-andesine (An 30). Biotite occurs as indefinitely oriented small flakes, associated with granular epidote. Both these minerals were probably native to the original igneous rock. The average grain size of the major components is about one millimetre.

This rock probably came from the same source area as the grey quartz diorite found in the Powstick Lake conglomerate. The differences in bulk composition appear less important when one considers the compositional variance of the grey granodiorites and quartz diorites which have intruded the Semple Lake Series.

The second granitic rock type is one which is not found in the Powstick Lake conglomerate. Pebbles and cobbles of this rock weather to a light creamy white, and have a generally light grey fresh surface. The average grain size is about 2.5 millimetres, which is more than twice that of the grey quartz diorite just described. A visual estimate of the bulk composition is as follows:

Quartz	35-40 per cent
Plagioclase (An20-An25).	50-55 per cent
Biotite Carbonate . . . . Epidote	5-10 per cent

Thin section examinations show the recrystallized quartz and incipient crushing already described in the grey quartz diorite. Plagioclases are generally anhedral, except where in contact with quartz. They are mostly twinned, and extinction angles measured on albite twins indicate a plagioclase composition approximately of oligoclase (An20-An25). Moderate sericitization and saussuritization have occurred. The epidote is probably the product of a deuteric alteration of the biotite but the carbonate was probably introduced during lithification and metamorphism.

Porphritic Rocks.

Two different types of porphyritic rocks are present in the Semple Lake conglomerate. The most common type of porphyry is composed of about fifty per cent feldspar phenocrysts. The rock has a rough, light grey weathered surface, and a dark grey fresh surface. On the fresh surface, greyish, translucent feldspar phenocrysts averaging two millimetres in diameter may be seen, set in a fine grained siliceous matrix.

Examination under the microscope reveals that the rock is composed of about fifty per cent of euhedral to subhedral plagioclase phenocrysts set in a fine grained quartz-feldspar-biotite groundmass. The absence of quartz phenocrysts distinguishes this rock from a similar light grey weathering porphyry found in the Powstick Lake conglomerate. The phenocrysts are concentrically zoned, and a few show both zoning and carlsbad twinning. Alteration of the phenocrysts is not extensive.

Seen under the microscope, the groundmass of the porphyry has an average grain size of less than 0.1 millimetres, and consists of an equigranular aggregate of quartz and feldspar, plus ten to fifteen per cent of tiny, greenish-brown, aligned biotite flakes. Scattered grains of primary magnetite, and a few grains of metamorphic muscovite, chlorite, and epidote dot the groundmass.

It was noted in the field that the conglomerate band is intruded in a few places by small dykes and sills of a porphyritic rock which appeared identical to the porphyry just described.

The second type of porphyry weathers to a brownish black. On the fresh surface, scattered clear quartz grains and a few translucent feldspar phenocrysts can be seen in a siliceous looking, black, aphanitic groundmass.

In thin section, phenocrysts make up about forty per cent of the rock, and are composed of quartz and plagioclase feldspar in about equal proportions. Strong shearing has partially crushed the plagioclase phenocrysts, and has caused the quartz phenocrysts to assume lens-like shapes, composed of recrystallized aggregates. Considerable saussuritization and sericitization has accompanied the crushing of the feldspars.

The dark color of the rock is the result of the extensive development of dark brown metamorphic biotite, which makes up about thirty per cent of the groundmass. The remainder is comprised of quartz and feldspar, plus a few hornblende needles, and scattered grains of chlorite, epidote, carbonate and magnetite. Some of the quartz and feldspar of the groundmass have recrystallized to granular aggregates, which together with the lenses of aligned biotite give the rock an appearance, under the microscope, resembling a coarse greywacke.

Matrix.

The matrix of the Semple Lake conglomerate has the appearance and composition of a greywacke. The grain size is generally finer and more uniform than that of the Powstick Lake conglomerate. Both the weathered and fresh surfaces are brownish black. The matrix has a fairly easy micaceous parting and is locally coarsely crenulated.

Under the microscope, a typical thin section consists of about sixty per cent of angular quartz and feldspar, having an average mean diameter of about 0.05 millimetres. The remainder of the bulk composition is made up mostly of dark brown biotite in aligned flakes, which rarely exceed 0.02 millimetres in length. Some fine granules of magnetite, and a very few flakes of green chlorite are scattered through the rock.

Summary of the Metamorphism of the Semple Lake Conglomerate.

The preceeding lithologic descriptions bring out the following points regarding metamorphism:

(a) Regional metamorphism of the conglomerate reached biotite zone.

(b) Local dynamic action, or regional deformational stress has been important during metamorphism, as is shown by the local crenulation of the matrix and the crushing of the phenocrysts of some of the porphyritic rocks.

Structural Geology. The absence of pillow lavas and other criteria commonly used in the determination of the attitude of layered rocks has greatly hindered the solution of structural features of the Semple Lake series. No major folding was recognized within the series, although the rocks have obviously been turned on edge.

Three major faults are recognized. One of these faults enters the area at its western bounday, north of Powstick Lake. This fault is continuous with a major break mapped by Milligan (1954). A second fault parallels a topographic lineament in the southeast corner of the area. The third fault extends in a northeasterly direction through the centre of Powstick Lake. This fault truncated the Powstick Lake conglomerate on the north, and is seen cutting porphyritic granite on islands in the lake. Associated with these faults are numerous short faults of minor displacement, whose formation is probably related to that of the major breaks.

The Relation of the Semple Lake Series to Other Rocks in the Region. To the south of the California Lake Area, the

Semple Lake series continues into the Oxford House area, where similar rocks have been mapped by Wright (1925,1931), and Morgan (1940). In the Oxford House area, the southward continuation of the Semple Lake series has been mapped as part of the Hayes River group.

The Hayes River group consists almost entirely of volcanic rocks, with minor interbedded sediments, and is overlain unconformably by the Oxford Series. Morgan recognizes "quartz-eye" granite that is intrusive into the Hayes River group, but which is older than the Oxford series. Substantial differences exist between the maps drawn up by Morgan[1] and Wright[2]. Both writers agree that extensive conglomerates form the base of the Oxford Series, but only Morgan recognizes minor comglomerate in the Hayes River group. Springer (1947) found conglomerate in the rocks of the Hayes River group in the Knee Lake area.

Granitic components are not reported in the Hayes River conglomerates. The Powstick Lake and Semple Lake conglomerates differ from the others in this regard.

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[1] J. H. Morgan, "The Application of Accessory Mineral Methods to the Pre-Cambrian Rocks of the Oxford House Area", (unpublished Doctor's thesis, The University of Wisconsin, 1940).

[2] See Geological Survey, Canada, Map 305A, Oxford House sheet, Provisional Edition.

The Oxford conglomerate is comprised, according to Wright, of about ninety-five per cent of granite fragments. The author is doubtful, on a petrographic basis, of the existence of any true granites in the Oxford conglomerate, but there is a distinct possibility that similarities exist between the "granite" pebbles of the Oxford conglomerate, and the quartz diorite pebbles of the Powstick Lake and Semple Lake conglomerates.

Porphyritic dacites and trachytes have been found in the Hayes River group in the Oxford House region. Bruce (1919) found similar rocks in the Knee Lake area. Descriptions of these rocks indicate a distinct resemblance between them and the porphyritic rocks found in the conglomerates of the Semple Lake series. Rhyolite occurs in very minor amounts in the Hayes River group of the Oxford House area, although pebbles of rhyolite are found in the Oxford conglomerate. It is possible that some of these pebbles may have been derived from rhyolites now exposed within the Semple Lake series.

The relation between the Semple Lake series and volcanic and sedimentary rocks of the northern part of the area is not clear. Metamorphism has obliterated the primary structures and textures of the Baker Lake series (to be described in the next chapter), and also the Bigstone Lake group described by Shepherd (1954).

This in itself does not constitute definite evidence of any large discrepancy of age between the Semple Lake series and the northern belt of rocks. However, Utik Lake and Merritt formations of Shepherd's Bigstone Lake group represent the deposition of considerably more sedimentary material than is commonly found in rocks of Hayes River age. Milligan (1952) describes a conglomerate in the volcanic sedimentary rocks around central Utik Lake. The author examined specimens taken from this conglomerate, and found at least a superficial resemblance between some of the granitic pebbles contained therein and the quartz diorite pebbles of the Powstick Lake conglomerate.

The following statements may be given in summary:

(a) The Semple Lake series can be lithologically correlated with rocks of the Hayes River group.

(b) Boulders in the Powstick Lake and Semple Lake conglomerates constitute the first undoubted evidence of pre - Hayes River granitic intrusions.

(c) Many of the porphyritic intermediate rocks found in the Powstick and Semple Lake conglomerates are possibly derived from dacites and trachytes, which are widespread in the Oxford House area.

(d) The relation between the northern and southern volcanic-sedimentary belts, within the California Lake Area, is not clearly understood. Granitic boulders found in the Powstick Lake conglomerate may possibly be correlative with those found in a conglomerate near Utik Lake.

CHAPTER IV

THE BAKER LAKE SERIES

Introduction.

The Baker Lake series consists of basic flows and greywacke type sedimentary rocks, which have been subjected to a considerably higher grade of regional metamorphism than has the Semple Lake series in the southern part of the area. The series is considered to be a structurally isolated portion of the Bigstone Lake group described by Shepherd (1954).

