Province of Manitoba

DEPARTMENT OF MINES AND NATURAL RESOURCES

MINES BRANCH

PUBLICATION 50-5

# GEOLOGY

# of the

# WASKAIOWAKA LAKE AREA

## Cross Lake Mining Division

## Manitoba

by

J.C. GILL

*Winnipeg*

*1951*

Province of Manitoba

DEPARTMENT OF MINES AND NATURAL RESOURCES

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# GEOLOGY OF THE WASKAIOWAKA LAKE AREA

## INTRODUCTION

### LOCATION AND ACCESS

The Waskaiowaka Lake area is bounded by latitudes 56 degrees 00 minutes and 56 degrees 46 minutes north and by longitudes 96 degrees and 97 degrees west, and comprises approximately 2,000 square miles. Mile 279 of the Hudson Bay railway, known as Landing River, in the southeast corner of the area, is the railhead for supplies going in by canoe and is 35 air miles from the centre of the area. Mile 296, Ilford, has an hotel and stopover facilities for float aircraft based at other points.

According to Dawson (1941, p. 13)[1]:

"The main canoe route into the area leads northwest from Mile 279 via Aiken river, locally known as Landing river, a distance of 17 miles to Split lake. Two portages, totalling 23 chains, are crossed enroute. To facilitate travel on the upper part of the river, a dam was built in 1939 at the first rapids by the Manitoba Government.

"Four canoe routes lead from Split lake to Assean lake. The best of these, and the one usually travelled, is at the west end of Split lake. This consists of two portages, 66 chains and 14 chains respectively, with an intervening small lake, and leads northward into Burntwood bay near the southwest end of Assean lake. The second route follows the north branch of a creek emptying into a long narrow bay west of the Hudson's Bay Company post. From the creek two portages, 80 chains and 24 chains, and a small lake, are crossed to reach the narrows of Assean lake. The third route starts from the bay to the north of the Hudson's Bay Company post and crosses a 120-chain portage to Fox lake. From Fox lake a creek is followed to the northeast end of Assean lake. From the extreme east end of Split lake, Assean river can be travelled upstream a distance of 16 miles to Assean lake. For upstream travel this is the poorest of the four routes, but going downstream the rapids can be run with little trouble.

"From the northeast end of Assean lake a canoe route leads north via Assean and Crying rivers to

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1 Dates and pages in parentheses refer to references listed in Bibliography on page 6.

Crying lake, crossing one 11-chain portage. From Crying lake a creek can be travelled to Crooked lake, and from here a 2-mile portage and a number of shorter portages cross the height of land to Waskaiowaka (Big) lake. Little Churchill river which drains this lake can be followed downstream to Churchill river.

"There is no canoe route from Crying lake northeast to Limestone lake, but a winter route is sometimes used by Indians and trappers."

## TOPOGRAPHY AND DRAINAGE

Again quoting from Dawson (1941, p. 14):

"Split lake and Assean lake are the two large bodies of water in the southern half of the area. The former is a widening of Nelson river and is 28 miles in length by airline. Strong current flows through a number of the narrower parts of Split lake and for this reason the water is very choppy in windy weather, especially so when the direction of the wind is against the current. There are numerous islands, particularly in the central and western parts of the lake, 320 having been mapped. Four of these are each several miles in length. The extremely irregular shoreline of Split lake is due to the differential erosion of the underlying gneisses which are variable in composition and hardness. The shores are for the most part rocky, with occasional boulder beaches and a few of sand. Some of the narrow bays and inlets have reedy shores.

"Assean lake lies to the northwest of Split lake and is 22½ miles long. The lake is elongated in a direction about north 65 degrees east, which corresponds to the strike of bedding and foliation of the underlying sediments and gneisses. Toward the southwest end the lake reaches its greatest width of 4 miles, while in the central part or "narrows" it is 400 feet wide.

"Assean lake differs from most lakes of the Canadian Shield in the manner by which it is fed. Clay river, which has a comparatively small flow of water, is the only stream of any consequence emptying into the lake. Assean river drains the lake and, in its upper part, is a broad, sluggish stream.

About $1\frac{1}{2}$ miles from Assean lake, Crying river joins Assean river; Crying river drains a large area to the north and has a large flow of water. At the time of spring floods part of this flow is diverted via Assean river into Assean lake, equilibrium is finally reached and Assean lake is later drained via Assean river into Split lake. The lake is thus a natural reservoir and for this reason the water level of Assean lake is high for some time after that of Split lake has subsided."

Hunting River drains Hunting Lake eastwards into Assean River and is difficultly navigable due to log jams and to its winding course.

"Like Split lake, Assean lake has rocky shore with some boulders and reeds. Along the north shore of the southwest end of the lake clay banks as high as 20 feet rise above the water, and good exposures of varved clay can be seen. Wave erosion of the banks makes the water muddy at this end of the lake.

"The area is not well wooded - by far the greater part of the timber has been burnt and in places there is a sparse second growth. Stands of timber suitable for mining operations are found on the north shore of Crying lake, at several points on Assean lake, and on many of the islands of Split lake. Difficulty might be experienced, however, in finding material for heavy stulls or large dimension timber.

"An Indian population numbering something over 450 live on the Indian reserve or hunt, trap and fish within the area. The Hudson's Bay Company has a store on the Indian reserve where there is also a Mission and school maintained by the Anglican Church.

"The area forms part of the Canadian Shield. The contact of the Palaeozoic rocks bordering on Hudson bay lies not far distant to the northeast of the map sheet, but its location was not determined.

"The greater part of the area is covered by a heavy mantle of varved, glacial-lake clay and, consequently, presents a flat, even surface. A few ridges of sand and boulder clay, and even fewer rock ridges, rise above the surrounding country. With few exceptions rock outcrops are confined to the shores of larger lakes and rivers."

Pelletier and Waskaiowaka (Big) Lakes form the main water route in the northern half of the area.

Pelletier Lake is an east-trending body of water approximately 14 miles long and 2 miles wide at its widest point. It is connected to Waskaiowaka Lake by a navigable river 13 miles long. Waskaiowaka Lake is approximately 20 miles long and 10 miles wide and is divided into two large bodies by a long north-extending peninsula. Whitefish are plentiful in this lake.

Immediately to the east of Waskaiowaka Lake, and connected to it by a narrows, lies Lake B, an expansion of Little Churchill River which, on the east, has numerous small rapids and is reported to be excellent for lake trout fishing.

The area between Assean Lake and Pelletier and Waskaiowaka Lakes is thickly covered by glacial clays; air observation reveals practically no outcrops. The intervening watershed is caused by high morainal sand ridges which have been deeply dissected by a dendritic pattern of rapidly downcutting streams. The shores of these two lakes are in general rocky except for the south shore of Waskaiowaka Lake which is gently arcuate in outline owing to its thick mantle of clay and sand. As at Split Lake, the irregular shoreline of the remainder of Waskaiowaka Lake is due to erosion of granite gneisses of varying composition. North of Pelletier and Waskaiowaka Lakes, rocky ridges are more numerous than at the shore and in most places consist of granitic rocks of a less gneissic character than those surrounding the lakes.

Unlike Split Lake these lakes have no strong currents, but their large size, shallow depth, and rocky bottoms cause the water to roughen quickly in a wind from any direction.

The timber on the north side of Waskaiowaka Lake has been extensively destroyed by fire. The south shore is fairly well wooded for a few miles inland. A few stands of timber suitable for mining operations were seen, though in few places are the trees of large dimension.

## PREVIOUS WORK

According to Dawson (1941, p. 14):

"The early history of the region is associated with that of the fur trade. It is thought by some that the first white man to visit the area was Henry Kelsey, in 1691.[1]

"The first fur traders in the area were the North-West Company, followed at a later date by the Hudson's Bay Company. In 1792 Split lake was crossed by David Thompson, surveyor for the Hudson's Bay Company, who ascended Nelson river as far as Sipiwesk lake and the following year returned to York Factory via Burntwood river and Split lake. His map of the Northwest Territories was compiled in 1814 and served as a basis for general maps of the region until comparatively recent times.

"In the years 1878-9, R. Bell made a track survey down Nelson river to Split lake and traversed the route from Split lake to the Churchill river via Assean and Crying lakes. He mentioned the occurrence of granite, sedimentary rocks, grey gneiss and diorite dykes on Split lake.[2] Wm. McInnes visited Split lake in 1906 and also travelled north from there to Churchill river. His description of this area is included in a memoir published in 1913[3]."

In 1939 A. S. Dawson of the Geological Survey of Manitoba conducted a survey of the region between Hunting River, Crying Lake, Assean River and the southern shore of Split Lake. The results of this work were published as Manitoba Mines Branch Geological Report 39-1, which included a map on a scale of 1 inch to 2 miles. The gold deposits of Assean Lake were described in detail. This report is now out of print and so is extensively quoted.

## PRESENT WORK

The present survey was conducted during a three month period from June to September, 1950 with the object of extending the previous work of A. S. Dawson to the boundaries of the area. All this work was of a reconnaissance nature because a much wider area was covered. Mapping was done on a scale of 1 inch to 2 miles by pace and compass and shorelining methods. Traverses were planned to cross the regional strike at intervals of approximately one half to one mile.

