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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 270

# WELDON BAY MAP-AREA, MANITOBA

BY

J. Kalliokoski

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EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
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## PREFACE

Weldon Bay map-area lies in the Flin Flon-Sherridon-Snow Lake mineral belt of west-central Manitoba, in which mining developments and prospecting activities are closely dependent on the interpretation of the genesis, sequence, and structural relations of the associated Precambrian volcanic, sedimentary, and intrusive rock groups.

According to the present report, the abundant volcanic rocks of the Archæan Amisk series are separated from the adjacent sedimentary strata of the Kisseynew gneisses in the northern part of the area by a strong, easterly trending fault zone, which, with its tributary faults, has exerted a principal control in the localization of many of the mineral deposits of the region. Structural and petrographic studies have indicated that the Kisseynew strata have been thrust southward and over, and are probably younger than, the Amisk series; and that the grade of metamorphism in the Amisk increases northward toward the Kisseynew fault contact. Within the Amisk terrain itself, three broad groups of intrusive rocks have been distinguished, some of which are variously metamorphosed. Separate metamorphic zones are indicated in the area of Kisseynew gneisses, and attention called to the conspicuous development of sillimanite in zones of intense deformation.

The report provides a connecting link with areas already mapped to the southwest and northeast, and is illustrated by several plates and figures and by a geologically coloured map on a scale of 1 inch to 1 mile.

GEORGE HANSON,
*Chief Geologist, Geological Survey of Canada*

OTTAWA, May 9, 1952

# Weldon Bay Map-area, Manitoba

## CHAPTER I

## INTRODUCTION

### GENERAL STATEMENT

Weldon Bay map-area comprises about 170 square miles in west-central Manitoba from 54°45′ to 55°00′ north latitude and 101°15′ to 101°30′ west longitude. Naosap Lake, in the central part of the area, lies about 18 miles east of Flin Flon and 20 miles south-southwest of Sherridon, Manitoba. The area can be reached by canoe routes from Flin Flon, Millwater, Optic Lake, Fay Lake, and Sherridon, or by air from Channing, Cranberry Portage, or Cold Lake. Geological mapping was commenced in the 1948 field season, and completed the following year.

Many mineral deposits, several of them mines, are located around Flin Flon and also near Sherridon. A principal purpose of the geological mapping of the Weldon Bay map-area, in the potential mineral belt between these two mining areas, was to denote those parts of it favourable for prospecting, and to study any mineral deposits already found there.

### ACKNOWLEDGMENTS

The field work was conducted under the supervision of J. M. Harrison of the Geological Survey of Canada, and during the subsequent study of the field data the writer has been able to consult with him and with C. H. Stockwell, also of the Geological Survey, on details of local and regional geology. The study was completed at the Department of Geology, Princeton University[1], under the guidance of Professors A. F. Buddington, J. C. Maxwell, and H. H. Hess, to whom the writer expresses his sincere thanks.

Capable assistance and effective co-operation in the field were given in 1948 by T. O. H. Patrick, J. G. Stout, G. Haugrud, and H. S. Fraser, and in 1949 by R. M. Proctor and R. N. Daw.

### PREVIOUS WORK

Bruce (15)[2] included the Weldon Bay area on his map of the Athapapuskow Lake area published in 1918 on a scale of 1 inch to 3 miles, and restudied a part of the area in 1929. In 1928, J. F. Wright mapped the Kississing Lake area, which extends into the present area to the south shore of Kisseynew Lake and Weldon Bay (67), and in 1928 and 1930 examined the mineral deposits along Fay Creek (68). D. S. Robertson studied the Kisseynew-Amisk contact from Weldon Bay to north of Flin Flon in 1950 for the Geological Survey (51).

[1]In partial fulfilment of requirements for the degree of Doctor of Philosophy.
[2]Numbers in parenthesee are those of references in Bibliography at the end of this chapter.

## PHYSICAL FEATURES

Weldon Bay map-area is typical of much of the relatively flat-surfaced part of the Canadian Shield. Although its hills are low, with only a few rising 60 to 80 feet above the level of adjacent lakes, the area as a whole is relatively well drained.

The shape and size of individual hills are governed by both the number and attitude of regional joints and by the resistance of the bedrock to glacial scour. Consequently, areas of granitic rocks stand in higher relief than those underlain by volcanic rocks.

The character of the lakes reflects the nature of the underlying rock, those lakes in areas of less resistant rocks having swampy shores. The effect, too, of geological structure on the shape of the lakes can be seen best from the larger ones. Kisseynew Lake is elongate, following the trend of the gneisses, and Weldon Bay is developed over an open anticlinal arch. Naosap Lake consists of two half-moon-shaped parts and Nesosap Lake is convex northward, both lakes closely following the trends of formations and gneissic structure. Where jointing has been pronounced, lakes tend to be angular in shape, as best exemplified on the map by the triangular lake, 1 mile west of Nesosap Lake, and by the southern half of Collins Lake. Two of the elongate lakes in the southwest part of the area have been developed along faults. Vamp Creek also follows a fault valley for most of its length.

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# CHAPTER II

# GENERAL GEOLOGY

## GENERAL STATEMENT

All of the rocks in Weldon Bay map-area are Precambrian in age, and most of them may be Archæan. The stratified rocks consist of the Amisk series, which is volcanic, and the Kisseynew gneisses, most of which in this area are of sedimentary origin. The two lithological groups are separated by the Weldon Bay fault, which may follow an unconformity at the base of the Kisseynew gneisses.

Intrusive rocks of several ages cut the Amisk series. The oldest, consisting of granodiorite ('quartz-eye' granite) and quartz diorite-gneiss, outcrop northwest and northeast of Nesosap Lake. The younger bodies are predominantly of granodioritic composition but their relationship to those emplaced in the Kisseynew gneisses is not known. Those intrusions that outcrop in the southeast half of the map-area are situated on the west margin of a large batholith that underlies large parts of the adjoining areas.

## AMISK SERIES

### Introduction

In his description of the general geology of the Amisk-Athapapuskow Lake district, Bruce introduced the names 'Amisk series' and 'Amisk volcanics' to define "a complex of very ancient surface flows, fragmental rocks of volcanic origin such as ash beds and agglomerates, and, to a lesser extent, of intrusive rocks that are probably closely related to the surface types" (15, p. 23).

The early work leading to the present knowledge of the stratigraphy and nomenclature of the Amisk series near Flin Flon has been reviewed in considerable detail by Harrison (30), who has concluded that the succession established by Bruce in 1918 is essentially correct with the exception that mappable amounts of sedimentary material, not recognized by Bruce, occur in the Amisk series.

### Thickness

Because it is not possible to determine the structure of the volcanic rocks, the true thickness of the Amisk series in the Weldon Bay area remains unknown. It is unlikely, however, that more than 15,000 feet of volcanic rocks are exposed.

### Lithology

The main body of Amisk lavas lies between Naosap and Kisseynew Lakes in the west part of the map-area. The lavas are composed primarily of altered basic flows, with pillows evident in only a few places in the south. Most of the pillows are so elongate that top determinations are impossible. However, agglomerate and pillow lava are well developed on the east shore of the small lake 2,000 feet west of Naosap Lake, where the pillows are the

best preserved of any in the entire area. Many small bodies of mottled basic intrusions are mapped with the flows throughout the area, but pyroclastic rocks are not abundant, except possibly on the north shore of Naosap Lake.

## TABLE OF FORMATIONS

| Age | | Formation | Description |
|---|---|---|---|
| Quaternary | | | Sands, gravels, clays |
| | | *Great unconformity* | |
| Archæan or Proterozoic | | Youngest intrusive rocks | Biotite granodiorite, hornblende granodiorite, quartz diorite, alaskitic granodiorite, gabbro; granite; quartz latite, dacite, pegmatite |
| | | *Intrusive contact* | |
| | | Intrusive rocks of intermediate age | Hornblende gabbro and hornblende diorite; 'Porphyritic latite' |
| | | *Intrusive contact* | |
| | | Oldest intrusive rocks | Alberts Lake granodiorite (in part 'quartz-eye' granite); 'Fine-grained granodiorite'; 'Quartz diorite-gneiss'; porphyritic dyke rocks |
| | | *Intrusive contact* | |
| Archæan | | Amisk series | Massive and pillowed basic lavas; basic flow breccia, agglomerate, and tuff; rhyolite; associated basic intrusions; greenstone, amphibolite, pseudo-diorite, pseudo-gabbro |
| | | *Fault contact* | |
| Archæan or Proterozoic | Kisseynew complex | | Pegmatite; quartz latite |
| | | *Intrusive contact* | |
| | | | Hornblende diorite<br>Gneissic, alaskitic granodiorite |
| | | *Intrusive contact* | |
| | | Kisseynew sedimentary gneisses | Granitized and metamorphosed paragneisses; biotite-plagioclase-quartz paragneiss; conglomerate-gneiss; amphibolite |

In the southern and western parts of the main body, the volcanic rocks are fine-grained, schistose greenstones that weather green and brownish green. In thin section this variety consists of albitic plagioclase and acicular actinolite, altered to prochlorite. The rock is veined both parallel with and obtusely to the foliation by calcite, coarsely granular epidote, and quartz. Schistose lavas also occur near some of the faults.

Southeast and east of Blueberry Lake the typical volcanic rocks are dark green weathering, fine-grained amphibolites in which stretched amygdules or structures attributable to volcanic breccias can be identified only locally. Near Blueberry Lake, some outcrops consist of a hard, massive, blue-grey rock cut by very narrow quartz stringers and by wider quartz-feldspar veinlets along the edges of which the rock is partly feldspathized. Epidote knobs, up to 3 inches in diameter and with indistinct boundaries, also occur in this type of rock. North of Blueberry Lake the amphibolite breaks into tabular sheets, and garnets occur in it sporadically. Towards the northeast, the volcanic rocks have been further recrystallized into coarser, massive pseudo-gabbro and pseudo-diorite.

Well-foliated greenstones, with some tuffs, extend towards Nekik Lake in a long tongue, and similar rocks outcrop from south of Nekik Lake eastward to Vamp Lake in the adjoining map-area. In both bands the greenstones grade laterally into coarser amphibolitic types, and no primary structures are preserved.

Along the northwest shore of Naosap Lake, south of the large area of greenstones, the volcanic rocks are layered (*See* Plate I A and Figure 9). Thin, discontinuous, epidotic layers, light green or yellowish green in colour, alternate with thicker amphibolitic ones that weather dark green. The rocks generally exhibit a good parting parallel with the banding, and in the more northeasterly exposures some of the layers are siliceous. The layered rocks may have been derived from pyroclasic material in which metamorphism has obscured any original bedding structures, or they may be sheared pillows (28, p. 18). A somewhat similar stratiform layering is exhibited by greyish green volcanic rocks a mile southeast of the Dismal Lake granodiorite-gneiss body. The layers, up to 4 inches thick, are marked by changes in grain size of the hornblende metacrysts.

The small, triangular area northeast of Alberts Lake contains the least deformed volcanic rocks in Weldon Bay map-area. They are mostly flows, but the chief marker-bed is a layer of agglomerate and tuff, about 100 feet thick, which is traceable for 6,000 feet. About 700 feet south of the agglomerate zone, a continuous layer of flow-breccia consists of very irregular, ropy masses of vesicular basalt in a finer grained matrix.

Rhyolitic rocks occur in two small areas in the west-central part of tp. 68, rge. 27. They are chloritic and moderately sheared, and on the weathered surface exhibit the same textures as the greenstones, differing from the latter in carrying small quartz phenocrysts.

## Chemical Composition

Because of the degree of metamorphism in the Amisk lavas, their original mineral composition cannot be determined microscopically. For example, much of the epidote and some of the quartz in the altered lavas were derived from the alteration of the original calcic plagioclase to

the present, more sodic type. Thus, it is impossible to determine directly the composition of the original plagioclase and, hence, suitable petrological names cannot be assigned to the lavas.

If the metamorphism of the lavas in the Weldon Bay map-area has been one essentially of mineral reconstitution with negligible metasomatism, it may be assumed that the specific gravity of the lavas has remained relatively constant during metamorphism. Working on this assumption, the writer found the specific gravity of seven specimens to vary between 2·8 and 3·0, five of them being 2·9. The specific gravities of nine specimens of andesitic lavas from the petrographic collection of the Department of Geology, Princeton University, ranged from 2·0 to 2·89, with most of them between 2·4 and 2·6. Johannsen states that of two hundred and six determinations on rocks called basalts, the specific gravity varied between 2·3 and 3·2, but mostly fell within the range of 2·75 and 3·00. The average was 2·87 (33, vol. III, p. 262). The specific gravities given for two analyses of augite basalt were 2·915, and for Deccan trap 2·916 (idem, p. 261). Thus, on the basis of their high specific gravity, the chemical composition of the Amisk flows is more nearly that of basalt than andesite. Bateman reached the same conclusion from a study of the volcanic rocks in the Flin Flon district (9, p. 807).

## OLDEST INTRUSIVE ROCKS[1]

As a result of the present mapping, it is possible to separate the intrusive rocks in the area underlain by the Amisk series into three broad categories on the basis of their relative ages and certain lithological characteristics common to each group. However, this does not imply that all the intrusive rocks in any one group are of exactly the same age, but rather, that they were intruded at somewhat the same time. Thus, the oldest intrusive rocks clearly pre-date those of the youngest group, and some of them, but not all, are intruded by rocks of intermediate age. Similar relationships have been found in other map-areas. It is not possible to correlate these three groups of intrusive rocks with those rocks that occur in the Kisseynew complex although some similarities will be pointed out in a later chapter (page 37).

### Alberts Lake Granodiorite

An elongate body of granodiorite lies in the area between Nesosap Lake and the Alberts Lake fault, and extends from there southwesterly into Mikanagan Lake map-area. Most of the rock is characterized by phenocrysts of bluish quartz that have given the rock the local name of 'quartz-eye' granite, but the southwestern part of the body changes gradationally into more equigranular granodiorite and quartz diorite. To facilitate geological description, this whole body will be referred to as the Alberts Lake granodiorite, because its marginal facies outcrops on the east shore of Alberts Lake.

#### EARLIER INVESTIGATIONS

A distinct kind of porphyritic rock containing blue quartz was first noted by Bruce between Cliff and Ross Lakes in the Flin Flon region

[1]The nomenclature of igneous rocks used throughout this report is that proposed by I. C. Brown of the Geological Survey of Canada, Bull. Can. Inst. Min. Met., vol. 55, pp. 54-57 (1952).

(15, p. 30). In his memoir he refers to this rock briefly as follows: "The Cliff Lake granite porphyry weathers to a pink colour, mottled with lavender-coloured phenocrysts of quartz. On fresh surfaces the phenocrysts are pale blue".

Subsequently, a similar type of rock has been described from many areas in Manitoba (28, 49, 50, 53, 54, 57, 60), to which most of the recent writers have applied the name 'quartz-eye' granite following the usage of Wright (69, p. 10). Both Stockwell and Harrison have emphasized the great lithologic variability of this rock, and metasomatism or granitization around some of these bodies has been described by Harrison (28, pp. 20, 35-36) and by Robertson (49). Harrison has also presented some evidence to suggest that bodies of 'quartz-eye' granite may be characteristic of more than one period of igneous activity (29, p. 13).

## LITHOLOGY

### *Megascopic Description*

The Alberts Lake granodiorite is usually porphyritic in the centre and gneissic near the margin except at its southwestern end where the rocks are equigranular and lack the quartz phenocrysts.

The weathered surface of the typical 'quartz-eye' granite exhibits a porphyritic texture with phenocrysts of opalescent, light blue, reddish violet, or white quartz in a fine-grained, light pinkish brown groundmass. The phenocrysts range from small grains to others with a diameter of ¼ inch or more, and their shape varies from crudely hexagonal and subrounded to oval, elongate, or angular.

The groundmass consists of pinkish to greenish grey plagioclase, fine-grained quartz, epidote, and chloritized dark minerals. Garnets are rare. With the exception of epidote, none of the dark minerals can be identified in a hand specimen.

Near the northwest contact of the granodiorite, where inclusions are abundant, oligoclase occurs locally in small phenocrysts. Oligoclase phenocrysts also occur sporadically in the southeastern part of the body, both north and south of the triangular lake.

Southwest of the porphyritic facies, along the northwest margin of the body, the granodiorite is equigranular in texture, and commonly faintly gneissic in structure. The content of dark minerals is low, and the contact with the porphyritic facies appears to be gradational.

The first change towards the equigranular habit is that the 'eyes' no longer stand in relief, and instead of being rounded, they occur as irregular, shapeless clusters that exhibit locally a graphic texture. East of the south end of Alberts Lake, in Mikanagan Lake map-area, the clusters are smaller and colourless. Here the rock is a fine-grained hornblende granodiorite and quartz diorite that exhibits shades of brown, green, or red, depending on the amount of dark minerals, epidote, or disseminated hematite present.

North of Jenny Lake in the adjoining map-area, the rock is a massive, medium-grained, equigranular hornblende granodiorite, grey to dark grey in colour, and containing up to 25 per cent hornblende. Quartz still occurs as the largest grains, but the texture is not porphyritic.

*Microscopic Description*

In thin section, the phenocrysts of quartz in the Alberts Lake granodiorite are not as distinctive as they are in the hand specimen. They are composed of irregular clusters of strained quartz that merge with the groundmass through the increase in the amount of plagioclase interstitial to the grains. The clusters are commonly divided into several areas within which the constituent quartz grains have a nearly similar orientation, but different from that in adjoining areas.

The groundmass consists of randomly oriented, anhedral grains of plagioclase, usually chlorite, and less commonly amphibole. Where the phenocrysts consist of plagioclase with the composition of oligoclase ($An_{25}$), the rock is more idiomorphic. The plagioclase contains abundant grains and shreds of epidote and chlorite, and under polarized light most phenocrysts are seen to consist of a single-twinned euhedral crystal. Others are composite in nature and yet exhibit a subhedral outline. This suggests that a euhedral grain has been fractured and the fragments rotated, but only so slightly that the cluster retains the outline of the former crystal. In these rocks the interstitial quartz is only slightly strained.

Southwest from the area of the porphyritic facies, much of the Alberts Lake granodiorite exhibits a graphic texture that is not usually recognizable in the hand specimen. The texture is formed by one or several quartz grains, crudely intergrown with one or more, randomly oriented plagioclase grains. Twinning in the intergrown plagioclase component is common, so that a single twin-lamella can be traced commonly through the wedges that are interrupted by quartz.

A second, less common type of micrographic texture consists of radiating intergrowths of quartz and feldspar, similar to, but coarser than, myrmekite.

Rocks in which quartz is more abundant in relation to plagioclase are centrally located in the Alberts Lake granodiorite. In some of these, marginal to the typical 'quartz-eye' granite, a very crude, graphic-like texture is likewise developed, but the geometric pattern is less exact. The final stage in this sequence may be represented by feldspar in irregular shreds and masses within larger grains and clusters of quartz, or as long tongues separating quartz grains into several optically continuous parts (Figure 1a). In some thin sections the wisps of plagioclase appear to form part of an hexagonal zone within large, subhedral grains of quartz (Figure 1b).

A pseudo-graphic, or intersertal[1], texture is also developed in some of the marginal rocks of the Alberts Lake granodiorite. It consists of clusters of randomly oriented, euhedral to subhedral plagioclase laths included in, or protruding into, large quartz grains (Figure 1c). In one thin section the grain of interstitial quartz is more than 5 mm. in diameter and contains parts of a dozen laths. The intersertal texture appears to grade into the one described above in which the plagioclase occurs as shreds between optically continuous quartz grains. However, some of the narrow bands of plagioclase between the quartz grains may be of vein albite.

[1]The term, 'intersertal' denotes a texture that is characterized by the insertion between divergent laths of feldspar, of glass, palagonite, chlorite or other primary or secondary minerals that take the form of the interstitial spaces (Holmes). It is similar to 'ophitic' texture in diabasic rocks. The term 'interstitial', when applied to the habit of a mineral, indicates that it fills an interstice or intergranular space.

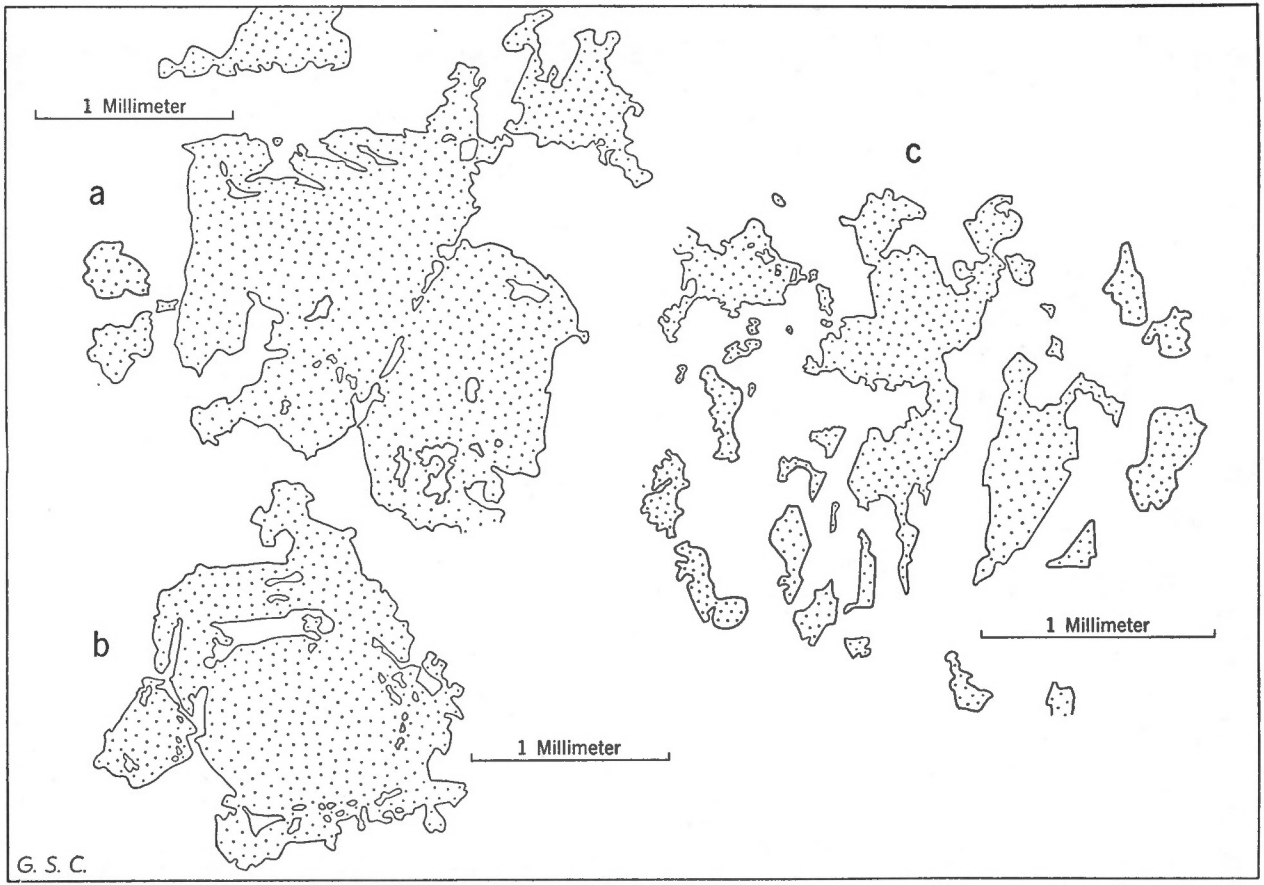


Figure 1. Drawings from photomicrographs to illustrate habit of quartz (stippled) in the Alberts Lake granodiorite: a, a grain of intersertal quartz replacing plagioclase (unpatterned); b, interstitial quartz, with a partial hexagonal zone formed of inclusions of plagioclase; c, a quartz grain intersertal to numerous plagioclase laths whose subhedral and euhedral habits are shown by the somewhat sinuous or straight contacts, respectively, against the quartz. Magnification, ×25.

## ORIGIN OF THE QUARTZ PHENOCRYSTS

The field relationships between the porphyritic and the more equigranular facies of the Alberts Lake granodiorite are remarkably similar to those between albite granite and quartz diorite described by Gilluly from near Sparta, Oregon (25). Also, the rocks in these two localities are very similar in mineral composition, their essential differences being in the composition of the plagioclase and in the habit of the quartz. In the Alberts Lake granodiorite, the plagioclase usually has the composition of sodic oligoclase, $An_{12}$, rarely $An_8$, whereas in Oregon it is $An_{4-8}$. Some of the rocks in the Oregon albite granite (= 'quartz-eye' granite) "show a remarkable pseudo-porphyritic texture, with large, irregular aggregates of bluish quartz as much as 2 centimetres in diameter set in a groundmass of greenish plagioclase and subordinate epidote". However, "in some specimens there are small veinlike masses of bluish quartz 3 or 4 centimetres long and 2 to 5 millimetres wide" (page 68). These veins are lacking in the Alberts Lake body.

