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ELBOW-HEMING LAKES AREA MANITOBA

By
J. C. McGlynn

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Preface

The Elbow-Heming Lakes area lies in the Flin Flon-Sherridon-Snow Lake mineral belt of west-central Manitoba, where 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 types.

According to the present report, the predominantly volcanic rocks of the Archæan Amisk group are partly separated from the adjacent largely sedimentary strata of the Kisseynew gneisses, in the northern part of the area, by complex fault zones and are partly conformable. The grade of metamorphism varies locally but in general increases from south to north. Six separate groups of granitic rocks have been distinguished. Petrographic and structural studies have indicated that some of these are intrusive and some are the result of granitization. All the rocks have been cut by faults and these have exerted the principal control in the localization of many of the mineral deposits of the region.

The report provides a connecting link with previously mapped surrounding areas and is illustrated by two coloured geological maps on a scale of 1 inch to 1 mile.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, May 29, 1958

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CHAPTER I

INTRODUCTION

Heming Lake map-area extends from 54°45′ to 55°00′ north latitude and from 101°00′ to 101°15′ west longitude; it lies between Cranberry Portage and Sherridon along the Canadian National Railways connecting the two towns. Elbow Lake map-area adjoins Heming Lake map-area on the east extending from 54°45′ to 55°00′ north latitude and from 100°30′ to 101°00′ west longitude. The north boundary of the area is 10 miles south of Sherridon and the centre of the area is about 40 miles east of Flin Flon.

Heming Lake map-area is most easily accessible from the railway; Elbow Lake area is reached from Cranberry Portage by canoe by way of the Cranberry Lakes and Grass River. Charter aircraft are based at Channing and Sherridon.

The area was mapped for publication at a scale of 1 inch to 1 mile except locally where more detailed mapping was necessary to ascertain structural relations. Mapping began in 1949 and was completed in 1952.

Acknowledgments

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In 1949 the mapping was under the direction of D. S. Robertson who mapped small areas around Elbow Lake. His work has been incorporated in the map.

Previous Work

The first geological reconnaissance in the area was that of J. B. Tyrrell (1902)[1] in 1896, but the first geological work of consequence in the

[1] Names and numbers in parentheses refer to Bibliography at the end of this report.

general region was done by E. L. Bruce. Late in 1916, Bruce made a geological reconnaissance from Cranberry Portage to Wekusko Lake and later expanded his work (Bruce, 1917, 1918). Gold was discovered in Elbow Lake district in 1921 and the deposits were examined by P. Armstrong (1922) during the following summer. Gold discoveries were made in the east part of the area around North Star Lake in 1927. In 1930, J. F. Wright (1930) examined some of the deposits in Elbow Lake area. Prospecting activity was renewed in Elbow Lake district in 1934 and, in the same year, C. H. Stockwell (1935) studied most of the gold deposits including those around North Star Lake and revised the early geological maps. No further geological work was done in the map-area but adjoining and nearby regions were mapped by J. F. Wright (1929, 1933) and C. H. Stockwell (Wright and Stockwell, 1934), J. D. Bateman and J. M. Harrison (1945, 1946), J. M. Harrison (1949), D. S. Robertson (1950), J. O. Kalliokoski (1952), and T. Podolsky (1951). J. M. Harrison (1951b) published an excellent review of problems of the regional geology and Kisseynew gneisses.

Physical Features

The Elbow-Heming Lakes area features the low, hummocky, rather monotonous topography that is typical of this part of the Precambrian Shield. Hills are generally less than 100 feet above nearby lakes. Much of the district, including the area around Heming, Peterson, Elbow, Webb, Claw and Sewell Lakes, is drained to the east by the Grass River system. North Star and Loonhead Lakes and the surrounding areas are drained to the north by File River. The region around Fay and Syme Lakes and to the east is drained to the west.

The topography of the region bears some relation to the lithology and structure of underlying rocks. High areas are generally underlain by granitic rocks; faults, particularly those in volcanic rocks, are marked by lineaments consisting of long narrow valleys. The 'grain' of the country is characterized by low ridges which are approximately parallel to the regional trend of foliation in the underlying rocks. Similarly, lakes in areas underlain by gneissic or schistose rocks commonly are elongated parallel to the trend of these structures. Lakes in areas underlain by granitic rock are rather small and their shapes are to some extent controlled by jointing in the granitic rocks.

Sand-plains in the area support a growth of widely spaced jack pines and spruce in a carpet of moss. Outcrop in most of the map-area is adequate but except in recently burnt-over sections lichen obscures the rock surface.

CHAPTER II

GENERAL GEOLOGY

All consolidated rocks in Elbow-Heming Lakes area are of Precambrian age and, probably Archæan (early Precambrian). In 1934, C. H. Stockwell (1935) classified all the old volcanic and sedimentary rocks as Wekusko group and stated that they were conformable and of the same general age. Two successions have been distinguished in these rocks and Stockwell's opinion as to their age relations has been confirmed. The older group consists chiefly of basic volcanic rocks and is considered to be equivalent to Amisk as defined by Bruce (1918, p. 9) in the Flin Flon district. The younger group consists of sedimentary rocks overlain by basic volcanic rocks. Correlation with other sedimentary groups in the general region is very uncertain but this group is considered part of the Amisk.

A narrow band of sediments occurs east of Sewell Lake. The same rock type is found in scattered areas in File-Tramping Lakes area. They are unclassified as to age by Harrison (1951b, p. 5) and the author, because of lack of pertinent evidence concerning their age relationship. Thus, the rocks called Wekusko by Stockwell are divided into the Amisk assemblage, including volcanic and sedimentary rocks and an unclassified assemblage of sedimentary rocks.

Kisseynew gneisses are found in the northern part of the area. Bruce (1918) first mapped these rocks north of Flin Flon and concluded that Kisseynew rocks overlie the Amisk group conformably. Later workers in the region have proposed other hypotheses and there is as yet no final agreement on the age relations of the Kisseynew rocks. In parts of Elbow-Heming Lakes area, Kisseynew rocks are in fault contact with the Amisk but north of Fay Lake (Heming Lake map-area) the Kisseynew overlie the Amisk rocks without a structural break. The relationship of the rhyolitic rocks in the area is in part obscure. Stockwell (1935, p. 7) related them to the 'quartz-eye' granite; Harrison (1951b) considered these rocks to be older than the basic intrusions and possibly related to the quartz-eye granite. The rhyolites in the vicinity of Sewell Lake are considered by the author to be older than quartz-eye granite and basic intrusions. Dykes, stocks and flows of rhyolite west and north of Elbow Lake are considered to be in part about equivalent to Amisk and in part younger than Amisk but older than the granites in the area. West of Webb Lake dykes of porphyry cut the hornblende-biotite quartz diorite and are therefore younger than the granitic rocks.

Table of Formations

Age	Formation	Description
Quaternary		Sands, gravels, boulder deposits
Great unconformity		
Archæan or Proterozoic		Pink biotite granodiorite Peterson Lake syenodiorite Claw granodiorite Hornblende-biotite granodiorite Diorite
		Intrusive contact
		'Quartz-eye' granite[1]
		Intrusive contact
		Meta-gabbro, meta-diorite, meta-pyroxenite
		Intrusive contact
		Porphyritic rhyolite, rhyolite
		Intrusive contact
	Kisseynew complex	Granodiorite and pegmatite Granitized and granitoid gneisses Hornblende-plagioclase gneiss Biotite gneiss, locally garnetiferous
	In part fault contact, in part structurally conformable contact	
Archæan	Amisk group	Hornblende plagioclase gneiss, probably altered basic lavas
		Garnetiferous staurolite schists and gneisses; biotite schists and gneisses, locally garnetiferous.
		Minor rhyolitic flows and intrusions, interbedded iron-formation; massive amphibolite, chlorite schists, derived from basic flows; hornblende plagioclase gneiss, in part garnetiferous, derived from basic flows; basic flows, pillow lavas, minor tuff and flow breccia; undifferentiated diorite intrusions
Relations not known		
Archæan or Proterozoic	Unclassified[2]	Garnetiferous biotite-hornblende gneiss, interbedded slate and greywacke

[1] Age uncertain, possibly older than Kisseynew complex.
[2] They are younger than Amisk but relations to Kisseynew rocks are uncertain.