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1 Alcock, F. J.: Geol. Surv., Canada, Sum. Rept. 1920, Part C, p. 7.

2 Bell, R.: Surv., Canada, Reports of Explorations and Surveys, 1878-9, p. 12C.

3 McInnes, Wm.: "Basins of Nelson and Churchill Rivers," Geol. Surv., Canada, Memoir 30, 1913.

A copy of the topographic sheet 64A, Southern Indian area was photostatically enlarged from a scale of 1 inch to 8 miles to 1 inch to 2 miles providing a rather inaccurate base map. The geology was plotted without the aid of vertical aerial photographs, but trimetrogon photos were found to be of occasional value. A new base map compiled from vertical aerial photographs has since become available, and the geology has been replotted on this map.

Isolated outcrops in large drift-covered areas have been represented by a symbol on the map, but on shorelines of lakes and rivers where outcrops are found at fairly frequent intervals, the outcrop area has been represented as if it were continuous.

Some work was done within parts of the area previously mapped by Dawson with a view to determining the nature of contacts with more accuracy, but complete re-mapping was not attempted. Certain changes in map units appear on the present map. These do not indicate that Dawson's interpretation is necessarily incorrect, but are the opinion of the writer based on observations which, like those of Dawson, were severely limited by the extensive cover of glacial drift, and are not to be regarded as final.

Large drift-covered areas in the north and central part of the map-area were not mapped by traverses but were checked by careful observation from a low-flying aircraft. Several hours were spent in the work of eliminating these areas. The Assiak-watamo River north of the map area was found to be very difficultly navigable owing to the presence of rapids and falls.

Special consideration was given to the mapping of basic intrusive rocks in the area south and west of Split Lake.

Capable assistance in the field was rendered by Messrs. L. S. Binda, D. H. Anderson and R. L. McPherson, students of the University of Manitoba. Suggestions and guidance from Professor J. W. Ambrose of Queen's University are gratefully acknowledged. Thanks are also due to Messrs. J. Dunbrack and M. Hatley of Split Lake and O. Lindal of Ilford for unstinted helpfulness.

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## GENERAL GEOLOGY

### GENERAL STATEMENT

The consolidated rocks of the area are all of Precambrian age and consist of interbanded sedimentary and volcanic types intruded by numerous large and small masses of igneous rock, which range from felsic to ultramafic types.

Most of the rocks are highly metamorphosed and except for the younger basic intrusives and some of the granitic intrusives, are commonly gneissic. Where metamorphism and granitization have been severe only indirect evidence as to the origin of many of the gneisses can be found. The gneisses have been classified as igneous or sedimentary according to their mineralogical composition and from field evidence, such as gradation into rocks of known origin either across or along the strike.

Previous nomenclature has been followed in calling the volcanic-sedimentary types the Assean Lake series which has been variously considered to be correlative with the Hayes River group and the Keewatin series on rather doubtful grounds. Dawson's term "Pre-Assean Lake group" has not been used, as it is based on doubtful evidence of an unconformity between this group and the Assean Lake series. These will be discussed further in the description of rock types. The writer has been able to contribute little to Dawson's descriptions of map units which are extensively quoted for the sake of completeness and are augmented by new field and petrographic observations.

Considerable effort was directed towards the separation of the various types of basic intrusives which range in composition from diorite to peridotite. Special attention has also been given to the granitization of sedimentary and volcanic rocks. Numerous examples of this process were noted. Many of the granitic gneisses classed here with the intrusive rocks for the sake of convenience, are considered by the writer to be products of the granitization of older rocks by fluid agencies.

The accompanying table of formations illustrates the classification of rocks found within the area.

TABLE OF FORMATIONS

| | | | |
|---|---|---|---|
| Recent and Pleistocene | | River alluvium, peat, etc.<br>Glacial lake clay<br>Boulder clay, sand, gravel | |
| | | Unconformity | |
| ARCHAEAN or PROTEROZOIC | Intrusive Rocks | Diabase, trap<br>------ Intrusive Contact ------<br>Granite, pegmatite, aplite, felsite<br>------ Intrusive Contact ------<br>Gabbro, diabase, diorite, pyroxenite, peridotite, anorthosite<br>------ Intrusive Contact ------<br>Altered fine-grained acidic intrusives<br>Granite gneiss, pegmatite, greisen, lit-par-lit gneiss, quartz-diorite gneiss<br>------ Intrusive Contact ------<br>"Quartz-eye" granite gneiss<br>------ Intrusive Contact ------<br>Grey tonalitic quartz-feldspar-hornblende gneiss, diorite gneiss, hornblendite, feldspar-garnet- hornblende gneiss | |
| | | Intrusive Contact | |
| ARCHAEAN | | Quartz-mica gneiss, )<br>gneissic quartzite, )<br>garnet-mica gneiss, )<br>mica schist; )<br>some actinolite- )<br>chlorite schist ) | Probably derived from Assean Lake series |
| | | Conglomerate, altered )<br>greywacke, and meta- )<br>morphic equivalents ) | Relative age doubtful |
| | Assean Lake Series | Volcanics: Basalt, andesite, dacite<br>Sediments: Quartzite, arkose, greywacke, chert, argillite | |

## DESCRIPTION OF ROCK TYPES

### Assean Lake Series

Interbanded sedimentary and volcanic rocks whose original nature is usually evident are found on the shores of Assean and Split Lakes and the Burntwood and Odei Rivers. These rocks constitute a folded, faulted, and steeply dipping series with gneissic banding generally parallel with original bedding. This relationship is deduced from the remarkable continuity of bands of uniform composition parallel with the strike of the formation. Dawson reports crossbedding in a few places, but no bedding tops were observed by the writer.

Dawson concluded that two series of sedimentary rocks are present in the area, the Assean Lake series, and an earlier more highly metamorphosed Pre-Assean Lake group. The present author believes that Dawson's "Pre-Assean" rocks are metamorphic equivalents of the Assean Lake series. His conclusions as well as Dawson's are presented below.

Concerning the Assean Lake series Dawson states (1941, p. 20):

"These sediments have a clearly defined contact with the sedimentary gneiss on Assean lake, although the contact is exposed in very few places. Evidence for an unconformity between the two series of sedimentary rocks is as follows:

1. The extreme difference in degree of metamorphism together with the fact that the contact is not gradational.

2. The contact is apparently irregular in contour, suggesting deposition of the younger series on the eroded surface of the older.

3. Slight angular discordance.

"Some facts relative to the above were also discussed in connection with the grey gneiss at Crying lake.

"Near the northeast end of Assean lake the sediments in the vicinity of the contact of the granite mass lying to the south are baked, highly altered and impregnated with granitic material."

The writer was able to spend very little time in traversing the contact between the two series, but found only highly granitized remnants of greywacke on the shore of Assean Lake south of Location B and no sharp difference in rock types near the contact where it had been plotted previously. Relatively pure quartzite was found in the northwest corner of Burntwood Bay, but this rock was probably more resistant to metamorphism than greywacke members. Extensive granitization and drift cover thus create doubts as to the existence of a non-gradational contact, but do not disprove the view held by Dawson.

## Sedimentary Rocks (1) [1]

A single belt of sedimentary rocks up to $1\frac{1}{2}$ miles wide extends southwest for at least 30 miles from a point some 7 miles northeast of Assean Lake throughout the length of the lake to Burntwood River.

A second belt extends from $1\frac{1}{2}$ miles below the portages on Landing River through the numerous islands of Split Lake and westward to the Burntwood River which it follows for approximately 45 miles, thus making a total of 75 miles. The two sedimentary belts are of similar lithology and probably represent the limbs of a major fold.

These sedimentary rocks consist of quartzite, arkose, greywacke, chert, and argillite. Arkose and some of the quartzite are more thickly bedded than the other types, beds in places being a foot thick. Other quartzites, cherts, and argillite are mainly thinly bedded and in places intricately folded on a small scale. The various types of sedimentary rock are interbedded and variations from one type to another appear along the strike.

Quartzite occurs in pure and arkosic varieties, ranging in texture from cherty porcellanous to medium-grained types. Quartzite is commonly pure white or yellowish in hand specimen, but grey, greenish, and pink varieties also occur according to the impurities present, chiefly biotite, feldspar, and argillaceous material. Quartzite and arkose commonly have sericite developed along bedding and shear planes.

A belt of arkose extends for several miles along the south shore of Landing River.

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[1] Numbers in parentheses are those of the map units used on the accompanying map.

Most of the arkose is a reddish crumbly rock in hand specimen, and appears much like granite at a distance of a few feet. A few elongate pebbles of reddish feldspathic material 3/4 inch across were found. The rock consists mainly of lens-shaped aggregates of orthoclase, microcline, and quartz, about 1 inch long, separated by films of sericite and epidote. Some specimens have considerable epidote and chlorite. This net-like structure causes the rock to crumble and split easily into large slabs where weathered, but bedding planes are seldom distinguishable. The flaser structure is thought to be due to strong compressive shearing and granulation.