Microscopically, the rocks in these two areas are almost identical, especially with respect to the texture between quartz and plagioclase. The occurrence of possible veinlets of albite-oligoclase in quartz clusters in the Alberts Lake granodiorite is also noteworthy because this suggests that some of the feldspar may be quite late, thereby adding further to this petrographic similarity.

Gilluly reached the conclusion that the albite granite and the blue 'eyes' of quartz are a product of albitization and partial silicification of an earlier brecciated quartz diorite.

The embayed nature of the margins of quartz grains in thin sections suggests that the 'eyes' in the Alberts Lake granodiorite may have been produced by silicification of the granodiorite by introduced quartz. However, White is of the opinion that "deuteric silicification, if accompanied by large embaying replacements, rather than by quartz veining, would be extremely difficult, if not impossible, to distinguish from primary quartz" (64, p. 972). The obvious way to determine whether silicification has taken place is to find whether quartz has been introduced into the rock. The amount of silica in some of these rocks was determined for the writer by R. J. C. Fabry of the Geological Survey of Canada. A typical porphyritic 'quartz-eye' granite contains 73·16 per cent $SiO_2$, and the equigranular facies exhibiting the intersertal texture contains 76·09 per cent. A specimen from the type locality at Cliff Lake near Flin Flon yielded 69·14 per cent $SiO_2$. Before silicification can be proved beyond doubt, a granitic rock must contain at least 78 per cent $SiO_2$. Percentages around 76, although high, are not uncommon and, therefore, do not prove silicification of the rock. Thus, if silica has been introduced into these granodiorites, either during or after their crystallization, the addition has not been extreme.

The occurrence of numerous quartz veinlets in the Oregon granite but not in the Alberts Lake granodiorite suggests further that the quartz 'eyes' in the Alberts Lake granodiorite may not be due to silicification as they are in the other body. In the Alberts Lake granodiorite, the 'eyes' are crushed, but many are peanut-shaped rather than rod-like; they could represent slightly sheared phenocrysts but none are likely the remains of rolled quartz veinlets. Also, their regular distribution in the granodiorite

suggests that they are a primary feature rather than of secondary origin. Thus, viewing the problem on the level of field mapping, rather than of thin-section study, it would appear that the quartz 'eyes' are primary.

One more point remains to be considered. 'Quartz-eye' granite has been found to be the earliest granitic rock to cut the volcanic strata in northern Manitoba (28, p. 6). It would appear, therefore, that all these bodies either came from a common magmatic source and are not of metasomatic origin, or else that the processes of granitization responsible for their origin were controlled by peculiar factors, not duplicated in later stages or periods of orogeny.

### AGE RELATIONSHIPS

On its northwest and west margins, the Alberts Lake granodiorite has intruded a narrow band of Amisk volcanic rocks. West of Nesosap Lake, a fine-grained, granoblastic facies contains a few, small, lenticular inclusions of amphibolite, which, although now several miles from the nearest exposures of Amisk volcanic rocks, were probably derived from them at the time when they covered the entire area.

At its northeast end, about 500 feet southwest along the Alberts Lake fault, pink hornblende granodiorite, possibly related to the Naosap body, contains inclusions of the Alberts Lake granodiorite. Elsewhere at this end, the phenocrysts are reddish and locally become indefinite in outline, occurring in the groundmass as indistinct, angular, quartz-rich areas or as long, lenticular streaks. The texture, also, becomes more massive and less porphyritic towards the east so that, west of Nistosap Lake, it is not possible to draw a contact between the 'quartz-eye' granite and the Naosap granodiorite. Furthermore, on some exposures up to ½ mile east of Nistosap Lake the small, interstitial grains of quartz in the Naosap granodiorite are opalescent or blue, so that the contact between the two bodies cannot be defined even on the basis of the presence of coloured quartz.

Tapukok granodiorite intrudes fine-grained mylonitic facies of the Alberts Lake granodiorite west and northwest of Nesosap Lake.

### THE ORIGIN OF BLUE COLOUR IN QUARTZ

Phenocrysts of blue and opalescent quartz are common in the 'quartz-eye' granite body as well as in some of the felsitic, quartz latite dykes south of the western part of Naosap Lake. None of this quartz is blue in thin section no matter how intense its colour in the hand specimen. Instead, at low magnification and under direct illumination, occasional grains exhibit a very faint, pale yellowish colour, which is irregularly distributed through the grain.

Inclusions in the coloured quartz consist of unreplaced plagioclase and ferromagnesian minerals, and of rods of apatite. Smaller inclusions consist of pale green prisms, subrounded grains—some of which may be sections across prismatic crystals and irregular granules. Under oil immersion, at a magnification of 800 X, many of the non-opaque rods exhibit fringes of parallel or diverging diffraction lines, depending on the orientation of the prisms. The presence of many other rods can be deduced only from these fringes as the rods themselves are beyond the resolving power of the microscope. One rod, the thickness of which was barely discernible under oil immersion, was 0·2 mm. long and only 0·0005 mm. thick.

No optical properties could be determined for these small prisms in the coloured quartz. Some of them have the appearance of apatite, but a spectrographic analysis of the blue quartz by B. J. Stallwood, Mines Branch, disclosed a trace of titanium, so that they could be rutile. No relationship was observed between the intensity of the blue colour in a hand specimen and the abundance of included needles except that the latter are confined to the coloured grains.

To account for the blue colour in quartz, some early workers suggested that it is related to the strained condition of the grains (20). Others have attributed it to the scattering of the incident light ray by inclusions, usually of rutile, and Postelmann is of the opinion that the blue colour can be produced only by rutile (47). Because small rods of rutile have been described from uncoloured (34), rose (31), and smoky (63) quartz, it seems that the inclusions must be both abundant enough and small enough before they are capable of producing the colour.

In discussing the colour in minerals, Kennard and Howell point out that colour can originate in seven different ways (40), based on chemical composition and structure. The blue in quartz can be referred to only two of these: (1) body colour, and (2) the colour of a turbid medium, that is, to selective scattering. A body colour is due to the selective absorption of part of the light that enters within a coloured substance, whereas the colour of a turbid medium is produced by "the selective scattering of light by particles or structures the size of which, compared with the wavelength, is small" (40, pp. 415-416). Because blue quartz is colourless or faintly yellow under direct illumination rather than blue, it is evident that the colour is not a body colour, but must be due to selective scattering of light by small particles in quartz.

It appears from the study of literature that the blue colour can be produced by small inclusions of any substance, not only of rutile but of apatite (32), and, perhaps, certain oxides. However, from the scanty evidence on hand, the occurrence of blue quartz in the Weldon Bay map-area seems to be another in which the blue colour in the quartz grains is produced by the scattering of light by small rods, possibly of rutile.

It was noted in a few of the thin sections that some of the needles are not confined to one grain of quartz but may extend into another grain that is not in optical continuity with the first. This relationship suggests that the needles are younger than the quartz and may have crystallized in it during post-consolidation alteration.

## 'Fine-grained Granodiorite'[1]

Fine-grained, alaskitic granodiorite occurs in two bodies in the western part of the map-area. The larger body, with a quartz latite-porphyry border, lies south and west of the west arm of Naosap Lake; the much smaller faulted body lies ¾ mile northwest of the west end of Naosap Lake. The 'Fine-grained granodiorite' may be correlated with the Alberts Lake granodiorite.

The larger body of 'Fine-grained granodiorite' is intrusive locally into the Amisk series, its contact zone with that series in most places

[1]Textural terms that denote distinct lithological types comprising a body are 'Fine-grained granodiorite', 'Quartz diorite-gneiss', and 'Porphyritic latite'. This convention is used throughout the memoir.

represented by the quartz latite border facies. At its east end, the granodiorite body is intruded by a medium-grained, hornblende granodiorite facies of the Naosap granodiorite. The contact relationships are complicated and in part obscured, on the south side of the body, by both an irregular body of amphibolite, which may be a highly recrystallized tongue of Amisk volcanic rocks, and by the Alberts Lake fault. Along this fault the rocks are heterogeneous in both composition and texture, and weather reddish or pinkish brown. They have been altered to felsitic and granular, garnetiferous gneisses, some of which are mylonitic, and separate the 'Fine-grained ganodiorite' from the Alberts Lake granodiorite.

Dykes, with phenocrysts of blue quartz and of feldspar, and some with inclusions of 'quartz-eye' granite, intrude the marginal parts of the 'Fine-grained granodiorite'. It is also cut by a few, large, barren, pegmatitic quartz veins, which are more common near the Alberts Lake fault.

### LITHOLOGY

The 'Fine-grained granodiorite' is usually pink and alaskitic in the centre of the larger body, and greyish pink or greyish green near the margins. In its western part it grades in two small areas into porphyritic granodiorite and biotite-albite granite in which the phenocrysts are of colourless or slightly bluish quartz and of albite. In some parts the non-porphyritic rock exhibits a graphic texture of plagioclase and quartz, and is fractured locally on the north side of the body, the narrow, epidote-filled fractures imparting a mottled, greenish hue to the rock.

Lithologically the smaller body of 'Fine-grained granodiorite' resembles the larger. It is usually alaskitic, and in its eastern part is porphyritic.

Inclusions of amphibolite and of quartz latite-porphyry are common in the granodiorite south of the west end of Naosap Lake. The inclusions occur as dark blobs with indefinite outlines. South of the small lake west of Naosap Lake, as much as two-thirds of the rock consists of hazy, greenish to salmon-pink inclusions, but these are not as common on the south side of the body.

On the northwest and south margins of the 'Fine-grained granodiorite' body, the marginal facies, consisting of quartz latite-porphyry, is generally light grey or light greenish grey in colour, felsitic in texture, and massive in appearance. Weathered surfaces of the porphyry commonly exhibit small, rounded phenocrysts of bluish quartz, rarely more than 2 mm. in diameter, but locally the rock is felsitic. In places the rock is ridged in a manner suggestive of flow layers in rhyolite.

Under the microscope the common type of 'Fine-grained granodiorite' is hypidiomorphic to granoblastic in texture and without any foliation. The common minerals are quartz and albite-oligoclase. Epidote and chlorite are the dark constituents. Towards the centre of the main body, the rock exhibits a micrographic texture. There sphene and apatite occur in small amounts.

South of the west end of Naosap Lake, the contaminated granodiorite exhibits a characteristic fabric: tiny plagioclase laths form a hypidiomorphic-granular texture in which grains of strained quartz occur interstitially to form an intersertal texture in some parts of the thin section. The laths are saussuratized, commonly untwinned, and generally embayed by quartz.

The 'Fine-grained granodiorite' has been altered to blastomylonite[1] locally along the Sourdough Bay fault. The lighter bands in dense, banded blastomylonite consist of very fine-grained quartz, plagioclase, and a few dark minerals. The darker bands contain epidote, green hornblende, sphene, biotite, and muscovite. The epidote grains are alined parallel with the foliation.

#### CORRELATION

Certain lithological similarities between the 'Fine-grained granodiorite' and the Alberts Lake granodiorite may permit the correlation of these two bodies. The main features of similarity are: (1) both bodies are intrusive into the Amisk series and are themselves cut by younger Naosap hornblende granodiorite; (2) micrographic texture is common in certain parts of the two bodies but is lacking in all others; (3) the quartz latite-porphyry is similar to some of the rocks on the northwest margin of the Alberts Lake granodiorite; (4) blue quartz phenocrysts are restricted to the Alberts Lake and 'Fine-grained granodiorite' bodies and to dykes associated with them; (5) equigranular, medium-grained facies, similar to that in the southwest part of the Alberts Lake granodiorite occurs in the southern part of the 'Fine-grained granodiorite'; and (6) the inclusions of 'quartz-eye' granite in some of the dykes that cut the 'Fine-grained granodiorite' may represent blocks derived from deeper parts within this granodiorite where the grain size would be coarser.

A somewhat similar correlation has been made by Stockwell in areas to the east (53, p. 7; 54, p. 10).

### 'Quartz Diorite-gneiss'

North and east from Nesosap Lake, certain rocks with the composition of quartz diorite exhibit a distinctive lithology. Rocks of this composition form an elongate, curved body, characterized by a contorted gneissic structure that has been superimposed even on elongate inclusions of amphibolite.

#### LITHOLOGY

The 'Quartz diorite-gneiss' is usually medium grey, but locally grades to light pink or to darker shades of grey. On the weathered surface, it exhibits a contorted foliation, the result of indistinct, discontinuous layers of ferromagnesian minerals in a light-coloured, quartz rich matrix (*See* Plate I B). It is not possible to estimate the trend of foliation in such rocks, but the plunge of many crumples appears to be steep, and locally may be vertical.

Another characteristic of the diorite-gneiss is its content of extremely attenuated and contorted *schlieren*. One of these is shown in Plate II A. Near the amphibolite band on the east side of the gneiss, some of the inclusions are involved in gneissic folds at one end and attached to larger amphibolite masses at the other. Consequently, most of the *schlieren* are probably inclusions of the wall-rock that have been folded and sheared. Contorted inclusions, similar to these contorted *schlieren*, were seen only in the sheared rocks near the Vamp Creek fault, so that it is possible that the contorted fabric in the diorite-gneiss was developed likewise after the rock had solidified. This possibility is strengthened by the granoblastic

[1] Crystalline schist showing faint traces of cataclasis, derived from mylonite.

fabric in thin section and by the occurrence of granulitic, platy quartz in some of the amphibolites along the east margin (*See* Plate II B).

At its west end and on its north flank, the diorite body is less gneissic near the amphibolite contact. There the inclusions are angular or lenticular in outline rather than elongate and sinuous. A short distance from the contact the diorite exhibits the characteristic contorted structure.

At its western end, north of Nesosap Lake, the foliation of the 'Quartz diorite-gneiss' becomes more planar. Near the creek, on the south shore of Nistosap Lake, the rock is a white weathering gneiss in which the hornblende clusters exhibit a definite lineation and a faint, undulatory foliation. Quartz is evenly distributed through the lighter phase of the rock. Inclusions are elongate but not contorted. At the southwest corner of Nistosap Lake, the texture of the rock is similar, but the feldspar and quartz are pink, and the quartz occurs in small clusters, with indefinite outline. This type of rock grades into 'quartz-eye' granite to the west and into more massive hornblende granodiorite to the north, with no apparent structural or textural discontinuity.

Microscopically the 'Quartz diorite-gneiss' is granoblastic in texture and coarsely foliated. Andesine ($An_{45}$) constitutes from 30 to 60 per cent of the rock, and occurs in anhedral, elongate grains up to 5 mm. long. Locally these are fresh and irregularly twinned, but in the pinker varieties of gneiss they appear to be partly albitized. Quartz occurs in irregular, strained grains, 2 mm. long. Green hornblende forms up to 10 per cent of the minerals, and in one thin section appears to be the alteration product of pyroxene. Some of the hornblende is altered to yellowish brown biotite, chlorite, and epidote. Biotite constitutes less than 5 per cent of the rock. Apatite, in squat prisms, zircon, and sphene are common accessory minerals, and the alteration products are chlorite (penninite), carbonate, and epidote.

### AGE RELATIONSHIPS

The 'Quartz diorite-gneiss' is younger than the marginal amphibolitic rocks. It is older than the elongate body of 'Porphyritic latite' that cuts it east of Nesosap Lake: nowhere was a contact seen between these two rock types, but from its distribution, massive appearance, and freshness, the latite probably represents a dyke-like body intrusive into the gneiss, and emplaced after the quartz-diorite had acquired its foliation.

The gneiss is also older than the more massive Tapukok granodiorite. This is indicated by both the areal distribution of these two, slightly south of east from Nesosap Lake, and by the fact that the granodiorite cuts the latite.

North of the latite dyke, the lithological difference between the diorite-gneiss and the surrounding granodiorite is not as great. On the northeastern and northern margins of the body, the gneiss is bounded by ridgy weathering, pinkish, granoblastic granodiorite-gneiss. However, the transition from the contorted foliation of the quartz diorite-gneiss to the planar foliation of the granoblastic granodiorite is abrupt and definite. The presence of amphibolite in this transition zone suggests that the contact may be along a narrow screen of volcanic rocks that have been intruded by both the diorite and the granodiorite. The age relations of the quartz diorite-gneiss to the Alberts Lake granodiorite in the southern part of Nistosap Lake are not clear.

## INTRUSIVE ROCKS OF INTERMEDIATE AGE

A second group of intrusive rocks, younger than the rocks described above, comprise several smaller bodies, most of them of gabbroic or dioritic composition.

### Hornblende Gabbro and Hornblende Diorite

A discontinuous dyke of hornblende gabbro extends southwest from the east side of the triangular lake that is situated west of Nesosap Lake. The dyke has been cross-faulted intricately into several units so that it terminates abruptly at both ends in a fault and, south of the lake, about 700 feet of the dyke has been removed by a series of faults (page 64).

The gabbro dyke is intrusive into mylonitic rocks that may be derived from the 'quartz-eye' granite. Some pegmatitic veinlets that may be related to the Tapukok granodiorite occur within the dyke, traversing it in all directions, but most commonly parallel with its length. These veinlets are about 2 inches wide and rather indistinct in outline. In thin section the texture of the gabbro is hypidiomorphic, and locally, where quartz occurs in microscopic quantities, micrographic.

Rocks that vary in composition between hornblende gabbro and hornblende granodiorite constitute several heterogeneous bodies that outcrop in the area around the eastern end of the Dismal Lake granodiorite stock. The most common rock type is hornblende diorite. There appears to be no regular change in composition across the strike of any particular body, but mafic minerals appear to increase towards the northwest end of the body northeast of Blueberry Lake. Those bodies near Naosap Lake consist of equigranular, massive rocks; the sheet northeast of Berry Lake is gneissic; and the one north of Dismal Lake is gneissic and schistose.

Massive rocks of a similar lithology outcrop 1½ to 2 miles northeast of Blueberry and Dismal Lakes. It is not possible to differentiate these from the pseudo-gabbro and pseudo-diorite of the Amisk series on the map.

The age relationships of the mapped bodies are uncertain. Some of them are cut by dykes of granite, and on this basis may be older than the granodiorite rocks. The possibility also exists that these rocks may have been emplaced during Amisk volcanism, so that, instead of having the same age as the hornblende gabbro, they are much older. Those rocks associated with pseudo-gabbro may be related to the contaminated facies of the Nekik granodiorite.

### 'Porphyritic Latite'

Northeast and east of Nesosap Lake 'Porphyritic latite' occurs in several small disconnected bodies. The easternmost dyke-like mass extends across the body of 'Quartz diorite-gneiss'. The two western bodies of 'Porphyritic latite' are locally intruded by the younger, Tapukok granodiorite, as indicated in part by the criss-crossing of certain outcrops by granitic dykes. Marginally to the 'Porphyritic latite' bodies the intrusive relations are more intricate (*See* Figure 11 and Plate III A), and are described more fully on later pages (pages 53, 54).

### LITHOLOGY

The weathered surface of the 'Porphyritic latite' is characterized by small glomeroporphyritic clusters and individual, randomly oriented, euhedral phenocrysts of fine- to medium-grained, white plagioclase in a dark groundmass. In the groundmass, plagioclase alone can be recognized megascopically. The phenocrysts thus form a felted pattern against a salt-and-pepper background. On the fresh surface, the plagioclase phenocrysts appear as dark cleavages, but the other minerals are too fine to be identified.

In thin section, the phenocrysts of twinned and faintly zoned oligoclase reach a maximum size of 0·3 by 2·6 mm. The largest crystals occur in glomeroporphyritic knots, but the smaller ones form the hypidiomorphic-granular texture characteristic of the porphyry. Most of them are quite fresh, but a few are sericitic. The groundmass is formed of smaller, less idiomorphic laths and grains of plagioclase. Brownish green hornblende occurs in smaller, anhedral granules and subhedral prisms. Small books of dark brown biotite may be in part secondary after hornblende. Quartz is minor in quantity, but most abundant in the interstices of the glomeroporphyritic clusters, and forms the base in which small rods and needles of apatite are set. Epidote occurs along narrow veinlets, but a few grains are scattered through the groundmass with hornblende. Chlorite is the main alteration product of hornblende, and dark, opaque minerals occur in irregular granules within the hornblende crystals.

## YOUNGEST INTRUSIVE ROCKS

The youngest intrusive rocks, comprising a number of bodies of granodiorite, underlie the southeastern two-thirds of Weldon Bay map-area. Most of these granodioritic rocks contain either biotite or hornblende, or both, but a few are alaskitic. Locally, some of these youngest intrusive rocks have the composition of granite, and most of the bodies grade toward the margins into quartz dioritic facies.

According to his description and map, these youngest intrusive rocks comprise Bruce's 'Kaminis granite' (15, pp. 41-42). Two facies of this granite were described by Bruce as follows: "It [one variety] is a very fresh, bright pink, granitic rock shown by microscopic examination to consist of feldspar, quartz, hornblende, biotite, magnetite, kaolin, sericite, apatite and zircon. The feldspar is about equally divided between orthoclase and an acid plagioclase near oligoclase in characteristics. ..... The grey hornblende variety [the other facies] is as fresh as the red variety but contains a large amount of basic minerals, and plagioclase, of about the composition of andesine is the most abundant mineral present. The predominance of plagioclase over orthoclase makes the rock classifiable as a granodiorite rather than a true granite".

In the present report, these granitic rocks are separated into four bodies, here named Tapukok, Naosap, Nekik, and Vamp Creek granodiorites. The validity of this division is substantiated by the distribution of the various facies within the four bodies, all pointing to the presence of a centrally located, more alaskitic or biotitic core in each of them. Of the bodies to be described, only the Naosap body lies entirely in Weldon Bay map-area and has been delimited by the present mapping.

## Tapukok Granodiorite

The zoned Tapukok granodiorite body forms the northern end of a larger body of unknown extent. The rock grades in colour from pink, in the area around Uyenanao Lake, to pinkish grey and dark grey around Nesosap Lake. A few exposures around Uyenanao Lake are white. The proportion of dark minerals increases outward, and the rock grades in texture from massive, medium grained, and equigranular at the core to gneissic at the border. A simplified geological map, Figure 2, presents the relationships of the various lithological zones in an idealized form.

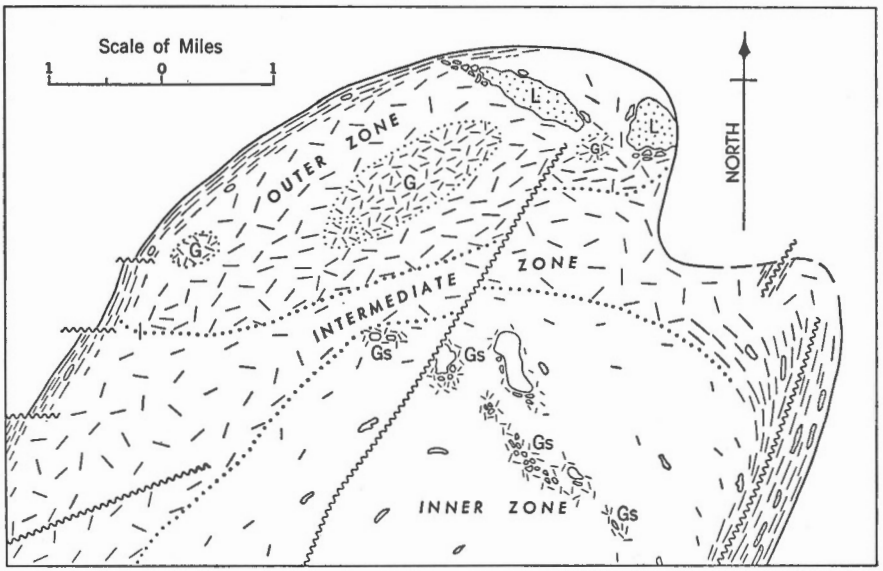


Figure 2. Diagrammatic sketch of Tapukok granodiorite body, showing pseudo-gabbro (Gs) inclusions in the inner zone, areas of pyroxene-bearing gabbro (G) in the outer zone, and inclusions of 'Porphyritic latite' (L) near the northeast margin. Degree of gneissosity is indicated by the dashed pattern, and faults by sinuous lines.

The Tapukok granodiorite is younger than the surrounding rocks. On the west side it intrudes the mylonite that is marginal to, and possibly gradational from, the Alberts Lake granodiorite. On the northeast margin it intrudes the 'Poryphyritic latite' bodies and also the 'Quartz diorite-gneiss'. On its east flank, the granodiorite intrudes amphibolitic Amisk rocks.

Although inclusions are not abundant in the outer zone, angular inclusions of pyroxene gabbro are found in the hornblende-diorite facies west of Nesosap Lake.

Coarse-grained pseudo-gabbro and fine-grained amphibolite inclusions are most common in the core of the Tapukok granodiorite where they are arranged in a northwesterly trending zone. The smaller, elongate inclusions are irregular in distribution, but most of them are concentrated in the same zone with the larger inclusions, commonly forming a long swarm at the ends of these. If the criterion is acceptable, evidence for its intrusive nature is found even in the core of the Tapukok granodiorite.