Various types of basic intrusions are found in the west half of the area. They are found only in the Amisk volcanic rocks but are altered by quartz-eye granites, and therefore are later than Amisk and earlier than quartz-eye granite. Their relationship to the Kisseynew gneisses is unknown. They are equivalent to basic rocks common to all areas mapped in this part of Manitoba.

Quartz-eye granite cuts Amisk, alters the basic intrusions in the Amisk, and is cut by the younger granites in the area. It is not in contact with the Kisseynew gneisses and age relationships between the two rock types are unknown.

Cutting all the above-mentioned rocks is a series of granitic rocks of composition varying from diorite to granite and syenite. Granitized rocks are associated with granitic rocks especially where they are in contact with sedimentary rocks.

Amisk Group

Bruce (1918) first applied the name Amisk to rocks of volcanic origin, which are the oldest rocks in the Flin Flon district. Later workers have used the term throughout the region for similar rocks having the same relative age relations. Harrison (1951b, p. 29) defined the Amisk as a conformable succession consisting essentially of basic volcanic rocks but with interbeds of acidic volcanic and sedimentary rocks in varying amounts.

The Amisk in Elbow-Heming Lakes area consists, for the most part, of metamorphosed basic volcanic rocks but also includes minor amounts of acidic volcanic rocks, pyroclastic rocks and iron-formation. Intrusions of fine-grained diorite are mapped with the volcanic rocks. A band of meta-sediments which occurs west, north and south of North Star Lake overlies conformably the basic volcanic rocks. South of North Star Lake the sedimentary rocks are intercalated with the older lavas over a width of about 500 feet. The sedimentary strata consist mainly of biotite schist and gneiss, commonly garnetiferous, and garnetiferous staurolite gneiss. The meta-sediments are overlain conformably by hornblende-plagioclase gneisses lithologically similar to metamorphosed lavas.

The sediments probably correlate roughly with Amisk sediments, with similar relationships, mapped west of Flin Flon (Wright and Stockwell, 1934; Stockwell, 1946) and in the Mikanagan Lake area (Bateman and Harrison, 1945). Because of their structural relations to the older volcanic rocks they are not of Missi age. The structural relationships and facies differ from those of the Snow group mapped in the adjoining map-area to the east (Harrison, 1949) and make correlation unlikely.

Lack of detailed structural information makes it impossible to determine the true thickness of the volcanic and sedimentary rocks. It is improbable that more than 15,000 feet of volcanic rocks are exposed. Roughly 2,000 feet of sedimentary rocks and not more than 2,000 feet of younger volcanic rocks are exposed around North Star Lake.

Lithology of the Amisk Volcanic Rocks

Most Amisk rocks south of Webb Lake, around Elbow Lake, and in the south half of Heming Lake map-area are metamorphosed basic lavas. Pillow lavas occur on some of the islands in Elbow Lake but are not common. Here and there narrow discontinuous bands of basic pyroclastic rocks are found in the lavas. Small intrusions of fine-grained meta-diorite or gabbro, which are not differentiated from the lavas on the map, occur in the volcanic rocks. All these rocks are fine grained, dark green weathering and slightly schistose, and in thin section are seen to consist of roughly oriented light green amphibole and plagioclase (An_{5-15}), with minor quartz, epidote and sulphides. The amphibole is roughly oriented parallel to schistosity but is not segregated into bands. Epidote forms approximately 1% of the rock and occurs as small grains or clusters of grains scattered uniformly throughout it. Chlorite occurs locally as an alteration product of amphibole and where sulphides are abundant the weathered surface is a rusty colour. The meta-diorites differ slightly in that they are somewhat coarser grained and the plagioclase is dusty with alteration products. The pyroclastic rocks contain more quartz and feldspar than the lavas.

Acidic volcanic rocks occur locally throughout the lavas but are most common northwest of Elbow Lake. They weather light grey and consist of a fine felt of quartz and untwinned feldspar with minor amounts of biotite. Locally such rocks are porphyritic with either or both feldspar phenocrysts and 'eyes' of quartz. The feldspar in the phenocrysts is always acidic plagioclase and as far as can be determined the feldspar in the groundmass is similar. A few outcrops of rusty weathering, siliceous, banded iron-formation were found on the east shore of the long bay in the northeastern end of Elbow Lake.

Chlorite-epidote-albite-quartz schists and chlorite-carbonate-quartz schists are common in the Amisk rocks around Elbow Lake and south of Peterson Lake (Heming Lake map-area). These schists are derived from basic lavas that have been intensely sheared, and are most extensive in lavas which are cut by many faults (e.g., around Elbow Lake). The schists are green weathering, fine-grained rocks with a variable mineral composition. Chlorite is usually the most abundant mineral and is white to light green in thin section. Albite and quartz occur as very fine grains; the plagioclase is rarely twinned. Epidote or carbonate occurs as narrow elongate aggregates of small grains.

Large parts of the Amisk rocks, particularly those around Webb Lake, north of Elbow Lake, and around Saddle, Rodwalsh, Fay and Syme Lakes, are thoroughly recrystallized to amphibolites or hornblende-plagioclase gneisses. In the northern areas the rocks are very well banded. The essential minerals are blue-green hornblende, plagioclase (An_{15-65}), and quartz. Epidote, biotite, garnet, and sphene occur locally. In the banded rocks the minerals are segregated into alternating bands of hornblende and plagioclase-quartz. The rocks vary considerably in mineral constitution and the details of this variation and textural variation are discussed in the section on metamorphism.

Hornblende occurs as elongate oriented grains which are pleochroic, X=yellow, Y=olive-green, Z=bluish green. Intensity of colours in the hornblende varies considerably. Garnet, when present, is a reddish colour and in thin section is seen to be poikilitic, rounded and a faint pink colour. Foliation sweeps around garnets, and snowball structures are occasionally noted. The garnet grains are usually rimmed by a mosaic of small quartz grains. Epidote, where present, is found as small grains scattered throughout the rocks and is faintly pleochroic from colourless to yellow, indicating an appreciable iron content.

South of Loonhead Lake bands of garnetiferous hornblende-plagioclase gneiss are intercalated with the hornblende-plagioclase rocks. The garnetiferous rocks have essentially the same mineral composition as the other gneisses but contain less hornblende and more plagioclase and quartz.

Locally, the basic lavas have been converted to rocks consisting of large, roughly oriented, hornblende porphyroblasts up to an inch in maximum dimension in a groundmass containing small hornblende grains, oligoclase, epidote, quartz, and minor sphene. Such rocks, called coarse-grained amphibolite in the field, are found in units mapped south of Webb Lake and around Paton Lake, although they are present in other parts of the area. East of Paton Lake, these rocks were found to grade along strike into normal basic rocks. The coarse amphibolites occur at contacts of granites and basic lavas and are considered to be due to the action of granite on the volcanic rocks.

Hornblende-plagioclase gneisses, derived from basic volcanic rocks, overlie the Amisk sedimentary rocks; they are similar in all respects to such gneisses on the lower part of the Amisk.