Greywacke was found in several places in the area including Assean Lake and the shore of Split Lake north of the Landing River. The typical rock is medium to fine grained and dark grey on the weathered surface. Gradation into argillite is commonly observed. The minerals in the greywacke consist of sodic plagioclase, actinolite, and quartz, with considerable alteration to chlorite, epidote, zoisite, carbonate, and sericite, with minor apatite, magnetite, and pyrite. Proportions of the essential minerals vary considerably.

Dawson reports the finding of cherts consisting of about 75 per cent quartz, the remainder being chiefly biotite and sericite in parallel alignment. Some of the quartzites seen by the writer have a texture approaching the fineness of chert.

## Volcanic Rocks (2)

Volcanic rocks are interbedded with sedimentary members along the north shore of Assean Lake near Location A, also in three places on the shore east of Location B. Some occur as thinly intercalated flows, not over a few inches thick. Other flows are hundreds of feet thick, and volcanic inclusions of considerable size occur within grey granitic gneisses immediately to the north. Northwards, the inclusions of greenstone decrease in size and become more highly altered.

The volcanics are fine-grained dark-green rocks consisting mainly of green actinolite and plagioclase which ranges from sodic to calcic varieties. Andesites, dacites, and basalts probably occur within these rocks in which the small size of grain renders precise determinations of plagioclase difficult. There are no apparent primary structures, but some areas are slightly schistose. Alteration products are epidote, zoisite, and chlorite.

In the Pelletier - Waskaiowaka Lakes portion of the area numerous inclusions of basic material occur within pegmatite stockworks and granite gneisses. On the northern arm of Waskaiowaka Lake such inclusions are associated with minor amounts of greenstone.

## Sedimentary Gneiss (4), and Conglomerate (3)

Gneiss of sedimentary origin (4) underlies the area about Burntwood Bay on Assean Lake and forms a belt which trends northeast and is about 9 miles long and as much as 3 miles wide. As previously stated, the writer suspects that these are metamorphic and granitized equivalents of the Assean Lake Series. Because these rocks were not mapped in systematic detail by the writer, their description by A. S. Dawson (1941, p. 17) is herein quoted. His comments on the conglomerate and altered greywacke (3) are also included.

> "These rocks weather dark grey and the outcrops commonly have a ribbed appearance due to differential erosion of alternate bands. The typical rock is coarsely-banded quartz-mica gneiss. The quartz is usually finely granular and forms bands up to 1 inch in width. Narrow bands consisting largely of coarse flakes of black biotite are interlaminated with the quartzose bands. Feldspar, hornblende, chlorite and sericite are present in varying minor amounts. In places, this gneiss grades into gneissic quartzite of which quartz is the chief constituent along with thin films of biotite and sericite. Locally, mica schist sometimes 2 to 3 feet in width may represent argillaceous material interbedded with the impure quartzites which were the original constituents of the bulk of the gneiss. Conglomerate was encountered in very few localities at the southwest end of Assean Lake. Where found, the beds are thin and lenticular in habit, passing along the strike into typical gneiss devoid of pebbles. The matrix of such conglomerate is quartz-mica gneiss; the pebbles are not abundant and consist of granite, greenstone and quartz. The pebbles are greatly elongated in a direction parallel to the gneissic banding.
>
> "On the northwest shore of Assean Lake near the mouth of Clay river a belt of garnetiferous quartz-mica gneiss outcrops. The outcrops weather red to grey and have a massive, granitic appearance. The fresh rock is seen to consist chiefly of mica, hornblende, quartz, feldspar and garnet, the mafic materials predominating. The garnet is pink and occurs in round clusters which also contain quartz. Feldspar having the composition of intermediate plagioclase occurs in irregular grains.

"The area between Four Mile lake and Crying lake, extending southwest along Hunting river, is also underlain by rocks of sedimentary origin. The southwestern part of this belt is underlain by quartz-mica gneiss, sometimes feldspathic, and in general similar to the gneiss described above. These rocks pass northward into a large belt of conglomerate ..........which is at least 1 mile wide and outcrops along the north shore of Four Mile lake, extending at least 4 miles to the west of this lake. South of the junction of Hunting and Crying rivers a large conglomerate ridge rises about 100 feet above the surrounding country and forms a landmark which is plainly visible from the lower part of Crying river, from Four Mile lake and from higher ground in the vicinity for miles around. A similar ridge occurs about 2 miles northwest, to the north of Hunting river.

"The groundmass of this conglomerate is schistose, fine grained, contains many elongate bands of material rich in epidote and is in general similar to the altered greywacke ............ Pebbles are very numerous and form up to 80 per cent of the rock material. The most abundant pebbles are pink to grey granite, whereas few of vein quartz, greenstone, diorite, gabbro, and pegmatite were encountered. The pebbles are all greatly elongated. One of the larger pebbles measured 3 feet by 6 inches by 2 inches; a pebble of average size is 4 inches long by 1/2 inch by 3/8 inch. Smaller pebbles are more numerous and are not so greatly elongated in proportion to their size. The pebbles are elongated in the plane of schistosity of the matrix which strikes in a general east-west direction. The long axes of the pebbles are observed to plunge at about 30 degrees to the east.

"To the north pebbles become fewer and the conglomerate grades into altered greywacke. This is a slightly schistose, green-weathering rock in which evidence of original bedding has been obliterated. The green colour is due largely to the presence of material rich in epidote. The rock is fairly uniform in appearance wherever encountered, but exposures are few and scattered. Microscopic examination of a thin section of this rock shows it to consist of quartz and epidote in about equal amounts, with about 20 per cent of hornblende. The quartz is finely recrystallized and is present as irregular bands. Apparently all of the feldspar originally present in the rock, and possibly some of the hornblende, has been altered to epidote. The epidote occurs as small grains associated with hornblende which is present in somewhat larger grains. Magnetite in scattered crystals is a minor constituent of the rock."

These gneisses and schists are presumably derived from impure quartz sandstones, arkose, greywacke, and conglomerate. Extreme variability in composition across the strike and remarkable uniformity along the strike of individual bands indicates that the gneissic banding has been developed parallel or nearly parallel with the original bedding.

No rocks of volcanic origin were seen in direct association with these gneisses and schists, but volcanics of equivalent age may be represented by inclusions of actinolite-chlorite-feldspar schist which occur within the granitic gneiss in the central section of Split Lake and at the southwestern end of Assean Lake. None of these inclusions is large enough to be shown on the present map.

## Intrusive Rocks

Intrusive rocks ranging from peridotite to granite occur within the area. Crosscutting relationships and contact effects indicate that many of the more basic rocks are younger than the granitic gneisses and older than some of the massive granitic rocks. The writer found that in the southwest part of the area a few, at least, of the basic dykes are younger than fresh-appearing granites.

Thus it is believed that basic rocks are probably associated with two periods of igneous activity, although the late diabase and trap may represent derivatives of the latest granite and thus be nearly correlative in age with the latter.

Large areas of granitic rocks are highly gneissic, and parts of the gneiss contain abundant inclusions of basic rock and sedimentary gneiss. Dykes of pegmatite or granite cut most of the other rock types, including the granitic gneisses.

## Granitic and Other Gneisses

As previously stated, many of these gneisses are considered to be products of granitization and are not, therefore, intrusive in the strictest sense.

The gneisses under consideration range in composition from quartz-plagioclase gneiss to microcline granite gneiss and gneissic pegmatite. Contacts between the various types of gneiss are of necessity arbitrarily defined and approximate in position, for there are good reasons for believing that most of them are related in origin.

The grey tonalitic gneiss (5) is considered to be an exception to this rule as will appear in the following discussion. This rock has not been seen in direct contact with other rock types and its relations with them can only be inferred.

Grey Tonalitic Gneiss (5). Grey gneiss underlies the central, northern, and eastern parts of Split Lake, also an area north of Crying Lake, part of the south shore of Pelletier Lake and of the north shore of Waskaiowaka Lake. The rock is coarsely crystalline, even-grained, and strongly banded. In many places the weathered surface has a yellowish tinge. Examination of four thin sections by the writer disclosed that the plagioclase is typically oligoclase of composition about $An_{25}$. In some specimens the plagioclase appears to be antiperthitic, having small inclusions of a feldspar which has lower indices of refraction. One specimen contains labradorite. Quartz forms as much as 30 per cent of the rock. The dark bands consist of either biotite alone or biotite and hornblende. Minor constitutents are titanite, pyrite, and apatite. Feldspars are slightly sericitized. Some of the titanite is partly replaced by ilmenite.

The texture on the whole is strongly suggestive of an igneous rock. Bending in the biotite and feldspars of a specimen from Waskaiowaka Lake is some indication of movement while it was part of a plastic mass. If one assumes a magmatic origin for this gneiss one must assume that certain inclusions of quartz-biotite gneiss reported by Dawson are the result of a mechanism such as stoping from roof rocks.

On the other hand, abundant inclusions of hornblende-quartz diorite gneiss occur within granite gneiss near the tonalitic gneiss, suggesting that the latter could be a product of granitization of such inclusions. In such a process some removal of potassic constituents would be required. On Pelletier Lake similar tonalitic gneisses were found near basic inclusions in pegmatite stockworks, but a genetic relationship is for the present a matter of speculation.