The Baker Lake series takes its name from that given during the field season to the narrow lake on whose shores it outcrops. It should be noted that this body of water was given the name Baker Lake purely as a convenience in the field, and because no application was made to federal authorities to have the name verified, it has been shown on the accompanying map in quotation marks.

Distribution.

The main portion of the Baker Lake series lies in the upper half of the California Lake area, near its eastern boundary. Owing to extensive deposits of Pleistocene and post-Pleistocene material and the consequent scarcity of rock exposure in this region, little is known of the exact extent of the series. Rocks of a similar type outcrop on the Bigstone River, about one mile south of Bigstone Lake. It is possible that these rocks may mark the western boundary of the Baker Lake series, but the author has no justification for drawing even approximate contacts across the intervening three miles of drift covered terrain. Exposures of greenstones and sedimentary rocks found during a reconnaissance trip indicate that the Baker Lake series continues at least one mile east of the boundary of the map area.

Lithology and Metamorphism.

General Statement.

Basic lavas and metamorphosed sedimentary rocks, showing only slight variations in composition, comprise the whole of the Baker Lake series. The basic lavas are andesitic or basaltic in composition, and the sedimentary rocks are believed to have been originally feldspathic greywackes. As far as is known, pyroclastics, quartzites, conglomerates or limestones do not occur within the series. All of the rocks, and especially the sedimentary types, have been extensively intruded by dykes and sills of granitic type emanating from the surrounding batholith.

Basic Flows.

Lithology and Metamorphism. Basic flows almost invariably present a greenish-black weathered surface. Massive flows are commonly medium grained and have an equigranular texture. Schistose varieties are generally finer in grain size. On their fresh surfaces, dark green hornblende is the dominant mineral, accompanied by granular plagioclase, and locally, biotite.

The mineralogy of the basic flows is simple. Thin sections studied show them to be composed of about sixty per cent of hornblende, with the rest of the rock composed of plagioclase feldspar, plus one or two per cent of magnetite. Apatite and biotite are local accessory minerals.

Hornblende in the basic rocks has a subhedral acicular habit, but does not occur in the extremely elongate forms seen in similar rocks of lower metamorphic grade, nor does it have the deep blue-green color seen in those rocks. Hornblende shows only a slight tendency towards porphyroblastic development. Plagioclase feldspars have a granular habit, and are untwinned. Magnetite occurs as anhedral grains.

Basic rocks in the Baker Lake series are in the plagioclase-amphibolite facies of regional metamorphism. Any epidote that was present in the lower facies has completely reacted with the plagioclase. In a similar manner, chlorite and calcite have been completely replaced by hornblende.

Sedimentary Rocks.

Lithology and Metamorphism. Outcrops of sedimentary rocks are generally a rusty brown color. Because of their lepidoblastic texture, and their relatively high ferriferous biotite content, these rocks are susceptible to chemical weathering, and exposed surfaces are often crumbly. Fresh surfaces are usually rust stained and have a very sandy appearance.

Fourteen thin sections made from a total of twelve specimens were examined under the microscope. Rosiwal analyses were conducted for three stained thin sections from specimens taken at different parts of the series. This study proved that the mineralogy, bulk composition, and texture of sedimentary rocks are remarkably constant over the entire series. The essential minerals of the sedimentary rocks are quartz, plagioclase, and biotite. Other minerals present in very minor amounts are garnet, cordierite, muscovite, apatite, zircon, magnetite and hematite. A unique mineral assemblage called "pinite", found in some of the specimens, will be discussed later.

The texture found in all sections examined is lepidoblastic. This textural name is applicable because of the general alignment of the biotite in the plane of schistosity. In a few sections, alignment is very slight, and biotite assumes an almost random orientation. Structurally, the rocks should be termed schists, although a micaceous cleavage is not well developed. The grain size averages from 0.25 millimetres to 0.5 millimetres, and is generally uniform.

Quartz and plagioclase have assumed a granular habit, with a local tendency towards elongation in the plane of schistosity. Crystal faces are never developed in these two minerals, and not trace of their original clastic nature remains. Both minerals have probably experienced an increase in grain size by recrystallization. Albite twinning is well developed in some plagioclase grains. Extinction angles measured on albite twins indicate a plagioclase composition of sodic andesine (An 30). Biotite is of a strongly pleochroic, yellow brown-deep reddish brown type and doubtless has a high iron content. Quartz, plagioclase and biotite are uniformly distributed throughout the rock, and there is no tendency towards the development of a gneissic structure. Garnet occurs as scattered poecilo-blastic nodules, and has not developed crystal faces. The other minerals occur as scattered grains. The results of three rosiwal analyses are shown in Table IV.

TABLE IV

RANGE OF BULK COMPOSITION OF SEDIMENTARY ROCKS OF THE BAKER LAKE SERIES

	M435	M465-A	M475
	Volume per cent	Volume per cent	Volume per cent
Quartz	48.1	31.3	42.0
Plagioclase	37.0	39.6	44.8
Biotite	14.4	28.4	11.9
Magnetite	0.5	-	1.8
Garnet	-	0.8	tr
Apatite	-	tr	tr
Zircon	tr	tr	tr

The mineral assemblage known as "pinite" is a minor constituent of some specimens. "Pinite" is a micaceous aggregate, consisting mostly of white mica, with a local chloritic admixture. Quartz is commonly associated with these minerals. "Pinite" forms as an alteration of cordierite, and is seen replacing that mineral in several sections. An X-ray diffraction powder photograph was taken of one "pinite" grain, but no conclusive results were obtained. The basic pattern was that of quartz, with extra lines due to the muscovite and chlorite.

The presence of "pinite" serves to introduce the problem of the metamorphism of these rocks. According to Harker (1939, pp 340-46), "pinite" can form in but two ways; either through regional metamorphism following simple thermal metamorphism, or during retrograde metamorphism of both types. When produced by repeated metamorphism, "pinite" occurs only in low grade regional metamorphism. Certainly, in the rocks under discussion, regional metamorphism has progressed well beyond low grade. This observation, considered together with the fact that all specimens containing "pinite" were taken from outcrops which are either within one hundred feet of granitic intrusive rocks, or are extensively injected by granitic dykes, led the author to the conclusion that the presence of "pinite" is the result of retrograde thermal metamorphism, caused by the intrusion of the surrounding granodiorite.

If the above reasoning is correct, it leads to some interesting conclusions. It implies that there have been two separate, though not necessarily unrelated, periods of metamorphism; moreover, the retrograde metamorphism is the second of the two types to occur, as its unique end products would quickly be destroyed by a third period of metamorphism.

It therefore follows that the regional metamorphism preceded the intrusion of the granitic rocks, at least to the extent that the regional temperatures and pressures did not alter the effect of the later thermal metamorphism. In short, regional metamorphism preceded regional intrusion.

The effects of the thermal metamorphism are probably localized to the immediate neighborhood of the igneous intrusions and injections. Regional metamorphism has reached at least the almandine zone. Almandine garnets occur in at least four localities in the eastern part of the series. The mineral is not abundantly developed where it does occur, and it is felt that its presence depends as much upon bulk composition as it does upon metamorphic grade. If this is true, then the fact that garnets were not found in outcrops in the western half of the series need not be regarded as specific evidence that the almandine zone was not reached in these parts. It is possible that metamorphism attained an even higher grade. Harker (1939, p. 248) states that if the original sediments were deficient in alumina, then the higher index minerals staurolite, cyanite, and sillimanite may be lacking, even though metamorphism reached the grade at which they were capable of forming.

The original sediment was possibly a feldspathic greywacke. The absence of the typical aluminous minerals chloritoid, staurolite, and sillimanite indicates that alumina was not excessive in the unmetamorphosed rock. Similarly, the presence of normal white mica in the present rock indicates that sericite was present in greater amounts than chlorite. Some of the muscovite is probably derived from the breakdown of potash feldspars which are unstable at these grades of metamorphism, and which are not found in any of the rocks.

At the commencement of metamorphism, the rock probably consisted of quartz, feldspars, sericite, clay minerals, chlorite, hematite, rutile and magnetite. As temperature and pressure began to rise, hematite was reduced to magnetite and the clay minerals formed sericite. Throughout the chlorite zone recrystallization processes continued. Any basic plagioclase present was unstable, and broke down to albite, forming epidote and carbonate as by-products. A strong schistosity was probably developed, and the rock type might be named an albite-chlorite-sericite schist.

When temperatures and pressures reached those marking the commencement of the biotite zone, biotite began to form from reactions involving chlorite, sericite, quartz, magnetite and rutile. As metamorphism passed through the biotite zone, recrystallization continued and the quartz and feldspar began to assume rounded forms, thus losing all trace of their detrital beginnings. Albite would begin reacting with epidote, and the anorthite content of the plagioclases increased. As the sericite and chlorite were used up by the formation of biotite, the marked schistosity of the rock began to decrease.

With sufficient temperature and pressure, the reddish garnet almandine was formed, where compositional factors allowed its production. Almandine probably formed from chlorite, drawing some of its alumina from biotite, and most of its iron from magnetite. Further increases in temperature and pressure were not accompanied by the formation of new minerals. The mineralogy of the rock became simpler. Chlorite was entirely used up in the formation of biotite and garnet. The excess white mica, now muscovite, remained as a minor constituent. Epidote has reacted completely with the soda feldspar, causing the plagioclase to have its present composition. The original magnetite content was much reduced by its contribution to the development of almandine and the highly ferriferous biotite. Both the plagioclase and quartz assumed a granular habit, and only biotite and muscovite remained in an orientation normal to the regional compression. With the completion of these metamorphic processes, the rocks had assumed the mineralogy and textures which they have at the present time.