Lithology of the Amisk Sedimentary Rocks

The Amisk sedimentary rocks have been converted by metamorphism to biotite schists and gneisses, garnetiferous biotite gneisses, and garnetiferous staurolite-biotite gneisses. Narrow bands of quartzite occur south and west of North Star Lake. In places, granitization has been extensive. Compositional changes across the strike give the rocks a bedded appearance; the strike of the rocks in all places observed is parallel to the strike of the foliation.

Biotite schists and gneisses that are locally garnetiferous are the most common rocks in the series. They weather a light grey and are a light grey on fresh surfaces. Small red garnets occur in some bands. In thin section, these rocks are seen to consist of quartz, plagioclase (An_{24-38}), biotite, and locally muscovite with sphene and sulphide as accessories. Quartz is the most abundant mineral, forming 70 to 80 per cent of the rock. Biotite forms less than 5 per cent of the rock. The minerals form in a mosaic texture typical of metamorphic rocks. Biotite is always well oriented and, as the rock becomes more gneissic, is found in rough bands or streaks. Garnets, when present, are cracked, rounded and a light pinkish colour in thin section. The schistosity swirls around the garnets, indicating rotation during their formation. Garnets have inclusions of quartz and iron oxide; chlorite is associated with some garnets.

Garnetiferous staurolite-biotite gneisses occur in long narrow bands too narrow to map as separate units. The rocks are always gneissic with planes of gneissosity swirled and drag-folded. They weather a light grey and are light grey on the fresh surface. Brown staurolite grains up to half an inch long lie in the foliation planes. In this section, the rocks consist of quartz, plagioclase (An_{18-25}), biotite, muscovite, staurolite, and garnet. The micas are well oriented and are segregated into bands or streaks. Staurolite forms in long narrow grains that are parallel to the foliation planes. Garnet occurs as rounded grains with the foliation planes, marked by mica, wrapped around them; long grains of staurolite also wrap around the garnet.

West of North Star Lake, a series of fine-grained biotite gneisses in the nose of the anticline is similar to other biotite gneisses except that microcline is present in fine-grained mosaic with the other minerals. Textural relations indicate that microcline is a metamorphic mineral and not the result of granitization.

A narrow belt of hornblende-bearing biotite gneisses occurs along the east contact of the band of sediments. The rock is similar to the common biotite gneisses with the exception that it carries about 2 per cent hornblende.

Hornblende which is the blue-green pleochroic occurs as elongate grains parallel to the schistosity. These rocks are commonly garnetiferous.

The sedimentary rocks are, in general, quartz-rich with about 10 to 15 per cent feldspar and less than 5 per cent biotite; they probably represent the metamorphic equivalents of sandstone containing feldspar and clay minerals along with quartz—possibly a subgreywacke. Bands of almost pure quartzite occur in the sedimentary units. The microcline-bearing sediments may represent meta-arkoses. Garnet-staurolite schists that contain more biotite than the average rock of this series and certain biotite-rich garnetiferous rocks are considered to be the metamorphic equivalents of shales.

Unclassified Sedimentary Rocks

Field Relations

Two bands of sedimentary rocks were mapped whose age relations to each other and to other rocks in the area are not entirely known. A narrow band of black metamorphosed shales and fine-grained greywackes is found east of Sewell Lake. The rocks lie between quartz-feldspar porphyry and a basic intrusion, and are intruded and slightly altered by a small plug of 'quartz-eye' granite. Harrison (1949), who mapped similar rocks in various parts of File Lake map-area, suggested that some may be of Missi age, whereas others may be equivalent to the Snow group, and still others represent sediments of Amisk age. The sediments in Elbow Lake map-area are not of Missi age as they are intruded by quartz-eye granite, which is pre-Missi. Field relations indicate that they are older than quartz-feldspar porphyry, basic intrusions, and quartz-eye granite, but age relations with the Amisk group are unknown.

The second group of unclassified sedimentary rocks is north of Webb Lake in the northwestern part of Elbow Lake map-area. These rocks are structurally conformable with volcanic rocks of Amisk age, and are intruded by the granitic rocks in the area. The meta-sediments may be correlated with similar rocks in Batty Lake area, which Robertson (1950) classified as Amisk. Also, they have the same structural relation to Amisk volcanic rocks as do meta-sediments of the Kisseynew complex in the northern part of Heming Lake map-area in that they are conformable and apparently interbedded with the volcanic rocks. However, the sedimentary rocks in Elbow Lake map-area cannot be directly traced along strike through Batty Lake area into Heming Lake map-area, and the rocks in Elbow Lake area differ in mineral composition from the Kisseynew rocks. Therefore they are not

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classified as part of the Kisseynew, but because they may be Kisseynew they are not included with the Amisk, but are grouped separately as unclassified sedimentary rocks.

Lithology

The sedimentary rocks east of Sewell Lake are chiefly fine-grained, grey weathering, dark grey metamorphosed shales and argillites with local interbeds of meta-greywacke. In thin section these rocks are seen to consist of a mosaic of quartz and plagioclase (An_{5-12}) with oriented dark brown biotite which tends to form at grain boundaries of the quartz and feldspar. Larger lath-shaped plagioclase grains are scattered throughout the rocks and are considered to be porphyroblasts formed during metamorphism of the rock. Minor amounts of epidote, muscovite, and magnetite are found in the rock. The muscovite is associated with and oriented parallel to the biotite. The meta-greywacke is similar to the finer grained meta-shales but contains more quartz and less biotite and muscovite.

The sediments north of Webb Lake are grey weathering, medium grey, roughly foliated fine-grained gneisses. Garnets are locally developed in the rock. Under the microscope, the rocks are seen to consist of a mosaic of quartz and oligoclase, (An_{27}), with oriented hornblende and biotite and minor amounts of iron ore. Hornblende and biotite are oriented parallel to the foliation and tend to be collected into bands that alternate with quartz-feldspar bands. Hornblende is pleochroic, (light green to bluish green) and is sometimes poikilitic containing quartz inclusions. Biotite is light brown and well oriented. Garnet, where present, is in poikilitic rounded grains containing inclusions of quartz and magnetite; individual grains are sometimes rimmed with a fine mosaic of quartz. The rock contains about 50 per cent quartz and 30 per cent oligoclase. Primary textures are lacking but present mineral composition indicates a sedimentary origin—possibly a limy shale.

Kisseynew Complex

The Kisseynew complex consists of a heterogeneous assemblage of rocks of various origins, all of which are complexly folded. Originally, these rocks were called the Kisseynew gneisses by H. Bruce (1918). The entire assemblage was named the Kisseynew complex by Bateman and Harrison (1946). Harrison (1949) mapping in File Lake area included Kisseynew type rocks with the Snow group. Robertson (1953) in Batty Lake area, north of Elbow Lake map-area, divided the Kisseynew into two groups—Nokomis and Sherridon. The Kisseynew biotite gneisses and hornblende-plagioclase gneisses in Elbow-Heming Lakes map-area are equivalent to the Nokomis of Robertson. Kisseynew rocks in the northeast corner of

Elbow Lake map-area are equivalent to the Snow group in File Lake area. The author prefers to retain the term "Kisseynew complex" for these rocks in Elbow-Heming Lakes area. These Kisseynew rocks are part of a belt up to 40 miles wide that can be traced in an east-west direction for at least 125 miles and possibly 200 miles.

The relation of the Kisseynew to Amisk has been a problem of local interest since the first mapping in the area. The results of studies by all workers in the area were summarized by Harrison (1951b, p. 40). He listed the four hypotheses advanced by various workers as follows:

1. The Kisseynew gneisses are a complex of different ages, probably including both Amisk and Missi strata, as well as some older and/or younger formations.
2. The Kisseynew gneisses are younger than Amisk rocks, conformable with them, and older than Missi strata.
3. The Kisseynew gneisses are younger than Amisk, lie unconformably above them, and are probably the equivalent of the Missi.
4. The Kisseynew gneisses are separated from the Amisk and Missi rocks by a major fault and, therefore, the relative ages cannot be determined by methods now practical.