Dawson's grounds for a magmatic origin were stated as follows (1941, p. 18):

> "Two belts of grey igneous gneiss were encountered. One underlies the central, northern and eastern portion of Split lake; the other lies to the north of Crying lake. This gneiss consists chiefly of coarsely-recrystallized hornblende and grey to white feldspar, with some quartz, a composition and texture which indicates igneous and probably intrusive origin. Confirmatory evidence is found in observed intrusive relations between the gneiss and the actinolite-chlorite schist inclusions. In one instance, dykelets of gneiss were found filling fractures in the schist close to the contact, while angular inclusions of schist were present in the nearby gneiss.
>
> "Inclusions of quartz-biotite gneiss occur within the grey gneiss and suggest that the latter is intrusive into the sedimentary gneiss of the southwest end of Assean lake. Different relations are indicated between gneiss and sediments in the vicinity of Crying lake. Here the banding of the gneiss along the north shore of Crying lake dips uniformly to the north at about 65 degrees, whereas the schistosity of the altered greywacke to the south dips steeply south, making an angular discordance of about 35 degrees. No exposures were found along or near the contact. If this discordance of secondary structures can be taken to indicate an unconformable contact, then it must be assumed that the grey gneiss is older than the sedimentary gneiss of the district, or that the altered greywacke and conglomerate to the south of Crying lake represent a metamorphic phase of the Assean Lake series of sediments."

In the writer's opinion the tonalitic gneiss is related in origin to the "quartz-eye" granite gneiss which forms an adjacent belt of rock and is cut by all other intrusives of the area. However, Dawson considers that the quartz-eye gneiss is definitely younger than the grey gneiss and possibly older than the Assean Lake series which it possibly underlies unconformably. He found small veins and stringers of blue quartz cutting the grey gneiss similar in appearance with the quartz of the "quartz eye" granite gneiss within ½ mile of the contact. He regarded this as evidence that the grey gneiss is older.

"Quartz-eye" Granite Gneiss (6). The typical "quartz-eye" gneiss consists of almost equal amounts of feldspar and quartz with about 15 to 20 per cent of other minerals, hornblende being the most abundant. As plagioclase (albite or oligoclase) is more prominent than orthoclase, the rock has the composition of a granodiorite. The blue quartz eyes are large and prominent and each usually consists of one crystal which has wavy extinction. The crystals are elongate and somewhat irregular in outline. Alteration products are biotite and epidote and the feldspar is considerably replaced by sericite. The rock is medium grained and equigranular except for the larger quartz-eyes.

An unusual feature of this gneiss is the presence of numerous boulder-like masses of basic material within it resulting in a conglomerate-like appearance. Stringers of granitic material fill fractures in the inclusions indicating that the gneiss surrounded the basic rock while the former was in a fluid state. Dawson suggests that these inclusions, some of which are more than 2 feet across are either early-formed magmatic segregations, or partly assimilated inclusions of a basic rock invaded by the magma. The latter supposition is the more feasible, as they are not greatly different from larger inclusions of actinolite-chlorite schist within the grey gneiss.

Granite Gneiss, Pegmatite, Greisen (7). Areas mapped as granite gneiss (7) include minor intrusions of pegmatite and greisen. The granite gneisses are somewhat variable in mineral composition, but all are cut by basic intrusives. They are believed to be younger than the rocks previously described.

The weathered surface of the rock is typically grey, but pinkish varieties occur. It is medium grained and consists mainly of pink and white feldspars and quartz interlayered with thin bands of hornblende, chlorite, and biotite. In a few samples studied in thin section the potash feldspar, chiefly microcline, exceeds the plagioclase (albite or oligoclase in amount, but on the whole the reverse proportion seems to be the rule. Most of the feldspar is considerably altered to sericite. Hornblende and biotite are the most common dark minerals, hornblende being in places considerably altered to chlorite. Scattered grains of magnetite, apatite and titanite are generally present.

The granite gneiss is younger than the Assean Lake series of sedimentary and volcanic rocks. It has many inclusions of materials from this series which are easily identifiable. Other inclusions of quartz biotite schist, and quartz diorite gneiss, some of which are several feet in diameter, may represent remnants of this series and of older basic intrusives.

On the west shore of the northwest arm of Waskaiowaka Lake a large body of basic rock is surrounded by granite gneiss. The rock underlies an area at least $1\frac{1}{2}$ miles by $\frac{1}{2}$ mile and ranges in composition from hornblende gabbro to quartz diorite gneiss. Coarseness of grain indicates that it is most probably the remnant of a basic intrusive older than the gneiss. Other basic inclusions in the gneiss at Pelletier Lake area and on the northeast arm of Waskaiowaka Lake contain fine-grained plagioclase, either oligoclase or andesine. Some in the latter location are associated with minor amounts of greenstone.

The writer believes that in general the layering of these granite gneisses represents relict bedding surviving from older sedimentary layered rocks after processes of granitization, possibly accentuated by differential stresses which have resulted in movement largely along the same planes of foliation. The principle reasons for this belief are:

1. Regionally, the granite gneisses in the general area of the two belts of rock comprising the Assean Lake Series have roughly the same strike and dip as the sedimentary rocks.

2. Inclusions of gneiss and schist of undoubted sedimentary origin are commonly found within the gneiss. At Witchai Lake layers of quartz-garnet-mica schist were found within the gneiss. In some places the inclusions are several feet in diameter, in others the gneiss is a thinly laminated type as found on the Grass River. Progressive granitization of a greywacke was noted on the south shore of Assean Lake. Several intermediate stages could be traced, including a "lit-par-lit" type of texture.

Dykes, sills, and irregular bodies of pegmatite are extremely common throughout the area. Only in places can these pegmatite intrusives be distinguished from later intrusions of similar rock, by the degree of alteration through shearing stresses and hydrothermal action which have produced a greisen in the older rocks. This group is also confined to those minor intrusives which are cut by gabbro dykes, although more than one age of basic intrusives certainly occurs. On the Nelson River near the Grand Rapids diabase dykes cut granite gneisses and fresh-appearing pegmatites.

Greisen occurs in places along the north shore of the central section of Assean Lake, and along the Nelson and Grass Rivers, white mica being the predominant mineral. The rock has a crude gneissic banding roughly parallel with the direction of regional shear. Dawson reports that some fractures in the greisens have been filled by irregular kidneys and stringers of quartz.

All pegmatites consist essentially of quartz, white mica, and orthoclase.

Altered Fine-grained Siliceous Rock (8). Hand specimens of fine-grained acidic intrusive rock (8) from the vicinity of Location B were examined by the writer. Panning of several samples disclosed gold colours. Dawson mapped this rock type in some detail and described it as follows (1941, p. 23):

> "Altered, fine-grained, acidic rock, locally called porphyry, underlies a prominent point and islands on Assean lake in the vicinity of the Dunbrack vein (Location B). The rock contains many inclusions of altered sedimentary rock, and the complex is cut by basic dykes. The rock is highly siliceous, dense, and contains much brown mica and some sericite. It is locally gneissic, and occasionally shows development of small pink garnets. While this rock is tentatively grouped as being related to the nearby bodies of granite gneiss, it may well be of earlier, and possibly sedimentary, origin. In thin section the rock is seen to consist of quartz, biotite and feldspar, quartz being the most abundant constituent. Biotite occurs in flakes of different sizes, often bent and broken and as a rule not oriented in any particular manner. Feldspars are orthoclase and

acid plagioclase, and are all to some extent altered with development of sericite. Pyrite is a minor accessory mineral. The rock is fairly even grained and the grain size is somewhat coarser than that of typical rhyolite. No definite evidence as to the rock's original nature could be found in the section studied. There is no suggestion of a porphyritic texture."

## Basic Intrusives (9)

Basic intrusives are numerous throughout the southern half of the area. As previously stated, more than one age of intrusion is suspected, and most of the basic dykes and sills are cut by dykes and stringers of granite or pegmatite.

The basic intrusives are generally black or dark green both on weathered and fresh surfaces. For the most part they are relatively unaltered, but a few are highly schistose. The writer believes that some of these rocks were intruded later than the main periods of crustal movement in the area, filling fissures and tension cracks created by such movements. Evidence for this belief is seen from the map which shows dykes continuing without horizontal displacement across the Burntwood River, which is in all probability, the site of a major fault. The parallel arrangement of a series of dykes on the same river at the Elbow strongly suggests that they occupy tension faults at an angle of approximately 45 degrees to the river-bed across which they can be traced.

The schistose character of other dykes and the fact that some contain shear zones indicates that some of the intrusives are older than some of the movements along fault planes.

Some dykes and sills, such as the one on the south shore of Split Lake, are traceable along their strikes for several miles. With a few exceptions, their attitude is concordant with the layering of the enclosing gneisses and sedimentary rocks. Dykes and sills range from inches in width to 1400 feet.

The most abundant type of basic rock is medium-grained hornblende gabbro (9a), which grades locally into diorite (9c). Other types noted are diabase, olivine diabase (9b), pyroxenite (9d) and peridotite (9e). Dawson also found anorthosite.