The intrusion of the surrounding granodiorite served only to modify this form. The formation of cordierite indicates that regional stress was not an important factor in the accompanying thermal metamorphism. Cordierite was probably formed at the expense of biotite, with the excess potash forming muscovite. As the magma cooled, and temperatures waned, cordierite became unstable, and altered partially to "pinite".

APPENDIX A

Selective Staining Technique. The staining technique used for thin section examinations is a modified form of the method developed by Keith (1939). The staining of thin sections proved to be an invaluable aid in determining both the textures of the rocks, and their bulk composition. Using this technique, the worker is able to distinguish, without hesitation, between quartz, plagioclase, and potash feldspars. As a consequence, the time consumed in making rosiwal analyses is much reduced. The method followed by the author is shown below.

(1) A preliminary microscopic examination of the thin section is made, and the minerals identified qualitatively. (In some instances, it was found convenient to make two thin sections, one of which was stained and the other kept for reference, without staining). It is advisable to make any necessary optical determinations before staining, as the treatment partially obscures the optical properties of some minerals.

(2) Stains are applied to thin sections which have been prepared without cover glasses.

(3) The exposed glass of the slide is covered with a thin coating of celluloid. (A celluloid solution is easily prepared by dissolving sheet celluloid in acetone until the solution has the consistency of glycerine). The celluloid solution protects the glass from the effects of hydrofluoric acid during the subsequent fuming and is easily applied with the camels' hair brush. It was found that the time devoted to the application of this protective coating was well spent. Any laxity during this part of the

technique was rewarded by thin sections whose backs were deeply etched.

(4) The section is carefully dried, placed in a lead tray (see diagram below), and exposed to hydrofluoric acid fumes at 65°C for a period of fifty seconds.

(5) After fuming, the section is immersed for thirty to forty seconds in the feldspar staining solution. Potash feldspar is stained a deep yellow. The feldspar staining solution is concentrated sodium cobaltinitrate, prepared by adding fifteen cc. of water to 12.5 grams of $Co(NO_3)_2$ and 20 grams of $NaNO_2$. Upon standing, a yellow precipitate is developed in this solution. The solution is apparently stable in contact with this precipitate, and should not be filtered.

(6) The section is washed by very gently rinsing in a beaker of water. No attempt should be made to wash the section under a tap, as the stain flakes away very easily.

(7) The cover slip should be applied with care. The fuming process tends to lift the edges of the section away from the canada balsam and rough handling during covering will result in a broken up section.

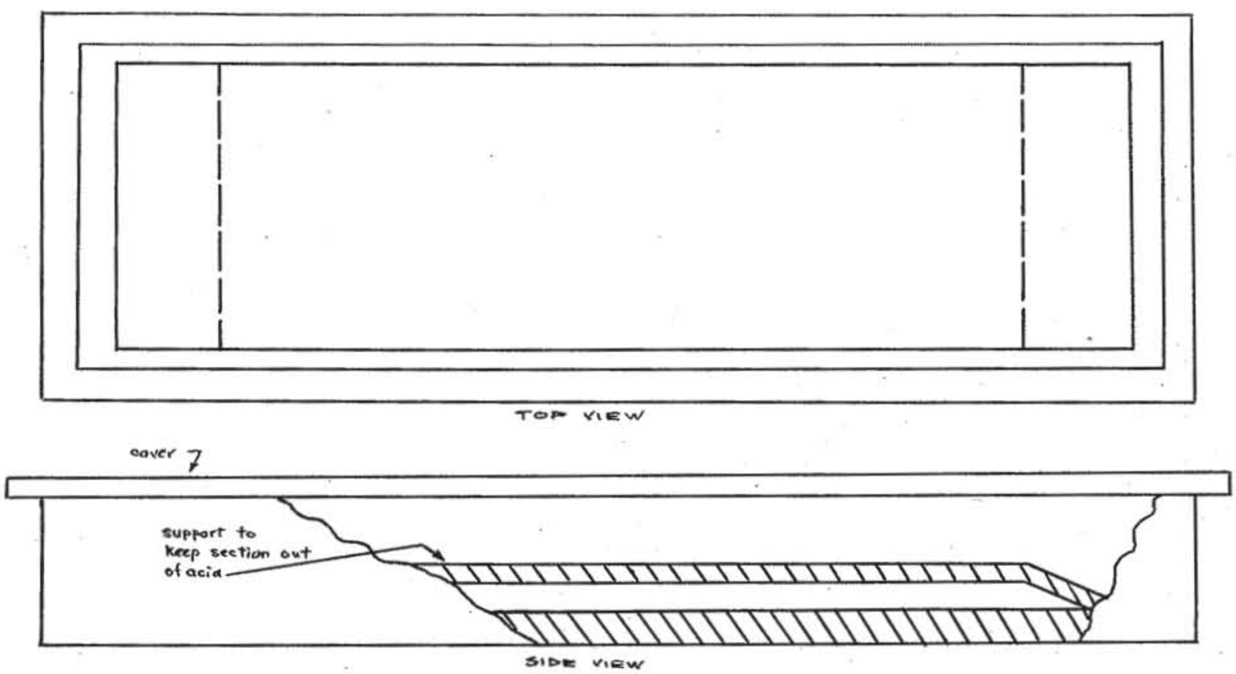

Fig. 2 Lead box constructed for the purpose of fuming thin sections in hydrofluoric acid.

APPENDIX B

The Precision and Accuracy of Rosiwal Analyses of Thin Sections and Mounted Grains. During the course of the laboratory studies, an attempt was made to find a quicker and more accurate method of determining the bulk composition of rocks than that of making rosiwal analyses of thin sections. To facilitate this study, a hand specimen was selected whose texture is essentially massive, and whose average grain size (1.5 millimetres) is representative of the granitic rocks found in the area. From this specimen five thin sections were taken at various places and cut in various directions. These thin sections were stained and counted. Three of the sections were counted twice, to determine the reproducibility of the results.

Upon the completion of this part of the study, a portion of the specimen was crushed in such a way as to keep the production of "fines" at a minimum. Crushing was continued until it was felt that all the grains consisted of discreet particles of one mineral or another. This material was then passed through a set of Tyler Standard Screens. Samples of the size ranges minus eighty to plus one hundred, and minus one hundred to plus one hundred and fifty were collected and stained. The stained grains were then mounted on glass slides covered with index oil, and counted, using a two-axis integrating stage. Two separate mounts were counted for the larger size range, and three for the smaller. The results of these studies are shown in tables V and VI.

TABLE V

MINERALOGICAL COMPOSITION AS DETERMINED FROM THE COUNTING OF SIZED AND STAINED GRAINS

SIZE RANGE -80 TO +100

Mineral	First count Volume per cent	Second count Volume per cent
Quartz	31.43	30.96
Plagioclase	42.83	51.88
Feldspar	12.96	6.69
Biotite	12.77	10.46

SIZE RANGE -100 TO +150

Mineral	First count Volume per cent	Second count Volume per cent	Third count Volume per cent
Quartz	26.47	26.81	26.17
Plagioclase	48.67	48.57	47.09
K Feldspar	10.26	9.67	11.20
Biotite	19.60	14.94	15.53

TABLE VI

MINERALOGICAL COMPOSITION AS DETERMINED BY ROSIWAL ANALYSES OF THIN SECTIONS

THIN SECTION #1

Mineral	First count Volume per cent	Second count Volume per cent
Quartz	27.85	26.60
Plagioclase	53.36	53.80
K Feldspar	11.52	10.94
Biotite	7.26	8.65

THIN SECTION #2

Mineral	First count Volume per cent	Second count Volume per cent
Quartz	28.88	27.40
Plagioclase	54.23	56.28
K Feldspar	8.72	8.28
Biotite	8.15	8.03

THIN SECTION #3

Mineral	First count Volume per cent	Second count Volume per cent
Quartz	36.74	37.58
Plagioclase	44.04	42.26
K Feldspar	13.84	13.36
Biotite	5.38	6.80

THIN SECTION #4

Mineral	Volume per cent
Quartz	28.63
Plagioclase	50.96
K Feldspar	13.57
Biotite	6.88

THIN SECTION #5

Mineral	Volume per cent
Quartz	35.57
Plagioclase	43.12
K Feldspar	14.88
Biotite	6.43

AVERAGE OF FIVE THIN SECTIONS

Mineral	Volume per cent
Quartz	31.16
Plagioclase	49.76
K Feldspar	11.89
Biotite	7.20

The following conclusions may be drawn from these results:

(1) Rosiwal analyses of a single thin section can

be reproduced within one or two per cent, but results are not accurate. Depending on the thin section, results differing as much as ten per cent are obtained.

(2) Grain counts of the size range minus eighty to plus one hundred cannot be reproduced with precision.

(3) Grain counts of the size range minus one hundred to plus one hundred and fifty can be reproduced with the same precision as can rosiwal analyses of thin sections, but the results are not accurate.

(4) The apparent biotite content is increased in grain counts, because the perfect cleavage of that mineral increases its number of particles during crushing.

In summation, it can be seen that the rosiwal analyses of a massive rock, where the average grain size is 1.5 millimetres, are fairly precise but not accurate. For this reason, in the text, percentages are not given with decimals for rocks of this grain size. Rosiwal analyses of the sedimentary rocks of the Baker Lake series are quoted with decimals because they are considered to be more accurate as a result of the finer grain size of the rocks. Crushed grain samples are easily produced and counted, and the time taken is shorter than that required for the manufacture, staining, and counting of a thin section. However, because a thin section was required of most specimens anyway, and also because the grain counting proved to be no more accurate than the rosiwal analysis of thin sections, the method was abandoned.