## LITHOLOGY

The rock comprising the inner zone of the Tapukok granodiorite is bright pink alaskite at the centre and grades to pink biotite granodiorite marginally where the dark minerals become more abundant. Hornblende is lacking in those rocks that contain less than 5 per cent biotite (*See* Table I, No. 1) but occurs in considerable quantities near mafic inclusions in the biotite granodiorite. The rocks in the inner zone are equigranular and massive so that a planar structure is indicated only by small, oval inclusions of amphibolite. Jointing is most pronounced in this zone, especially about 1 mile west of Tapukok Lake where the outcrops are cut by innumerable fractures. The granodiorite is cut by numerous joints also along the margin of the 'Quartz diorite-gneiss'.

TABLE I

*Modal Analyses of Rocks in Weldon Bay Map-area*

| | Plagioclase | Quartz | Microcline | Biotite | Muscovite | Hornblende | Pyroxene | Apatite | Magnetite | Sphene | Epidote | Chlorite | Garnet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 55·3 | 34·0 | 5·1 | 1·9 | 0·6 | 0·2 | | | | | 0·8 | 2·1 | |
| 2 | 56·2 | 21·7 | 3·1 | 5·0 | | 10·1 | | | 0·5 | 0·1 | 2·1 | 1·2 | |
| 3a | 57·8 | 5·9 | | 8·4 | | 4·0 | 23·6 | | 0·3 | | | | |
| b | 54·2 | 10·3 | | | | 26·9 | | | | | 1·1 | 7·4 | |
| 4 | 54·9 | 28·2 | 7·3 | 3·2 | 0·3 | 2·0 | 0·2 | 0·1 | 0·4 | | 1·6 | 2·4 | |
| 5 | 40·2 | 32·1 | 19·4 | 2·5 | 4·8 | | | | 0·9 | | | | |
| 6 | 43·8 | 4·9 | | | | 49·3 | | | | | | | |
| 7 | 27·5 | 40·6 | 0·6 | 27·3 | | | | 0·2 | 0·1 | | | | 3·5 |

1. Tapukok granodiorite, inner zone, average of 6 analyses.
2. Tapukok granodiorite, intermediate zone, average of 4 analyses.
3. Tapukok granodiorite, outer zone: a, gabbro facies; b, dioritic facies.
4. Naosap granodiorite, weighted average of 5 analyses.
5. Kisseynew granodiorite, average of 4 analyses.
6. Kisseynew hornblende gabbro, average of 2 analyses.
7. Crush rock, southeast of Weldon Bay.

In thin section, the Tapukok biotite granodiorite exhibits a hypidiomorphic-granular texture (*See* Figure 3a). Plagioclase, commonly oligoclase, occurs in twinned and zoned, subhedral crystals that are up to 4 mm. long. The larger grains are usually more nearly euhedral than the smaller, and the cores are more epidotic than the mantles. The feldspar is only slightly and sporadically sericitized and kaolinitized, and its red colour is produced by a finely disseminated reddish pigment. Microcline is interstitial to plagioclase; in one thin section a serrated grain extends over an area 5 mm. square between variously oriented laths of oligoclase. Thus, it crystallized late. Quartz occurs interstitially to the feldspar and dark

minerals, in grains with a maximum diameter of 3 mm. These are commonly strained, and exhibit embayed contacts against the other minerals. Where brown biotite occurs in small quantities as the only varietal mineral, it is commonly chloritized; where it occurs with small grains of hornblende it appears to be replacing the hornblende. Primary muscovite is not abundant and was nowhere seen in the same thin section with hornblende. Brownish green hornblende occurs usually as anhedral grains, subhedral in cross-section, forming clusters with biotite and chlorite, and, rarely, with spehne and epidote. Apatite is more common near the large inclusions, but forms only a small fraction of the rock. Large, euhedral grains of sphene may be primary. Zircon is rare, occurring in small, subhedral prisms.

In the Tapukok granodiorite an intermediate zone of biotite-hornblende granodiorite can be delimited in which the ferromagnesian minerals constitute between 10 and 30 per cent of the rock (*See* Table I, No. 2). The rock in this zone is gneissic in texture and pink in colour, and although in most parts the foliation is concentric to the massive core, in the eastern part, along the Vamp Creek fault, the foliation appears to have been modified by the fault in both degree of development and attitude.

The rocks in the outer zone of the Tapukok granodiorite are medium grained, and like those in the intermediate zone, gneissic in texture. Unlike them, however, they are darker on the weathered surface, and only locally exhibit a pinkish hue. In composition they range from quartz diorite to gabbro, the more mafic rocks outcropping near the south-central part of Nesosap Lake. On the weathered surface, the subhedral dark minerals, commonly amphibole, can be seen to form angular clusters up to 8 mm. long in a groundmass of grey or brownish plagioclase. Where these clusters are elongate, they form the foliation. Dykes of leucocratic granite that appear to extend northward from the intermediate zone of biotite-hornblende granodiorite, cut the rocks of the outer zone.

There are several varieties of mafic rocks in the outer zone of the Tapukok granodiorite. In one, a hornblende diorite, the feldspar is gradationally zoned andesine containing antiperthitic microcline. Quartz occurs in strained grains interstitially to the other minerals. Hornblende is the main ferromagnesian mineral, but biotite occurs in small quantities locally, commonly with epidote. Rare prisms of apatite are the only accessory constituents (*See* Table I, No. 3b).

The hornblende diorite is gradational into dark gabbro (*See* Table I, No. 3a) in the south-central part of Nesosap Lake. In thin section, the plagioclase occurs in zoned, anhedral to subhedral grains replete with small, oriented plates of a dark mineral, possibly specularite or ilmenite. Some of the feldspar grains are strained. Augite occurs in greenish, subrounded to angular grains in part surrounded by wisps of chlorite but more commonly mantled with hornblende and filled with grains of magnetite and a little white mica. It was rarely observed in contact with biotite. Anhedral grains of fresh, brownish green hornblende are always associated with pyroxene, suggesting that part or all of it is secondary after the pyroxene. A little quartz occurs interstitially to the other minerals. Similar gabbro containing less pyroxene occurs as inclusions in the diorite facies of the Tapukok granodiorite west of Nesosap Lake.

The origin and structural relations of the gabbro facies are conjectural. It differs texturally and mineralogically from the outermost facies of the Nekik granodiorite, near Soneau Lake, so that it cannot have been derived from volcanic rocks by some process of granitization. The lack of inclusions in the pyroxene-bearing gabbro likewise excludes the possibility that it has been derived from rocks, similar to those in the intermediate zone of the Tapukok granodiorite, by contamination by the intruded rocks. It is most probably an early facies of the Tapukok granodiorite. The facts that gabbro occurs as inclusions in diorite and that granitic dykes cut these rocks in the outer zone indicate that the more mafic rocks are older than the more felsic ones, but the writer is of the opinion that the age difference is slight.

## Naosap Granodiorite

A body of alaskitic and biotitic granodiorite, here named the Naosap granodiorite, is exposed north of the eastern half of Naosap Lake. Phenocrysts of oligoclase, with a maximum length of $\frac{3}{4}$ inch, are common in an irregular area in the central part, north of the large mass of amphibolite. Otherwise, hand specimens of rocks from the more central parts resemble those from the inner and intermediate zones of the Tapukok granodiorite (*See* Table I, No. 4). In thin section, however, some of the quartz is granulated and strained (*See* Figure 3b), and unaltered microcline replaces plagioclase, features not commonly observed in the Tapukok granodiorite.

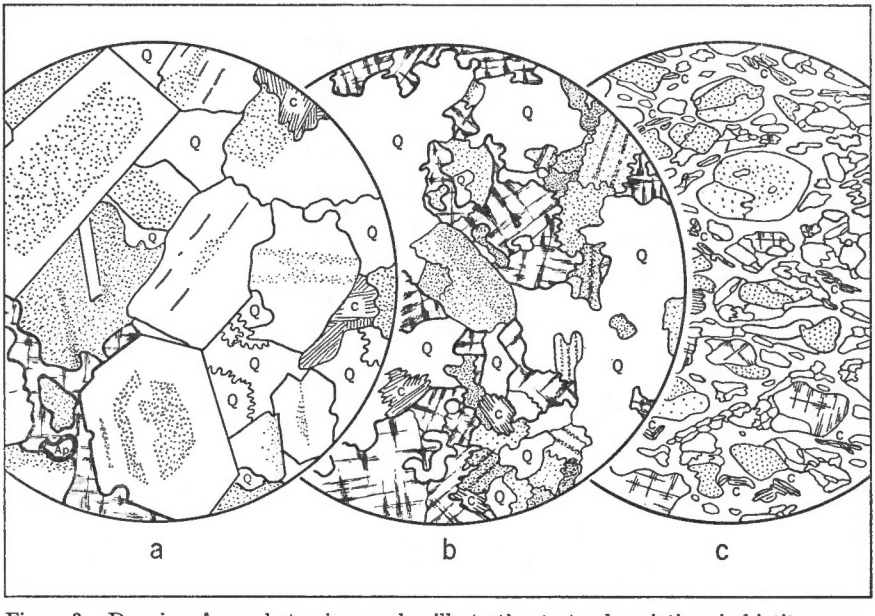


Figure 3. Drawings from photomicrographs, illustrating textural variations in biotite granodiorite: a, hypidiomorphic Tapukok granodiorite, × 12; b, slightly crushed Naosap granodiorite, × 13 (the extremely sutured condition of quartz in blank areas not shown); c, cataclastic Naosap granodiorite, × 13; the clear groundmass between the grains of quartz and plagioclase is composed of very fine quartz-plagioclase mortar; stippled areas are plagioclase; clear areas, quartz (Q); cross-hatched areas, microcline; c, chlorite; and Ap, apatite.

Between Nekik and Sewap Lakes the porphyritic biotite granodiorite intrudes a band of amphibolite, and plagioclase phenocrysts occur within 500 feet of the Vamp Creek granodiorite-gneiss contact. The lack of shearing near the contact, in contrast with the granoblastic fabric in the Vamp Creek body, suggests that these two bodies form separate structural masses.

The marginal facies of the Naosap granodiorite with the composition of hornblende granodiorite and quartz diorite, is heterogeneous in texture and composition; it is locally porphyritic or gneissic, and inclusions are common. In the south-central part of Naosap Lake and along Nistosap Lake some of these marginal rocks that intrude the 'Fine-grained granodiorite' contain microscopic quantities of pyroxene, which was not found elsewhere in the Naosap granodiorite. In this respect these rocks may have originated in an environment that is comparable with the environment that produced the outer zone in the Tapukok granodiorite. Another feature by which these marginal rocks differ from others in the Naosap body is the elongate habit of plagioclase. The ratio of length to width in the plagioclase is 6 or 8 to 1 rather than 3 to 1 as in the typical granodiorite. Although these differences may denote that these marginal rocks are genetically different from the Naosap granodiorite, they are not separated on the map.

On the north and west margins of the Naosap granodiorite, north of the possible fault, the rock is schistose in structure and cataclastic in texture with crushed plagioclase phenocrysts evident on some outcrops. Microscopically the quartz exhibits a mortar structure and the plagioclase occurs in fractured, anhedral grains (*See* Figure 3c). The largest grains of plagioclase are only 2 mm. long, whereas those in the less altered parts of the Naosap granodiorite, excluding the phenocrysts, exceed 3 mm.

### GRANOBLASTIC GNEISS

A narrow, elongate body of granoblastic hornblende-biotite granodiorite-gneiss extends for about 3 miles northerly on the southeast margin of the Naosap granodiorite, north of Baker Lake.

The gneiss is white to light grey weathering, of medium grain, and the foliation is exhibited by lenses of white quartz up to ¼ inch wide and 1 inch long, which form a ribbed surface on the outcrop. On surfaces parallel with the foliation the lenses are elongate, plunging northeast at shallow angles. Locally a fine-grained variety of the gneiss that resembles some of the rocks along the southern part of the Vamp Creek fault, exhibits a foliation formed by streaks of dark minerals.

Under the microscope, the gneiss is granoblastic in texture, composed of anhedral plagioclase and quartz, with minor amounts of amphiboles, pyroxene, biotite, chlorite, apatite, garnet, zircon, and opaque minerals. The plagioclase has the composition of oligoclase ($An_{16}$), and is fine grained, poorly twinned, and rarely zoned; it carries a little carbonate and sericite. Small grains of quartz are interstitial to the plagioclase, but the larger grains and clusters appear to have replaced parts of the other minerals so that the clusters or lenses are almost monomineralic. Some of the quartz is platy. Biotite, hornblende, and, less commonly, tremolite, are associated with minor subrounded grains of augite, and chlorite. Chlorite is of two kinds, one near clinochlore in composition,

occurring in veinlets, and the other an almost isotropic penninite. Poikilitic garnet, apatite, and zircon are present in small quantities, but opaque minerals are relatively abundant.

The lateral contact zones of the granoblastic gneiss are about 500 feet wide. In this distance it is possible to traverse from the gneiss into more massive rock. On the west side, at the northern end of the body, the gneiss is bounded by pink weathering Naosap hornblende-biotite granodiorite. North of Baker Lake the gneiss grades southward through a finer grained, layered zone into medium-grained, pink weathering, massive hornblende-biotite granodiorite of uncertain affinity. Nowhere do dykes of pink granodiorite cut the white or grey gneiss, nor does the pink facies of the granodiorite contain gneissic inclusions. Thus, all the rocks appear to be of the same age, differing only in the presence of the gneissic structure in some. The granoblastic fabric of the gneiss and the presence of garnets indicate that this rock has been subjected to dynamothermal metamorphism. Consequently, the gneiss could well have been derived from the surrounding granodiorite by means of this metamorphism.

The relationship between the granoblastic gneiss and the contorted 'Quartz diorite-gneiss' to the southwest, northeast of Naosap Lake, is uncertain. It appears, however, that the two rocks are not of the same age (page 17).

### Nekik Granodiorite

The central part of the northernmost of the youngest intrusive bodies, named the Nekik granodiorite, is composed of pink biotite granodiorite, mineralogically similar to the rock described from the inner zone of the Tapukok body. It is massive in the central part but more gneissic to the north, and only rarely porphyritic. This pink granodiorite is surrounded on all sides, except the north, by an irregular outer zone composed of more ferromagnesian-rich, medium-grained varieties that weather pinkish grey to dark grey and have a composition of hornblende granodiorite, hornblende quartz diorite, and hornblende diorite. It is significant (*See* page 59) that the outer, hornblendic facies are missing on the north side. The outer zone consists locally of as much as 40 per cent hornblende, but because a few, even darker, lenticular inclusions can be recognized in it, such dark rocks have been mapped with the border facies of the Nekik granodiorite rather than with the recrystallized intruded rock. Biotite is usually subordinate, but in some outcrops constitutes more than half of the dark minerals. The contact between the biotite granodiorite and the outer zone of hornblende granodiorite is sharp, but no intrusive relations were observed, and the two rock types are considered to be of the same age.

#### GEOLOGICAL RELATIONSHIPS ON THE NORTH FLANK

The northern margin of the Nekik granodiorite body is similar to the northern margin of the Tapukok body: the rocks exhibit features that indicate the action of strong shearing movements. The first visible change in the massive biotite granodiorite is indicated by the occurrence of crushed plagioclase phenocrysts and by the orientation of the biotite into thin lenses. Nowhere except near the sheared contacts does biotite have this habit. In one thin section, the quartz is strained and crushed, and myrmekite, an uncommon intergrowth in these rocks, is developed against some of the perthitic microcline. Within a few hundred feet of the north contact

the gneiss is greyer and breaks into sheets, some of which are faced with biotite schist that may represent sheared inclusions. Near the outer contact of the biotite granodiorite, the rocks pass abruptly into fine-grained, garnetiferous, biotite-quartz-plagioclase granulite (*See* Table I, No. 7). The granodiorite does not exhibit a chilled margin against the granulitic rock, and inclusions of it are missing. Also, pegmatite and granite dykes were not found cutting the granulitic rocks, nor were migmatite zones found in the granulite. No intrusive relations were recognized along this contact.

The lack of normal, medium-grained, contaminated rock at the north contact might be interpreted as due to the intrusion of the biotite granodiorite into the Kisseynew strata, which are compositionally more like the granodiorite than are the Amisk volcanic rocks. In this case the zone of contamination would be small. However, the lack of any observed intrusive relationships, with the possible exception of the sheets of biotite schist in the granodiorite, makes such a postulation improbable.

Robertson has suggested that the relationships at the north contact can be interpreted as showing the conversion of sedimentary material to granite by feldspathization (51, p. 10).

Another interpretation, which has been considered, is that the typical hornblende granodiorite border facies has been altered to granulite by cataclasis. However, such an hypothesis is untenable on the basis of the present work because the modal analysis of a granulite, thought to be fairly representative, discloses a high content of quartz (*See* Table I, No. 7), suggesting, thereby, that at least some of the granulite is probably a sedimentary paragneiss.

Whatever the interpretation of the relations at the north contact, the writer believes that the effect of shearing, either as a factor in the chemical alteration of the rocks or in the obliteration of the evidence of that alteration should also be considered. But from the lithological considerations discussed above, the writer concludes that the field relations can be best explained by a fault at, or near, the north contact of the Nekik biotite granodiorite.

### Vamp Creek Granodiorite

The rocks in the long granodiorite body in the eastern part of the map-area comprise essentially two main types. A pink, biotite granodiorite forms an elongate mass about ¼ mile wide and at least 4 miles long on the east side of Vamp Creek. Rock of a similar type outcrops on the northwest side of the creek near the eastern margin of the map-area and may represent a faulted part of the other mass. The remainder of the Vamp Creek body is a pinkish grey hornblende granodiorite.

The rocks are more gneissic than those of the Naosap granodiorite. Foliation is well developed along the amphibolite contacts and locally along the Vamp Creek fault. Otherwise, the rocks are similar mineralogically to those of the Naosap and Tapukok granodiorites.

### Emerald Lake Intrusion

A body of alaskitic microcline granite is exposed near the southeast corner of the map-area, about 1 mile north of Emerald Lake. Dark minerals

occur only in the narrow marginal zone, which is commonly no more than a few feet wide. The outer contacts with amphibolite are sharp. To the east, the granite becomes greyer, and contains variable quantities of biotite and hornblende, with very little microcline.

## Dismal Lake Granodiorite-gneiss

The eastern end of an elongate, lithologically distinctive granitic stock lies in the northwestern part of the map-area south of Dismal Lake.

Tectonically the stock appears to have served as the core of a buttress against which the adjoining Kisseynew gneisses to the north have been thrust. The gneissic structure in the stock may have resulted from this compression, but more probably is an earlier structure that has been emphasized to its present prominence by it.

### LITHOLOGY

The rock is white to light pink or pinkish grey; is everywhere porphyritic; and is generally gneissic. The phenocrysts consist of euhedral and subhedral oligoclase, up to three-quarters inch long, some of which are antiperthitic. They conform with the foliation to a considerable degree, but do not exhibit a marked linear orientation. Megascopically, the groundmass consists of feldspars, quartz, and a variable quantity of biotite, which emphasizes the foliation. In thin section, the plagioclase occurs in subhedral laths and anhedral grains, and also in myrmekitic growths against microcline. Perthitic microcline is abundant locally. The other minerals are quartz, biotite (altering to penninite), zoned epidote, apatite, zoned sphene, and limonite.

Near the north contact, the stock is finer grained, and contains a greater amount of dark minerals. A very few, long, dark, amphibolitic streaks were also observed, but with the exception of these no mafic masses were recognized that might represent inclusions of older rocks.

Locally, in the centre part of the stock, shearing along northward dipping surfaces has reduced the rock to fine-grained, mylonitic, layered gneiss. Minor crumples defined by the flakes of biotite in some zones have a slight eastward plunge. Under the microscope, the quartz and plagioclase can be seen to be crushed and strained, but phenocrysts of perthitic microcline, rimmed with myrmekite, show no such strain. Thus, they appear to have been introduced subsequent to the shearing.

### CORRELATION

There are no intrusive contacts of the Dismal Lake granodiorite-gneiss with the Amisk series. In this respect the granodiorite is similar only to the Emerald Lake intrusion. The lithology of the stock differs from the other bodies in being porphyritic and gneissic everywhere, and its composition shows a low content of potash (15). Because of these differences, and because the age relationship to the other younger granodirite bodies is not known, the Dismal Lake intrusion cannot be correlated with them on the basis of the present work. However, because it is more like the youngest intrusions than the oldest, it is included tentatively with them.

## DYKE ROCKS

Many quartz latite dykes intrude the marginal parts of the 'Fine-grained granodiorite', southwest of Naosap Lake. The dykes weather light grey, light greenish grey, and light brown, and range from a few inches to 5 feet in width. The porphyritic dykes are the wider, and contain phenocrysts of grey or pinkish plagioclase and blue or white quartz in varying proportions in an aphanitic groundmass. The felsitic dykes of quartz latite are similar in appearance to the groundmass of the porphyritic dykes, and both are similar to the extremely fine-grained border facies of the 'Fine-grained granodiorite', which they have intruded. This suggests that they may have a common origin. Those dykes that carry phenocrysts of plagioclase cut others in which the phenocrysts are of blue quartz.

South of Alberts Lake fault, two dykes of porphyritic quartz latite appear to be tongues that extend into the Amisk volcanic rocks from the 'quartz-eye' granite. One of these is 2 feet wide, light brownish grey in colour, and exhibits phenocrysts of bluish quartz and small clusters of biotite on the weathered surface.

Less than a mile east of north from the northern tip of Naosap Lake, two dykes of felsitic quartz latite cut across the structure of the Amisk volcanic rocks. Both of the dykes exhibit small crumpled ridges and elongate lumps on the weathered surface that may represent flowage. Except locally, the volcanic rocks and the dykes are undeformed along contacts. The texture is allotriomorphic-granular, with an average grain size of about 0·2 mm. Some of the larger, strained and crushed grains of quartz are up to 1·5 mm. in diameter. The varietal minerals are biotite and muscovite, which occur in flakes up to 0·7 mm. long, and the accessory minerals are apatite and tourmaline. The rock exhibits a foliation, indicated by elongation of the minerals and the orientation of mica and epidote.

About 1,300 feet south of the east-west fault that extends into the map-area 3½ miles northwest of Naosap Lake, somewhat similar foliated and ribbed rocks occur as a narrow sheet within the volcanic rocks. The quartz latite is grey to pinkish grey weathering and extremely fine grained. Rare laths of feldspar and inconspicuous phenocrysts of quartz are the only minerals discernible to the naked eye. Microscopically the rock is a micro-granular aggregate of quartz and potash feldspar in which are set a few grains of strained quartz. Foliation is lacking. The abundance of potash feldspar suggests that the rock may be related to the granodiorite stock to the north.

Porphyritic dacite dykes, some with hornblende and others with plagioclase phenocrysts, are common in the areas underlain by volcanic rocks, and are numerous on the east side of the second smallest body of diorite, northwest of Naosap Lake and in the Tapukok granodiorite. Lamprophyre dykes, now consisting of a felted mass of chloritic amphibole, are rare.

Dykes of granite-pegmatite and of graphic granite outcrop in the southwest part, and on the south-central shore of Naosap Lake, and dykes of granodiorite occur sporadically in the Tapukok granodiorite and around the other granodiorite bodies.