Gabbro, Diorite Gabbro, Norite (9a). A typical gabbro from the vicinity of the Elbow consists of about 60 per cent feldspar and the remainder chiefly a strongly pleochroic amphibole. The amphibole is in part acicular, and larger crystals contain remnants of pyroxene which have inclined extinction. The amphibole is apparently of the uralite variety, and the process of uralitization is nearly complete. Minor amounts of pyroxene of the varieties enstatite and augite are present as discrete crystals. The feldspars are subhedral crystals of plagioclase, some of which are zoned. Zones vary in composition from andesine $An_{33}$ to labradorite $An_{56}$, the latter being at the centre of a crystal. The feldspars are considerably sericitized and kaolinized. Accessory minerals are titanite, apatite, enstatite, and iron oxides, some of the latter having a sagenitic structure suggesting geniculated twins of ilmenite. The amphibole has been considerably chloritized on the edges of grains and in a few places is altered to biotite. The texture is in part diabasic.

Another dyke in the near vicinity is similar in composition but contains some quartz, and plagioclase which is borderline between andesine and labradorite, about $An_{47}$. The augite is much less highly uralitized, and the amphibole occurs in acicular and rosette-shaped aggregates. The name "diorite-gabbro" is considered appropriate for such rocks in which there are local differences in composition. A large dyke of this description occurs on the Grass River approximately four miles west of Grand Rapids.

Some bodies of gabbroic rock contain enstatite as the dominant pyroxene and therefore may be described as norite. They resemble the gabbros in most other respects, including degree of alteration. Dawson states that enstatite commonly has a schiller structure due to parallel orientation of minute inclusions. The writer found two fine-grained dykes of this description, one on the north shore of Assean Lake approximately two miles east of Location B, the other on the south shore immediately south of Location B.

Diabase, Olivine Diabase (9b). Diabase is common throughout the southern part of the area. Textures range from coarse to very fine grained. A medium- grained dyke on the south central shore of Split Lake is almost identical in composition with the gabbro from the Elbow, but contains no enstatite. In general the feldspar in the diabase is more calcic. Another occurrence of rock of strikingly similar composition is a large mass which intrudes Assean Lake sedimentary rocks. The lattice or sagenitic structure of ilmenite distinguishes all three.

Other large dykes of diabase occur along the Nelson River. A large body of olivine diabase underlies a deep bay in the south central region of Split Lake about four miles west of the Ripple River. The rock is greenish weathering and coarse in grain with little indication of feldspar in the hand specimen, so that it resembles a pyroxene peridotite. In thin section a diabasic texture is revealed, with about 20 per cent labradorite ($An_{56}$), 20 per cent olivine, 35 per cent pyroxene, 20 per cent amphibole, and about 5 per cent white mica. Plagioclase forms small euhedral laths. The pyroxene is predominately enstatite intergrown with augite, both being replaced by an amphibole of peculiar pleochroism: X - colourless, Y - light brown, Z - brown. The olivine crystals are traversed by a few hair-like chrysotile-antigorite veinlets and are extensively serpentinized. This rock is intruded in several places by stringers of whitish pegmatite.

On the northwest shore of Witchai Lake a large outcrop of medium-grained gabbro is intruded by a large dyke of fresh-appearing pink granite. The granite in turn is cut by a small dyke of fine-grained diabase, which consists chiefly of plagioclase and amphibole. This diabase has no obvious resemblance to other diabase in the area. On an island in the lake a granite very similar to the dyke just mentioned intrudes granite gneiss and another fine-grained basic dyke.

A similar relationship was observed on the Burntwood River south of the rapids, where small trap (fine-grained basic) dykes appear to be of youngest age. From these occurrences, two ages of diabase are inferred, separated by an era of granitic intrusion. Some of the larger diabase dykes which are not intruded by granite may belong to the group of younger age, but, lacking positive criteria of relative age, this must be considered only as a possibility.

Diorite (9c). The fresher appearing diorites (9c) were found to differ only slightly in composition from previously described gabbros and to which they are probably related in origin, as for example, the Grass River diorite-gabbro.

Certain schistose diorite dykes are included with this group, although they may originally have been either diorites or gabbros. Such a dyke intrudes sedimentary rocks at the east end of Assean Lake and contains numerous small garnet crystals, derived no doubt from contamination by the sediments. The rock consists of approximately 30 per cent plagioclase, a calcic variety of oligoclase $An_{28}$, 15 per cent quartz, and 40 per cent actinolite. The amphibole contains numerous minute euhedra of magnetite. This dyke may represent a schistose portion of the noritic dyke also on the south shore south of Location B. The latter differs in having considerable titanite as well as enstatite.

Another schistose dyke occurs on the south shore of the Burntwood River east of the Elbow and at the extreme east end of Assean Lake. The latter contains staurolite, probably derived from older sedimentary gneisses of the wallrock.

The schistose nature of all these dykes is probably due to their nearness to major faults and shear zones. The first two described are certainly near the Assean Lake fault. The intrusion of the large central granite mass near their southern border no doubt also contributed to their metamorphism.

At the east end of Split Lake a square-shaped island about ½ mile in diameter is underlain by pyroxenite (9d). This rock consists chiefly of orthorhombic pyroxene and augite, thus showing a definite relationship to noritic rocks previously described. The minerals and their alterations are similar to those in the gabbros. Augite appears to be the last-formed primary mineral in the rock except in some pyroxenites in which the hornblende is apparently primary.

Pyroxenite (9d). A pyroxenite consisting chiefly of augite and some hornblende was found on the Grass River about 1 mile north of Witchai Lake. This rock contains a considerable amount of pyrrhotite and a little pyrite, and assays showed a trace of nickel.

Peridotite (9e). Two isolated outcrops of peridotite (9e) were found in the south bay of the southwest end of Assean Lake. The rock is highly serpentinized and contains numerous minute stringers of cross-fibre asbestos which traverse the rock in various directions.

Anorthosite. The writer saw no anorthosite in the area, but Dawson describes some occurrences as follows (1941, p. 24):

> "Anorthosite is occasionally seen in lenticular masses up to 10 feet in length occurring within bodies of gabbro, with which it shows gradational contacts. The anorthosite masses lie near the centre of gabbro dykes 30 or more feet in width and are elongate parallel to the strike of the dykes. The rock is composed essentially of coarse crystals of basic plagioclase, probably labradorite. It appears to represent a residual phase of the gabbro magma, and to have been the last portion of the gabbro dykes to crystallize."

## Granite, Pegmatite, Aplite, Felsite

All the acidic intrusives that lack any gneissic character have been included in this group. Because the various occurrences are grouped together merely on grounds of lithologic similarity some doubt exists as to their relative ages, but in some places the relationships are clear. On the north shore of Split Lake near the Hudson's Bay post, granite dykes were observed cutting gabbro bodies that are intrusive into the grey tonalitic gneiss. On the northwest shore of Witchai Lake similar intrusive relations with gabbro and granite gneisses were observed.

Numerous bodies of massive granite occur throughout the area. Direct evidence of their intrusive relationships with older gneisses was seldom seen in the northern half of the area where contacts seem to be mainly of a gradational character except those of the pegmatite dykes. Nevertheless the writer believes that most of these massive granitic bodies are of similar age and probably of magmatic origin. It seems possible that they had the same source as the granitizing media which transformed sedimentary rocks into granite gneisses, but if so, they must have been intruded much later, preceding irruptions of basic magma. Contacts between granite (10) and granite gneiss (6, 7, 8) are of necessity arbitrarily defined and only approximately located on the map.

The largest body of granite seen in the area lies between Split and Assean Lakes. The rock is typically a pink, medium- to fine-grained granite with blue quartz and some biotite. It consists of approximately 50 per cent potash feldspar (orthoclase, perthitic microcline and myrmeckite), 20 per cent each of quartz and plagioclase, and minor apatite and iron oxides. Biotite occurs as small regularly distributed flakes. Other bodies of very similar granite were found at Witchai Lake, and south of Split Lake approximately 8 miles west of the Grand Rapids on Nelson River.

Most of the outcrops mapped as granite in the northern part of the area are similar to those in the southern part except for a large body of porphyritic granite on the southeastern shore on Waskaiowaka Lake. The phenocrysts are of flesh-pink feldspar, some attaining a length of 2 inches. The groundmass contains considerable quartz and biotite, a fast-weathering material in which the phenocrysts stand out in relief on the surface. Apparently this porphyry grades into medium-grained granite.

Lenses, dykes, and irregular masses of pegmatite are numerous throughout the area, but none are large enough to be mappable on the scale used. As previously mentioned, some are gneissic, or altered to greisen. These and other fresh-appearing dykes which are cut by basic dykes are probably similar in age to the granite gneisses and are grouped with them (7). Those pegmatites which intrude basic dykes are considered to be similar in age to the latest medium-grained granites (10) and are grouped with them. The writer did not see such granites intruded by pegmatite, aplite, or felsite at any location.

Difficulty is admitted in distinguishing between the two ages of pegmatite in many places where the older has no gneissic structure.