In fairness to both methods, it should be pointed out that the investigation did not probe the problem thoroughly, and that the conclusions are coloured by the shortcomings of the experimental data.

The effect of cleavage upon the determination of the biotite content has already been mentioned. A complete study of the grain count method would require an investigation of the influence of cleavage upon the increase in grains of different minerals during crushing. For a specific method of crushing it is probable that constants could be determined to correct for those increases.

Assuming that it could be perfected, the grain count method could be used to advantage in studies where the percentage composition of a rock is the only information desired.

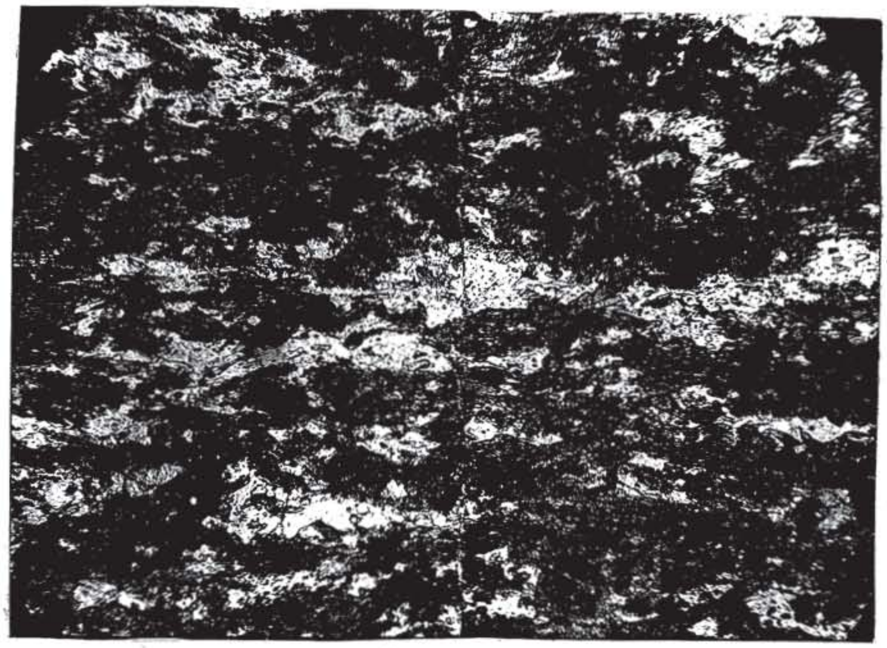

Plate I. Photomicrograph of a tuffaceous sediment from the Semple Lake series. The dark minerals are hornblende and magnetite. The clear minerals are mostly plagioclase feldspar, with a little quartz and calcite. Note the developement of very fine bedding. (X 25)

Plate II. Photomicrograph of a thin section of basic lavas from the Semple Lake series. Minerals present include hornblende (Ho), plagioclase (Pl), and magnetite (M). (X25)

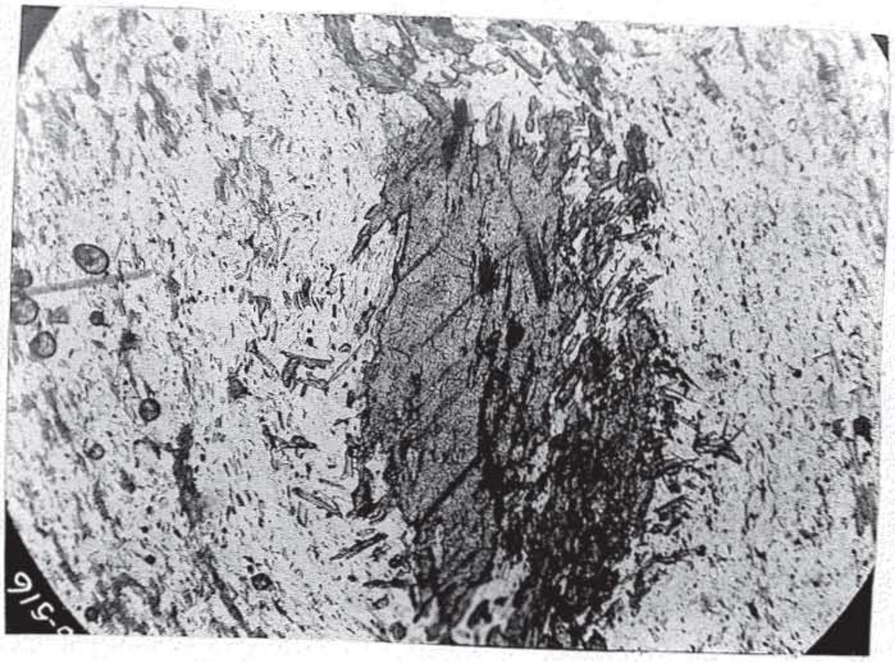

Plate III. Photomicrograph of a grain of hornblende formed by replacement of chlorite. Note the ragged outline of the crystal. Parts of the grain have the low birefringence of chlorite, but the entire grain has the same optical orientation. See text, p. 26. (X80)

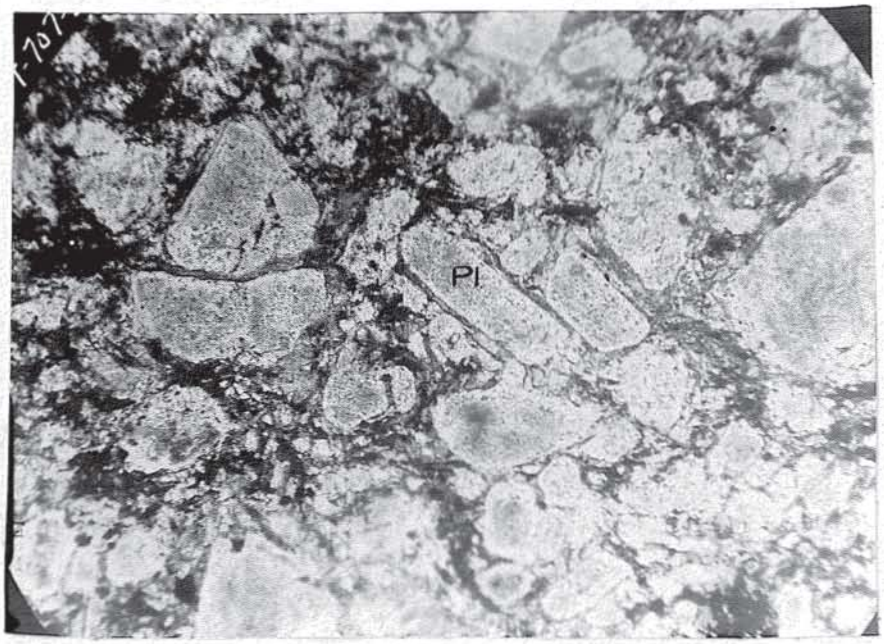

Plate IV. Photomicrograph of a thin section of a porphyritic rock from the Powstick Lake conglomerate. The phenocrysts are composed of plagioclase feldspar, and are rimmed with a zone of very fine muscovite. Other minerals in the ground mass are quartz, biotite, epidote and magnetite. (X25)

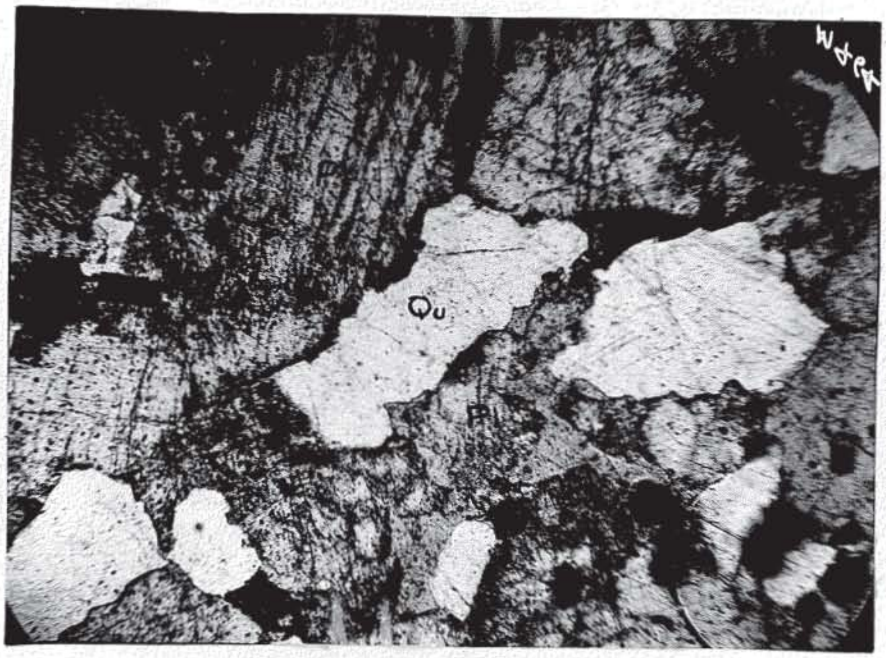

Plate V. Photomicrograph of a specimen of granodiorite. The thin section has been stained. The effect of the staining on the plagioclase and its lack of effect on the quartz can be easily seen. (X25)