METHOD OF EMPLACEMENT

Many of the dykes have been intruded into fractures along which movement had occurred (*See* Plate I A and Figure 4f), but the lack of complete correlation between the walls might be explained by a slight vertical movement, which may serve to explain the termination of one of the earlier dykes in Figure 4c. There appears to have been little or no move-

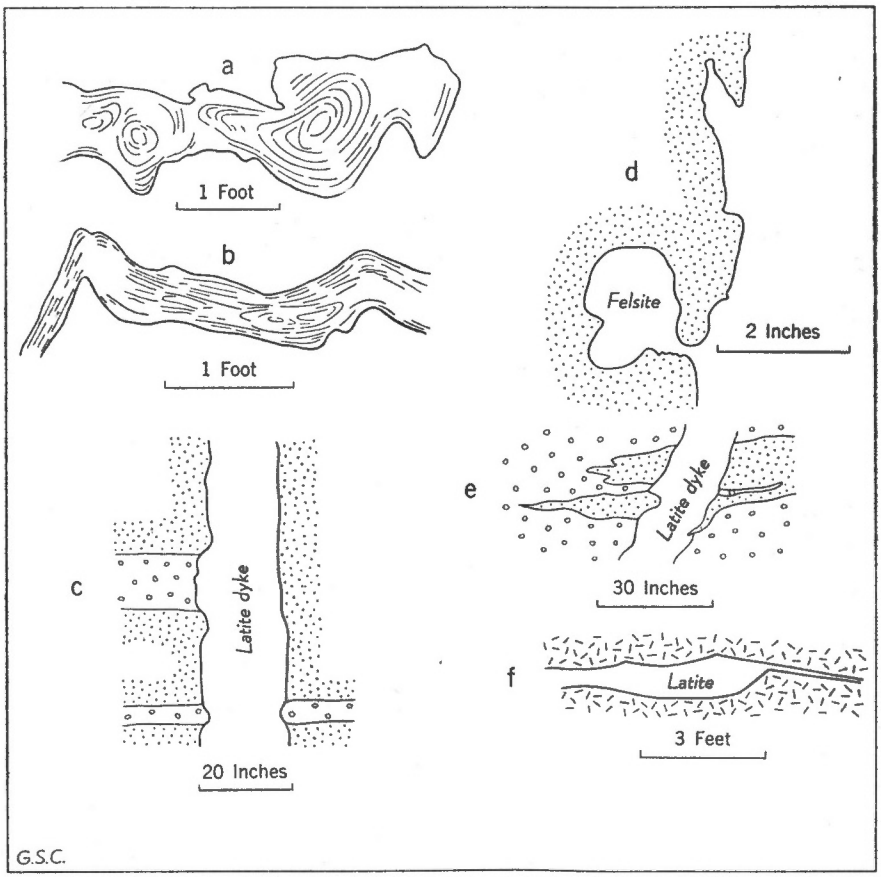


**Figure 4.** Field sketches illustrating the mode of emplacement of dykes; a, b, indicating magmatic flowage in felsitic dykes 1½ miles northeast of Alberts Lake; c, termination of older dyke of quartz latite in silicified greenstone at crosscutting latite dyke; at north margin of 'Fine-grained granodiorite' south of Naosap Lake; d, replacement of amphibolite wall-rock by felsite dyke, 1 mile northeast of Alberts Lake; e, amphibolite inclusions in porphyritic quartz latite show no offset at crosscutting latite dyke; south of Naosap Lake margin of 'Fine-grained granodiorite' south of Naosap Lake; d, replacement of amphibolite wall-rock by felsite dyke, 1 mile northeast of Alberts Lake; e, amphibolite inclusions in porphyritic quartz latite show no offset at crosscutting latite dyke; south of Naosap Lake near c; f, fissure-filling of latite in 'Fine-grained granodiorite', southwest of Naosap Lake.

ment along some other fissures (*See* Figure 4e). A few of the felsitic dykes exhibit a well-defined textural banding, which is evident on the weathered surface but not visible on a fresh surface (*See* Figures 4a, 4b). Some of

the small ridges, produced by the differential weathering of the dyke rock, parallel the walls, but locally, in the wider parts, they form concentric swirls. Such banding can have originated only in a fluid medium and, therefore, suggests very strongly that the dykes were emplaced in a magmatic state. The distribution of the concentric flow lines indicates that the magma was able to flow more easily in the wider parts of the fissure where the drag on the walls was less. The above is the best evidence found in the field that at least some of the dykes are magmatic, and contradicts the view held by others that the shape, attitude, and texture of all dykes are due entirely to metasomatism (52). That some replacement or stoping of the wall-rocks is a common feature in these magmatic dykes is indicated by the minor differences in the shape of the two walls.

Other dykes exhibit features that indicate a greater metasomatic activity. Some of the embayments can be explained only by replacement (*See* Figure 4d). Similarly, the contacts of another dyke (*See* Figure 4c) indicate how the nature of the wall-rock has controlled the width of the dyke. It is suggested, however, that the metasomatic action on the walls may indicate magmatic corrosion consequent on the intrusion of the dyke rather than complete metasomatism of the host rock along a fissure.

## KISSEYNEW COMPLEX

### Introduction

The Kisseynew complex comprises a heterogeneous assemblage of metamorphosed sedimentary rocks intruded by granite and gabbro in the northern part of the map-area. Originally, these rocks were given the name 'Kisseynew gneisses'[1] by Bruce (15, p. 27), and later, in 1929, he used the term 'series' when referring to the stratified rocks in this group although he realized that in many places it would be impossible to separate them from the granites. The entire assemblage was named the Kisseynew complex by Bateman and Harrison in 1944 (11). This and other problems associated with the Kisseynew gneisses have been discussed recently by Robertson (51) and Harrison (29, 30).

The rocks in the Kisseynew complex are separated from those in the southern part of the area by a fault, so that the stratigraphic relations are unknown. Consequently, the rocks in these two areas must be treated as separate geological units. In a later section of the report (pages 55-61), the geological relations at the contact between these two units, which led to the interpretation of the contact as a fault, are described, and certain other conclusions are drawn from these observations.

### Kisseynew Sedimentary Gneisses

Kisseynew sedimentary gneisses consist of argillaceous, arenaceous, and conglomeratic rocks with some amphibolitic layers of uncertain origin. All the rocks have been recrystallized, some of them more than once, so that it is possible to classify them only rarely on the basis of their original mineral composition or texture.

[1]These gneisses form part of a belt that varies from 15 to 25 miles in width and extends east-northeast for about 200 miles "almost transverse to the dominant structure of the schists in the southern part of the district" (15, p. 27).

In this report the sedimentary rocks are subdivided into four units on the basis of broad lithological characteristics. Thus these rock units have no definite stratigraphic position. Those sedimentary gneisses that have been altered to mylonite along the Weldon Bay fault zone are described in the section dealing with the evidence for the Weldon Bay fault (pages 57-59).

## LITHOLOGY

### *Biotite-plagioclase-quartz Paragneiss*

The least altered type of Kisseynew sedimentary rock in the Weldon Bay map-area is represented by outcrops on the islands and the mainland east of Lobstick Narrows on Kisseynew Lake. The rock is a light grey weathering, recrystallized sandstone, composed of fine-grained quartz, with some plagioclase, and minor amounts of biotite and garnet. A delicate mineral banding on the weathered surface is formed by the planar arrangement of biotite. The intervening rock between biotite layers forms fairly persistent beds from ½ inch to 1½ inches in thickness.

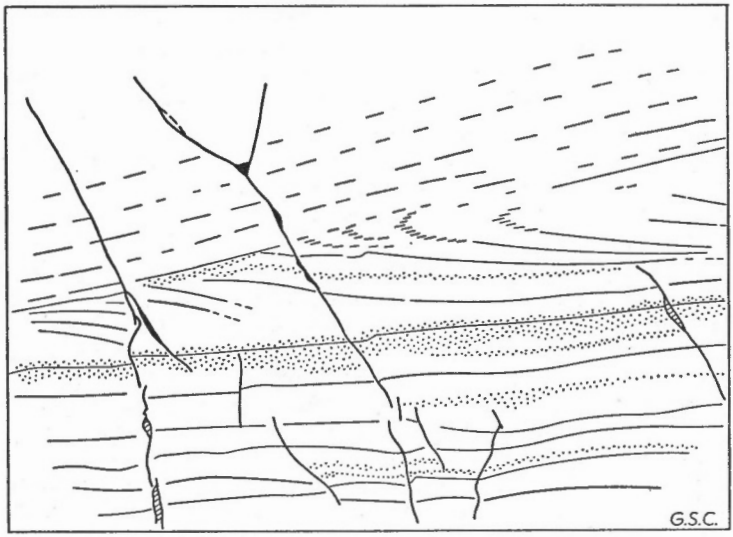


Figure 5. Sketch from a photograph taken by J. M. Harrison, Geological Survey of Canada, illustrating possible crossbedding in Kisseynew sedimentary rock on Kisseynew Lake, ½ mile east of Lobstick Narrows. Scale: 1 inch = 8 inches.

On the east side of the large island east of Lobstick Narrows, a structure that may represent either concave crossbedding or a sheared isoclinal fold was observed in the meta-sedimentary rocks (*See* Figure 5). Elsewhere on the island some of the thin beds, outlined by biotite, have been thrust on each other, resulting in a structural pattern that much resembles crossbedding. However, if the illustration is of crossbedding in sandstone, the occurrence is one of few that has been recognized to date in these rocks.

Foliation in the biotite-plagioclase-quartz paragneiss is first exhibited by a crude parting parallel with the bedding, that is, bedding-plane foliation.

Away from the axial areas of the folds, where bedding-plane slippage may have been greater, the primary structures are obliterated, and a strong foliate parting is the only planar structure remaining in the rocks. Although the foliation may everywhere parallel the bedding, both structures are indicated by the foliation symbol on the accompanying map.

Farther to the east of Lobstick Narrows the foliation is coarser in the paragneiss, consisting of an undulatory and locally crenulated parting, paralleled in some outcrops by a colour banding of alternating light pinkish grey and light grey zones in a predominantly grey rock. Locally, small, reddish and brownish garnets are arranged in strings parallel with the foliation, and small joints may be coated with fine magnetite. Where the well-foliated gneiss contains many small-scale folds or crenulations, abundant veins of fractured grey and white quartz follow the foliation closely, in places terminating as a hook or an irregular, radiating mass. In thin section, this type of paragneiss consists primarily of strained quartz, sodic plagioclase, and chlorite after biotite. The grain size seldom exceeds 0·8 mm. and is usually about 0·3 mm. Quartz occurs in irregular, sutured grains showing no dimensional orientation. Where it is associated with magnetite, the feldspar is altered to sericite. Staining, according to the procedure described by Keith (36), failed to disclose any potash feldspar. Muscovite is interstitial to quartz in the more granular parts of the slides, and commonly replaces chlorite. Some thin sections are traversed by narrow zones of magnetite and subhedral tourmaline.

The narrower and less abundant pinkish layers are about 2 inches wide. They are granular and slightly coarser grained than in the adjoining rock, and consist of more than 50 per cent plagioclase, the remainder being quartz and clinozoisite.

In the northwestern part of the map-area, the Kisseynew paragneiss is finer grained, and more uniform in composition and texture. Except in the northwest corner, foliation is poorly developed, with the major parting planes (bedding ?) as much as 10 feet apart. Garnets occur sporadically, and both granitic layers and quartz veins are rare. The minerals are quartz, plagioclase, brown biotite, brown hornblende, garnet, apatite, tourmaline, calcite, prochlorite, clinozoisite, and opaque minerals. Faint, wavy bands, outlined by ferromagnesian minerals on the weathered surfaces of some outcrops probably represent beds; the largest folds seen are only a few inches from crest to crest, and in turn have even smaller crenulations superimposed on them. A fissility, which is parallel with the bedding, is extremely irregular in attitude in these folded areas, but because of the lack of differential erosion between the various layers in the almost homogeneous paragneiss, many smoothly glaciated outcrops appear on casual inspection to be structureless.

About ½ mile north of the west end of Lobstick Narrows, rods composed of quartz and sillimanite occur in the rocks of a small area near the axial zone of a syncline. These rods lie almost parallel with the plunge of the axes of the minor and major crenulations. Because sillimanite occurs in only certain beds, its distribution is probably governed by the original composition of the rock. Quartz veins are rare in the sillimanitic rocks.

About a mile northeast of the east end of Lobstick Narrows, the Kisseynew paragneiss exhibits a well-developed linear structure. It is compressed into many tight, similar folds, with an amplitude of ½ inch and a wave

length of ¾ inch. Quartz occurs as irregular, rounded rods in the anticlinal parts of these tiny folds, and wrinkles on the surface of these rods parallel the axes of the small folds. This structure may be related to a fault.

### *Conglomerate-gneiss*

Certain rocks interpreted to be conglomerate-gneiss outcrop on the northwest side of the long point, ¾ mile due west from the mouth of Fay Creek. A stratiform foliation divides the gneiss into sheets, and the matrix between the pebbles comprises about two-thirds of the rock. Because most of the pebbles have weathered more readily than has the matrix, they appear as elongate, shallow pits on the surface of the conglomerate-gneiss, arranged parallel with the direction of foliation. The ratio of width to length of the pits ranges from 2 : 3 to 1 : 10 and their length varies between ¼ inch and 6 inches, with an average length of 1 inch. The largest fragment seen was of bluish grey quartz, 4 inches by 6 inches in section. The megascopic composition of the weathered pebbles is: coarse-grained white quartz; medium- to fine-grained white quartz; fine-grained granite; amphibolite; and bluish quartz. None of the pebbles were garnetiferous, and, because of their advanced state of weathering, none were collected for microscopic study.

Another occurrence of probable conglomerate is on a small point in the northwest end of the second lake drained by Fay Creek, about 1½ miles east of the mouth of the creek. Elsewhere, small, lenticular, pebble-like bodies of white to brown quartz are common in the Kisseynew paragneisses. Most of these may represent stretched and rolled quartz veins, as in some instances it is possible to reconstruct the vein from these disconnected lenses. Also, there is no variation in composition among the various lenses in this type of rock.

### *Amphibolite-gneiss*

Amphibolite-gneiss occurs as a large, folded sheet in the northwest part of the map-area, and as minor, thin layers both intercalated with and crosscutting the paragneisses.

The main body of amphibolite-gneiss weathers dark grey to greenish grey and is of variable mineral composition. Essentially it consists of about 50 per cent hornblende and 35 per cent plagioclase, with varying amounts of quartz and biotite. The quartz-content is higher near some narrow dyke-like bands of grey biotite-plagioclase-quartz rock, and biotite is more abundant locally along the limbs of folds. Porphyroblastic garnets are common only in the northwest part of the amphibolite sheet, where they occur in small lenses paralleling the foliation. Locally, the amphibolite contains very narrow, indistinctly gradational, continuous layers of plagioclase and quartz.

Because of the apparently gradational nature of the contacts of the main amphibolite body with the biotite-plagioclase-quartz paragneiss in the Weldon Bay area, the writer is inclined to agree with the opinion expressed by Wright (65, p. 81) concerning the origin of this type of amphibolite. He stated that "the hornblende-bearing gneisses [amphibolites] alternate with the quartz-mica gneisses of undoubted sedimentary origin without the sharp contacts they should show if they represented recrystallized lava flows or metamorphosed intrusive bodies". It seems probable,

therefore, that much of the amphibolite may be of sedimentary origin although, on the basis of chemical analyses, Harrison (30, p. 39) has been able to demonstrate that some amphibolites in the Sherridon area are mafic igneous rocks.

The main body of amphibolite-gneiss terminates abruptly on the north shore of Lobstick Narrows and Kisseynew Lake (*See* Figure 13b). The north limb of a syncline is exposed on the north shore of the Narrows, but the south limb has either been removed by faulting or else has been extremely attenuated in a fold so that it may be represented by small layers of amphibolite farther east, too small to map.

Southwest of Lobstick Narrows, amphibolite outcrops on the east end of the Kisseynew Lake anticline. The amphibolite is well foliated and parts into flat sheets. Parallel with this foliation, and intercalated with the more typical amphibolite, are layers of more feldspathic material, which comprises from 10 to 15 per cent of the rock. Such layering is not characteristic of the amphibolitic Amisk volcanic rocks that outcrop to the south of the Kisseynew contact.

From his studies of these amphibolitic rocks as far west as Lobstick Bay in Mikanagan Lake map-area, Robertson concluded, primarily on structural grounds, that they should not be included with the Kisseynew gneisses but rather that they are part of the Amisk series (51). The writer disagrees with this interpretation because certain important structural considerations have been overlooked. These considerations are discussed elsewhere (page 59).

Small bodies of amphibolite-gneiss, not large enough to be mapped separately, outcrop along Kisseynew Lake. The amphibolite occurs in stratiform layers from a few inches to several feet thick, and locally some layers transect the plagioclase-quartz paragneiss. Amphibole comprises from 30 to 50 per cent of the rock, the remainder consisting of fine-grained quartz, plagioclase, and minor biotite and garnet.

Some of the amphibolitic rocks along the Weldon Bay fault are of uncertain affinity. Southeast of Weldon Bay two layers of fine-grained amphibolite are separated from the hornblende gabbro sheet by biotite-plagioclase-quartz gneiss. These amphibolites contain the same amounts of amphibole, plagioclase, and quartz as the hornblende gabbro sheet. Southwest of the mouth of Fay Creek, similar amphibolite, possibly the continuation of the same layers, is intruded by the gabbro, so that it must be pre-gabbro in age. Near lake level, the amphibolite exhibits oval pits that seem to have been produced by the leaching of some minerals from the rocks by lake water, but that form a pattern similar to that of a weathered volcanic flow breccia. Away from the shore, most of these amphibolites are well foliated, but some of them, especially south from the mouth of Fay Creek, exhibit a coarser texture resembling that of some exposures of the hornblende gabbro sheet.

Foliated, garnetiferous amphibolites outcrop on the northwest margin of the gabbro sheet, about ½ mile southwest of the mouth of Fay Creek, and on the south shore at the entrance to Weldon Narrows. Gneissic, and in part garnetiferous, amphibolites, some interlayered with minor hornblende-plagioclase gneiss, occur also southwest of Weldon Bay, south of the hornblende gabbro sheet. The occurrence of these disconnected amphibolite layers is subject to various interpretations: all, or only some of

them, may be older than the gabbro age. Those that are older may either be volcanic flows or mafic sills that are interlayered with the Kisseynew sedimentary gneisses; or they may have been derived from an earlier gabbro, subsequently sheared and crumpled, that was intruded into the Weldon Bay fault zone; or they may represent metamorphosed Amisk lavas.

### *Mixed Gneisses*

In certain parts of the map-area, commonly around each of the younger granodiorite bodies, the Kisseynew paragneisses contain granite and granite-pegmatite dykes that have been emplaced parallel with, or at a small angle to, the foliation. Such heterogeneous rocks are termed 'migmatites', and the lower and upper limits set at 30 and 60 per cent introduced granitic matter respectively. However, the migmatites in which additions are obvious in the form of pegmatitic dykes or finer grained *lit-par-lit* injections are more easily mapped than those rocks in which granitization processes have been less obvious through permeation or "soaking", or in which the composition and grain size were close to that of the granite initially. Because these two kinds of altered rocks are closely associated in the field, they are grouped together on the map with associated unaltered paragneisses, and are considered together under the broad term of 'mixed gneisses'.

Mixed gneisses, comprising an irregular sequence of grey, biotite-plagioclase-quartz gneiss, pink granitoid gneiss, aplite, and granite-pegmatite, outcrop in the area south of Thunderhill Lake and east of Weldon Bay. The various rock types occur as interlayered sheets, which, with the exception of pods of pegmatite, appear to have considerable lateral extent. Similar mixed rocks outcrop on some of the islands in Weldon Bay and along the south shore of Kisseynew Lake, and are especially abundant in the area south of Lobstick Narrows.

North of Kisseynew Lake, fine-grained, massive, lavender-coloured rocks that may be intrusive granite have been mapped as 'mixed gneiss'. Associated with them are other rocks with poor to excellent foliation and parting, and a pinkish colour. Their distribution around the granodiorite bodies and their granitic character led to their classification as 'mixed gneisses'.

In the northern and northwestern parts of Weldon Bay the rocks, much of which are pinkish quartz-plagioclase-biotite paragneiss, are cut by dykes of granite and granite-pegmatite. Locally, they exhibit a compositional banding, probably relict bedding, parallel with the foliation. Knots composed of quartz and sillimanite occur along some of these bands. Sillimanite is more abundant in the rocks along the southeast margin of the granodiorite body in the northwest corner of Weldon Bay. Although the schist is tightly contorted locally, the foliation is commonly planar, parallel with the foliation of the surrounding rocks. Near the lake the schist is grey weathering and exhibits a knobby surface, with knots of quartz, sillimanite, and magnetite, distributed about one for every square inch of surface. The knots decrease in abundance northwestward, so that about 300 feet from the lake shore there is only one knot per 4 square inches of surface. Shearing also becomes less pronounced. The rock weathers lavender-grey, and the texture on fresh surfaces is granular.

## Gneisses and Schists of Uncertain Derivation

Some of the deformed rocks along the Weldon Bay fault zone are of uncertain derivation. The lithology of these rocks will be described briefly and certain problems concerning them indicated.

About ¾ mile southwest of Weldon Bay, a few outcrops of pink weathering granitoid gneiss and felsic schist lie in part between the sheets of hornblende gabbro and of amphibolite. The rocks are very fine grained and felsitic in texture, composed essentially of plagioclase and quartz, with variable amounts of biotite and garnet. In some outcrops the more massive rock has the appearance of mylonitic granite. About ¾ mile west in the same zone there are several outcrops of grey weathering, Kisseynew-type, crumpled, sedimentary gneiss and schist. However, the relationship of the pinkish rocks to the sedimentary gneiss and schist is not known.

Southeast of the amphibolite in the area southwest of the mouth of Fay Creek, grey, grey-brown, and pinkish, granular, fine-grained rocks, similar to those at the southwest corner of the larger lake ½ mile to the southwest, have certain characteristics that are intermediate to those of the Kisseynew sedimentary gneisses and the Nekik granodiorite, namely:

(1) The fine-grained rocks have the appearance of quartzose sedimentary gneiss. They exhibit a fair schistose foliation, but no compositional layering, suggestive of bedding, was observed. Mineralogically, these rocks appear to contain less biotite than the sedimentary paragneisses, although, as in them, small garnets are common. However, dark minerals appear to increase toward the amphibolitic rocks to the northwest.

(2) The only place where these fine-grained rocks outcrop in Weldon Bay map-area is along the north margin of the Nekik granodiorite.

(3) A few inclusion-like bodies of amphibolite occur in the more massive facies of the fine-grained rocks about 2,500 feet south of the mouth of Fay Creek.

(4) The Nekik granodiorite contact with these fine-grained rocks is abruptly gradational, and does not exhibit intrusive relationships. The grain size of the rocks decreases, but apparently there is no change in composition at the contact.

(5) Cataclasis in the Nekik granodiorite increases towards its north contact.

(6) Texturally similar, granular rocks are intrusive into amphibolite, although, away from the contact, the rock has the appearance of a sedimentary gneiss (pages 41, 71).

As stated previously (pages 25, 26), many of the rocks between Fay Creek and the Nekik granodiorite are of undoubted sedimentary origin. However, the field evidence suggests that some of the fine-grained rocks could have been derived from the Nekik granodiorite by cataclasis.

Similar granular rocks have been described by Wright from the B.C. Copper group of claims west of the east end of Fay Lake, about 7 miles east of the above locality (68, p. 39). All the rocks there appear to occupy a structural position between the mass of granodiorite to the south and the Kisseynew gneisses to the north, identical with that in the Weldon Bay area. Wright differentiated the rocks into grey quartzite and black

micaceous quartzite. However, he adds that "trenches in the middle locality are for the most part in a grey, siliceous rock believed to be a fine-grained marginal phase of the granite mass".

The fine-grained, granular rocks along the Weldon Bay fault zone in Weldon Bay map-area have been studied by Robertson (51, p. 10). He states that they have "every appearance of medium grained Kisseynew gneisses or of granitized parts of the sediment found in the Amisk. Thin sections show the features of recrystallization common in meta-sediments but do not show granulation. Pink garnets are not uncommon and the rock grades by the accession of feldspathic material into foliate granite". Thus, he is in agreement with the writer that some of the rocks have characteristics intermediate between those of sedimentary gneiss and granite, but he thinks that the characteristics can be related to granitization by feldspathization of the rocks.

The lack of granulation in thin section is not significant when determining the origin of these rocks. For example, the granoblastic gneiss southeast of Naosap Lake has been deformed, as have the 'Quartz diorite-gneiss' east of Nesosap Lake and the Tapukok granodiorite along the Vamp Creek fault. Yet, cataclastic features are rare in these rocks, garnets occur sporadically, and the rocks exhibit features of recrystallization.

Thus, the problem of the origin of the granular rocks cannot be approached by the study of textures in thin sections, but rather by the study of mineral composition. Certain possibilities concerning the mineral composition might also be kept in mind. If the fine-grained rocks have been derived from granodiorite, and if the granodiorite contained abundant inclusions of amphibolite, then the resulting crushed rocks would contain abundant ferromagnesian minerals. Robertson states that introduced feldspar increases in amount towards the granodiorite. If this feldspar is potassic, some of the potash could also combine with the primary amphibole to produce biotite, and the abundance of biotite would not be anomalous in such rocks. The writer believes that only a high content of quartz or a very high content of biotite will prove which of these fine-grained rocks are of sedimentary origin and which might be of crushed granitic material.

## Intrusive Rocks

As in the Amisk terrain, there are several ages of intrusive rocks in the Kisseynew complex, but, because none of the intrusions crosses the Kisseynew-Amisk contact, there is no way by which the ages of the intrusive rocks in the north can be compared with the ages of those in the south. In both areas granodiorites are younger than gabbroic rocks and older than pegmatitic dykes, but this may mean no more than that intrusions with similar lithologies have similar ages relative to other types of intrusions. Such a series of intrusions may be a product of certain processes of petrogenesis about which little is known but which have yielded a similar sequence of igneous rocks in orogenic belts that are widely separated in both space and time (57).

### HORNBLENDE GABBRO

Near the south margin of the Kisseynew paragneisses, a sheet of hornblende gabbro, 250 to 3,000 feet thick, extends continuously from

southeast of Lobstick Narrows to the east margin of the map-area. No evidence was obtained to suggest that the gabbro occurs as discontinuous bodies as has been stated by Robertson (51, p. 11).

About 500 feet southwest of the mouth of Fay Creek, the gabbro cuts amphibolitic rocks that may be of volcanic origin (page 34). A conformable, tabular inclusion of garnetiferous paragneiss, 100 feet thick and 600 feet long, is included in the gabbro about 1,700 feet north of the mouth of the creek.

The gabbro is intruded by cataclastic quartz latite (*See* page 41) about 3,500 and 4,500 feet south-southwest of the mouth of Fay Creek. It is cut on the north margin, west of the creek that drains into the southern part of Weldon Bay, by a tourmaline-bearing granite-pegmatite. The sheet may thus be older than the Kisseynew granodiorite.