To the list may be added the hypothesis of Byers (1954) that the Kisseynew represents the highly metamorphosed equivalent of Amisk and Missi rocks. This hypothesis is more specific but similar to (1) of the above list.

In the northeast corner of Elbow Lake map-area, the Amisk and Kisseynew rocks are in fault contact and, therefore, age relations were not obtained. North of Fay and Syme Lakes, in Heming Lake map-area, the Kisseynew-Amisk rocks are highly faulted (*see* Chapter IV) but information concerning the age relations is available. North of Fay and Rodwalsh Lakes, Kisseynew-type biotite gneisses were found to be conformable with Amisk meta-volcanic rocks, with no intervening structural break, angular discordance, or recognizable erosional unconformity. East of Syme Lake and on the east-trending peninsula in Syme Lake, Kisseynew-type biotite gneiss also occurs in conformable relations with Amisk meta-volcanic rocks. Structures indicating tops have been destroyed by metamorphism and shearing; therefore, relative ages of these rocks are not certainly known. However, rocks north of Fay, Rodwalsh, and Saddle Lakes all dip north at 60 to 80 degrees giving the impression that the Kisseynew-type biotite gneiss overlies the Amisk rocks. These relations agree with those found by Robertson (1951) west of the area mapped by the author. Robertson found Kisseynew-type rocks interbanded with Amisk volcanic rocks.

The above observations indicate that Kisseynew rocks, at least locally, overlie Amisk rocks conformably. The age relations have been complicated by faults which, as pointed out in Chapter IV, are concentrated in the contact area, and in some areas (Loonhead Lake) actually occur at the contact between the two groups of rocks.

The Kisseynew rocks are subdivided into four units as follows: biotite gneisses, amphibole-plagioclase gneisses, mixed gneisses consisting of granitoid and granite gneisses, and granodiorite.

Biotite Gneiss

Biotite gneiss occurs as relatively narrow bands, up to a mile in width, persisting for many miles along strike. It is a brown weathering, well foliated, fine-grained gneiss.

Under the microscope, it is seen to consist of plagioclase, quartz, biotite, and iron oxide. Hornblende, muscovite and garnet occur in minor amounts locally; muscovite is abundant where the rock is sheared. Plagioclase varies in composition from oligoclase (An_{24}) to andesine (An_{38}) and is found as slightly elongate grains, well twinned and fresh. Quartz occurs in a mosaic pattern with the plagioclase as equidimensional grains and may or may not show strain shadows. Biotite is found as long narrow books which are oriented and collected into rough bands. Rounded grains of magnetite are scattered throughout the rock. Hornblende, if present, forms less than 3 per cent of the rock and occurs as elongate grains oriented parallel to biotite. Muscovite occurs locally in minor quantities associated with biotite. Garnet where present is found in small red grains (up to one-sixteenth inch) which are rounded and fractured. The garnets usually contain small inclusions of quartz and iron oxide.

Point-counter analyses of two biotite gneisses are given below. The gneisses vary in composition particularly in amount of plagioclase so that the figures below give only an approximation of the composition.

Table I

Mineral Composition of Kisseynew Biotite Gneiss

Minerals	Volume % (1)	Volume % (2)
Plagioclase	25.7	37.6
Quartz	47.3	46.5
Biotite	20.6	15.5
Garnet	5.9	....

Robertson (1953) compared chemical analyses of these rocks to available analyses of greywackes and rightly concluded that the biotite gneisses are probably derived from greywacke-type sediment.

Biotite gneisses in the vicinity of Fay and Syme Lakes, occurring as they do in a zone of faulting, are intensely sheared in some places. The sheared gneisses consist of biotite, oligoclase (An_{23-27}), quartz, muscovite, magnetite, and locally garnets. On the outcrop the schistosity planes are contorted and drag-folded, the amount of contortion being an index of the intensity of shearing. These rocks differ from the common gneisses in the abundance of muscovite, for in strongly sheared rocks, muscovite forms up to 15 per cent of the schist. Some is oriented parallel to biotite but much of it is oriented at about 40 degrees to this direction, which is parallel to foliation. In some sections, the second orientation is very obvious because quartz and oligoclase display a dimensional and optical orientation parallel to the muscovite. These relations are the result of formation of muscovite during shearing associated with faulting. The shearing and muscovite are later than the original metamorphism of the rock.

Locally, where shearing is very intense, as along the fault that runs through Syme Lake, garnets are developed to an amazing degree. Red garnets up to an inch in diameter occur in the highly contorted and sheared rocks and may form 15 per cent of the rock. Veins and pods of quartz, which tend to form in the crests of drag-folds, contain abundant garnet. There again it seems that intense shearing aided their development. The abundance of garnets cannot be related to the original composition of the sediments because the garnetiferous rock grades along strike into less intensely sheared biotite gneiss that contains a normal amount of garnet.

Hornblende-Plagioclase Gneiss

Hornblende-plagioclase gneiss occurs as bands up to a mile in width, persisting over great lengths. The rock is dark grey to brownish weathering but fresh surfaces are grey to black with compositional banding commonly visible. In thin section the rock is seen to consist of amphibole, plagioclase, quartz with magnetite, apatite and, locally, sphene, biotite and garnets as accessories.

Amphibole is hornblende $2V=73°$, $Z \wedge C=21°$, X=greenish yellow, Y=olive-green, Z=blue-green. Hornblende occurs as elongate grains collected into bands and, in many cases, oriented to form a marked lineation. Plagioclase varies in composition from oligoclase (An_{27}) to labradorite (An_{53}) and is found as rectangular grains which locally exhibit a dimensional orientation parallel to foliation. It is fresh and usually well twinned. Quartz forms rounded grains which are associated with plagioclase. Garnet, where present, occurs in small rounded red grains (up to one-sixteenth inch) which are cracked and around which the hornblende bands swirl indicating rotation.

Some garnets are rimmed by a narrow quartz-rich zone but the relation is not seen in all thin sections. Small chlorite grains are sometimes associated with garnet. Biotite commonly occurs locally as narrow books oriented parallel to foliation; yellow to reddish brown, it rarely exceeds 2 per cent of the rock.

Results of fifteen point-counter analyses are averaged below. Thin sections were etched to distinguish quartz and feldspar.

Table II

Mineral Composition of Amphibole-Plagioclase Gneiss

Minerals	Volume %
Plagioclase	34.6
Hornblende	57.8
Quartz	5.4
Accessories	2.1

These rocks have been assigned various origins by workers in the region. Bruce and Matheson (1930), Wright (1930), and Robertson (1950) considered the hornblende gneisses to represent metamorphosed sediments—limy shales being suggested as the original rock. Bateman and Harrison (1946) and Harrison (1951b) considered the rocks to be mostly metamorphosed basic volcanic rocks. The author agrees with the last interpretation.

The relative thinness of the bands compared to their great length at one stratigraphic level, lack of pyroxene or olivine remnants, banded appearance, and gradational contacts between the hornblende gneisses and biotite gneisses have all been cited as evidence of sedimentary origin. Lack of pyroxene and olivine and banding are the expected results of intense metamorphism. Long narrow bands of rocks known to be of volcanic origin are common in areas underlain by Amisk volcanic rocks. Gradational contacts between amphibole and biotite gneisses were not observed by the author but, in the contact area between the two rock types, hornblende occasionally was present as a minor constituent in the biotite gneisses. The same relationship is found in biotite gneisses of Amisk age along their contact with Amisk volcanic rocks between North Star and Loonhead Lakes. Therefore, the above evidence for a sedimentary origin cannot be considered conclusive.