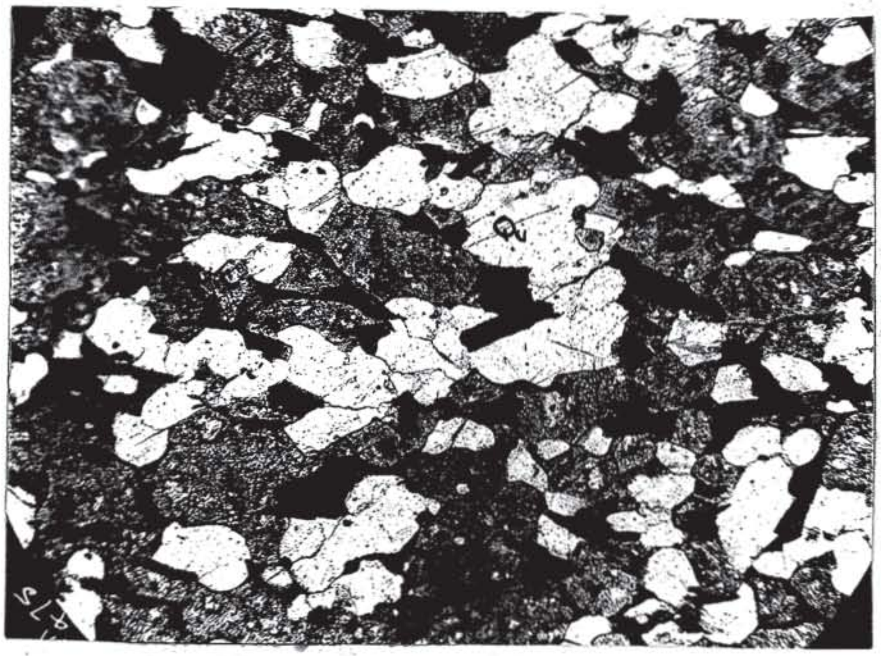

Plate VI. Photomicrograph of a thin section of a sedimentary rock of the Baker Lake series, illustrating the well developed lepidoblastic texture of the rock. The thin section has been stained. (X25)

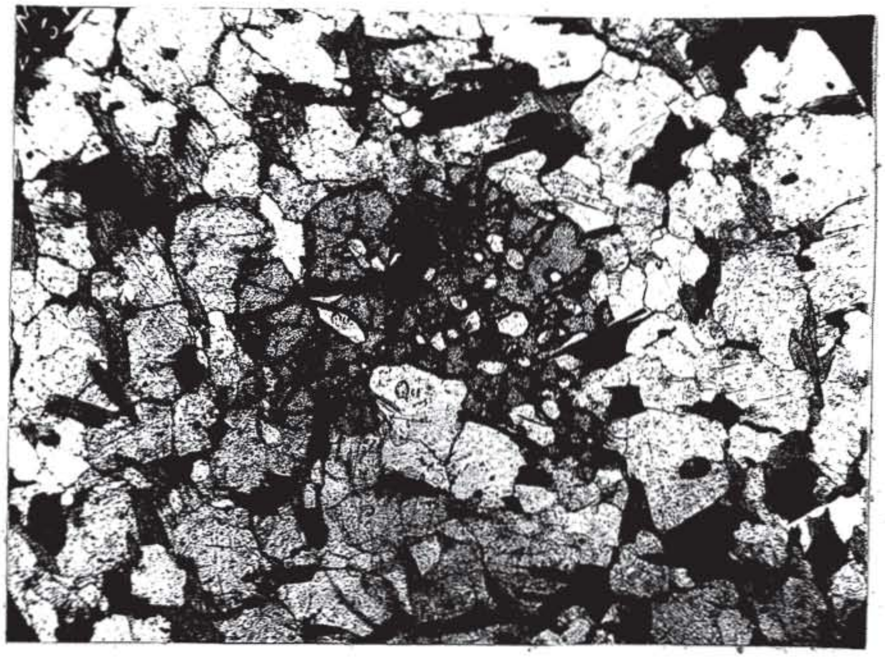

Plate VII. Photomicrograph of a thin section of a sedimentary rock from the Baker Lake series. The central grain in high refief is a porphyroblast of almandine garnet, which has a poeciloblastic texture. The enclosed mineral is quartz. Other minerals shown are quartz and plagioclase feldspar. (X25)

Plate VIII. Photomicrograph of a thin section of a sedimentary rock from the Baker Lake series, showing the mineral assemblage 'pinite' (P) replacing cordierite (Co). Other minerals are quartz (Qu) and biotite (B). (X80)

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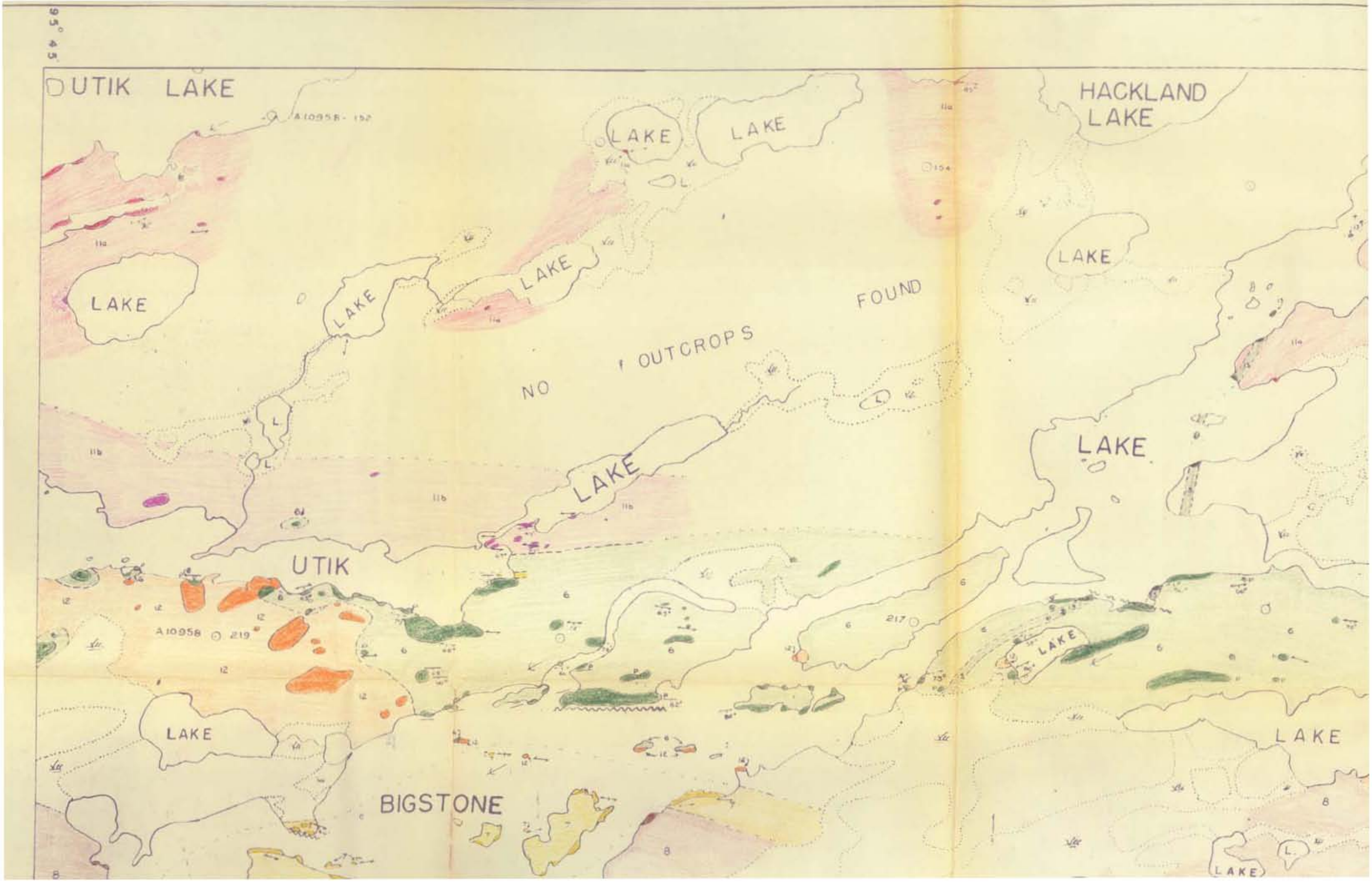
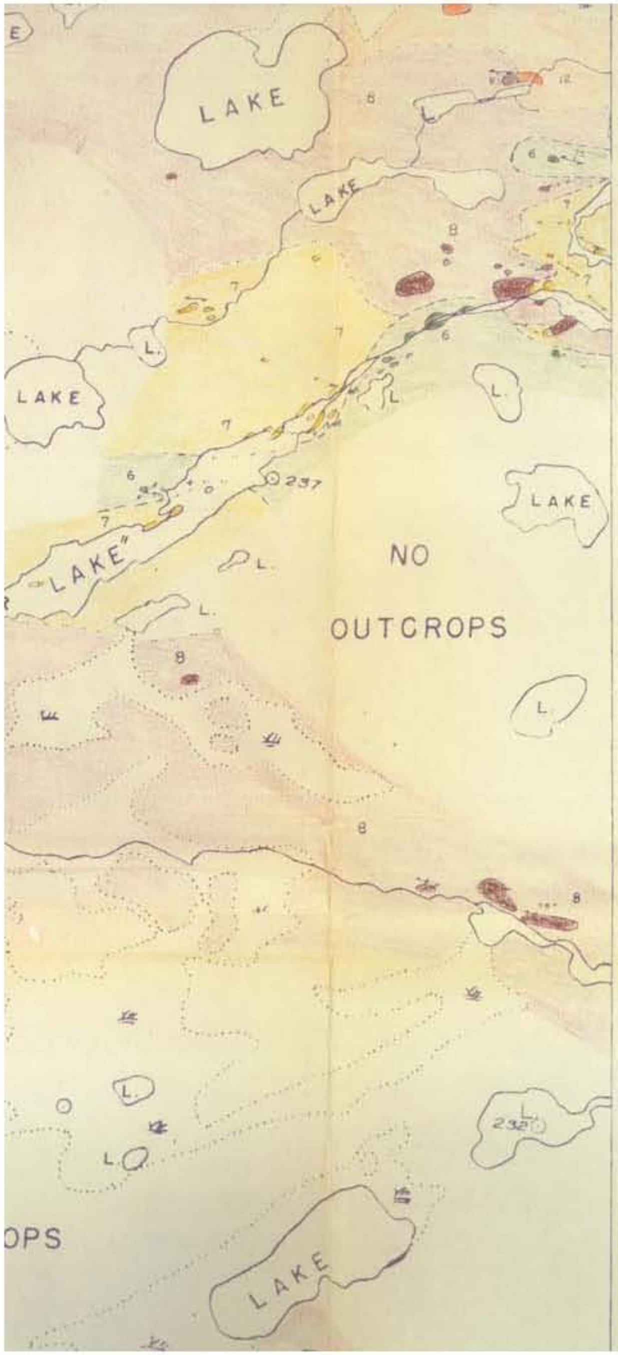
CALIFORNIA LAKE AREA