### *Lithology*

On the weathered surface, the typical hornblende gabbro is greenish black; close observation discloses a mottled surface with small, discontinuous, greenish lenses, about ½ by ¾ inch in size, that contain clusters of hornblende crystals in a disjointed network in which hornblende is less abundant. Certain exposures are criss-crossed in a rectangular pattern by narrow veins along which the gabbro is lighter in colour. Identical mottled rock also outcrops on an island 1¼ miles northwest of the west end of Lobstick Narrows, and on the south shore of the narrows, at its eastern end.

Near the west end of the gabbro sheet and locally in its eastern part, especially southeast of Weldon Bay, the gabbro exhibits a fine-grained, gneissic texture and an almost black weathered surface. Foliation is emphasized by quartz-feldspar lenses ⅛ to ½ inch wide and up to 1 foot long. The weathered surface also exhibits tiny, lenticular grains of feldspar, and individual, or knots of, oriented hornblende prisms. The writer is inclined to map these fine-grained, amphibolite facies as dynamothermally metamorphosed gabbro rather than as sedimentary gneiss, as has been done by Robertson (51, p. 11). If these finer grained rocks are interpreted to be gabbro, then the gabbro sheet is continuous; if they are mapped as sedimentary amphibolite gneiss, then coarse-grained gabbro and fine-grained sedimentary gneiss form parts of a continuous belt or layer, with no apparent contacts between them along the strike.

Regardless of its massive appearance on outcrop, microscopically the gabbro everywhere exhibits a granoblastic texture and a gneissic structure. In the western part of the gabbro sheet, the rock consists of clusters of well-twinned plagioclase grains in a hornblende-plagioclase groundmass. Some of the hornblende crystals are crushed. In the eastern part of the sheet, some of the hornblende is in larger, more euhedral crystals, and garnet occurs in small quantities in the groundmass. A modal analysis of hornblende gabbro appears as No. 6 in Table I. Where the gabbro exhibits the typical, mottled surface, a thin section shows the rock to have a strongly oriented fabric. Lenticular clusters of hornblende consist of a core formed of one or more larger grains surrounded by a mantle of smaller grains. The structure is similar to that in a flaser gneiss, with the exception that although the grains are small, about 0·3 to 0·5 mm.,

crushing is not evident. Nevertheless, the gabbro does not exhibit a primary texture anywhere, and for this reason it is believed that the grain size may be related to the amount of crushing undergone by the gabbro, rather than that the fine-grained parts are derived from metamorphosed sedimentary rocks.

### *Structure of the Gabbro Sheet*

Hornblende is well oriented in the area around the mouth of Fay Creek, and because the gabbro body exhibits a granoblastic texture the lineation is probably a secondary structure, related to post-consolidation movements. Near Fay Creek the sheet is curved parallel with a recumbent fold in the Kisseynew gneisses. This folding of the Kisseynew strata into eastward plunging, recumbent folds may be associated with faulting along the Amisk-Kisseynew contact. Because the hornblende crystals have a relatively consistent direction and angle of plunge, approximately parallel with the plunge of this fold, this crystal lineation is most probably related to the folding.

Southwest of Fay Creek, the variations in the attitude of foliation in the hornblende gabbro sheet may indicate a minutely folded fabric.

## KISSEYNEW GRANODIORITE

Several small bodies of very fine-grained, alaskitic granodiorite outcrop within the area of the Kisseynew paragneisses (*See* Table I, No. 5). The distribution of the bodies appears to be structurally controlled. Their relationship to those granodiorite bodies that cut the Amisk rocks is not known; they are different texturally but similar compositionally (68, p. 19).

### *Lithology*

The colour of the weathered surface of the Kisseynew granodiorite ranges from white, in the southwesternmost body, to mauve-grey and pink in the others. The lighter shades of pink are confined to the marginal parts, and may correspond with the contaminated facies seen in the other granodiorite bodies to the south. No inclusions were observed, but these may have been sheared into thin ribbons to form some of the grey bands. In the central parts of the granodiorite bodies, where the contamination would have been less, the colour is usually flesh-pink.

The coarsest granodiorite outcrops north-northwest of Weldon Bay, near the area where the power-line crosses the tongue of granodiorite. On the fresh surface, flecks of biotite curve around small lenses of granular feldspar, but on the weathered surface the granite appears structureless. In thin section the texture is allotriomorphic-granular, with a tendency to be granoblastic. The grains have irregular, embayed outlines, but the quartz is only slightly strained. The largest grains are of microcline, about 1·5 mm. in length. Quartz and plagioclase are rarely more than 0·7 mm. long. The microcline surrounds some of the grains of plagioclase in the manner of cement in a sandstone and long wisps of it follow the boundaries of other grains. Garnet occurs as minute inclusions in microcline, and tourmaline is associated with the biotite. Sphene occurs as small, anhedral grains.

The small phacolithic mass of granodiorite in the anticlinal core north of Lobstick Narrows is granoblastic in texture and much finer grained. A few

of the grain boundaries are sutured, but most of them are smoothly curved. The grains are elongate in the plane of foliation, and their average length is about 0·4 mm. for the feldspars and 0·2 mm. for quartz. The quartz grains are only slightly strained.

Chemical analyses of granodiorites from Manitoba, similar to the ones above, have been listed by Grout (26, Nos. 32, 33, 34).

The Kisseynew granodiorite commonly exhibits a gneissic structure, which in most bodies is faint. It is shown either by the planar orientation of biotite or muscovite, where these minerals are abundant enough for their orientation to be recognized, or by a colour banding.

Foliation, shown by colour and textural banding, is best developed in the marginal parts of the granodiorite bodies, and is exemplified in the sheet that outcrops from south of Kisseynew Lake to east of Weldon Bay. The rock is fine-grained, alaskitic granodiorite in composition, and the colour banding is formed of alternating light and medium pink facies. The pinker bands, locally consisting of 0·5-mm. plagioclase grains and elongate quartz plates, vary from ⅛ inch to several inches in width, and some may exceed 10 feet in length. In some outcrops the grain size varies to a minor degree from one band to the next, providing, in addition, a faint textural banding to the surface.

Much of the most southwesterly body exhibits very poor planar structures, but lineation is well developed. The linear structure is shown by elongate rods of biotite or of quartz, and by wrinkles defined by mafic knots and ridgy quartz veinlets.

On certain outcrops, the northwestern body exhibits tight, isoclinal folds, which are defined by a faint colour banding, emphasized in some folds by pegmatitic dykelets.

Only the marginal parts of the granodiorite body west of Weldon Bay exhibit planar foliation. The central parts are closely folded, with the structures plunging northeast at shallow angles. The general structure of the granodiorite body may be anticlinal (*See* Figure 13a).

The banded granodiorite sheet south of Kisseynew Lake is defined sharply on the south side against slabby, sillimanite-bearing and garnetiferous quartz-plagioclase schist and on the north side against paragneiss. Its texture varies from granoblastic on the north side to cataclastic on the south. The average grain size is about 0·3 mm., but elongate clusters of strained quartz become more abundant to the south, and along the south margin of the granodiorite sheet quartz occurs in long ribbons in which the grains show preferred orientation.

The petrographic study of the granodiorite sheet suggests that quartz grains are first crushed by shearing processes. Under continued stress some of the quartz is granulated, but some migrates and recrystallizes into small lenses or eyes. The end product appears to be the crystallization of quartz into thin sheets or ribbons with preferred orientation, and the association of colour banding with the fine-grained granodiorites that show cataclastic textures or ribbon quartz strongly suggests that post-consolidation movements may have produced the banding.

Wright classified rocks such as these as 'aplite' because of the fine grain. He reports that aplite dykes are fairly abundant from the north end of Bartlett Lake southwest to Kisseynew Lake and in the area several miles east of these lakes, but that no aplite dykes were seen in the north or

towards the west side of the map-area (67, pp. 87-88). According to this, the distribution of 'aplite' (or the fine-grained Kisseynew granodiorite ?) appears to be restricted to the area in which rocks occur in recumbent folds, and the relationship, if true, bears out the suggestion that the fine grain and the colour banding in the granodiorite bodies are both related to post-consolidation movements rather than that they are primary features. Such an idea of post-consolidation deformation is not new. From a study of similar phacolithic granites from the Adirondacks, Buddington states that many of them have been deformed after consolidation with the production of a finer grained rock (18, p. 157), and Quirke describes similar, fine-grained, banded, granitic rocks from near the Huron-Mistassini lineament in Ontario, although he does not attribute the stratiform banding to shearing.[1]

A few outcrops of very fine-grained Kisseynew biotite granodiorite are exposed at the northwest corner of the larger lake southeast of Weldon Bay. On the weathered surface the rock is pink weathering and poorly foliated, but on fresh surfaces the predominant structure is a lineation formed by clusters of biotite, which constitute about 10 per cent of the rock. The largest mineral grains, of plagioclase and of platy quartz, attain a length of about 2 mm., but the average grain size is about 0·2 mm. The fine grain size and the lineation of the biotite clusters are thought to be a product of strong deformation, partly cataclastic in nature, and as this is not evident in thin section the rock is thought to have been partly recrystallized.

Two conclusions may be drawn from the above considerations: (1) because the stratiform colour banding in the granodiorite appears to be related to a granoblastic or cataclastic texture that could only have originated late in the cooling history of the rocks, this banding does not prove magmatic flow in the rocks; neither can this kind of banding be used as direct evidence to prove that the granodiorite was derived from sedimentary rocks by metasomatism; and (2) regardless of the physical state in which the granitic matter reached its present position, whether it was as a magma or as a granitizing solution, the distribution of the granodiorite bodies appears to be structurally controlled. Most of them occur near or along the crests of anticlines or along or near fault zones. For magmatic material, such areas of emplacement would solve the space problem, but Newhouse considers that such zones are favoured by the processes of granitization (43).

### DYKE ROCKS

Small dykes of granite-pegmatite outcrop at several places along Kisseynew Lake and Weldon Bay, commonly in association with the granodiorite. These dykes consist of quartz and microcline, with a little muscovite and tourmaline. The largest prisms of tourmaline are about 3 inches long and ¼ inch thick, but all are fractured. Marginal to some of these dykes the intruded rocks have been recrystallized.

At the site of No. 5 diamond-drill hole on the north side of the Weldon Bay fault, ⅜ mile south-southwest from the mouth of Fay Creek, a fine-grained, grey weathering quartz latite intrudes amphibolitic rocks, as evidenced by contact relationships in the outcrop (page 71). The same

[1] Quirke, T. T.: Granitization near Killarney, Ontario; Bull. Geol. Soc. Am., vol. 51, pp. 237-254 (1940).

quartz latite also intrudes amphibolite on the northwest side of the point at the northeast end of the small lake south of the No. 5 drill-hole. This is significant because the latite in the drill core has the appearance of a sedimentary rock, quite similar to what might be expected from cored Kisseynew paragneisses (*See* Plate III B).

## Kisseynew-Amisk Relationship

### HISTORICAL SUMMARY

The determination of the stratigraphic and structural relationship between the predominantly sedimentary Kisseynew gneissic complex to the north and the predominantly volcanic Amisk series to the south is one of the basic problems of the Precambrian geology in Manitoba. A tabulated summary of the possible relationships between these two rock types is given below, but the reader is referred to a more complete review of this subject by Harrison (30).

a. Conformable contact, Kisseynew younger
   i. Gradational from Amisk rocks to Kisseynew rocks (15, 67)

b. Contact locally conformable, locally unconformable, locally obscured by faults (51)

c. Unconformable contact, Kisseynew younger (11)

d. Faulted contact, relationship unknown
   i. Local faulting (28, 24, 49)
   ii. Regional faulting (36, 29)

e. Combination of the above relationships

f. Undeterminable relationships (57)

### DESCRIPTION

The distribution of volcanic rock in the Flin Flon-Snow Lake region is shown on Figure 6. Both east and west of Weldon Bay map-area the Amisk structures have a north-northeast trend; however, west of the area, this trend changes to northwest and west about 6 miles south of the Kisseynew contact.

The folding of the Amisk rocks is described in Chapter IV. The evidence is fairly conclusive for the interpretation that the sudden westward bend of the volcanic rocks in Mikanagan Lake and Flin Flon map-areas is a secondary structure, produced by cross-folding of the originally north-northeast trending volcanic rocks along northwest and west directions (page 66). The conformable attitude of the foliation along the Kisseynew-Amisk contact in that region is also interpreted to be related to this secondary deformation. That is, although the foliation in the Amisk rocks is parallel with that of the Kisseynew gneisses along the contact of the two rock groups, this does not in itself prove that the contact represents stratigraphic conformity.

It can be seen from the Weldon Bay map that the east-northeast trend of the early mountain system, reflected by the trend of the west flank of the granodiorite batholith, is truncated by the east-west trend of the Kisseynew gneisses (*See* Figure 6). It is interesting to note that

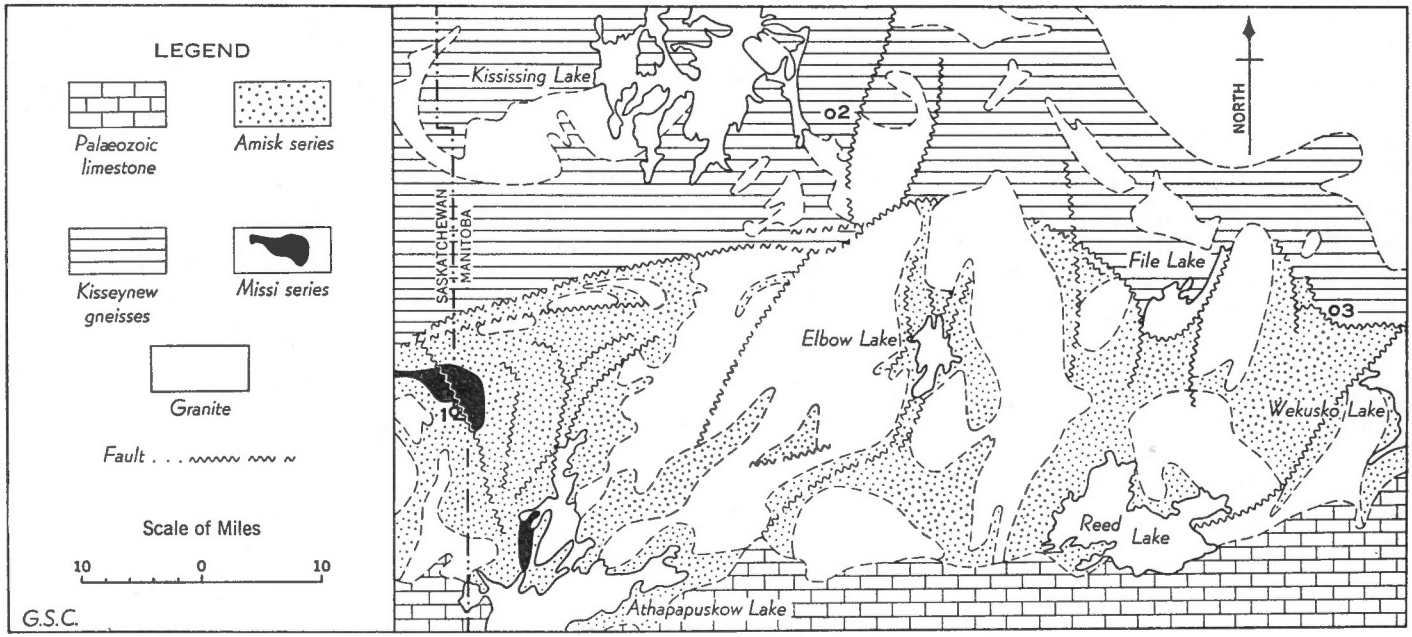


Figure 6. Sketch map of the Flin Flon-Sherridon-Snow Lake region to illustrate distribution of the main rock types. 1, Flin Flon; 2, Sherridon; 3, Snow Lake.

Bruce recognized this relationship during his early work (15, p. 27). The possible relationships between the two units of stratified rocks as seen from this figure are either an unconformable contact, with the Kisseynew younger, or a faulted contact, with the structural and stratigraphic relationships between the rocks uncertain.

The evidence for a fault along the contact in Weldon Bay map-area is presented in a later chapter, and is regarded as conclusive. Consequently, stratigraphic evidence for the age relation between the Amisk series and the Kisseynew gneisses is lacking in the Weldon Bay area. From regional consideration the writer believes that stratigraphic evidence is also lacking in Mikanagan Lake map-area (36, 38). However, it may be that the fault movement has taken place along the surface of an unconformity at the base of the gneissic Kisseynew sequence. That the Kisseynew gneisses are younger than the Amisk rocks is suggested by two geological features: (a) the belt of Kisseynew gneisses transects the trend of the Amisk rocks; (b) the east-west trend has been superimposed on the Amisk rocks near the contact, but the Amisk trend does not appear in the Kisseynew strata north of Weldon Bay map-area. Thus, whereas the Amisk rocks have been affected by two periods of folding, the Kisseynew rocks have been affected by only one, and, therefore, would appear to be younger.

## OVERBURDEN

Bruce summarizes the glacial features of the Amisk-Athapapuskow Lakes area as follows: "The part of this area comprising the Precambrian province was not an area of much deposition during the Glacial period. Boulders are found over the whole district but moraines are not common. In places where the rock protuberances have given protection, small deposits of till have been left, but they are not numerous. There are a few areas of sand-plains, evidently the result of outwash from the front of the retreating ice, but during the Glacial period this particular section was one of erosion rather than of deposition" (15, p. 18).

Fine-grained, uniform sand has accumulated in the western part of the map-area, extending from southwest of Nesosap Lake to the western part of Naosap Lake in a series of low, long, north-trending hills on top of which are scattered erratic boulders. The east side of some of the hills is gently sloping, but the western side is usually steeper, rising from about 10 to 20 feet above the surrounding land in some places.

About 1,500 feet upstream from the mouth of a small stream that empties into the east side of the northernmost bay of Naosap Lake, a small terrace on both sides of the creek has an elevation of about 20 feet above the creek level. The terrace consists of silty sand in which small lenses of clay form irregular layers. A few rounded pebbles, about 3 inches in greatest diameter, are distributed irregularly in the sand. Such a bench may be the remains of a kame-terrace that once filled the entire valley. When drainage was re-established in the valley, the fine sediment was washed away and redeposited in the lake where it now forms a small delta at the mouth of the creek.

Clay is abundant only near the long, nameless lake that lies south of Weldon Bay.

Scattered boulders overlie the other glacial materials except the kame-terraces. Along a few hillsides, boulders and cobbles form a pavement suggestive of an elevated beach. A few of the boulders in the southern part of the map-area are of buff weathering, fine-grained Palæozoic dolomite that are thought to have been ice-rafted northward from the Palæozoic escarpment when this part of Manitoba was a large lake (6, p. 45). The distance between these blocks and the escarpment is only 16 miles, so that ice rafts might have traversed this distance under the action of drainage currents or wind before melting.

# CHAPTER III

# ALTERATION

## GENERAL STATEMENT

Most of the rocks in Weldon Bay map-area have been altered subsequent to their emplacement or deposition. In many, the alteration has been slight; in others, it has involved recrystallization, shearing accompanied by recrystallization, or predominantly shearing or crushing, processes that are given the names 'thermal', 'dynamothermal', and 'kinetic' or 'dislocation' metamorphism respectively. If the presence of certain index minerals in the dynamothermally metamorphosed rocks is recorded, it is possible to indicate the degree of metamorphism in these rocks, and if the areal distribution of these minerals is plotted, the extent of the variously metamorphosed rocks can be determined.

Some of the rocks in the map-area have been altered in such a manner that they have some of the compositional features of an igneous rock, for which process the term 'granitization' is applied.

## METAMORPHISM OF AMISK ROCKS

The Amisk rocks afford an opportunity to study the physical characteristics of a single rock type that has been affected by heat and stress applied at intervals and under various conditions. Except near bodies of granite, their metamorphism has generally been accomplished without the introduction of additional material.

### Thermal Metamorphism

About a mile north from where the Alberts Lake fault enters Naosap Lake, the Amisk volcanic rocks have been recrystallized to spotted amphibolite (*See* Plate IV A). The rock is composed of alternating layers in which the amount of amphibole is variable. During crystallization, some of the amphibole has migrated from a bleached halo to a common centre to form poikiloblastic metacrysts. That the metamorphism was accompanied, at least locally, by plastic deformation is indicated by the wavy outline of a crosscutting dyke. Before this recrystallization, the enclosing rock and the dyke may have resembled those shown on Plate I A. No foliation was observed under the microscope in the spotted amphibolite and none of the minerals show preferred orientation, so that their metamorphism appears to have been largely thermal.

### Dynamothermal Metamorphism

The rocks that comprise the main body of Amisk series become more deformed northward, in which direction there is also an increase in the grade of metamorphism.

In the western part of the map-area, near the Alberts Lake fault and west of Naosap Lake, the Amisk volcanic rocks are very little altered, and primary structures such as bedding, pillows, and amygdules can be

recognized. West of the northern tip of Naosap Lake many pillows are elongated, and northeast of the lake certain knobby outcrops may represent agglomeratic volcanic rocks, and some epidotic streaks may have been derived from flow breccia. All rocks more than about 2 miles north of Naosap Lake lack primary structures, and the generalization can be made that the zone in which the northeast trend of the volcanic rocks changes to an east-west trend, roughly demarcated by the Mikanagan Lake fault in Weldon Bay map-area, is the boundry north of which primary structures are rare.

The degree of deformation of the diorite intrusions in the Amisk volcanic rocks resembles that of the host rock, the texture in the diorite grading from hypidiomorphic, in the irregular body northwest of Naosap Lake, to granoblastic-gneissic in the body northeast of Dismal Lake.

There is a rough parallelism between degree of deformation and metamorphic grade in the Amisk series. In the area of less deformed rocks to the south, the rocks are green schists, with local areas of epidote amphibolites. Northward, green schists are rare except along certain shear zones, and epidote amphibolites increase in abundance. This change is also reflected by the darker colour of the rocks and by their slightly less schistose structure. North and east of Dismal Lake many of the volcanic rocks belong to the amphibolite facies, as indicated by the observed occurrence of garnets in outcrops and of pyroxene in thin sections.

### ORIGIN OF THE DYNAMOTHERMAL METAMORPHISM

The Amisk rocks have a general north-northeast trend in the area between Naosap Lake and Flin Flon. Only near the Kisseynew contact do they strike east-west. This feature presents the possibility that the volcanic rocks that were folded regionally along north-northeast axes may have been cross-folded along east-west axes, and many have been metamorphosed dynamothermally during such deformation (38).

One of the main points of evidence for this cross-folding is the similarity in deformation and grade of metamorphism of the Amisk rocks in Weldon Bay map-area and the cross-folded Missi strata near Flin Flon. In the two areas both the deformation and metamorphism increase northward, and Ambrose (2, 3) concluded that metamorphism in the Missi rocks was caused by dynamic forces rather than by any intrusive body. However, the metamorphism was dynamothermal in character.

An analysis of the Kisseynew structures between Weldon Bay and Sherridon indicates that these gneisses were folded and metamorphosed by southward acting forces, and it seems highly probable that the adjoining Amisk volcanic rocks to the south were also affected to some degree by these same mountain-building forces.

## GRANITIZATION

### PSEUDO-GABBRO AND PSEUDO-DIORITE

West of Soneau Lake, granoblastic, pyroxene-bearing Amisk gneissic amphibolites are cut by veinlets of granitic material, and hornblende porphyroblasts up to ½ inch in diameter have been developed in the amphibolites marginal to these veinlets. This relationship is interpreted to indicate that the dynamothermal metamorphism that produced the amphibolites was followed by a stage of granitization and recrystallization.

The recrystallized amphibolite is massive, with a rough, granular weathered surface and a hypidiomorphic texture in thin section. Also, it contains variable amounts of plagioclase and quartz that were introduced at the time of intrusion of the granodiorite. These features differentiate it from the dynamothermally metamorphosed Amisk rocks, and such rocks are termed pseudo-gabbro and pseudo-diorite, depending on the amount of introduced granitizing material.

In detail, the lithological changes from gneissic amphibolite to pseudo-gabbro and pseudo-diorite are as follows: in certain exposures the gneissic amphibolite is penetrated intimately by narrow granitic veinlets. Poikilitic, brownish green hornblende porphyroblasts that range in size from less than ⅛ inch to almost ½ inch occur marginal to these veinlets. Nearer the granodiorite, where granitization has been more intense, patches of pseudo-gabbro are more extensive and continuous, and the gneissic foliation of the amphibolite is lacking. Only the granitic veinlets give the rock a crude directional orientation. Large exposures of the rock are generally very heterogeneous in texture and composition. Some splotches of relatively uniform, coarse-grained pseudo-gabbro are surrounded by a grey diorite, and the pseudo-gabbro is penetrated by veinlets of granitic material along irregular fractures.

Where granitic veinlets are more numerous, the pseudo-gabbro contains more feldspar and quartz, and the hornblende is replaced to some degree by reddish brown biotite. With the increase in the amount of granitic material in the rock, the amphibole becomes finer grained. Within the Nekik granodiorite body itself amphibolitic inclusions are commonly fine grained, with relatively sharp borders, and where the amount of granitic matter exceeds 50 per cent, the rock is classified as igneous rather than metamorphic. In certain instances, however, it is impossible to determine whether the rock is the granitized host or the contaminated granodiorite.