Chemical composition and pillow remnants are cited as evidence that the gneisses were originally volcanic rocks (Harrison, 1951b). Also hornblende gneisses which can be traced into recognizable Amisk volcanic rocks occur around Fay and Loonhead Lakes. These rocks are indistinguishable from Kisseynew hornblende-plagioclase gneisses. Detailed point-counter analyses on both rock types (15 Kisseynew and about 70 Amisk specimens) show that the present mineral composition of the two rock types is very similar. Both types of hornblende gneiss vary in composition but the range of variation is the same for each type. Basic lavas commonly occur with greywacke-type sediments whereas considerable thicknesses of limy rocks are not commonly associated with greywackes in younger less metamorphosed successsions. The above facts suggest that Kisseynew hornblende gneisses are most probably derived from basic volcanic rocks; however, the evidence for either hypothesis is admittedly not conclusive.

Kisseynew Granodiorite

FIELD RELATIONS

Kisseynew granodiorite occurs as sill or sheet-like bodies which are conformable with the regional structure. Discordant granites are rare in all the Kisseynew so far mapped. The granites are common at the crests or troughs of folds and, in places, appear to thicken in crests of folds, a feature often more apparent than real.

PETROGRAPHIC DESCRIPTION

The Kisseynew granodiorite is a pink weathering, fine-grained, faintly gneissic rock which under the microscope is seen to consist of plagioclase, microcline, quartz, biotite, with magnetite and apatite as accessories. Plagioclase is oligoclase (An_{15-20}) and is fresh and well twinned. Evidence of replacement of plagioclase by microcline was found in several thin sections. Biotite forms books which are oriented parallel to the gneissosity and which may or may not be gathered into rough bands. Muscovite where present is associated with biotite.

Much of the rock mapped is even grained and displays a mosaic texture typical of metamorphic rocks. In marginal zones, it becomes more gneissic and irregular in grain size as it grades to the granitized gneisses described below. Point-counter analyses give the following mineral composition, which is that of a granodiorite.

PEGMATITES

Field Relations. Pegmatites occur almost exclusively in the Kisseynew gneisses. A few very small, fine-grained pegmatites are found in the Amisk rocks, but they are rare and seem related to aplite dykes, which they resemble in all respects except grain size.

Table III

Mineral Composition of Kisseynew Granodiorite

Minerals	Volume %
Plagioclase	41.3
Microcline	18.7
Quartz	31.6
Biotite	5.1
Muscovite	2.2
Magnetite	0.9

In the Kisseynew gneisses, the numerous pegmatites occur as dykes, lens-like bodies and concordant stocks. Most are relatively small but they may be up to an eighth of a mile wide and half a mile long. They are commonly concordant with foliation in the surrounding rocks but cross-cutting dykes have been noted. One of these dykes is known to be a non-dilation type but no evidence as to type was available in the other dykes mapped.

Pegmatites have no geographical or spatial relations to the granites in the area. Their occurrences may be structurally controlled. In the vicinity of Loonhead Lake, pegmatites are very well developed along the limbs and nose of a domal structure. Northwest of Loonhead Lake, they are numerous along the nose of a syncline. In detail, the small pegmatites are found often in the noses of small drag-folds in the country rock. Their occurrence is not related to faulting in the gneisses.

In only a few places were contacts between pegmatite and country rock exposed. In some observed contacts, hornblende gneiss was altered for a few feet from the pegmatite. The amount of hornblende decreased, biotite was formed, the plagioclase became more sodic and quartz increased slightly. This altered zone changed rather abruptly to pegmatite. Country rock within 10 to 15 yards of large pegmatite bodies remained relatively unaltered in most places and at one place the country rock was totally unaltered even at the contact.

Petrography and Petrology. Two types of pegmatites, white and pink, occur in the area. The pink pegmatites consist of acidic plagioclase (An_{9-15}), quartz and microcline. Minor amounts of biotite and muscovite occur and, in large pegmatites, have an erratic distribution. Small red garnets are found here and there in most of the pegmatites examined. No mineralogic zones were noted in any of the pegmatites despite careful examination.

In thin section the plagioclase is seen to occur as roughly rectangular well-twinned grains. Some grains were cracked but no crushing was noted. Quartz forms irregular grains that have a patchy distribution. All quartz grains have strain shadows and undulatory extinction. Microcline occurs as irregular grains and excellent evidence of microcline replacing plagioclase was found in all thin sections. 'Islands' of plagioclase, all optically parallel and with parallel twin planes, occur in microcline grains which in some cases form rough pseudomorphs of plagioclase. Microcline embays plagioclase and in some sections such embayments are controlled or directed by twin planes in plagioclase. The relative amounts of these minerals were impossible to even estimate in thin section because of the coarse grain size. In hand specimen quartz forms about 20 per cent of the rock. Micas are a minor constituent, less than 2 per cent. The relative amounts of feldspars vary considerably but they commonly are present in about equal proportions.

The white pegmatites are similar in most respects to the pink pegmatites except that white pegmatites contain much less microcline, approximately 10 per cent. However, microcline replaces plagioclase.

Granitized Rocks

FIELD RELATIONS

Granitized rocks occur in the Kisseynew gneisses as elongate bands of varying width that are concordant with the gneisses even in detail. The width of individual bodies tends to increase in the crest of folds. There is complete gradation from granodiorite to a granitic gneiss to a granitoid gneiss to amphibole or biotite gneiss.

PETROGRAPHY AND PETROLOGY

The first sign of granitization of biotite gneiss is in an increase in grain size and a slight disruption of the foliation planes. In several places biotite gneiss grades directly to a granite gneiss, the change being marked by increase in plagioclase, decrease in biotite, and finally by appearance of microcline; plagioclase becomes more acidic as granitization progresses. At many localities granitoid gneiss is developed; that is, a gneiss with definite bands of mafics and porphyroblasts of feldspar. Epidote, magnetite, and locally garnet occur in the granitized rocks.

The incipient stage of granitization of hornblende gneisses is commonly marked by development of feldspar porphyroblasts. As the process continues, plagioclase increases in amount and becomes more acidic, quartz and biotite increase, whereas hornblende decreases until none is present. Epidote and magnetite are common in the granitized rock. The resulting rock is grey weathering, obviously gneissic and 'porphyritic' with bands of biotite visible in hand specimen. Hornblende gneisses seem to resist granitization more effectively than do the biotite gneisses. In many, the process goes no further than the development of porphyroblasts and increase in amount of biotite or the formation of migmatite zones. In the author's opinion, most porphyroblastic granitic gneisses in this area are the results of granitization of amphibole gneiss. The more even-grained granitic gneisses result from the granitization of biotite gneisses. However, exceptions to the above statement are known to occur.

In thin sections certain notable features of these rocks are seen. Plagioclase varies with intensity of granitization from andesine (An_{32}) to oligoclase (An_{24}). In rocks that are thoroughly granitized, hornblende is only rarely present but in less granitized rocks that grade to hornblende gneisses, it forms up to 15 per cent of the rock. Epidote and muscovite are always present in small amounts associated with biotite. Biotite is gathered in clots or bands, is well oriented, and varies in amount up to 15 per cent and locally is partly altered to chlorite. Sphene occurs in minor amounts, usually associated with biotite. Magnetite is always present, sometimes forming one or two per cent of the rock. Quartz is marked by undulatory extinction indicating strain.