NORTHERN MANITOBA


95° 45'
UTIK LAKE
A10958 - 152
HACKLAND LAKE
NO OUTCROPS FOUND
UTIK LAKE
A10958 219
217
BIGSTONE LAKE



LEGEND

Diabase Dykes.

GRANITIC ROCKS

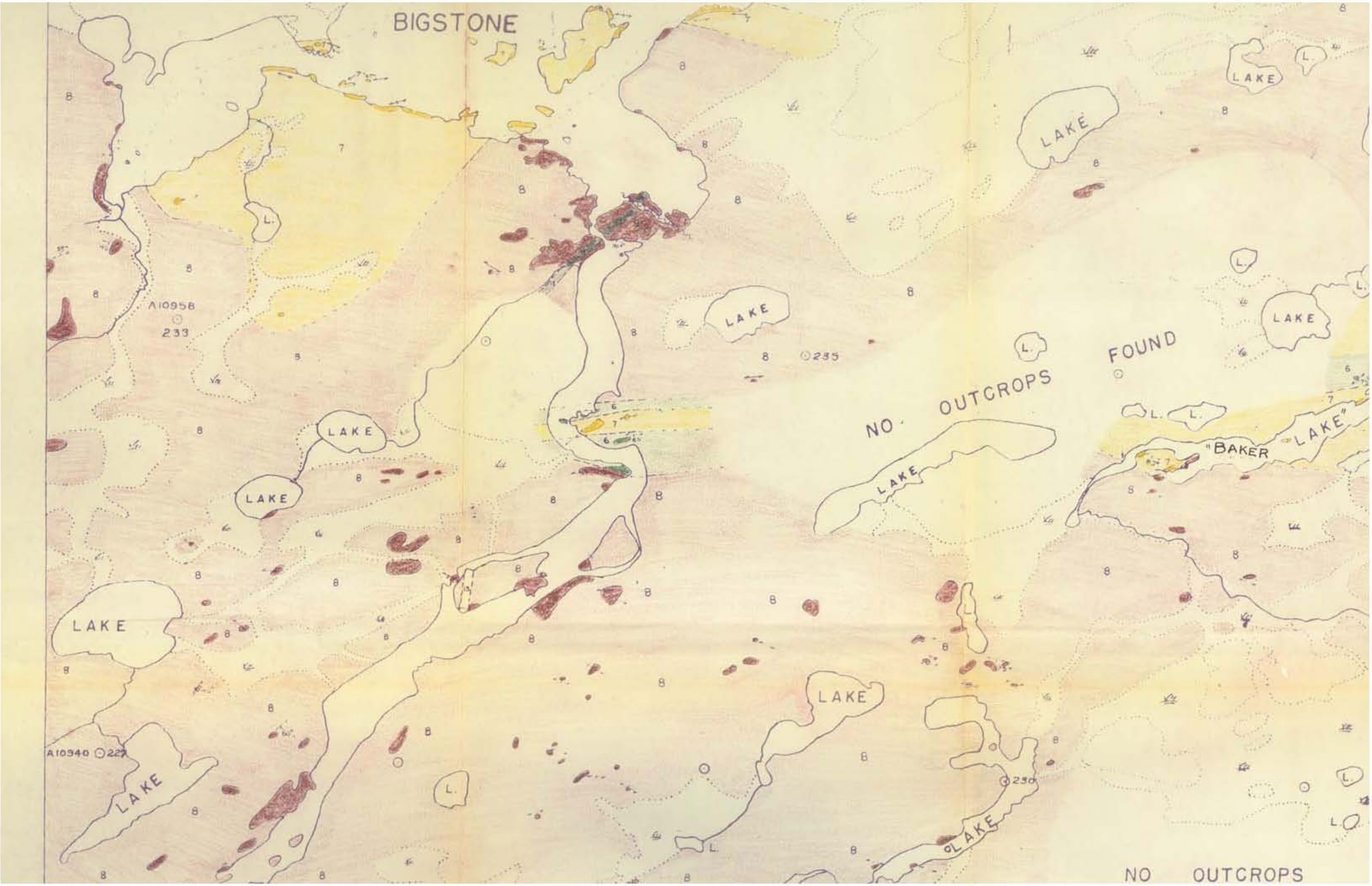
12 — Alaskite.

11a, 11b — Northern quartz monzonite and granodiorite, (11a); Gneissic marginal phases (11b).

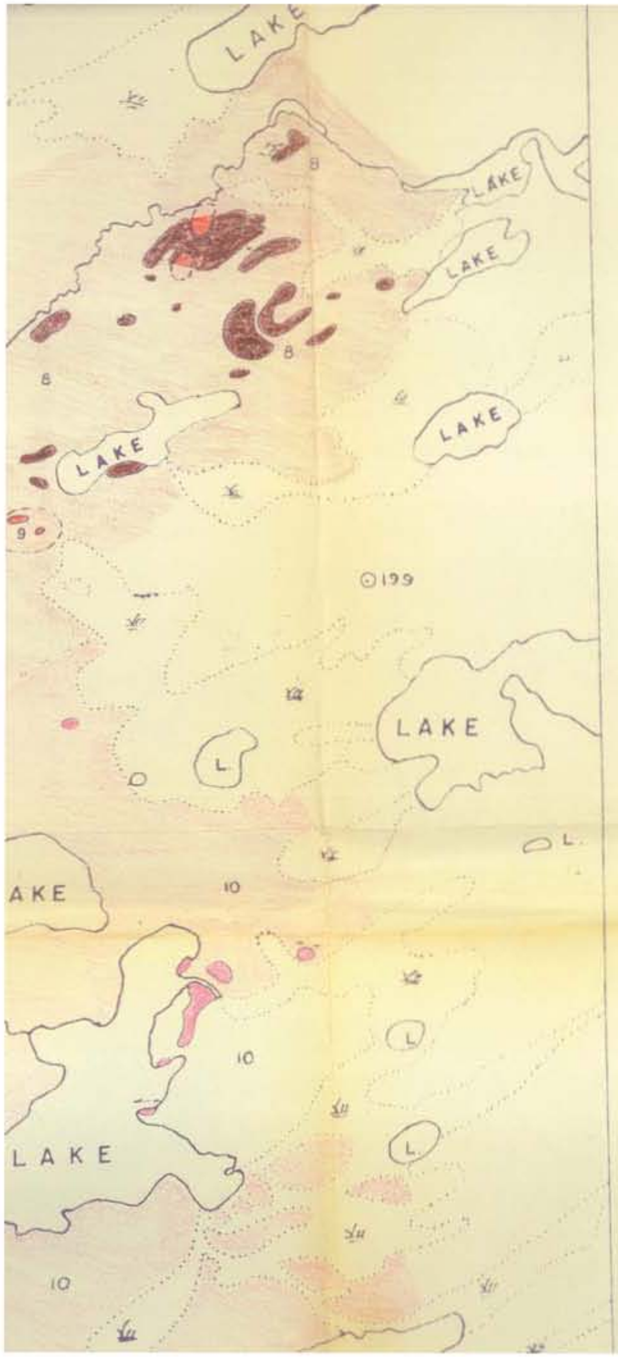
10 — Porphyritic granodiorite.

9 — Pink massive quartz monzonite.

8 — Grey and buff quartz monzonite, granodiorite, and quartz diorite.



BIGSTONE
A10958
233
235
NO OUTCROPS FOUND
"BAKER LAKE"
A10940 227
230
NO OUTCROPS
LAKE



8 — Grey and buff quartz monzonite, granodiorite, and quartz diorite.

SEDIMENTARY AND VOLCANIC ROCKS

Baker Lake Series

7 — Metamorphosed greywocke type sediments, incl. Merritt Formation and Utik Lake Formation.