Typical pegmatite is coarse and pink coloured and consists chiefly of orthoclase and quartz with few other minerals. An interesting feature of the pegmatite is the intrusion of older rocks by pegmatite stringers forming a complex stockwork. A typical example of coarse gabbro thus intruded occurs on the eastern shore of the Nelson River where two tributaries form a fork around a large island in Split Lake. Similar stockworks are numerous on the shores of Pelletier and Waskaiowaka Lakes.

Aplite (10) is not common in the area, but a few stringers of aplite and pegmatite were found cutting grey granitic gneisses and granite gneisses along the eastern shore of Waskaiowaka Lake.

A few small irregular intrusive bodies of massive fine-grained pink felsite that resembles rhyolite in appearance were found in the large bay of Assean Lake south of Location B.

## GRANITIZATION STUDIES

### OBJECT AND METHODS

In several places in the southern half of the area rocks of sedimentary and volcanic origin grade into granitic gneisses. This relationship strongly suggests replacement or transformation of these surficial rocks by granitic emanations.

The formation of granitic rocks by such metamorphic processes is termed granitization. Grout's (1941) definition of granitization is especially appropriate to the present study: "....... that granitization includes a group of processes by which a solid rock (without enough liquidity at any time to make it mobile or rheomorphic) is made more like granite than it was before, in minerals, or in structure, or in both."

In an attempt to demonstrate the changes which come about by some of these processes and to deduce the nature of the granitizing medium, a number of specimens in various stages of granitization were collected. The relative degree of granitization in these specimens was estimated visually.

Thin sections were made for petrographic analysis. Volume percentages of the essential minerals in the two specimens representing maximum and minimum granitization were estimated by the Rosiwal method.

Chemical analyses were made by Mr. I. Spector, analyst and assayer for the Manitoba Mines Branch.

Several limitations to the value of the investigation are recognized, of which the following probably are the most important:

(1) Owing to the small number of specimens studied and the small area, the investigation is not of the statistical type needed for most conclusive results.

(2) All specimens show at least a trace of granitization and the method of visual estimation is admittedly rough. On the other hand, the two extreme examples could be expected to show significant contrasts in chemical and mineral composition.

(3) The assumption of a heterogeneous composition in the original sediment has been made. Here again statistical study would be of greater value.

(4) The difficulty of accurate separation of certain elements such as sodium and potassium is a common experience to the analyst.

In view of the above limitations this research cannot be expected to contribute a great deal to the problem of the origin of great bodies of granite, but field relations indicate that the processes deduced probably apply to large areas of granite gneiss in the Waskaiowaka Lake area.

## THE FIELD EVIDENCE

Five specimens were collected from an area measuring only tens of feet in diameter on the south of Assean Lake immediately south of Location B. The rock underlying this area is a gneissic complex, the gneissic layering of the more granitic parts having the same strike and dip as the layering of the parts which are of obviously sedimentary origin. Layers of sedimentary material range from several inches down to minute thicknesses, and they tend to fray out or lense out along the strike into more granitic rock.

The sedimentary rock forms a band which can be traced along the strike for several miles. Locally the least altered parts consist of greyish medium-to fine-grained rock, fairly homogeneous in appearance and probably in composition.

One specimen as free from granite as possible was taken, one as completely granitized as possible, and three of intermediate types. Almost any one type may be seen in contact with any other type in the field, and even where the contact is superficially sharp, some evidence of gradation can usually be detected. True "lit-par-lit" layering is considered to be present in places because of its parallelism to the layering of the sedimentary band as a whole.

One contact specimen of a basic volcanic rock was collected from the north shore of Assean Lake for petrographic study.

## THE PETROGRAPHIC EVIDENCE

### Unaltered Sedimentary Rock (1)[1] PLATE IA

In hand specimen the least granitized sedimentary rock is grey in colour both on the fresh and weathered surfaces. It is rather fine-grained, grains averaging about 0.5 millimeters in diameter, and is thinly but regularly layered. Numerous thin black layers of biotite and chlorite are present. Less common are thin whitish quartzitic layers. Minor warping of layering was found in places.

In thin section the rock was found to consist of about 50 per cent plagioclase, 30 per cent quartz, 15 per cent biotite, and 5 per cent accessories and alteration products. The plagioclase occurs in thicker layers than the quartz and has the average composition of oligoclase approaching andesine, about $An_{28}$. Quartz grains are generally slightly larger than the feldspar grains and are chiefly disposed in narrow quartzitic layers. The grains are ovoid in shape. A greenish brown biotite is typical of the rock. Small grains of titanite and apatite are scattered through the rock and very minor amounts of pyrite, magnetite, and zircon are present. Small masses and grains of carbonate, flakes of white mica, and epidote replace the feldspars.

Another sample of similar rock (2) was found to have undergone a slightly different degree of metamorphism. A penninite type of chlorite is replaced by green biotite. White mica is fairly abundant, making up about 10 per cent of tne rock. The plagioclase is andesine, $An_{30}$ in places considerably altered to epidote, zoisite, and sericite.

A layer of granitic material 2 millimeters in thickness lies parallel to the foliation. It consists of a nearly continuous layer of quartz with less continuous and regular layers of potash feldspar with no twinning.

### Partly Granitized Rock (3)

This rock is considerably more granitic in appearance than the specimens of the above category. It consists of thin non-continuous pink and grey layers which represent granitic and sedimentary material respectively. In thin section the plagioclase has a composition of $An_{25}$ and is replaced by more white

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[1] Numbers in parentheses are those of the chemical and Rosiwal analyses listed on page 32.

mica and carbonate indicating breakdown of a more calcic feldspar. Clastic quartz grains have lost their former ovoid shape and are considerably more elongated. Grains of both quartz and feldspar have straighter mutual boundaries showing a greater degree of recrystallization.

## Lit-par-lit-gneiss (4)

This specimen is composed of alternate layers of brownish mainly sedimentary material and pinkish mainly granitic material, which average about 3 millimeters in thickness and several inches in lateral extent. A thin section reveals fairly continuous layers of quartz about 0.1 millimeter in thickness, separated by finer grained aggregates of quartz, feldspar, micas, and carbonates. Quartz forms about 25 per cent of the rock. White mica is more abundant than brown biotite and replaces it. Fresh-appearing potash feldspar, much of it showing the characteristic twinning of microcline, is fairly abundant. The plagioclase is oligoclase of composition about $An_{25}$ and is considerably more altered than the potash feldspar and is believed to form part of the sedimentary material. Relative quantities of the different feldspars were difficult to estimate without using the Rosiwal method.

Although the layers of contrasting material are distinct in hand specimen, the microscope reveals a little granitic material in the mainly sedimentary layers which consist chiefly of quartz and plagioclase believed to be of primary origin.

## Granitoid Gneiss (5) PLATE IB

Parts of the gneissic complex in this area are very highly granitic in appearance and this specimen is believed to be fairly typical. Similar rock was seen in several places in contact with rocks of all types previously described, and it has layering parallel to these rocks. It weathers pink like granite, and black lichens which prefer granitic rocks grow on the surface. Layering is well developed but non-continuous and is caused by thin layers of green chlorite. The greater part of the rock is rather fine grained, resembling rhyolite.

Under the microscope potash feldspar is seen to be about twice as abundant as plagioclase, which is oligoclase about $An_{18}$, much more sodic than that in the other specimens.

Wisps of chlorite occur throughout the rock, and considerable white mica in flakes is present. Biotite was not found. It has probably been replaced by the chlorite. Carbonate occurs in veinlets and numerous grains. Small aggregates of epidote and zoisite were noted.

The texture of this rock is distinguished by the complexity of crystal intergrowth and greatly increased grain size, up to 1.5 millimeters. Layers chiefly of plagioclase indicate survival of considerable sedimentary material in spite of the highly granitic appearance of the rock, and show its affiliation with less granitized types.

## Granitized Volcanic Rock (6)

This rock is green, fine grained, and schistose. It is invaded by reddish tongues of fine-grained granitic material, about one inch long, with sharp contacts. Under the microscope the line of contact still appears fairly sharp, but the composition of the two rock types is more gradational in character. The greenstone contains numerous subhedral to anhedral metacrysts of potash feldspar contributed by the granite which has feldspars of similar size, up to 2.5 millimeters.

The greenstone has a dark, fine-grained groundmass consisting of epidote, zoisite, and chlorite with larger anhedral grains of green hornblende and feldspar. Abundant small untwinned crystals are probably of sodic plagioclase.

Metacrysts developed in the lava consist of quartz and potash feldspar. They are subhedral to anhedral and their edges are irregular in detail suggesting growth by replacement. The feldspars are patch and ribbon perthites, some with Carlsbad twinning. The presence of any plagioclase is considered doubtful.

The relationships observed are considered to indicate some process of replacement rather than injection of molten rock into available zones of weakness. The granite has a porphyritic texture, and much of the fine-grained groundmass has considerable epidote and chlorite, material derived no doubt from the greenstone. The groundmass is made up of intimately intergrown crystals, mainly of quartz and perthite. The larger crystals are similar to those in the greenstone. The texture is not poikiloblastic, but a pattern of interlocked grains of irregular elongate shape. No twinned feldspars were found, and no plagioclase could be identified. The quartz exhibits undulose extinction.