Similar types of pseudo-gabbro and pseudo-diorite have been developed along other granodiorite margins, as for example southeast of Vamp Creek. However, the alteration of the amphibolites has been much more irregular than on the west side of the Nekik granodiorite.

A somewhat similar type of alteration can be studied in the Amisk volcanic rocks a short distance to the east of the small body of hornblende diorite that outcrops on the north shore of the west arm of Naosap Lake. The volcanic rocks there consist of layered and foliated greenstones cut by small dykelets of diorite (*See* Plate I A). They are intersected by numerous joints, marginal to some of which the rock is coarse grained, but locally the coarse texture is developed irregularly, and obliterates the banded nature of the greenstones (*See* Figures 7a and 7b). From a megascopic study, the process appears to be hydrothermal in character, the alteration of the greenstone to coarse-grained amphibolite having been guided by fractures along which the materials for the mafic constituents of the coarse rock have been introduced.

Another type of pseudo-gabbro and pseudo-diorite occurs as inclusions in the Tapukok granodiorite, many of them large enough to be shown on the map. The inclusions occur in a zone that extends southeast from the northern part of Kakat Mitatut Lake. These rocks are commonly

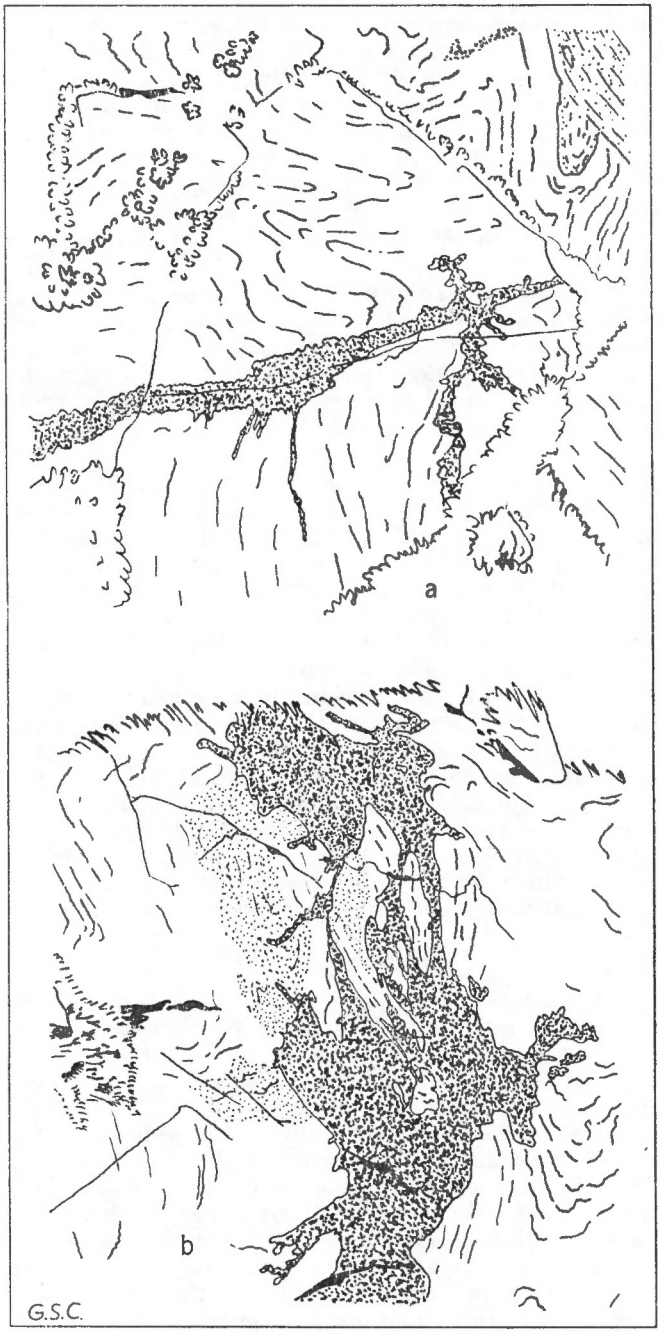


**Figure 7.** Sketches from field photographs to illustrate alteration of foliated Amisk greenstone to pseudo-gabbro (heavy stipple) north of the west arm of Naosap Lake: a, early stage of alteration, possibly along a fracture and guided in part by foliation; b, irregular, more advanced stage of alteration; showing detached, unreplaced inclusions of greenstone in the pseudo-gabbro. Scale 1 inch to 10 inches.

coarse grained, with a rough, weathered surface, and contain from 50 to 90 per cent hornblende. The hornblende grains are subhedral, and range up to ½ inch in cross-section and 1½ inches in length. Although the average grains are more equidimensional, about ⅛ inch in diameter, the few larger ones give the rock its coarse, almost porphyritic, texture. Pegmatitic pods along anastomosing streaks of granite in the pseudo-gabbro contain hornblende crystals up to 3 inches long. Locally the amphibolite contains plagioclase porphyroblasts. Some parts of the inclusions are finer grained, similar in texture to the Amisk amphibolite; the change in crystallinity is abrupt.

Pyroxene occurs interstitially to the large grains of hornblende in an inclusion in the southeastern part of the zone of inclusions. Nearby, another inclusion contains porphyroblasts of plagioclase more than ¾ inch in cross-section. These weather into nodules, but contain so much granular pyroxene that they cannot be identified as plagioclase porphyroblasts megascopically. The above two inclusions are the only ones that were observed to contain pyroxene.

The only magmatic rocks in the map-area that resemble the coarse pseudo-gabbro and pseudo-diorite of these large inclusions outcrop on a small island on the east shore of the northern part of Collins Lake. Similar intrusive rocks, but containing coarse, stubby pseudomorphs of hornblende after pyroxene, with minor feldspar, have been mapped by Podolsky from the area to the southwest (46). Similar rocks have also been mapped by Tremblay in Quebec, where they occur within bodies of igneous rock. Although he presents the possibility that the coarse-grained amphibolites might have been derived from inclusions of basic volcanic rocks, Tremblay believes that they are basic differentiates of hornblende monzonite (58, pp. 34-35). However, on the basis of similarity between the less recrystallized, fine-grained facies in the inclusions in the Nekik granodiorite and the Amisk amphibolite, and between the coarser facies and the pseudo-gabbro derived from the Amisk rocks, the possibility remains that these inclusions have been derived from basic volcanic rocks by recrystallization. For that reason, which by no means proves their origin, the writer has included these rocks with the others of more obvious derivation.

### Silicification

The Amisk volcanic rocks are generally silicified near the contacts of the Fine-grained granodiorite southwest of Naosap Lake, the zone of silicification being narrower and more regular on the north side of the granodiorite than on the south. The silicification is represented on the weathered surface by a lighter green colour and by an increased hardness of the rock. Most of the primary textures have been obliterated. In thin section, much of the quartz is evenly distributed through the fine-grained fabric of the volcanic rock, forming a very fine granophyric intergrowth with plagioclase in some rocks, and replacing laths of plagioclase in others. The less altered plagioclase laths are mottled with quartz, but the more altered ones lose their elongate outline completely. These silicified rocks can be differentiated from intrusive rocks by their abundant content of fine-grained epidote, chlorite, and opaque minerals.

Silicified volcanic rocks are also associated with pseudo-diorite, about ½ mile northwest of the west end of Naosap Lake.

# METAMORPHISM OF THE KISSEYNEW ROCKS

## Dynamothermal Metamorphism

When a rock of uniform composition is metamorphosed under conditions of increasing temperature and pressure, certain index minerals are formed that characterize definite stages of metamorphism. As metamorphism increases, other index minerals form, again characteristic of the increased temperatures involved. This feature was recognized almost 60 years ago by Barrow (8). Thus, it is possible to subdivide the Kisseynew gneisses into zones of increasing metamorphism by delimiting the areal extent of the index minerals biotite, garnet, and sillimanite. The distribution of these minerals is shown on Figure 8. In some places, the index minerals indicate a condition of higher metamorphism than that represented by the total mineral assemblage; that is, some of the rocks have been altered to a slightly lower grade, a process known as retrograde metamorphism, shown by the association of chlorite, sericite, albitic plagioclase, and epidote with garnet in some rocks, and the alteration of plagioclase to sericite and of biotite to chlorite in others. However, the use of the index minerals does not change the essential features of the metamorphic pattern.

Only the distribution of sillimanite bears a relationship to geological structures in Weldon Bay area. Along the southern margin of the Kisseynew complex, sillimanite occurs in rocks[1] that are associated with mylonite. Similarly, some of the sillimanitic rocks north of Weldon Bay occur along a schistose zone that lies between the overturned, anticlinal granodiorite body on the northwest and the Weldon Bay anticline on the southeast. Because there appears to be no connecting syncline between these two structures, the sillimanite zone coincides with a zone of more intense movement. The westernmost sillimanite zone probably represents a normal peak of dynamothermal metamorphism, and there the distribution of sillimanite is related to the composition of certain beds, being restricted to them. However, it seems unlikely that the occurrence of sillimanite in deformed rocks, as along the Weldon Bay fault zone, is related only to the composition of those rocks. A more probable explanation would be that the change from the garnet to the sillimanite grade was induced by the addition of stress or heat, produced by the greater deformation of the rocks.

# METAMORPHISM OF GRANITIC ROCKS

## Dislocation Metamorphism

Fine-grained, layered and foliated gneisses and schists, many of which have the appearance of stratified, quartzose sedimentary rocks or rhyolite flows, outcrop in the southern part of Weldon Bay map-area, within the area of Amisk volcanic rocks. Because corresponding stratified rocks are lacking or rare in the Amisk series, the abundance of these rocks along fault zones presents a peculiar relationship. The conclusion is reached that they are derived by crushing from the rocks marginal to the fault.

[1]Because of the importance of these rocks to the interpretation of the Weldon Bay fault zone, they are described in considerable detail in another section of this report (pages 57-59).

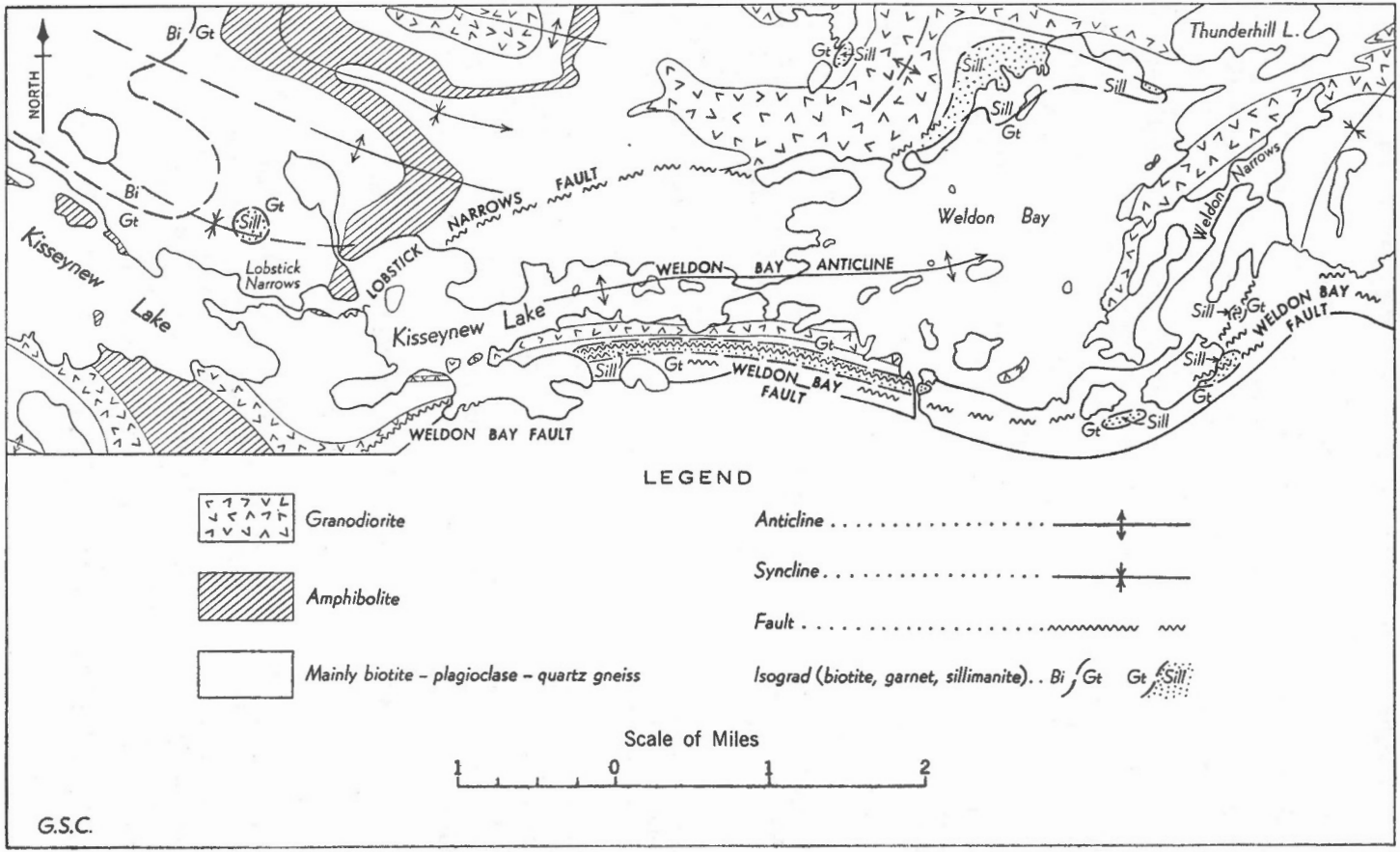


**Figure 8. Sketch-map to illustrate metamorphism and structure of the Kisseynew gneisses in Weldon Bay map-area.**

Granitic crush-rocks[1] were recognized along the southern part of the Vamp Creek fault, along the Alberts Lake fault, along the southeast margin of the Alberts Lake granodiorite body, along the northern part of the Sourdough Bay fault, between Sewap and Naosap Lakes, near the south end of the Payukosap Lake fault, and along the Weldon Bay fault zone. They form zones that vary in width from a few feet to 700 feet.

### LITHOLOGY

The weathered surface of the granitic crush-rocks is usually foliated, rarely structureless. Near the outer margin of some of the crush zones, some of the uncrushed rock occurs as lenticular pods in a fine matrix of crush-breccia. In the central part of the crush zones, the rock is extremely fine grained, commonly laminated or schistose, and has a sedimentary appearance. The lamination parallels the trend of the fault, although there may be microscopic swirls in it, and the colour varies from white and grey to brown, green, or yellowish, depending on the content of ferromagnesian minerals, especially epidote. Small eyes of quartz, probably porphyroclasts, are a characteristic feature, and the grain size increases laterally so that the crush-rocks grade into granoblastic gneisses. Along the Alberts Lake fault this gradation occurs within a few feet, and along the Vamp Creek fault the gradational zone into gneissic biotite granodiorite is about 100 feet wide.

Some of the crush-rocks have the appearance of lava. Near the Sourdough Bay fault, they are pink weathering and exhibit fine, greenish streaks formed of porphyroblastic epidote. Locally along the Alberts Lake fault, the crush-rock contains small, nodular lenses and chains of lenses of quartz-epidote. The fine, ribbed foliation in the matrix, as observed on outcrop surfaces, swirls around these lenses so that the texture is fluidal in character.

In thin section, all of the crush-rocks are seen to be fine grained, the average grain size ranging from 0·05 mm. in some rocks to 0·5 mm. in others. Unlike most crush-rocks, those described here have been partly recrystallized, to the extent that most of the cataclastic features have been obliterated, except in the rocks along the Payukosap Lake fault. Thus, the crush-rocks exhibit a fine-grained, granoblastic texture and an excellent foliation. Quartz is commonly strained.

The minerals of the crush-rocks are similar to those in the source rocks. Garnets are abundant locally, and chlorite and epidote are common in some of them. It may be pointed out that the only place south of the Kisseynew gneisses where sillimanite was found was along, or close to, the Alberts Lake fault. It would appear from this relationship of increased metamorphic grades near faults (page 51), that movement along the fault was the genetic factor responsible for its development.

## Replacement of the 'Porphyritic Latite' by Granodiorite

East of Nesosap Lake the 'Porphyritic latite' has been intruded by a younger granodiorite in an intricate manner, dividing it into small, irregular blocks (Plate III A). The latite walls do not match and exhibit scalloped

[1]The classification of mylonites compiled by Waters and Campbell (62) is too detailed for the description of these rocks, and although Raguin has extended the term 'mylonite' to include rocks similar to those described here (48), the writer prefers the term 'crush-rock' because of its less exacting connotation. Many of the rocks would be 'blastomylonites' or 'hartschiefers' in the sense of Waters and Campbell.

edges against the granodiorite (*See* Figure 9). In some places there is a definite zone between the granite and the latite that consists of medium-grained, brownish pink diorite; in other places between the latite blocks the granodiorite is pegmatitic.

In certain outcrops at considerable distances from the nearest exposures of granodiorite, rounded masses of pink granodiorite surrounded by the 'Porphyritic latite' have the appearance of inclusions. Other outcrops were observed in which similar, rounded masses of granodiorite occur in small latite inclusions in the granodiorite. The granodiorite has replaced

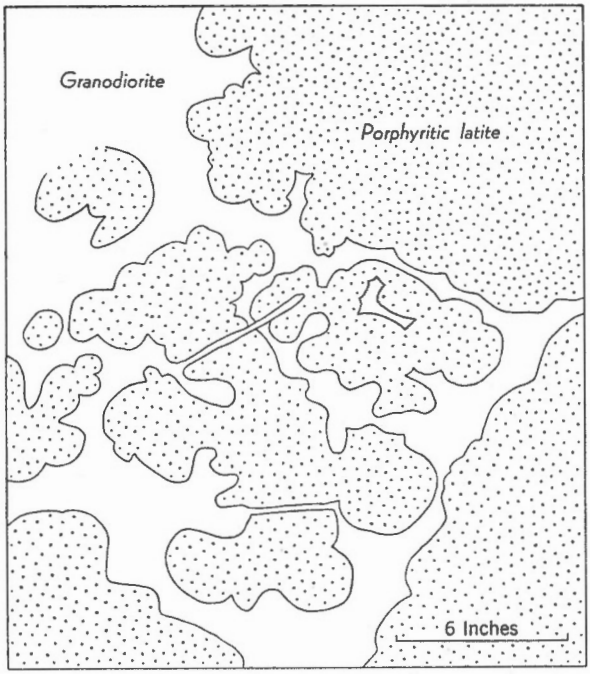


**Figure 9. Field sketch to illustrate replacement of 'Porphyritic latite' by granodiorite, 1 mile east of Nesosap Lake.**

the latite inclusions along their margins so that they are deeply embayed, and it seems probable that even the isolated inclusion-like bodies of granodiorite in the latite may actually be fingers of granodiorite replacing the 'Porphyritic latite'.

As is evident from Figure 11, the method of emplacement involved more than the mere filling of fractures by granodiorite. The rounded granitic embayments, the non-matching walls of some of the granitic veinlets, and the scalloped edges of the porphyry blocks all point toward replacement of the porphyry by the granodiorite. In these examples the replacement has occurred to the extent of several inches, and appears to have been controlled in part by some pre-existing fissures along which replacement has taken place. However, there appears to have been no such fracture-control for the emplacement of the rounded tongues and fingers of granodiorite.

# CHAPTER IV

# STRUCTURAL GEOLOGY

## GENERAL STATEMENT

Folds can be recognized only in the Kisseynew gneisses of Weldon Bay map-area. The Amisk rocks curve around the east end of the Dismal Lake granodiorite stock, but the interpretation of this flexure is uncertain. Faults are numerous and important in all parts of the map-area.

Movement within rock masses and along planes of weakness has produced various kinds of linear elements. Some of these are defined by the orientation of prismatic crystals or of elongate knots of minerals, and others are defined by wrinkles or crumples on planar surfaces. The attitude of all of these is indicated on the map.

## LINEATION

Lineation may be produced either parallel with the direction of shearing movement (*a*-lineation) or perpendicular to this direction (*b*-lineation). Many recent workers have interpreted their observations by regarding most lineation as of the *b* type, but recently Anderson (4), in a theoretical paper, has questioned the validity of this interpretation, and has suggested that all lineation may be *a*-lineation. However, as he appears to question the applicability of megascopic structural terms as used in the field to the discussion of movement within small, hypothetical rock units, his criticism of present-day interpretations may not be wholly warranted. For this reason the writer is retaining the old terminology (19) whereby many of the linear elements, such as along faults, are regarded as of the *b* type, particularly as many of the structures could not otherwise be explained.

## FAULTS

The rocks in Weldon Bay map-area have been intersected by numerous faults. Most of these have a northeasterly trend, but a few strike east or north. The presence of cross-faulted gabbro dykes along some of the faults suggests that there may be considerable difference in the age of the faults, but because the nature of the movement along most of them is unknown they cannot be classified genetically, nor can their relative importance be determined.

### Weldon Bay Fault

The following pages deal with evidence that points to the presence of a fault zone along the Kisseynew-Amisk contact in Weldon Bay map-area. This feature, which has been interpreted as a braided fault and named the Weldon Bay fault, extends easterly along the south margin of the Kisseynew complex. Thus, whereas the individual faults form a fault zone, collectively these faults are interpreted to constitute the Weldon Bay fault. Evidence of deformation by shearing can be recognized along

it from an area south of Lobstick Narrows to the eastern margin of the map-area, a distance of almost 8 miles.

Subsequent to the field work done by the writer, Robertson has mapped the Amisk-Kisseynew contact for a length of about 35 miles (51), but his observations differ from those of the writer in several important respects. For example, Robertson states (idem, p. 11) that "south of Lobstick Narrows, it has been established that no fault lies between the 'greenstone' and the granite.....". However, it seems to the writer that some of the critical outcrops in this part of the contact were not visited, and that, in consequence, the evidence for the continuation of the fault was not seen.

Another point on which Robertson and the writer differ is on how to interpret the field evidence in relationship to faults, and how to evaluate it for the amount of movement that may have taken place along these faults. Thus, what the writer considers to be adequate evidence for movement over a great length, is interpreted by Robertson to indicate only discontinuous, intense faulting.

The amount of deformation and alteration along a fault is no indication of the length of the fault nor of the amount of movement along it. Many faults of both transcurrent and thrust types are known that have resulted in displacements measurable in miles, and yet are relatively inconspicuous surface features. Thus, the fact that some of the shear zones along the Weldon Bay fault zone are narrow does not invalidate the evidence derived from other considerations that the Weldon Bay fault is a major structural feature.

### PHOTOGRAPHIC EVIDENCE

A low north-facing scarp that extends along the north margin of the long tongue of biotite granodiorite-gneiss from southwest of Weldon Bay to an area south from the west corner of the bay is evident on Royal Canadian Air Force photographs A902-18 to A902-30. From there the lineament continues as a valley across the northern tip of the Nekik biotite granodiorite. Because schistose rocks occur to the north in the west end of the lineament, the scarp there might be the result of differential erosion along a lithological contact. However, the lineament is transgressive in the east and, consequently, does not demark a lithological boundary for its entire length. Yet the Nekik granodiorite has been less resistant to erosion along this zone, as is indicated by the presence of the valley. Because many of the schistose rocks in the western part of the lineament are sheared, this topographic feature may have been developed along a fault, and the valley, which is the eastern continuation, may represent a shatter zone through the granodiorite body.

### TEXTURAL EVIDENCE

The textures of the rocks along the Weldon Bay fault zone show clear evidence of strong shearing movement. The rocks are gneissic to schistose and mylonitic in character. Mylonites are restricted to, and schists are much more common along, this zone than anywhere else in the northern part of the map-area. The Nekik granodiorite exhibits features along its northern boundary that are thought to have had a cataclastic origin, and similar rocks are described from Fay Lake.

### MINERAL DISTRIBUTION

Certain minerals are related spatially to the Weldon Bay fault zone. These include the metamorphic minerals sillimanite, garnet, and graphite, and sulphides, especially pyrrhotite. The distribution of sulphides indicates that suitable openings along the fault zone aided the circulation of sulphide-bearing solutions, and that these openings are related to structural conditions existing along the Kisseynew-Amisk contact. The importance of the fault as a possible regional control for ore deposition has been discussed by Harrison (29).

### LITHOLOGICAL EVIDENCE

About 1 mile west of Weldon Bay, south of Kisseynew Lake, laminated garnetiferous and sillimanitic schists outcrop between the sheets of Kisseynew granodiorite and gneissic hornblende gabbro. Some of the laminated rocks are exceedingly fine grained, and otherwise exhibit the distinctive features characteristic of mylonite and hartschiefer. Because these rocks, derived from Kisseynew sedimentary gneisses, are restricted to the south margin of the Kisseynew complex, their lithology will be described in considerable detail.