6 — Andesite and basalt; incl. Greenstone formation.

Semple Lake Series

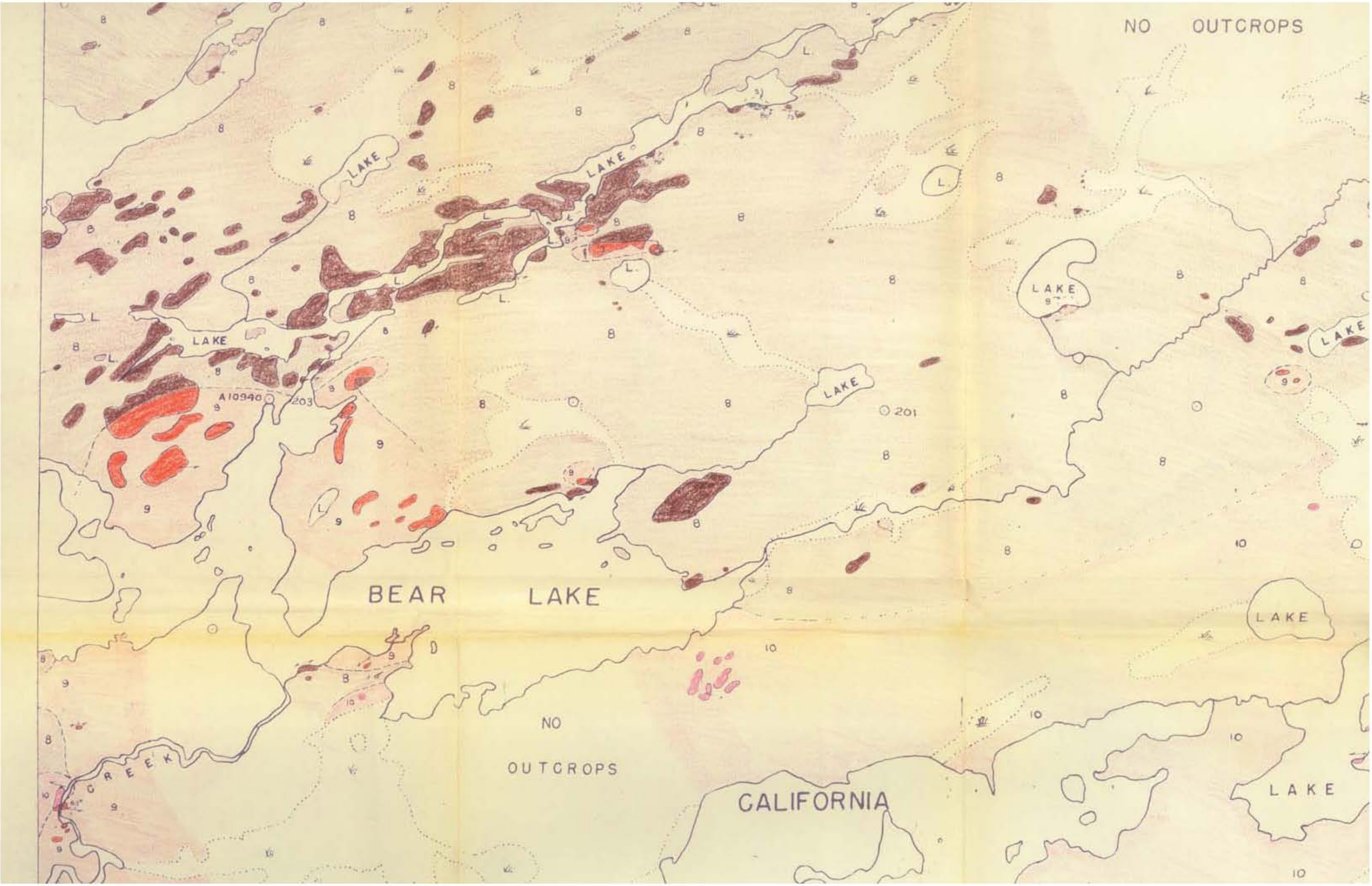
5 — Andesite and basalt.

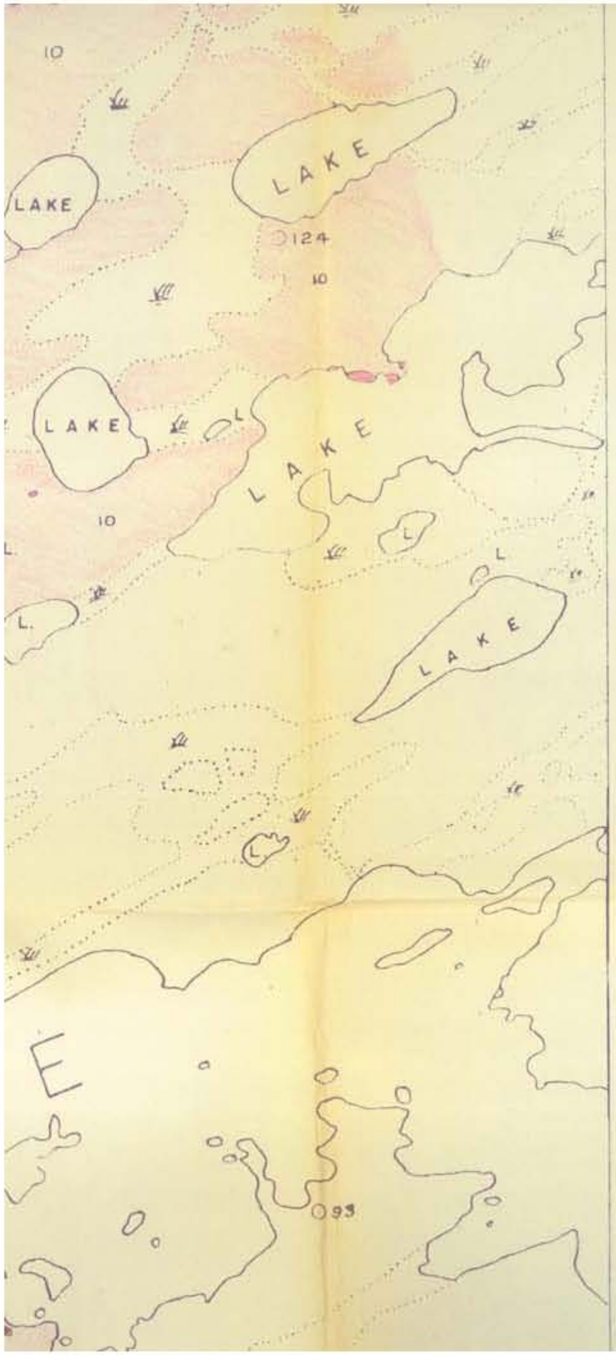
4 — Intermediate to acid volcanics: dacite and rhyolite.

3 — Tuff and agglomerate.

2 — Greywacke.

1 — Conglomerate.


NO OUTCROPS
BEAR LAKE
NO OUTCROPS
CALIFORNIA
CREEK
A10940
203
201



SYMBOLS

Area of outcrop in swamp or muskeg.

Geological boundary: defined, approximate, assumed.

Swamp.

80° — Strike and dip of beds: inclined, vertical, top known.

80° — Strike and dip of schistosity or foliation.

Strike of fault or shear zone: observed, projected, relative movement.

P — Pillow lavas.

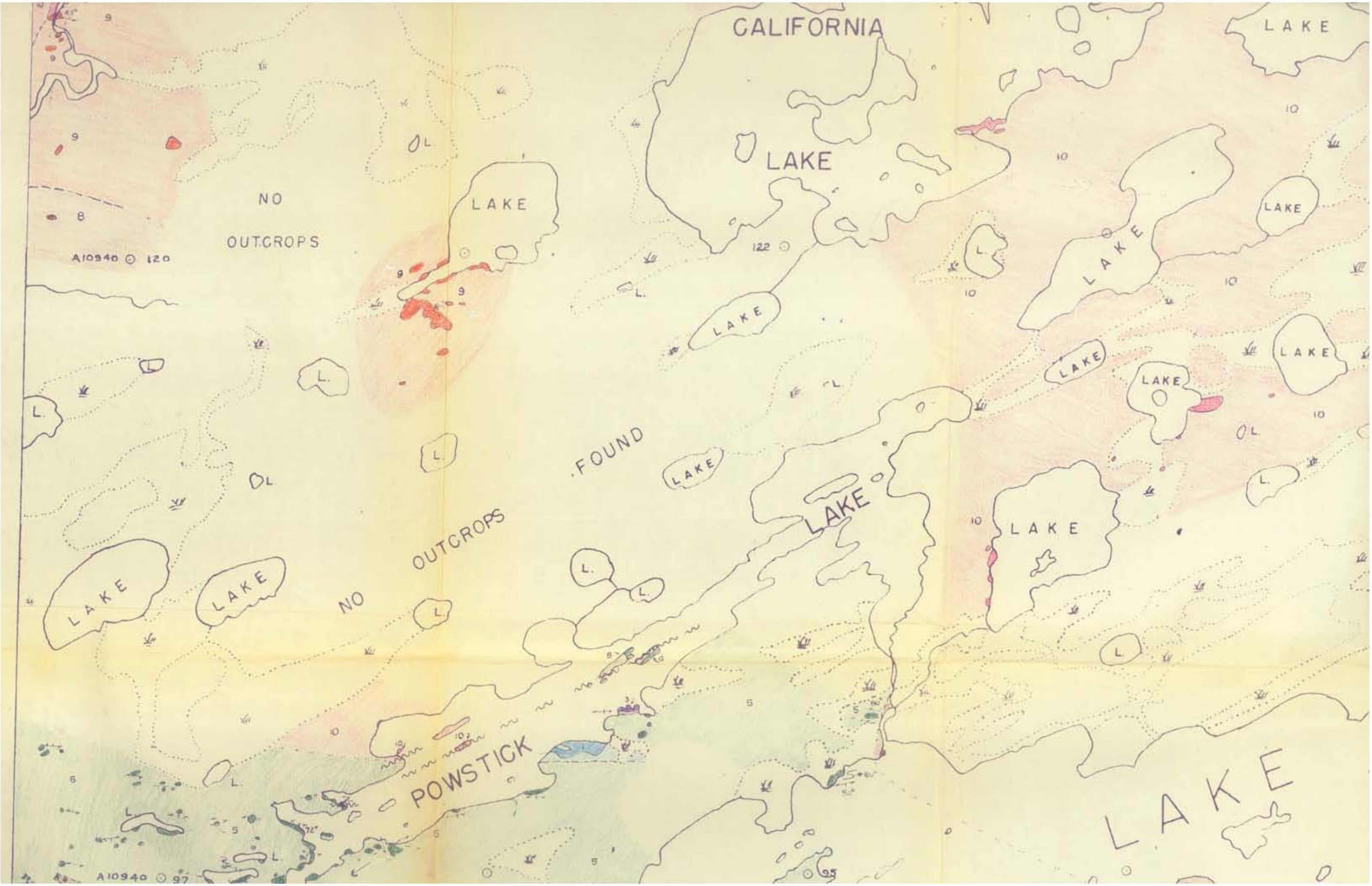
60° — Drag fold with plunge of linear feature.