The porphyroblasts vary in character. They may consist of a number of small grains of quartz, plagioclase and microcline, or of a mixture of plagioclase and microcline in larger grains. In some rocks, the porphyroblasts are single grains of microcline. In most thin sections examined, there was excellent evidence of microcline replacing plagioclase. Myrmekite occurs as small grains associated with microcline. The porphyroblasts have been rotated during their formation, as indicated by biotite bands swirling around them and rough snowball structures. Minor granulation is a common feature in all the rocks.

The sequence of the granitization is probably as follows: First, there was an influx of sodium, some potash, and silica which resulted in an increase of plagioclase and the formation of biotite. As the process continued the amount of introduced potash increased and microcline began to replace plagioclase. The occurrence of these rocks and of the granodiorites described above at the crests or troughs of folds strongly suggests that their position is partly structurally controlled and therefore syntectonic. Migration into such low-pressure areas is to be expected. At the same time magnesium, calcium and iron must have been removed. Some was fixed in such minerals as epidote, magnetite (which is a very minor constituent of unreplaced rocks) and biotite. However, an examination of chemical analyses of hornblende gneisses, biotite gneisses, and the Kisseynew granodiorite indicates that considerable cafemic elements must have been removed even though there is no evidence in the area for a basic front. Amphibolite or biotite gneisses near granitized material show no evidence of having been enriched in mafic minerals. Because granitization was widespread in the area, it can be argued that, in this zone of intensive granitization, physical chemical conditions were not suitable for the fixation of these elements and that they must have migrated out of the zone into areas having favourable conditions for their fixation.

ORIGIN OF GRANODIORITE AND PEGMATITES

The Kisseynew granodiorite is considered to represent the final stage of the granitization processes for the following reasons: (1) it grades into the gneisses, (2) almost all bodies of granodiorite are surrounded by granitized gneisses, (3) it is concordant with structure in older rocks and, in fact, can be considered almost as a stratigraphic unit, (4) foliation and lineation in the granodiorite are always parallel to the regional structure, (5) there is no disturbance of structure in the older rocks such as would be expected to accompany the intrusion of magma, (6) its occurrence in folds suggests that its position is in part structurally controlled, and (7) it has a mosaic texture that in no way resembles an 'igneous' texture.

The pegmatites are equivalent in age to the granitic rocks in the Kisseynew as the localization of both was in part controlled by structures of the same age. The above reasoning applies to the origin of pegmatites. In addition the following features are significant: the non-dilation character of some of the crosscutting pegmatites, the suggestion of structural control of localization of some pegmatites, the relations of the two feldspars in the rock, the composition of the pegmatites, alteration of the country rock around certain pegmatites and the lack of zoning in the pegmatites.

Many of the above facts do not conform with a magmatic origin for the pegmatites. The non-dilation dykes point emphatically to a replacement origin for the particular pegmatites. Pegmatites of magmatic origin, if they are of considerable size, should display mineral zoning because after intrusion of magma, the highest temperature minerals (biotite, basic plagioclase) should crystallize first, presumably along the walls, and more acidic plagioclase and microcline should be concentrated in the centre of the bodies. Such relations are not evident. Also the lack of disruption of structure is difficult to explain if the pegmatites are magmatic. The pegmatites therefore probably have an origin similar to that of the granodiorites. Both are of about the same composition, indicating that in the Kisseynew rocks granodiorites were the stable end point of granitization.

Summary

The biotite gneisses are considered to be metamorphic equivalents of greywacke. Some amphibolites are metamorphosed basic volcanic rocks and some may represent altered limy shales. The whole sequence, therefore, represents highly metamorphosed remnants of geosynclinal rocks. Those rocks, and, therefore, the old geosyncline can be traced in an east-west direction for some 200 miles. Granitization was effective in the formation of granite gneisses, granodiorite and pegmatites.

Porphyritic Rhyolite, Rhyolite

Field Relations

Rocks of this group include dykes, stocks and sills of porphyritic (quartz and feldspar-quartz) rhyolite and rhyolite. Most of the dykes are too small to show on the map; however, mappable units occur north of Elbow Lake, north and south of Sewell Lake, and near Webb Lake. The porphyries are of different ages but are considered together for the sake of convenience and brevity.

Stockwell (1935) considered the porphyries to be related to the 'quartz-eye' granite, both genetically and in time. Harrison (1949, p. 17) considered them to be older than the basic intrusions. Actually there are several ages of porphyry, all of which are of very similar composition and appearance. The porphyry in the vicinity of Sewell Lake cuts Amisk volcanic rocks, is cut by a basic sill, and is, therefore, older than the basic intrusions and quartz-eye granite. However, porphyries near Webb Lake cut granites related to hornblende-biotite granite, which is younger than both the basic rocks and quartz-eye granite. When porphyries occur in the lavas, it is difficult to determine their ages. The older porphyries are more thoroughly metamorphosed than the younger ones, and on the basis of this criteria most of the porphyries are considered to be older than the granitic rocks in the area.

Dykes vary in width from a foot to about 60 feet; some are continuous along their strike for hundreds of feet but others are only a few feet long. Dykes are both parallel and oblique to the regional schistosity. Some porphyry bodies are sheared but almost massive units are common.

Lithology

The sill around Sewell Lake is a light grey to green weathering rock with small phenocrysts of plagioclase up to a thirty-second of an inch and eyes of quartz. The mafic mineral content in this porphyry body varies considerably; in fact, three types can be distinguished. The most common is a rock consisting of albite (An_5), and quartz with varying amounts of chlorite, carbonate, and minor muscovite and sulphide. The chlorite type is found around Sewell Lake and north to Preaston Lake. The second type is similar in all respects to the chlorite phase including the composition of the feldspar with the one exception that biotite is present in amounts of up to 5 per cent. The biotite is oriented parallel to chlorite. The third type contains blue-green hornblende, epidote, biotite, albite, (An_{10-15}) and quartz. Chlorite and carbonate are not found in this phase. The biotite and biotite-hornblende phases were found north of Preaston Lake. The two phases could not be distinguished in hand specimen and so they were not mapped separately in the field.

All three rock types have similar textures. Rectangular albite and rounded quartz phenocrysts occur in a groundmass consisting of a very fine-grained mosaic or felt of these two minerals which form over 90 per cent of the rock. Locally, chlorite is abundant, forming up to 15 per cent of the rock. In all thin sections examined the phenocrysts and eyes were crushed, bent and, in some sections, were locally stretched out into elliptical masses of fine grains. In the groundmass, crushing occurs in elongate zones with only incipient mortar structure developed outside the zones. There is no correlation between degree of crushing and mineralogy.

A few thin sections of small dykes of this rock which occur in the volcanic rocks west of Sewell Lake and north of Preaston Lake were examined. The rocks are similar to the biotite and, less commonly, hornblende phases of the porphyry. Chlorite seems to be less common in the dykes but, as few specimens were collected, this may be a false impression. The chlorite and carbonate in this body and others are considered to be related to shearing because chlorite occurs abundantly only in the sheared porphyries.

The porphyries around Elbow and Webb Lakes are similar to the above, although some of those around Webb Lake are of a different age. They are pink to light grey weathering rocks which are pink to grey on the fresh surface. Feldspar-quartz porphyries, feldspar porphyries, quartz porphyries, and nonporphyritic rhyolites all occur. The plagioclase phenocrysts up to an eighth of an inch are partly altered to sericite. Albite is the common plagioclase but, in some bodies, oligoclase occurs. The groundmass is commonly quartz and plagioclase with biotite plus accessory magnetite and apatite. When the rocks are sheared, as around Elbow Lake, chlorite, some muscovite, brown weathering carbonate and locally pyrite are developed. In some dykes, a distinct blue possibly soda-rich hornblende is found; these rocks carry no biotite.