## THE CHEMICAL EVIDENCE

Chemical analyses of four of the specimens of granitized sedimentary rock previously described are listed below. Analyses of (1) and (5) are accompanied by volumetric estimates of mineral composition obtained by Rosiwal methods.

Chemical Analyses

| | (1) | (3) | (4) | (5) |
|---|---|---|---|---|
| $SiO_2$ | 69.24 | 70.29 | 71.49 | 74.88 |
| $Al_2O_3$ | 15.24 | 16.08 | 14.80 | 13.30 |
| $Fe_2O_3$ | .79 | .30 | .28 | .36 |
| FeO | 2.27 | 1.66 | 1.45 | .74 |
| MgO | 1.46 | .92 | .61 | .51 |
| CaO | 3.99 | 3.36 | 2.21 | 1.09 |
| $Na_2O$ | 2.82 | 2.58 | 2.41 | 2.33 |
| $K_2O$ | 3.10 | 3.94 | 5.26 | 5.34 |
| $H_2O$ + | .67 | .69 | .38 | .50 |
| $H_2O$ - | .02 | .01 | .01 | .03 |
| $TiO_2$ | .38 | .36 | .27 | .26 |
| $P_2O_5$ | .08 | .12 | .10 | .05 |
| MnO | .05 | .03 | .02 | .02 |
| Total | 100.11 | 100.34 | 99.29 | 99.41 |
| Specific Gravity ($\pm$ 0.005) | 2.728 | 2.705 | 2.675 | 2.656 |

Rosiwal Analyses

| | (1) | (5) |
|---|---|---|
| Quartz | 26.0 | 30.4 |
| Plagioclase | 43.5 | 21.0 |
| Potash feldspar | 14.5 | 40.4 |
| Mica | 13.4 | 6.9 |
| Alterations | 2.5 | 1.3 |
| Total | 99.9 | 100.0 |

## CONCLUSIONS

Both the petrographic and chemical analyses clearly show that changes other than thermal recrystallization have taken place in the sedimentary rock. With advancing granitization there is a substantial increase in potash feldspar and decrease in plagioclase. This has been accompanied by expectable increase in $K_2O$ and $SiO_2$ and decrease in $Na_2O$, CaO, and mafic oxides such as $Fe_2O_3$, FeO, and MgO. Plagioclase has broken down with liberation of free calcite but the calcium content of the rock has diminished markedly.

It is evident that an important transfer of material has occurred, too great to be explained by simple injection of magma into open spaces. "Lit-par-lit" texture, like that of other types of foliated gneiss in this area is not simply due to metamorphism or anatexis. Some type of replacement must be appealed to in spite of attendant space and energy problems. Replacement by feldspathisation is well shown in the granite-volcanic contact specimen.

The type of replacement may not have been of a forcible type, but the medium seems to have acted like a highly fluid form of matter. Evidence for this is found in the ability of the granitizing agent to penetrate fairly dense, fine-grained rocks.

Highly fluid behaviour is seen also in the tendency to follow open spaces or zones of low pressure in the rock, primarily the planes of foliation, producing a layered gneiss. There is no evidence of metamorphism beyond the biotite grade. Presence of microcline is not generally supposed to be an indicator of extreme temperature. A thin fluid medium at moderately high temperature seems to fit the above conditions best.

## STRUCTURAL GEOLOGY

### FOLDING

The entire area has been subjected to repeated folding, faulting, and igneous intrusion. Detail of the accompanying map and the scarcity of outcrops does not permit of a final structural interpretation, but in the southern half of the area the outlines of major folds have been deduced.

The rocks of the Assean Lake series are believed to have been warped into a large fold in the north central region of Assean Lake. Because the writer was unable to trace the foliation in these sedimentary and volcanic rocks around the presumed apex of the fold, and found no bedding tops, it is not possible to determine whether an anticlinal or synclinal type of fold is present. The structure has also been too much complicated by cross faulting to identify corresponding members outcropping in the narrows on each limb, but a fold is indirectly inferred from the disappearance of the volcanics against sedimentary formations to the east.

Dips within these rocks are generally steep. On the northern limb of this presumed fold they are rather less steep, about 65 degrees, than on the southern limb which has an average dip of nearly vertical. Direction of dip on both limbs is south.

Numerous minor drag-folds were observed throughout the length of Assean Lake. Almost invariably the drag-folds were found to have the same attitude, and were observed to plunge at approximately 60 degrees southwest. Drag-folds are apparently the result of differential movements in a northeast-southwest direction with the effect of displacing the northwest side of the zone mainly to the northeast. Minor reversals in the drag-folds occur, but they are few.

Dawson has observed the pitch of elongation in pebbles of a sheared conglomerate west of Four Mile Lake to be 30 degrees northeast. Thrusting movements in a vertical plane parallel to the pebble elongation could also produce drag folds pitching 60 degrees southwest.

A possibility that this major fold is related to movements along the Assean Lake fault is suggested. In areas of intense movement, such as the narrows of Assean Lake, folds have had a tendency to pass into minor thrust faults measuring inches in displacement. Small trap dykes of the vicinity are affected by this folding, indicating that some of the thrusting occurred at a fairly late date.

Complex folds in the Assean Lake series at the east end of Assean Lake contain interlaminated felsitic material suggesting that the intrusion of the central granite mass was accompanied by the thrusting movements.

Sedimentary rocks in the Split Lake area form a band which is roughly parallel to the direction of regional shear and schistosity which varies from approximately east in the western part to about south 70 degrees east in the Landing River region. This band joins the Assean Lake band thus forming a V-shaped structure. Three explanations for such a structure are suggested:

1. The two bands represent the limbs of a major fold, having an east-striking axis in the central area between Assean and Split Lakes. A minor anticline is indicated by dips in the Landing River area which could be a secondary fold on the southern limb of a major structure.

2. The two bands described above represent members of a concordant series split widely asunder by the wedging action of granitic intrusions, i.e. the central granite mass and possibly some of the gneisses.

3. The two bands represent two different series separated by an angular unconformity.

Although the contact of the two sedimentary bands lies under thick drift cover, Theory 1 is thought to be most probable by the writer. Drag folds are not plentiful in the Split Lake band and those found are not very consistent in attitude.

Theory 2 requires immense forces to effect such a large displacement, although a similar theory has been advanced to account for some of the arches in layered rocks of the Lynn Lake area of Manitoba.

Against Theory 3, the two sedimentary bands are of fairly similar lithology and degree of metamorphism, and have similar relationships to other rocks of the area thus strongly suggesting similarity in age.

## SHEARING, FAULTING, FRACTURING

The more competent rocks of the area, such as siliceous sedimentary rocks and gneisses, have yielded to deformation by fracturing and development of gneissic banding parallel or nearly parallel with bedding planes. It is believed that most of the stress in such rocks was taken up by movement along these planes. On the other hand, a strong schistosity was found in almost all of the less competent andesites, dacites, and basalts, and some of the basic dykes.

Much of the gneissic banding and schistosity is evidently related to the folding and faulting, the latter being responsible for strong lineaments in the topography. Folds in areas of most intense movement, such as the narrows of Assean Lake, have had a tendency to pass into minor thrust faults which measure inches in displacement.

Such folds are the chief criteria that movements on the Assean Lake fault were mainly in the same direction and related to the drag folds previously described.

Dawson (1941, p. 26) lists three lines of evidence for existence of a fault underlying the narrows of Assean Lake and these have been substantiated by the writer's findings:

"1. The impossibility of correlating the geology between one side of the narrows and the other, although the two shores are often no more than 400 feet apart.

2. Strikes of bedding and gneissic banding towards the west end of the north side of the narrows differ by as much as 30 degrees from the strike of banding in the granite gneiss immediately across the narrows.

3. Minor faults, roughly parallel to the direction of the narrows, are commonly observed along the north shore."

This fault is difficult to trace southwest from Assean Lake, owing to drift cover, but it would seem reasonable to assume that it extends along the Burntwood River for some distance.

On the indirect evidence of drag folds which are probably related to the thrust faulting, and some of which pass into minor faults roughly parallel with the main lineament, movement on the fault is considered to have displaced the rocks on its northwest side towards the northeast.

A minor fault roughly parallel with the main fault probably occupies the long bay and river east of Location A. The evidence of direction of movement is the same as that for the major fault.

Cross-faulting in a roughly north-south direction with considerable horizontal displacement can be inferred at several places. East of Location A a band of gneissic sedimentary rocks ends abruptly against a wide zone of volcanics, which seem to form part of a major fold. The contact is covered by a large area of swamp. A smaller dislocation probably occurs along the Burntwood River at its confluence with the Odei River. The fault continues up a tributary north of the Odei River. A band of Assean Lake sedimentary rocks is not continuous in strike southwest across the river junction, and the west side has apparently been displaced towards the north.