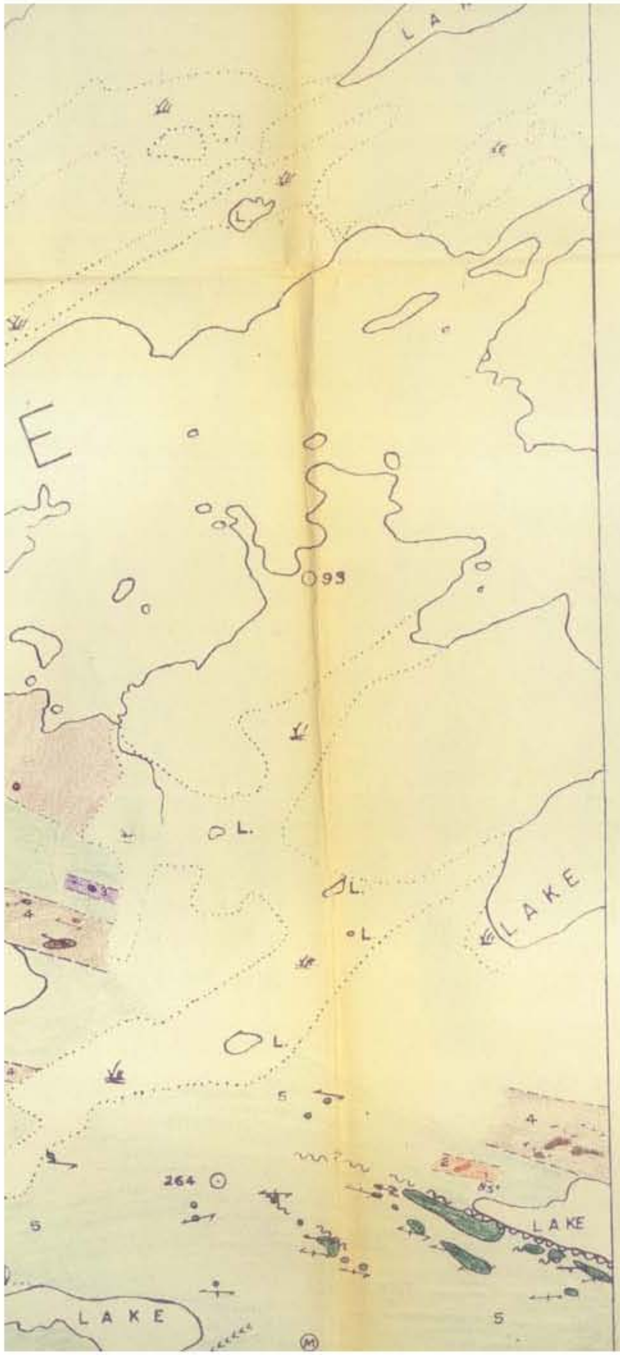
40° — Strike and plunge of linear feature.

210 — Centre of vertical aerial photograph.

Scale: 2 inches = 1 mile.

Magnetic declination $3\frac{1}{2}°$E (1953)


CALIFORNIA
LAKE
NO
OUTCROPS
A10940 ⊙ 120
122 ⊙
NO OUTCROPS FOUND
LAKE
POWSTICK
LAKE
A10940 ⊙ 97



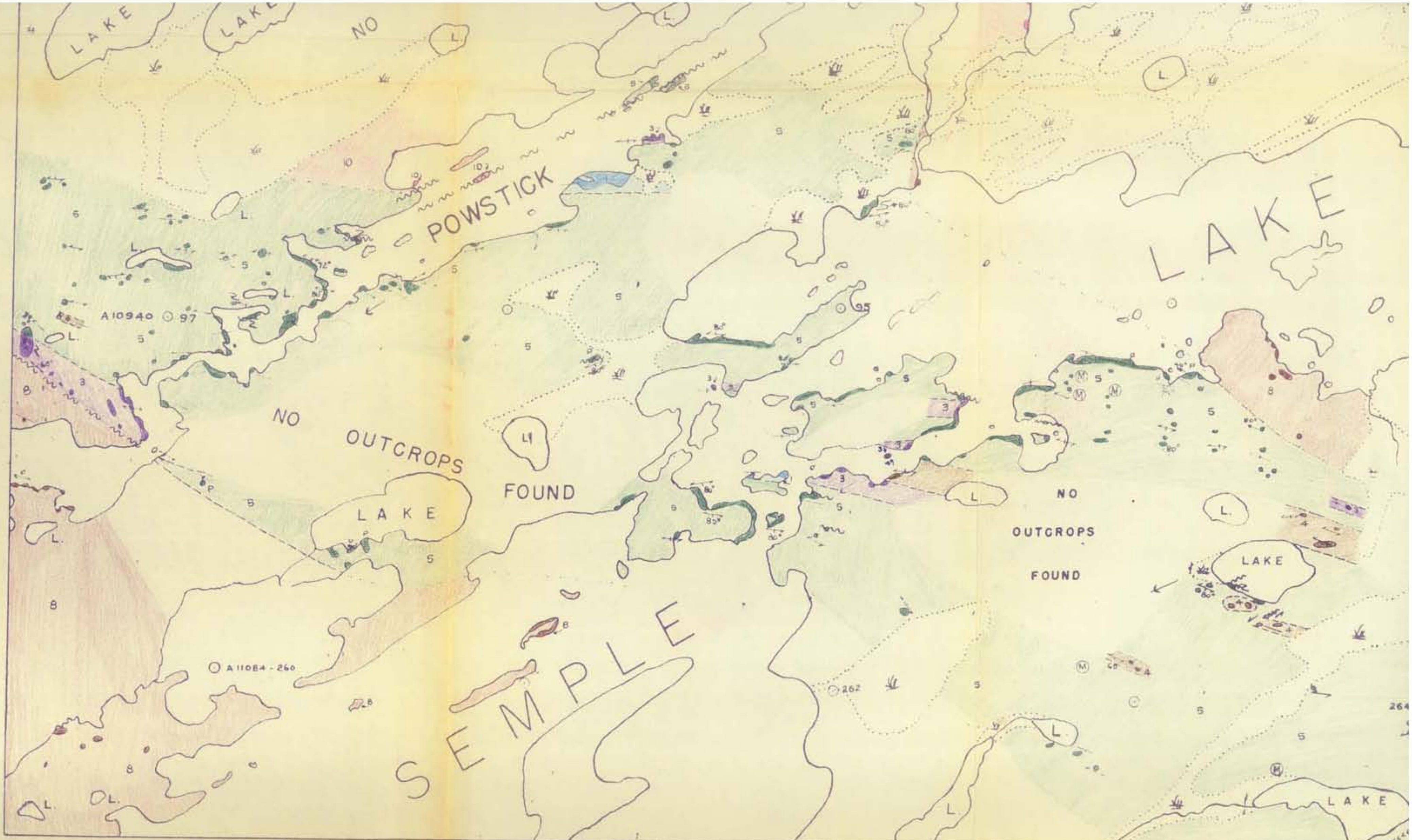
80°	Strike and dip of schistosity or foliation.
	Strike of fault or shear zone: observed, projected, relative movement.
P	Pillow lavas.
80°	Drag fold with plunge of linear feature.
40°	Strike and plunge of linear feature.
⊙ 210	Centre of vertical aerial photograph.

Scale: 2 inches = 1 mile.

Magnetic declination $3\frac{1}{2}$°E (1953)

GEOLOGY BY M.D.MOORHOUSE & J.H.SHEPHERD

1953


POWSTICK LAKE
SEMPLE LAKE
NO OUTCROPS FOUND
NO OUTCROPS FOUND
LAKE
LAKE
LAKE
LAKE
LAKE
A10940 97
A11084 - 260
262
264