Basic Intrusions

Field Relations

Basic rocks of various compositions occur east and west of Sewell Lake, east of Preaston Lake, and south and west of Loonhead Lake in the east half of Elbow Lake area. Similar rocks are mapped east of Claw Lake.

These rocks are similar to those mapped in other areas in northern Manitoba. Stockwell (1935) in his table of formations, placed the basic intrusions below quartz-eye granite and described dykes of the granite cutting the gabbro but also stated that north of Reid Lake, south and east of Elbow Lake area, gabbro grades to quartz-eye granite. He considered the gabbro to be an early phase of the granite. West of Sewell Lake, gabbro is separated from quartz-eye granite by a very narrow band of meta-volcanic rock. However, both the gabbro and volcanic rocks have been altered and partly replaced by the granite. Gabbro east of Sewell Lake is also altered around a small plug of quartz-eye granite. Therefore, the gabbro is considered by the author to be older than the granite. North of Sewell Lake, gabbro intrudes quartz-feldspar porphyry and is, therefore, the younger rock. Relations between Kisseynew rocks and the basic intrusions are unknown, as the two are not found in contact. To summarize, the basic rocks are younger than the Amisk group of rocks, the porphyritic rhyolites, and older than all the granitic rocks in the area.

The rocks are mostly massive, but locally, they are schistose along their marginal zones. The body near Loonhead Lake is faintly schistose across its whole width.

Lithology

All the basic rocks in the area have been metamorphosed so that their original compositions are somewhat obscured. Basic rocks east and west of Sewell Lake are meta-gabbros. They are fine- to medium-grained, speckled weathering, dark green rocks which under the microscope are seen to consist of amphibole and plagioclase with minor amounts of quartz, epidote, biotite, chlorite, and iron oxide. The amphibole is commonly a blue-green hornblende with X=greenish yellow, Y=olive-green, Z=bluish green, $Z\Lambda C=19°$, $2V=71°$. Locally, cores of brown hornblende occur in the common hornblende and their pleochroism is X=brownish yellow, Y=medium green, Z=greenish brown. In other specimens a minor amount of actinolite with X=colourless, Y=light green, Z=light green, is found as fibrous grains, which in one instance contained a core of blue-green hornblende. Plagioclase (oligoclase An_{14}) occurs as rough laths and is moderately altered to clinozoisite and white mica. Quartz occurs in minor quantities except in a zone along the western margin of the gabbro east of Sewell Lake. There blue quartz occurs as eyes up to a sixteenth of an inch in diameter. In thin section the eyes are seen to consist of an aggregate of grains all displaying undulatory extinction. In some sections it is evident that quartz replaces plagioclase. Quartz grains contain relict grains of plagioclase, all in optical continuity. In some slides, quartz occurs in lath shape and is considered to be a pseudomorph of plagioclase. These last three relationships are found only in the schistose part of the gabbro near the small body of quartz-eye granite east of Sewell Lake.

Biotite occurs locally, forming long narrow books associated with hornblende. Magnetite, with leucoxene in narrow bands forming a grid structure, occurs in all thin sections examined. Long rods of apatite measuring up to one centimetre in length are common to all gabbros around Sewell Lake. Grass-green chlorite is irregularly distributed as an alteration product of hornblende and is invariably associated with tiny grains of sphene. The gabbro east of Claw Lake is similar in most respects to the rocks described above. The mineral composition, by volume, was determined by averaging six point-counter analyses and is given below:

Table IV

Mineral Composition of Gabbro

Minerals	Volume %
Amphibole	65.2
Feldspar	31.4
Quartz	1.1
Accessories	1.5

The sill-like body east of Preaston Lake is a massive, speckled weathering, medium green rock consisting of tremolite and clinozoisite. In thin section it is seen that tremolite occurs as elongate, unoriented grains with ragged terminations. It is colourless, 2V=77°, with ZΛC=17°. In several grains, cores of a greenish yellow to medium green hornblende were noted. Colourless to pale green chlorite occurs in patches in the rock and along cleavage planes in tremolite. Clinozoisite occurs as large equant to elongate masses which consist of an aggregate of smaller grains. Sphene is found as tiny grains, which are almost always associated with chlorite, occurring in chlorite or at chlorite-tremolite boundaries. Muscovite is found as small books in the zoisite and occurs in very minor amounts.

The mineral composition of the rock as given by the average of three point-counter analyses is as follows:

Table V

Mineral Composition of Gabbro

Minerals	Volume %
Amphibole	59.5
Zoisite	40.5

If the zoisite is an alteration of plagioclase, this rock is then a metagabbro.

A sill-like basic body occurs south and west of Loonhead Lake. It differs from the others in that it is very slightly schistose, not only in the marginal regions but throughout the whole body. The rock is a dark green weathering, fine-grained, medium green aggregate of amphibole grains with minor plagioclase and a few pyroxene remnants. Amphibole occurs as elongate only slightly oriented grains with ragged terminations. It is slightly pleochroic, X=colourless, Y=light green, Z=faint green, $2V=80°$, $Z\Lambda C=18°$. Some grains are bent and have undulatory extinction indicating some strain. A few grains of pyroxene were noted in cores in actinolite grains. Measurements on one grain gave $2V=57°$ (−) $Z\Lambda C=46°$. The pyroxene is either diopside or augite. Actinolite not only rims the pyroxene but also occurs along cleavages in the pyroxene.

Andesine (An_{40}) makes up less than 5 per cent of the rock and, in most thin sections examined, only one or two grains were found. In every section examined, andesine is crushed and in some slides completely shattered to mosaic of tiny grains; in other sections the crushing is only incipient. Tiny rods of actinolite and small grains of clinozoisite occur in the crushed zones.

Chlorite occurs in minor amounts in some sections examined. It is an almost colourless to very faint green variety with grey interference colours. It is found in small patches consisting of a felt of small flakes. Scattered grains of sulphide and a few tiny grains of sphene are the remaining minerals in the rock.

The above mineral assemblage indicates that it is a metamorphosed ultrabasic rock possibly a pyroxenite. However, lack of remnants of primary minerals makes its original composition uncertain.

Granitic Rocks

The term granitic rock is used to refer to plutonic rocks, varying in composition from diorite to granodiorite and syenite. Quartz-eye granite is considerably older than the other granitic rocks and in the Flin Flon area similar granite is pre-Missi in age whereas the remaining plutonic rocks are post-Missi.

Five distinct structural and petrographic units of different ages, in addition to quartz-eye granite, are recognized in Elbow-Heming Lakes area. However, structural and petrographic considerations indicate that these granites are part of one orogenic period.

'Quartz-Eye' Granite

FIELD RELATIONS

Quartz-eye granite occurs as bodies of batholithic size and as small stocks and sills. The largest bodies are found east of Elbow Lake and west of Sewell Lake and smaller stocks and sills occur near them.

Quartz-eye granite, which is lithologically distinctive, was first described by Bruce (1918, p. 30) in Flin Flon area. Subsequently a similar rock type has been described in many areas in Manitoba (Harrison, 1949; Kalliokoski, 1949; Podolsky, 1951; Stockwell, 1935; Wright and Stockwell, 1934).

Quartz-eye granite cuts Amisk volcanic rocks and porphyries, alters basic intrusive rocks, and is cut by the younger granites. It is absent in the Kisseynew complex in the map-area and, according to Harrison (1949, p. 16), in the Snow group, which may be equivalent to Kisseynew rocks. Age relations between Kisseynew rocks and the granite are, therefore unknown; but because the granite does not occur in the Kisseynew, it may be the older of the two rock types. Granitized rocks are found in the contact areas of this granite.