Against the granodiorite contact and for about 100 feet south, the rock is grey weathering, muscovite-quartz schist that breaks cleanly into thin slabs bounded by micaceous surfaces. In thin section, it consists of irregular, flamboyant, fine-grained quartz, well-oriented muscovite, and minor plagioclase, biotite, garnet, apatite, tourmaline, and carbonate. The garnets occur as long strings along the foliation planes.

About 150 feet south of the granodiorite contact the parting is along planes spaced farther apart, and the rock fractures subconchoidally across the bands.

At 225 feet south of the contact, the rock contains considerable sillimanite within clusters of muscovite, and small grains of tourmaline and a little microcline occur along the foliation planes. The total mineral assemblage comprises quartz, plagioclase, biotite, muscovite, microcline, sillimanite, garnet, chlorite, and opaque minerals. Weathered surfaces of this rock exhibit a distinct and easily recognizable structure considered to represent pseudo-bedding. The rock weathers light brownish grey, and exhibits a persistent stratification in layers about 1 inch thick. Layers that contain the most quartz are grey, but where quartz decreases in amount in relation to feldspar the rock assumes a brownish hue. Its cataclastic texture, content of sillimanite and garnet, and association farther south with mylonite suggest that the rock has undergone sufficient metamorphism and deformation to indicate that the layering may not represent beds.

The pseudo-bedding ends abruptly, 310 feet south of the granodiorite contact. The weathered, relatively smooth surface becomes darker and exhibits high ribbing, with depressed layers, $\frac{1}{2}$ to $\frac{3}{4}$ inch wide, of amphibolite separated by more siliceous, grey weathering mylonite and hartschiefer. The amphibolite layers are slightly undulatory along strike, and constitute about one-third of the rock in this zone. These rocks are separated from the hornblende gabbro sheet to the south by 100 feet of drift.

On the weathered surface, the mylonite is light weathering and hard, parting into 1- to 3-inch slabs that have a uniform thickness and are

persistent along strike. The constituent minerals are so fine grained that the rock has a cherty or porcelainous aspect (*See* Plate IV B). On the fresh surface, the fine-grained quartz is the most abundant recognizable mineral, although some specimens show crushed eyes of garnet and very clear, glassy, quartz leaves about 2 by 8 mm. in size. A distinct, fine, compositional layering is defined in part by the quartz leaves. A thin section of the mylonite consists of quartz, microcline, plagioclase, muscovite, biotite, epidote, carbonate, and tourmaline. The quartz is in sutured, 0·2-mm. grains, 0·3- by 1·2-mm. leaves, and 1·5- by 2·5-mm. pods, and constitutes about half of the slide, some of the pods and leaves extending entirely across it. Several of the minerals occur in assemblages that form thin layers parallel with the foliation in the mylonite. Perthitic microcline occurs with quartz, tourmaline, and a little plagioclase in layers up to 2·5 mm. thick, and the plagioclase, which is albitic, is concentrated in other layers with biotite, quartz, and minor muscovite and microcline. Garnet is very abundant along still other thin layers. The change from one layer to the next is abrupt. Because quartz is only moderately strained it is evident that the mylonite has been partly recrystallized, and that the rock might be better described as a hartschiefer (62).

Similar schistose rocks can be recognized at a few localities 1 mile to the east on strike, south of the east end of Kisseynew Lake, and also 500 feet south of Kisseynew Lake about ¼ mile west of Weldon Bay. Wherever the pseudo-bedded structure was encountered, sillimanite was found to be one of the constituents of the rock, most abundant in a zone about 20 to 50 feet wide in association with cherty, porcelainous mylonite.

Elsewhere in this Weldon Bay fault zone, southwest of Weldon Bay, the rocks consist of crumpled, Kisseynew-type garnetiferous schists, as well as muscovitic and amphibolitic schists that appear to grade into coarser grained, granitoid rocks.

Southeast of Weldon Bay, sedimentary gneisses are interlayered with amphibolite, and the paragneiss is deformed sufficiently along one of these contacts to suggest that the contact may be along a fault. Farther south, the sedimentary paragneiss is granular in texture and massive on some outcrops. Mineralogically these rocks consist of quartz, plagioclase, biotite, garnet, and apatite (*See* Table I, No. 7). Porphyroblastic garnets, the size of pin-heads, are characteristic constituents, and small flakes of biotite are evenly distributed through the fabric. A thin section shows a granoblastic texture in which the largest grains, those of porphyroblastic garnet, rarely exceed 1·5 mm., and the average grain size is about 0·4 mm. All the minerals are fresh. Quartz is strained, and forms a mosaic fabric with poorly twinned oligoclase. A few grains of microcline form an anastomosing pattern interstitially to these. Where they are compositionally layered, some biotite-rich layers are schistose, and, rarely, other layers carry sillimanite.

Garnetiferous biotite-quartz plagioclase schist also outcrops along a narrow zone at the south shore of the larger of the two small lakes southeast of Weldon Bay, probably along a fault. Some of these schists are sillimanitic, and exhibit two sets of intersecting foliation suggestive of cleavage-bedding relationships in sedimentary rock. However, the restriction of this structure to schists makes such an interpretation improbable. Micaceous and siliceous schists possibly derived from sedimentary

rocks are also exposed on the north flank of the Nekik granodiorite, south of Fay Creek, but because the exact extent of the rock is problematic, these have not been distinguished on the map.

From the detailed petrographic description, the following conclusions may be drawn: (1) southwest of Weldon Bay the grain size in the Kisseynew gneisses decreases towards the south; (2) some of the minerals along this zone are indicative of high-grade metamorphism of these rocks; (3) the excellent foliation, the cherty or porcelainous texture, the compositional layering, and the habit of quartz in some of these rocks prove that they are crush-rocks or mylonites; and (4) schistose rocks are more abundant along this zone than elsewhere in the Kisseynew gneisses. All these features point to the existence of a strong dislocation zone that lies near the south margin of the Kisseynew complex. This is the Weldon Bay fault.

### STRUCTURAL EVIDENCE

Lithological units terminate at the Weldon Bay fault at two localities. The band of amphibolite that extends from Lobstick Bay, in the adjoining Mikanagan Lake map-area, to south of Lobstick Narrows in the Weldon Bay area appears to be continuous with the amphibolitic Amisk volcanic rocks. However, certain structural considerations strongly suggest that the amphibolite band cannot be correlated with the Amisk. For example, no section across the Kisseynew-Amisk contact in the Mikanagan Lake area can be constructed if the amphibolite layer is considered to be anticlinal and if the eastward plunge of the anticlinal dome of Kisseynew gneisses is retained in the construction. The assumption of more close folds in the Kisseynew gneisses will not simplify the problems encountered in such an attempt. It is possible to construct a section with the amphibolite layer having a *synclinal* structure, but this interpretation does not simplify the correlation of the amphibolite with the Amisk rocks. Thus, the amphibolite layer may be a member of the Kisseynew complex.

South of Weldon Bay, Weldon Narrows, and Fay Creek, the Nekik biotite granodiorite body is interpreted to terminate along the Weldon Bay fault zone. To the south, the medium-grained granodiorite is contaminated near the Amisk contact and around inclusions of volcanic rocks, but the texture and grain size of the contaminated rock at the contact remain the same as at the alaskitic core. Along the Kisseynew contact, however, the granodiorite exhibits textures that grade from gneissic to cataclastic, so that the normal, medium-grained, contaminated facies are lacking. It is concluded from these facts that a fault may extend along the north end of the Nekik granodiorite.

The degree of development of shear zones, and of foliate and linear elements in the rocks adjacent to the Weldon Bay fault zone indicate that this zone has been the locus of shearing movements. Shear zones, along which the rocks have been converted to soft, or more fissile schists, were observed at many localities, and rock structures and textures at several others have been interpreted to indicate that the outcrop is near similar shear zones. Most of these zones occur near rocks identified as mylonite, and their distribution and restriction to a relatively narrow, linear zone suggest that they may be parts of one or more parallel faults that form the Weldon Bay fault.

Because of the presence of gneisses, schists, and mylonitic rocks in the fault zone, planar elements are better developed there than elsewhere in the area. The foliation has an easterly trend and is steeply inclined towards the north. In its western part, the foliation conforms to the slight bends in the fault zone and in the lithological contacts, but in its eastern part, in the vicinity of Fay Creek, the trend of foliation near such contacts is disharmonious.

The only linear elements recognized along the Weldon Bay fault zone were mineral orientations and wrinkled foliation planes and quartz veins. Most of the elements plunge between 20 and 55 degrees easterly. The mineral lineation in the hornblende gabbro sheet appears to be related to folding of the Kisseynew gneisses (page 39). Along cataclastic zones, however, the lineation of mineral knots and wrinkles is obviously related to shearing movements. The wrinkles have been produced by a movement in the plane of foliation normal, or almost normal, to their axes.

Along the fault zone, the foliation trends east, and most of the wrinkles in the crumpled rocks plunge easterly at about 35 degrees; in several localities they have the shape of drag-folds, indicating that the direction of movement has been north side up and eastward. Because in a few localities lineation plunges east but drag-folds indicate the opposite relative movement, two or more periods of faulting may be represented.

### DISTRIBUTION OF YOUNGER INTRUSIONS

The emplacement of the steeply dipping sheet of hornblende gabbro near the south margin of the Kisseynew complex is thought to be controlled by a zone of weakness that demarcates either a lithological contact or a fault zone. As the adjacent rocks are in most places more crushed or deformed than the gabbro, it seems probable that they were sheared before its intrusion, and that, consequently, the gabbro was emplaced along a fault.

One of the post-gabbro intrusions southwest of the mouth of Fay Creek is now a cataclastic, grey weathering quartz latite (Plate III B). The degree of crushing it exhibits indicates that it is very close to a fault along which there has been post-gabbro and post-latite movement. Because rocks of this age were not recognized elsewhere, the restriction of the crushed latite to this area suggests that its emplacement may have been controlled by some pre-existing zone of weakness, such as along a fault.

### NATURE OF THE FAULT

The various faults along the Kisseynew-Amisk contact in the Weldon Bay map-area cannot be correlated along strike so that it would appear that these form parts of a braided network, here named the Weldon Bay fault. If the foliation of the rocks along the Weldon Bay fault is as closely parallel with the dip of this fault as it is with its strike, the fault has an indicated dip of about 80 degrees to the north.

The fault is considered to be a thrust for two main reasons: (1) the movement along it in the Weldon Bay area appears to have been to the southeast and up. The fault is parallel with the Kisseynew structures, but cuts across the Amisk trend. Therefore, the Kisseynew rocks appear

to form the active block; and (2) the regional structural relations can be best explained by means of a thrust hypothesis. For example, the geology near Weldon Bay provides evidence to show that the Kisseynew gneisses form large, recumbent folds that have over-ridden the Amisk rocks. This interpretation is illustrated by Figure 13a.

### Lobstick Narrows Fault

A possible fault extends along a discontinuous valley from Lobstick Narrows on Kisseynew Lake to the northern part of Weldon Bay. At Lobstick Narrows the sheet of amphibolite terminates at the fault in the manner illustrated in Figure 13b. Crushing near the fault is disclosed in a thin section of a specimen collected by Robertson from the south side of the narrows at its eastern end. The amphibolite sheet cannot be correlated with any other body on the south side of the fault.

North of Weldon Bay the foliation in the Kisseynew granodiorite body suggests an anticlinal structure, and because no evidence of a corresponding syncline was observed between it and the Weldon Bay anticline, these two structures may be separated by a fault. Such a relationship is further suggested by the schistose nature of the rocks along the granodiorite contact north of Weldon Bay and by the presence of sillimanite in this zone.

### Sourdough Bay Fault

West of Naosap Lake, the rocks are intersected by one main fault and by at least two, possibly three, splay faults or branches off it (*See* Map 1020A). The main, or Sourdough Bay, fault extends northeast across the west end of the 'Fine-grained granodiorite', and appears to be the continuation of a fault not indicated on the Mikanagan Lake map but recognized subsequently by Harrison (29, Figure 2). It parallels another that joins with a mapped fault in the north arm of Athapapuskow Lake (17). The occurrence of possibly a third splay fault was suggested from a study of air photographs. This fault would lie almost wholly in Mikanagan Lake map-area, as indicated on Figure 10. The geology, taken from the Mikanagan Lake map (11), is reinterpreted accordingly.

The main, Sourdough Bay fault may be a steep, transcurrent fault from which the splay faults originate and diverge. If the sheet of 'Fine-grained granodiorite' northwest of Naosap Lake can be correlated with the larger body of the same kind of rock south of the lake, the offset would be about 1½ miles along the easternmost splay fault. The difference in their outcrop widths suggests that the small sheet represents a structurally higher part of the granodiorite body, and that the west side has dropped considerably. At the second fault, the sheet of granodiorite is offset about 1,000 feet to the left. The apparent horizontal movement along the Sourdough Bay fault in the northern part of Alberts Lake would be an aggregate of these smaller movements, and the value of 1½ miles, with the northwest side moving northeast and down in relation to the southeast side, is merely an approximation.

Anderson believes that splay faults similar to those diverging from the Sourdough Bay fault may originate through renewed movement along an earlier transcurrent fault (4, p. 150). On a theoretical basis, he estimated that the splay faults should diverge at 22½ degrees from the main break in the direction of the movement. In the present instance the measured values lie between 20 and 40 degrees.

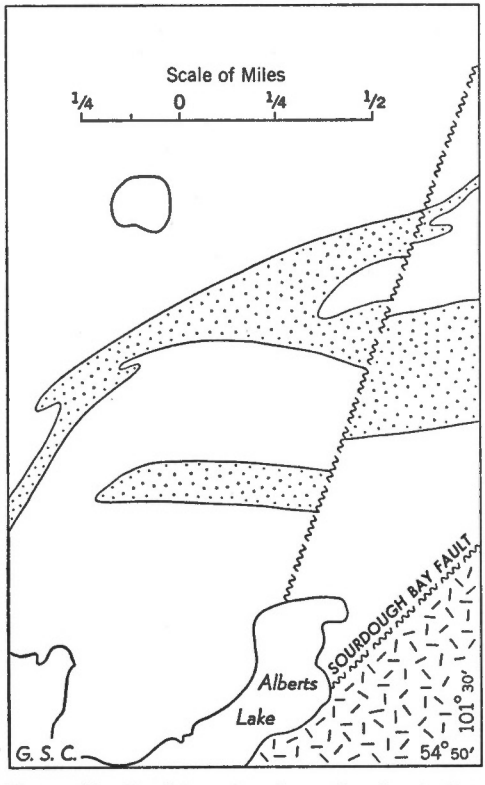


Figure 10. Possibly splay from Sourdough Bay fault north of Alberts Lake in Mikanagan Lake map-area. Stippled areas, hornblende metagabbro; dashed area, 'Fine-grained granodiorite'; blank areas, Amisk volcanic rocks.

## Alberts Lake Fault and Fault Zone

A well-defined fault extends from the small bay on the eastern side of Alberts Lake to a bay on the south shore of Naosap Lake. In this section, many of the rocks have been mylonitized. A narrow metamorphic zone, which consists of garnetiferous rocks with minor sillimanite, porphyroblastic anthophyllite amphibolites, and foliated rocks that may be cataclastic in origin, outcrops on the mainland and on some of the islands in the central part of Naosap Lake. This zone is thought to demarcate the northeast extension of the Alberts Lake fault.

## Payukosap Lake Fault

A fault extends from the southern end of the unnamed, long lake west of Uyenanao Lake to the west side of Payukosap Lake. It probably extends some distance farther northeast along Mistik Creek. Both the inner and outer gradational boundaries of the hornblende granodiorite facies of the Tapukok granodiorite are offset 1,000 feet to the left at the valley. The fault does not extend into the body of 'Porphyritic latite' east of Nesosap Lake, as shown by lack of offset there.

The foliation in the hornblende granodiorite zone of the Tapukok granodiorite dips from 65 to 80 degrees to the north. Using the value of 70 degrees as an average and assuming that the facies boundary is parallel with the foliation, the vertical movement along the fault would be 2,000 feet, with the west side down in relation to the east. If the dip were 80 degrees, the displacement would be about 4,000 feet.

## Vamp Creek Fault

The Vamp Creek fault follows the valley of Vamp Creek northerly for at least 8 miles and possibly 16 miles. The position of the fault can be defined fairly accurately along its entire length, with the exception of a segment 1 mile long due east of Mitatut Lake. Because this part of the fault was not mapped, the possibility remains that two ends meet, and that the apparent offset is due to either a bend in the fault or to a cross fault. The relationship of the fault to the Tapukok granodiorite may be, to use a homely simile, like that of a split that curves around a knot in a board.

The relative displacement along the Vamp Creek fault is unknown. If the two areas of biotite granodiorite in the northern part of the fault can be correlated, a horizontal movement of about 3 miles is indicated. However, if the boundary between the hornblendic and biotitic facies on either side of the fault has a shallow dip, the apparent offset may be the result of only moderate vertical movement. A relatively small horizontal component is also indicated by the outline of the Tapukok granodiorite where the circular, gneissic structure appears to continue along the main amphibolite-granodiorite contact east of Vamp Creek, with no offset apparent at the fault.

## Transcurrent Faults

Several transcurrent[1] faults intersect the hornblende gabbro dyke on the west flank of the Tapukok granodiorite. The faults follow linear valleys, the most prominent of which trend almost east, although not all of these are along faults. All of the easterly trending faults exhibit a right-hand displacement of the hornblende gabbro dyke or of the granodiorite contact. The displacement varies between 600 feet in the north and 2,500 feet in the south.

Figure 11d is a modified outcrop map showing the distribution of the four main rock types. The discontinuous nature of the dyke is apparent, and

[1]A transcurrent fault is one in which the net slip is practically in the direction of the strike of the fault. Thus, it is synonymous with strike-slip, tear, or transverse fault, or with flaw.

Figures 11c to 11a indicate how the dyke may be reconstructed by shifting the various fault blocks.

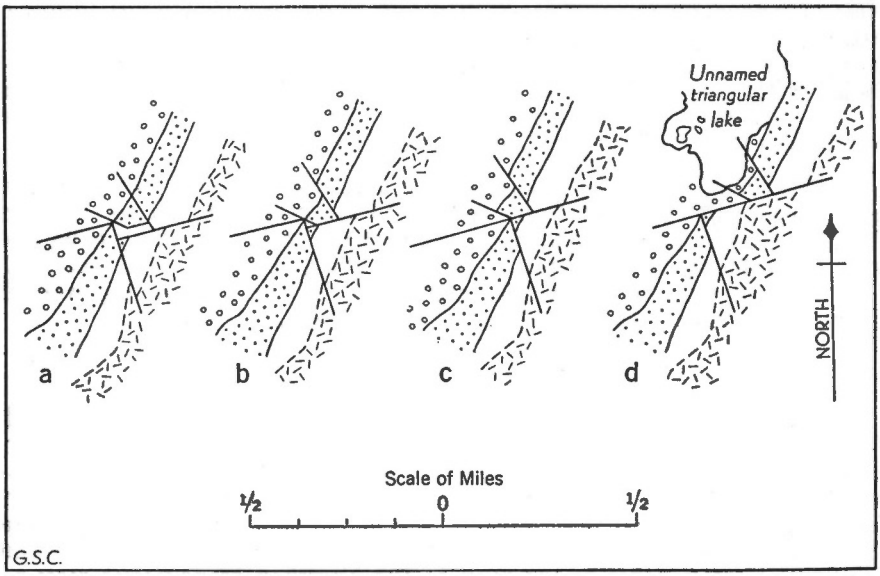


**Figure 11.** Drawings to illustrate resolution of fault movements along transcurrent faults intersecting hornblende gabbro dyke southeast of Nesosap Lake: d, the faulted dyke as mapped; note segment from which the dyke has been removed by faulting; a, reconstructed dyke before movement; the blank area is probably the result of some vertical movement between adjoining blocks; b, c, intermediate steps in movement of fault blocks. Areas with circles, Alberts Lake granodiorite; stippled areas, hornblende gabbro; dashed areas, Tapukok granodiorite; blank areas, mylonitic and gneissic rocks derived from Alberts Lake granodiorite.

If the diagrams are studied in order from 11a to 11d, they indicate the sequence of movements during faulting. Several interesting features are brought out:

(1) During stages 'a' and 'b' the middle block on the east side appears to be the active one. If so, the movement is right handed, indicating that the east-west transcurrent fault was formed at this time.

(2) Faulting separated the ends of two dyke segments by 500 feet, or lengthened a segment of the rocks by this amount.

(3) The forces that brought about the faulting have acted either perpendicular to the length of the dyke or with it.

(4) The other lithological boundaries cannot be correlated exactly. Evidently the blocks were not shifted in the horizontal direction alone but some vertical movement also took place during faulting.

(5) All of the transcurrent faults extend from the Tapukok granodiorite into various kinds of intruded rock, and from the study of the sequence of fault movements, the earliest movement seems to have been directed toward the west. It appears from this that certain stresses in the Tapukok

granodiorite have been relieved along these faults, which must have originated late in the sequence of orogenic events because they do not act as loci for later intrusions.

By means of these faults the west margin of the Tapukok granodiorite body was elongated from about 4½ miles to slightly more than 5 miles, or by about 10 per cent.

### Other Faults

Two major faults extend into Weldon Bay map-area from the west, but neither can be traced far. The first, about 1½ miles northwest of Naosap Lake, has been named the Mikanagan Lake fault by Harrison (29, Figure 2). Bateman believes that this is a thrust fault along which the volcanic rocks in the Lake Aimée fault block have been thrust some miles to the north (11). The second fault, about 4 miles northwest of Naosap Lake, is the continuation of a short fault mapped by Bateman (11). By studying air photographs Harrison was able to extend this fault farther west along the south flank of the Wabishkok Lake dome (29, Figure 3). His interpretation has been verified by Robertson[1].

About a mile north of Naosap Lake, two faults were mapped within an area of Amisk volcanic rocks. The position of the northern one is indicated by a sudden change in strike of the foliation from southeast to east. The evidence for the presence of the more southerly fault is not conclusive, but the rocks at the southern end of this zone are both sheared and mineralized.

A possible fault may bound part of the northwest flank of the Naosap granodiorite. Near the contact, especially near the small lake about 2½ miles northeast of Naosap Lake, the granodiorite is schistose and exhibits cataclastic textures in thin section. The lack of contact effects in the Amisk volcanic rocks, except north of Naosap Lake, can be interpreted in terms of this possible fault. If the interpretation is correct, the fault separates a narrow band of gneissic and cataclastic granodiorite on the north margin of the body from the more massive core.

A zone of shearing was noted on Wickstendt Island in Naosap Lake. The shear zone is narrow in the Naosap granodiorite, and the walls are silicified, but in a pit in the inclusion of volcanic rock at the northwest end of the fault, sheared, rusty weathering rocks are exposed across a total width of 30 feet.

A possible fault zone may extend along the narrow band of volcanic rocks between Sewap and Nekik Lakes. All the rocks are somewhat schistose, and a small shear zone was noted west of the second pond, south of Nekik Lake.

Anderson has studied the relationship between thrust faults and transcurrent faults and concludes that the latter form in front of a thrust mass (4, p. 56). Wilson has applied this concept to regional Precambrian structures (66). It is possible that the north-northeast trending faults in this vicinity may be related similarly to the major Weldon Bay fault. The possibility remains, however, that many of these faults are related to the earlier Amisk orogeny, and that recurrent movement has occurred along them at later times.

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[1]Personal communication.

# FOLDS

## Folds in Amisk Rocks

Because of the lack of structures from which top determinations are possible in the volcanic rocks, very little is known about the folds in the Amisk series of the Weldon Bay map-area. The volcanic rocks bend around the eastern end of the Dismal Lake granodiorite-gneiss, but whether the granodiorite has been emplaced along the axis of a tight flexure is uncertain. The intrusion of the volcanic rocks by this and other bodies of granodiorite and diorite, as well as their dislocation along faults, has further complicated the structure so that very little can be learned of the general fold pattern.

North of Dismal Lake the amphibolites are curved around the stock of granodiorite gneiss. Foliation in those rocks dips 20 to 60 degrees northeast. Fine needles of hornblende show near-horizontal lineation, and locally thin sheets of amphibolite form small wrinkles that plunge down-dip in the plane of foliation normal to these needles. Such a structural system may originate by shearing and compression of inclined, arcuate strata if the compressive force acts from the convex side of the curved strata. Because of shearing during compression, the small needles of hornblende are oriented in the planes of foliation. As the circumference of the curved strata shortens, because of centripetal compression, the excess length is accommodated by wrinkling. Thus the lineation system north of Dismal Lake suggests the influence of a southward-acting compressive force.

If the large structure of the Amisk rocks is considered to resemble that in the areas to the west, the eastward bend in the northern part of the lavas near Blueberry Lake must be interpreted as a cross fold; that is, the northeast trending structures in the lavas, shown more clearly in the map-areas to the west, have been bent westward near the Kisseynew contact, possibly by a force directed southwest.