Shear zones are plentiful in the less competent rocks, such as volcanics and basic intrusives. In sedimentary rocks and granite gneisses, differential movement has taken place chiefly along pre-existing planes of foliation. The Grass River lineament is the site of a strongly schistose zone parallel with the layering of the garnet-mica-granite gneiss, granite gneiss, and pegmatitic greisen of the region. Biotite and muscovite schist was found in places along the river, and narrow schistose zones occur in basic dykes although large horizontal displacements in those dykes which could be traced across the river were not observed. The writer concludes that this was an area of strong compressive stress with small differential movements along closely spaced planes of schistosity, the movements decreasing in intensity north and south of the river.

Direction of movement in this shear zone is not clear. Drag folds were not found in many places, but at one location near the Nelson River a displacement of the north side towards the west is indicated which may be related to movements in the shear zone.

A smaller shear zone was found in the Burntwood River at the Elbow, at the contact of a basic dyke with granite gneiss.

The northern half of the area is characterized by few obvious structures. A few creek beds appear to be the location of small open faults which trend northeast. This is particularly true of the area immediately north of Waskaiowaka Lake. Granite gneisses north of Pelletier Lake and some of those on Waskaiowaka Lake strike approximately east and have low dips in varying directions. Strike and dip of the schistosity in pink granite gneisses on the southwest shore of Waskaiowaka Lake are fairly regular, apparently resulting from the shearing of granite into plates striking east and dipping from flatly north to vertical. As far as can be determined, there is no marked difference in structure between the north and south shores of this lake.

## ECONOMIC GEOLOGY

### GOLD

The massive nature of the central body of granite in the area between Assean and Split Lakes suggests that movements associated with this latest period of granitic intrusion could have been the cause of the fracture systems into which the quartz veins, silicification, and gold deposits were introduced.

Gold values have been reported from narrow quartz veins in the southern half of the area particularly in the vicinity of the west channel of Nelson River at Split Lake. In 1928 claims were staked at that point, at the mouth of Burntwood River, and around Tea and Copper Lakes, but all have been allowed to lapse.

A group of claims was staked in 1939 at the north-eastern end of Assean Lake but was allowed to lapse in 1940. In 1936 the "Lindal vein" (Location A) was discovered, and a group of claims staked by Messrs. J. Dunbrack, G. Green, and associates. Encouraging gold values were found in surface trenches but diamond drilling brought inconclusive results.

The deposit is said to be lenticular in nature, quartz bodies as much as 175 feet by 7 feet occurring at intervals along a shear zone which strikes east in highly schistose sedimentary rocks. The zone has been traced for a length of 600 feet. The quartz is of a grey cherty type and contains considerable galena, pyrite, sphalerite, and chalcopyrite.

A specimen of bluish grey quartz from the dump was found to be sheared and heavily mineralized, chiefly with galena. Gold colours are easily obtained from panning the material of this deposit and of the "Dunbrack vein" (Location B) which, like the Lindal, can only be examined in summer when the water in the lake is low.

The "Dunbrack vein" was discovered by Messrs. Dunbrack and Green in 1937. Under an option agreement approximately 2,000 feet of diamond drilling was done by Sherritt Gordon Mines Limited, in 1938. Eight consecutive holes showed gold values ranging from 0.12 ounces to 0.98 ounces per ton for core widths of 1.6 to 3.0 feet. The vein was tested at approximately the 40-foot horizon.

The vein fills a fracture zone in an igneous-sedimentary complex, and consists of quartz and mineralized, silicified schist. The vein strikes approximately north 45 degrees east and dips 80 degrees southeast. High water prevented an examination of the outcrop, but samples were obtained from Mr. Dunbrack Abundant galena, sphalerite, chalcopyrite, and pyrite with minor pyrrhotite were found in the material. A grab sample of ore high in galena content showed a gold value of 3.18 ounces and 3.12 ounces of silver per ton, and 0.80 per cent of zinc, and 3.38 per cent of lead. Another selected sample showed 7.42 ounces of gold per ton.

About $\frac{1}{2}$ mile southwest of the Dunbrack vein, a similar vein occurs on a small island. The vein appears to occupy a fractured zone in a fine-grained intrusive gneiss. It is reported to contain visible gold in places, but a grab sample showed only traces of gold.

Other mineral occurrences have been observed by Dawson in the southern half of the area. They are said to consist of (1) cherty quartz veins and stringers containing galena and sphalerite; (2) grey, glassy quartz containing pyrite, pyrrhotite and chalcopyrite; (3) stockworks of quartz stringers accompanied by alteration and mineralization of the surrounding rock; (4) mineralized zones of schistose rock.

Such occurrences are supposed to have been observed chiefly in a broad zone that extends northeast through Assean Lake and the northern part of the Assean River, also at scattered points on Split Lake. Specimens of glassy blue quartz collected by the writer from islands in Split Lake showed no gold values, however.

The northern half of the area, including Pelletier, Waskaiowaka, and B Lakes is remarkably free from any sign of mineralization, as far as this reconnaissance type of exploration has revealed. No quartz veins were found.

The southern part of this area, which includes Assean and Split Lakes, contains large bodies of rock which have been subjected to wide-spread granitic intrusion accompanied by folding, fracturing and later injection of mineralized quartz. The Assean Lake Series, because of its highly varied nature and brittle members, is probably the most favourable formation for gold prospecting, particularly in the vicinity of Assean Lake where folding and fracturing and intrusion are particularly intense. The belts of sedimentary gneiss in the area also may be considered favourable for similar reasons.

An unfavourable feature of the structure is the presence of numerous small cross faults which are considered responsible for the discontinuous nature of some known deposits such as the "Dunbrack vein".

## NICKEL

As previously noted under "Basic Intrusives", several occurrences of nickel have been reported in the southern half of the area in gabbro, diorite-gabbro, and pyroxenite.

In the fall of 1950 the "Pat" group of 138 claims was staked by Canadian Nickel Company Limited, exploration subsidiary of International Nickel Company of Canada, Limited.

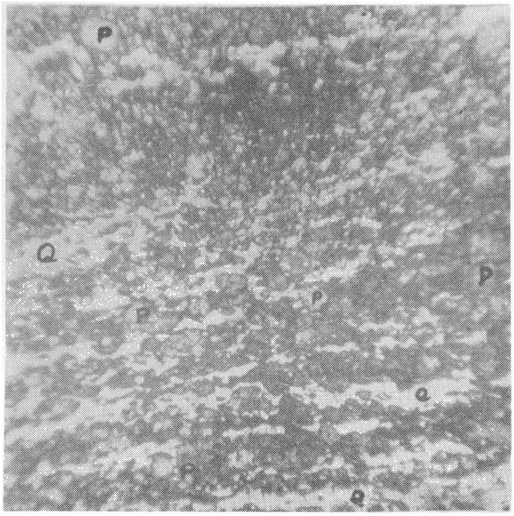
Abundant disseminated pyrrhotite has been reported from parts of the large gabbroic dyke on the south shore of Burntwood Bay in Assean Lake. Unfortunately such occurrences were not seen by the writer.

A small outcrop of pyroxenite was found at low water on the northern bank of the Grass River, approximately one mile east of Assean Lake. The exact location remains unknown due to map inaccuracies in this vicinity. Sparsely disseminated pyrrhotite and pyrite were identified, and assays yielded a trace of nickel.

The presence of large bodies of basic intrusive rock, some of which have a composition related to norite and contain mineralization in places, has aroused interest in nickel prospecting in the last few years.

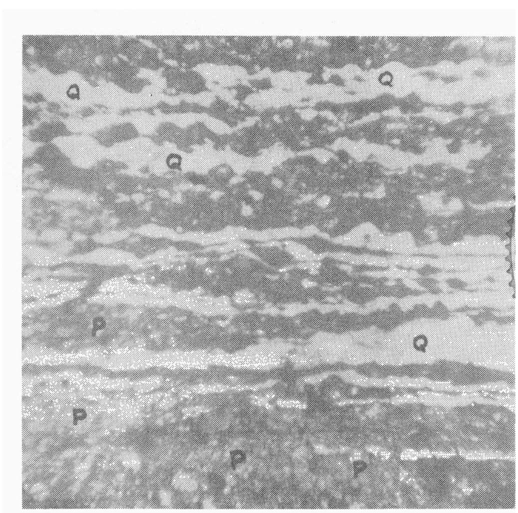
As nickel deposits are especially favourable for prospecting by geophysical methods, the extensive cover of glacial drift may prove less of an obstacle in making new discoveries of nickel than of gold, and more activity of this kind can be expected in the southern half of the area in the future.

Intermittent prospecting has been carried on in the northern half of the region, around Waskaiowaka Lake, for some years but without any known result. The writer, on the basis of a rapid reconnaissance, encountered nothing in this northern area to encourage prospecting efforts in the near future.




A - Photomicrograph of a thin section of sedimentary rock from Assean lake showing relatively unaltered composition and layering.

P - plagioclase (grey), orthoclase and microcline (black)
Q - quartz (white) Magnification: x70 (Page 29)




B - Photomicrograph of a thin section of granitoid gneiss showing highly granitic portions, and remnants of original sediment (plagioclase)

P - plagioclase (grey), orthoclase and microcline (black)
Q - quartz (white) Magnification: x70 (Page 30)