## Folds in Kisseynew Rocks

The nature of the structural data obtainable from a study of the Kisseynew paragneisses is open to various interpretations and, hence, the results of a study based on such data lack the accuracy and conclusiveness of a similar study conducted in less deformed rocks. It is thought that considerable bedding-plane slippage has occurred in the sedimentary gneisses, obliterating primary structures and superimposing a foliation that may be parallel with the bedding everywhere. Because possible primary structures from which tops of beds could be determined have been found at only one locality, structural measurements are limited to the determination of the attitudes of foliation and of lineation.

It is extremely difficult to determine the size and shape of folds in a gneissic sequence if marker-beds are lacking. In the present map-area, the structural pattern of the Kisseynew paragneisses is reflected by the distribution of the major amphibolite layer north of Lobstick Narrows, which is thought to be of surficial origin. The structures recognized by means of this sheet may be extended into the adjacent paragneisses.

The shape of those folds in which marker-beds are lacking cannot be determined with any accuracy. However, an approximate idea may be obtained from the dips of foliation planes provided the foliation can be assumed

to be parallel with the bedding. An attempt was made, consequently, to locate the axes of the folds along those zones in which linear structures, such as common orientation of prismatic minerals or crenulation, are most abundant (18, p. 310). In such zones foliation is not well developed.

It should be noted, also, that dips that face one another on a fold do not always indicate the presence of a syncline. For example, in the southern part of Weldon Bay those dips that face north are on the overturned part of the south limb of the Weldon Bay anticline. This is shown in the cross-section of the fold in Figure 13a, which does not have a syncline below the "Bay" of "Weldon Bay", although the facing dips on the geological map suggest such a possibility. A similar relationship is found on the south flank of the anticline in the Kisseynew gneisses in the Mikanagan Lake area (11) where the structure has been interpreted as synclinal by Robertson (51).

To differentiate between an overturned limb and a possible fold, the writer has found that if the dips steepen and change their direction through the vertical, and if their strike remains constant, the dips define an overturned limb; on the other hand, should the strike of the foliation vary more in the possible axial zone than in the adjoining strata, the dips define a plunging fold.

Some of the major folds in Weldon Bay map-area have been given geographic names, and all of the fold axes have been located on the structural map (*See* Figure 8).

In the southwestern part of the area of Kisseynew gneisses, the folds are oriented almost east-west, so that their origin can be attributed to north-south compression, but east of Weldon Bay the limbs of some of the folds strike north, so that the folds appear to have been produced by an east-west compression. Such an interpretation, however, is not upheld by closer study. The attitudes of the axes of these folds are indicated by arrows on Figure 8, and it can be noted that the arrows point in an easterly direction. Thus, the axes of these folds east of Weldon Bay are essentially parallel with the obvious east-west folds elsewhere in the gneisses in Weldon Bay map-area, so that all of the folds can be related to a common north-south compression.

Why then, do the folds east of Weldon Bay appear to be different? The direction of the plunge of these folds is known. Therefore, it is possible to construct a section through them by projecting the lithologic contacts to a vertical plane that is perpendicular to the plunge. In Figure 12 the writer has projected the contacts of only the Kisseynew granodiorite sheet, east of Weldon Bay, to the vertical plane. However, the shape and attitude of this sheet reflect those of the associated Kisseynew gneiss. From the diagram it can be seen that the folds are recumbent, plunging east, with a recumbent syncline lying between two anticlines. This is the important difference: whereas the axial planes of the other folds dip north at relatively steep angles, the axial planes of these are inclined to the east. A similarity may be noted between these folds and those studied in east-central Vermont by White and Jahns (65, Figures 10, 11).

The structural significance of the recumbent folds illustrated in Figure 12 is the fact that their uppermost limb does not originate in Weldon Bay map-area. In other words, these folds occur as recumbent lobes on the nose of an even larger fold that must extend into the adjoining Sherridon

map-area. The structure of the area between Weldon Bay and Sherridon is described in another publication (38).

Figures 13a and 13b are cross-sections through the Kisseynew gneisses in the Weldon Bay area. It can be noted that most of the folds are overturned or asymmetrical toward the south. Therefore, the compressive force must have acted in the direction of overturning, approximately normal to the axes, that is, southward. If this interpretation is correct, it must mean that the recumbent folds have been overturned from the north in a similar manner.

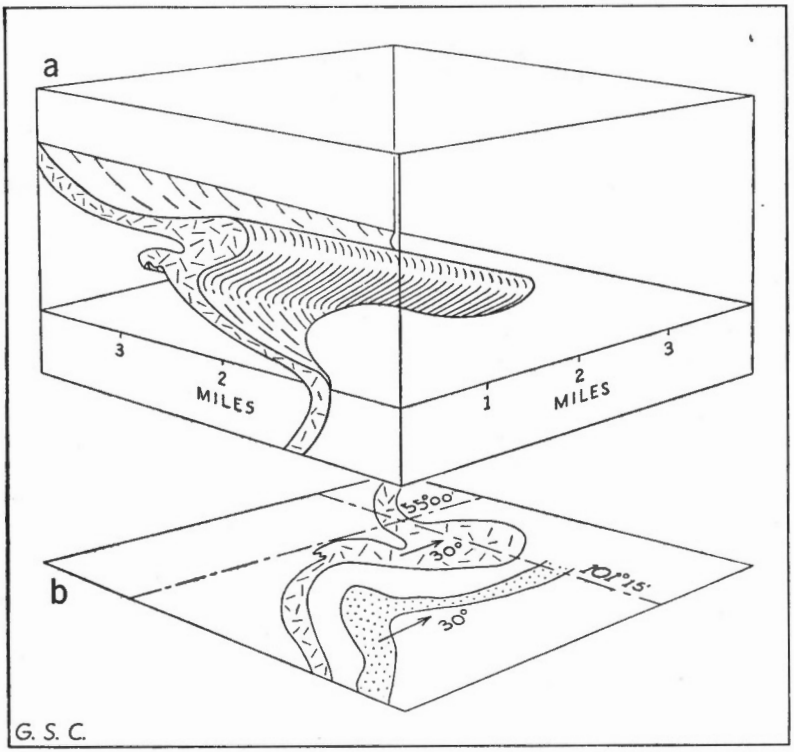



Figure 12. Recumbent folds in Kisseynew gneisses, east of Weldon Bay: a, block diagram of folded sheet of Kisseynew granodiorite; b, diagrammatic map illustrating oblique view of the area east of Weldon Bay, showing outcrops of the granodiorite (dashed) and of hornblende gabbro (stippled), which has been omitted from 'a'. Arrows indicate direction and amount of plunge of folds.

In Figure 13a two anticlinal folds, the more northerly of which is developed in granodiorite, appear to have no syncline between them. The structures are separated by a zone of sillimanitic rocks that may have been developed along a broad shear zone, along which the anticlinal granodiorite body has been forced against and in part over the paragneisses.

A somewhat similar structural relationship is denoted in Figure 13b. North of Kisseynew Lake, the amphibolite sheet is folded into an anticline, but the south limb of the adjacent syncline is missing and may have been

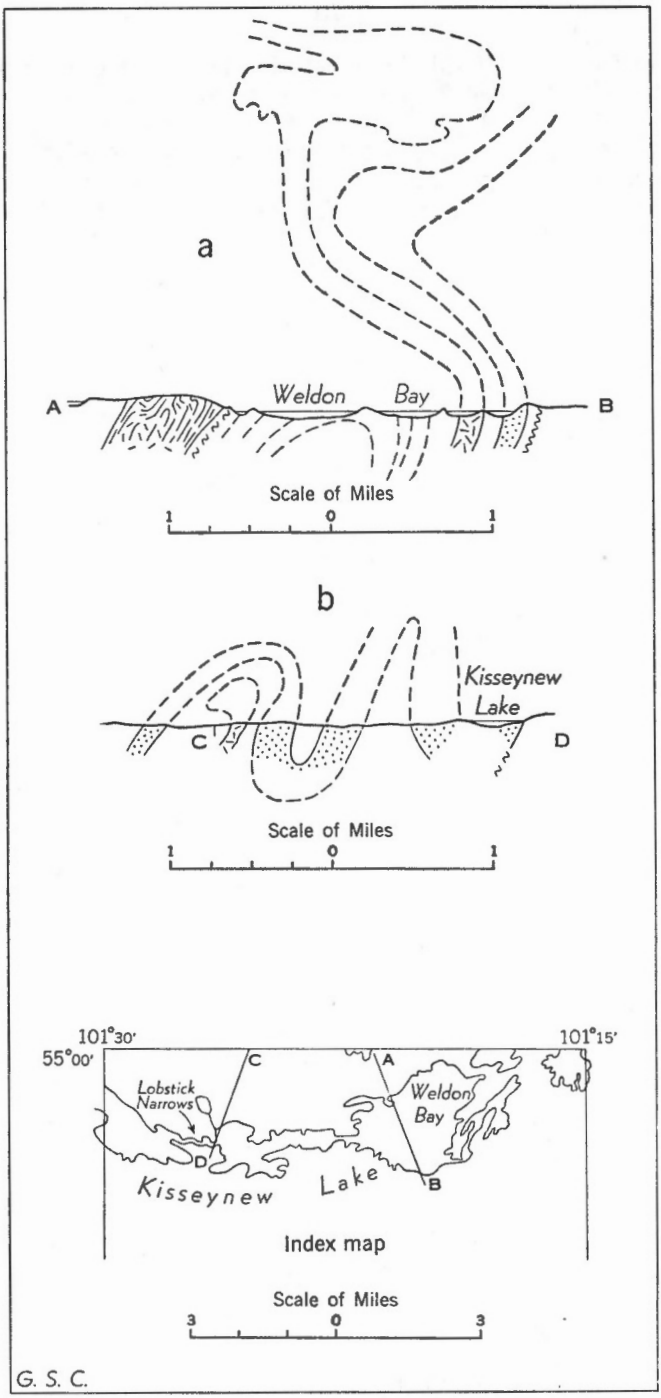



**Figure 13.** Vertical cross-sections through Kisseynew gneisses along lines A-B and C-D (Index map): a, section through Weldon Bay. The recumbent folds to the east of Weldon Bay have been projected to the plane of the section; b, section north through the eastern part of Lobstick Narrows; point C is at the northern boundary of map-area. Stippled areas, hornblende gabbro and amphibolite; dashed areas, Kisseynew granodiorite; unpatterned areas, Kisseynew biotite-plagioclase-quartz gneiss.

removed by faulting. If this interpretation is correct it may be possible to correlate this anticline with the anticline in the granodiorite body so that a possible fault occurs on the south flank of both folds.

Another feature to be noted in Figure 13a is that the recumbent synclinal folds from east of Weldon Bay have been projected to the plane of the cross-section (cf. Figure 12). These two types of folds form a disharmonious pattern.

# CHAPTER V

# ECONOMIC GEOLOGY

None of the mineral deposits in the Weldon Bay map-area is known to be of economic importance. Many small deposits have been discovered but, so far, none has proved to be sufficiently valuable to warrant development.

Pyrrhotite is the common sulphide in most of the deposits. With it occur lesser amounts of pyrite, and still less, or none, of chalcopyrite and sphalerite.

All of the deposits occur along or near faults, usually as replacement bodies in the wall-rocks. Where replacement has been slight, the sulphides form disconnected pods, disseminations, or interfingering networks in the host rock. Some of the occurrences are in quartz veins.

## WELDON NARROWS SULPHIDE DEPOSITS

Sulphides are exposed in several pits on the Star group of claims east of Weldon Bay, owned by W. Yakusavitch of Sherridon. They were examined by Wright in 1930 (68). In 1948, 1949, and 1951 some of the showings were drilled.

All of the deposits occur near the amphibolitic hornblende gabbro contact in grey, gneissic rock composed of quartz, plagioclase, biotite, and, locally, garnet. From an examination of the drill-cores from hole No. 2 on the Star No. 7 claim, the grey gneiss and amphibolite appear to be interlayered. At the contact, the grey gneiss contains considerable amphibole, but away from it the content of amphibole is less and biotite is the predominant dark mineral. Layers of amphibolite also become less numerous away from the contact, some of the thinner layers having a selvedge of biotite. Still farther from the contact, the gneiss is free of amphibolite layers and more massive in structure. This relationship can be interpreted to show the intrusive nature of the grey gneiss into the amphibolite and the decrease of inclusions away from the contact. Better evidence for the intrusive nature of the gneiss can be seen on the outcrop at the site of No. 5 hole in the eastern part of the Star No. 8 claim. In the drill-core this rock is similar to that in No. 2 hole, and a specimen from No. 5 hole, from a depth of 345 feet, is granitoid in texture and quite massive. The core shows no compositional banding that might be interpreted to represent beds except in the slightly interlayered contact zone.

These features are interpreted to indicate that on the Star Nos. 5, 7, and 8 claims, the grey gneiss is an intrusive rock that has been crushed and subsequently recrystallized. Some of the grey gneiss south of Fay Creek may have a similar origin. The coarse amphibolite lying to the west of the valley that extends southwest from the central part of the Star No. 5 claim is most probably derived from hornblende gabbro, but the finer grained amphibolite to the east may have been derived for the greater

part from volcanic rocks. On Star Nos. 5, 7, and 8 claims the common type of mineralization is a dissemination in the grey gneiss, very close to the amphibolite contact, consisting of pyrrhotite with minor pyrite, chalcopyrite, and sphalerite. Pyrite, chalcopyrite, and sphalerite also occur in quartz veinlets in the grey gneiss, but mineralization of this type is less common.

Along the south side of Fay Creek are two old pits in micaceous, siliceous rock. These workings were described by Wright (68) as exposing chiefly pyrrhotite, with minor chalcopyrite and sphalerite. Diamond drilling in the spring of 1949 disclosed that the valley floor is underlain by gneissic hornblende gabbro. Pyrrhotite mixed with graphitic material replaces the siliceous rock, and some sphalerite was observed in quartz veinlets. In polished section the sphalerite occurs as small grains within larger grains of pyrite, but most of the polished surface consists of pyrite and pyrrhotite. No ore minerals occur in the hornblende gabbro.

Massive pyrrhotite, with graphite and minor pyrite, has been exposed in three test pits a few hundred feet south of the mouth of Fay Creek. The replacement has taken place at, or near, the contact between the amphibolite and the fine-grained siliceous rock composed of quartz, plagioclase, and biotite. Drill-cores from the second pit show that pyrrhotite is restricted almost entirely to the siliceous rock.

Polished sections prepared from the drill-cores from south of the mouth of Fay Creek show chalcopyrite as small, residual blades along margins of larger pyrrhotite grains. Sphalerite is both veined by, and occurs as tiny inclusions within, pyrrhotite. The latter mineral occurs in shapeless clusters and as veinlets replacing the silicate minerals in the groundmass. Pyrite occurs in poikiloblastic cubes, with inclusions of pyrrhotite. Thus, the paragenesis appears to be: chalcopyrite and sphalerite, followed by pyrrhotite and pyrite. Specimens from the pits on the Star Nos. 5, 7, and 8 claims show similar relationships. Chalcopyrite is replaced by pyrrhotite, but its relations to sphalerite are uncertain. Pyrite is the last mineral to crystallize.

It may be significant that whereas in other deposits, such as Sherritt Gordon, pyrrhotite is the first sulphide to be deposited, here it is one of the last.

The restriction of the sulphides to the grey siliceous rocks suggests that the deposition was controlled by the brittle nature of the host rock. Movements along the fault shattered it more easily than the amphibolites to form channelways for mineralizing solutions. Fractures and joints so developed seem to parallel the lineation in the gneissic hornblende gabbro, which here plunges 25 to 50 degrees northeastward. The fractures have variable attitudes.

Fracturing has been more intense along the thrust fault that locally cuts across the direction of lineation. Because faulting probably preceded mineralization, all the intersections of fractures plunging toward the fault may have been important channelways for the localization of ore. It is possible that the ore minerals extend down the plunge of such intersecting fractures and that they may be most concentrated where the fractures pass into the amphibolite.

## SULPHIDE SHOWINGS IN KISSEYNEW GNEISSES

Southwest of Weldon Bay, pyrrhotite is disseminated through the southernmost layer of sheared felsic rocks, south of the hornblende gabbro body. No surface workings were found in this area, although the writer has been informed that interesting showings of chalcopyrite have been discovered recently. Farther south, about 1¼ miles northwest of Soneau Lake, pyrite and chalcopyrite are exposed in a pit. These minerals occur as weak disseminations in fractured pseudo-diorite.

Disseminated pyrrhotite occurs also in sheared biotite-feldspar quartz gneiss, about 1½ miles south of Lobstick Narrows. This is the most westerly showing of sulphides known to occur near the fault zone in the Weldon Bay area.

## NAOSAP LAKE SULPHIDE SHOWINGS

Chalcopyrite and sphalerite, with pyrrhotite, have been reported from the east shore of Blueberry Lake. This showing is in greenstone near a north-south fault. The area is covered by the Stan group of claims.

Pyrrhotite, with minor pyrite, occurs at several places around Naosap Lake. On the Neosap No. 1 claim, owned by T. Wickstendt, to the west of Wickstendt Island, pyrrhotite replaces narrow layers of siliceous volcanic rocks. In some layers only oval grains of quartz remain unreplaced. The specimens from this locality were obtained from the dump as the bedrock was no longer exposed in the pits.

On the Neosap No. 3 claim, Wickstendt Island, disseminated pyrite and chalcopyrite occur along a shear zone that extends near the west margin of a greenstone roof pendant. Some of the volcanic rock has been silicified. Two shear zones striking north, one about 15 feet wide and the other 3 feet wide, are exposed in the largest pit. Another shear zone is exposed in a smaller pit about 60 feet to the northwest. About 2,000 feet to the southeast, a shear zone, thought to be continuous with those above, cuts granitic rocks, which are silicified but only slightly mineralized.

Pyrrhotite also occurs in siliceous rocks on the south shore of Naosap Lake.

Near Sewap Lake, pyrrhotite occurs in granoblastic gneisses between the eastern granodiorite body and the Naosap granodiorite. About 20 feet of massive pyrrhotite is exposed in a pit on the Leo No. 1 claim, owned by T. Wickstendt, at the south end of the lake. The sulphide body is bordered by rocks in which the disseminated pyrrhotite is less abundant. On the north side of the lake, pyrrhotite occurs in lesser amounts.

## ALBERTS LAKE GOLD PROSPECT

About 500 feet north of Alberts Lake, a shear zone cuts diagonally across tuff and volcanic flows. The zone has been intruded by a porphyritic quartz latite dyke. Later shearing has fractured the dyke and younger quartz has filled these fractures and replaced parts of the dyke. Drill-cores were examined, but only pyrite and hematite were recognized in the parts remaining in the core boxes.

## OTHER DEPOSITS

Tourmaline-bearing granite-pegmatite dykes are associated with the long, narrow sheet of fine-grained granodiorite that parallels the Kisseynew gneisses south of Kisseynew Lake and Weldon Bay. West of the creek draining into the bay, a dyke contains tourmaline crystals up to ¼ inch in diameter and 3 inches long. However, they are so fractured that few segments longer than ½ inch can be obtained. The locations of other dykes in which small crystals of tourmaline were identified are shown on the geological map.

The most favourable prospecting areas should be: along the Weldon Bay thrust fault; in the volcanic rocks north of Naosap Lake, especially near the Sourdough Bay and associated faults, where these cut a variety of rocks differing in physical and chemical characteristics; and along the band of metamorphosed volcanic rocks extending northward from Sewap Lake.

K 5-6, 1948

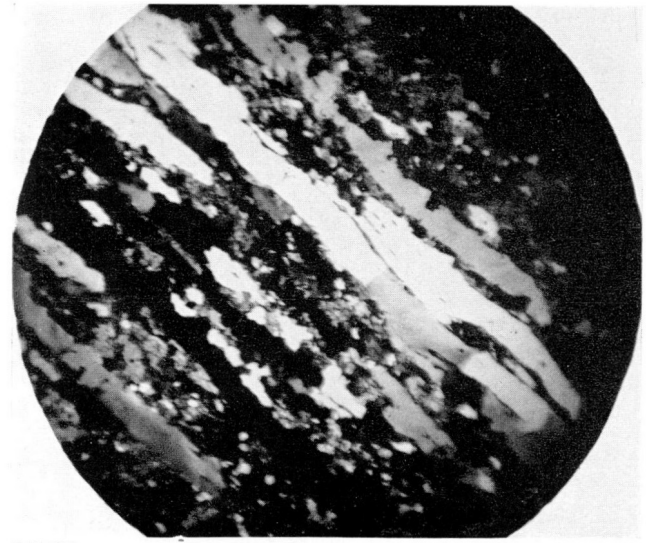
A. Foliated Amisk greenstone intruded along small faults by diorite dykes. Northwest of Naosap Lake. (Pages 7, 29, 46, 48.)

H 2-8, 1948

B. 'Quartz diorite-gneiss' with characteristic contorted gneissosity, 1½ miles east of Nesosap Lake. Photographed by J. M. Harrison. (Page 16.)

H 2-9, 1948

A. Contorted *schlieren* in 'Quartz diorite-gneiss', 1½ miles east of Nesosap Lake. Photographed by J. M. Harrison. (Page 16.)



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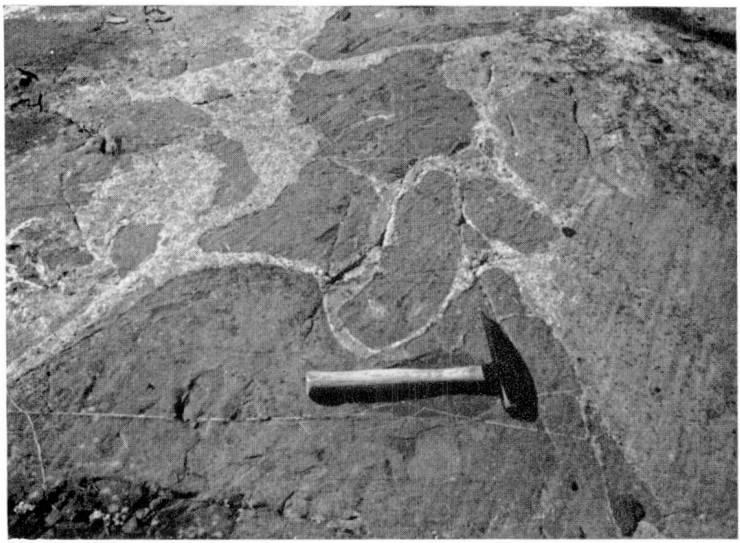
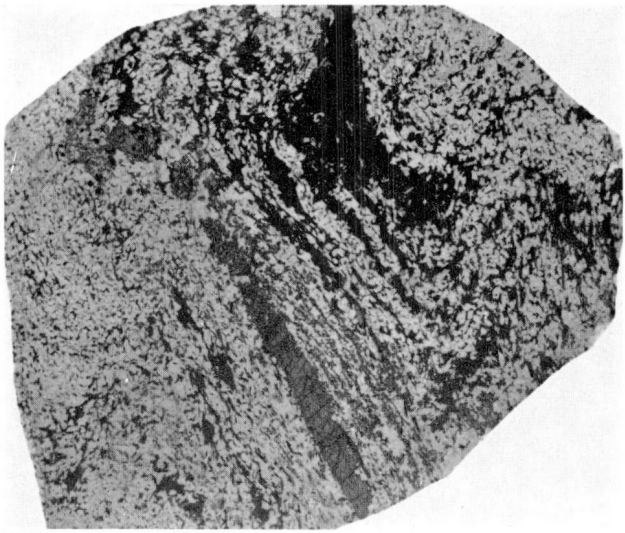
B. Platy or granulitic quartz in amphibolite on the east margin of 'Quartz diorite-gneiss'; crossed nicols, X 18. (Page 17.)



H 2-7, 1948

A. Replacement of 'Porphyritic latite' by granodiorite, 1 mile east of Nesosap Lake. Note the scalloped margins of the inclusions. Photographed by J. M. Harrison. (Pages 18, 53.)



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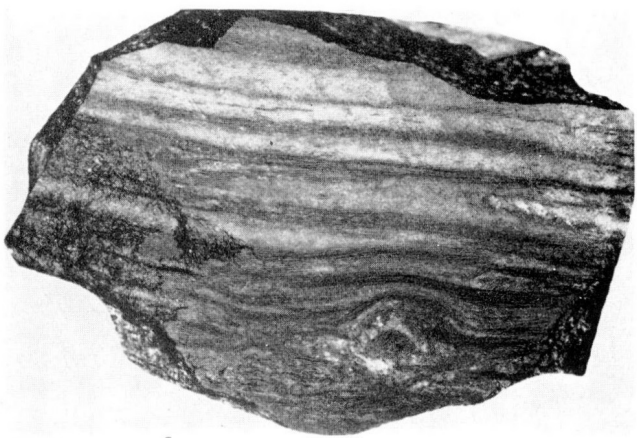
B. Crumpled, mylonitic quartz latite southwest of Fay Creek. Plain light, X 4·3. The dark minerals are biotite and garnet. (Pages 41, 60, 71.)

K 4-4, 1948

A. Spotted amphibolite from south-central Naosap Lake. Note wavy amphibolite dyke crosscutting the banding in the host rock. (Page 46.)



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B. Specimen of mylonite from Weldon Bay fault zone. Natural size. The oval body is a crushed garnet surrounded by quartz. (Page 58.)

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