LITHOLOGY

Typically, quartz-eye granite is a fine- to medium-grained rock that varies from light grey to pink and greenish. As the name implies, the rock contains distinct eyes of blue to white quartz which measure up to a quarter inch in diameter and which are evident on the weathered surface. The smaller bodies are often schistose; chlorite and sericite have formed in the sheared granite. The large body east of Elbow Lake is schistose and chloritic in its marginal zones; in hand specimens chlorite is visible and plagioclase has a greyish green waxy appearance. Away from the contact the granite is faintly gneissic and fine grained. The body west of Sewell Lake is gneissic and, for the most part, pink and fresh appearing throughout its whole width. Epidote is commonly visible on fresh surfaces of the granite in all its occurrences. Locally, quartz-eye granite becomes very coarse grained, particularly in the central parts of the large masses.

In thin section the fresh appearing quartz-eye granite is seen to consist of plagioclase, quartz, biotite, epidote, and minor amounts of pyrite or magnetite, apatite, chlorite, sphene, and white mica. Plagioclase occurs as roughly rectangular, well-twinned grains which vary in composition; commonly it is oligoclase (An_{15-24}) but locally it is sodic andesine. Minor mortar structure marks grain boundaries in some thin sections. Quartz forms rounded patches or eyes in the rock that consist of an aggregate of smaller grains that are slightly strained. In most thin sections there is evidence of quartz replacing plagioclase. In one slide, quartz was found in a replacement-type vein in plagioclase (the vein walls did not match). Islands of plagioclase, all in optical continuity, occur in quartz grains; quartz embays plagioclase and, in some instances, the embayments seem controlled by plagioclase twinning.

Biotite is in patches consisting of small grains that are poorly oriented, although in gneissic phases the biotite patches are roughly aligned. Epidote occurs as rounded grains and clusters of grains, both with plagioclase and with biotite, and is pleochroic from colourless to light yellow. In some slides, very small grains are concentrated in the cores of plagioclase grains. Both optical evidence and pleochroism suggest that epidote in plagioclase cores contains less iron than epidote in other parts of the section. Chlorite occurs in small amounts as an alteration of biotite. White mica is found as small books within plagioclase grains, but is not a sericite type of alteration being much coarser in grain size and not occurring as a felt of small flakes. A few grains of sphene are seen to occur with biotite in most thin sections. Small grains of iron oxide, possibly magnetite, are scattered in the rock. Hornblende in minor amounts is sparsely and erratically distributed in the granite.

The chloritic type of rock occurs in marginal zones, especially in the west side of Elbow Lake map-area near Grass River, which marks the position of a fault. Small stocks of quartz-eye granite around Elbow Lake are also sheared and altered in many places. Under the microscope, the rock is similar in many respects to the biotite phase described above. The plagioclase is, however, altered more extensively to sericite and clinozoisite; most plagioclase consists of a felt of small white mica flakes. Composition of plagioclase varies from albite (An_5) to oligoclase (An_{15}). In general, therefore, the plagioclase of the altered phase is more sodic than that of the fresh rock. Biotite is chloritized and in some places the alteration to chlorite is complete. Epidote is common and is colourless to a lemon-yellow and, as evidenced by the deeper yellow colour, seems richer in iron than epidote in the fresh rocks. Sulphide is the common opaque iron mineral in the chloritic rock.

Quartz-eye granite has a distinctive texture. The plagioclase tends to form in patches consisting of several grains of different orientations. Quartz occurs in eyes as described but is not abundant in the plagioclase zones. Biotite is found in patches consisting of small grains of varying orientation.

The average mineral composition (by volume) as determined by point-counter analysis is given below. The figures are averages of seven analyses of both phases. Alteration products were not distinguished in the analyses; no significant differences of essential minerals were found between the two phases described. The rock is actually a granodiorite.

Table VI

Mineral Composition of 'Quartz-Eye' Granite

Minerals	Volume %
Plagioclase	59.4
Quartz	34.8
Biotite	4.1
Epidote	2.5
Opaque	0.3

GRANITIZED ROCKS

Granitized rocks occur around quartz-eye granite where it is in contact with Amisk volcanic rocks. They are especially common west of Sewell Lake, west of Claw Lake, north of Elbow Lake, and around small stocks of the granite. Migmatite zones and hybrid rocks occur over an area varying in width from 100 feet to a quarter mile. The rocks vary in composition depending on the extent of replacement. The relations are complicated in some areas by the same shearing and alteration that affected the quartz-eye granites.

In general, the hybrid rock consists of oligoclase (An_{12} to An_{27}), hornblende, biotite, epidote, chlorite, and quartz. Oligoclase is a major constituent of the rock-forming rough rectangular grains which may be altered to sericite. The pleochroic formula of hornblende is X=yellow, Y=olive-green, Z=blue, which is different from that of hornblende in the adjacent volcanic rocks. The blue colour resembles that of the sodic amphiboles but the optical properties are those of common hornblende. However, the blue colour may indicate an increase in the soda content of the hornblende. Biotite is less abundant than hornblende and is associated with it. Epidote is pleochroic, colourless to lemon-yellow. The rock becomes more basic as the volcanic contact is approached in that hornblende increases in amount, biotite disappears, and quartz decreases and locally disappears. Some thin sections show areas of hornblende-feldspar rock, with the mosaic texture characteristic of volcanic rocks that are surrounded by quartz plagioclase with minor hornblende as in the granitic rocks. One exception to the general sequence in the transition zone is found east and west of Sewell Lake, where, in the volcanic rocks and meta-gabbros near the contacts the first appearance of alteration is marked by blue quartz-eyes. In thin section the quartz is seen to replace feldspar and to have inclusions of hornblende.

The hybrid rock grades into typical quartz-eye granite by an increase in quartz, plagioclase, and biotite and disappearance of hornblende. As the plagioclase and quartz increase, the typical texture is developed. The hybrid zone contains many concordant remnants or bands of volcanic rock varying in width from a few inches up to tens of feet.

Diorites

FIELD RELATIONS

Diorite occurs as rather small bodies south of Rodwalsh, Boot and Saddle Lakes and along the railroad tracks south of Fay Lake in Heming Lake map-area. Dioritic rocks which differ petrographically from these are found south of Syme Lake.

The diorites are the oldest of the group of granitic rocks described on the following pages. They cut Amisk volcanic rock and are cut by the hornblende-biotite granodiorite. The diorites south of Rodwalsh, Boot and Saddle Lakes occur along the margins of the large batholith of hornblende-biotite granodiorite. South of Saddle Lake and east of Heming Lake, dykes of hornblende-biotite granite occur in the diorite.

The contact of the diorite with Amisk volcanic rocks as exposed just west of Rodwalsh Lake is sharp with no visible change of mineral composition in the older rocks. However, as the diorite contact is approached, the foliation of the metamorphosed lavas becomes exceedingly contorted, twisted and drag-folded. Gneissosity in the diorite lacks such contortion and is parallel to the trend of the contact. East of the southeastern end of Fay

Lake, the volcanic rocks trend a little south of east but just east of the railroad tracks, as the diorite contact is approached, the foliation bends sharply to the south and in detail is very contorted. This marked change of strike takes place over a short distance, a matter of about 100 yards. Again, in this area, the gneissosity of the diorite is undisturbed and trends parallel to the contact. In this locality the diorite obviously cuts across the regional trend of the volcanic rocks.

The small bodies of diorite south of Syme Lake have somewhat different relations. There, the diorite grades into hornblende-biotite granite without well-defined contacts. No cutting relations are observed. Long narrow bands of hornblende-plagioclase gneiss are common in the diorite. In places, the diorite forms a migmatite, the alternate bands being hornblende-plagioclase gneiss.

LITHOLOGY

The diorite south of Rodwalsh, Boot and Saddle Lakes is a fine- to medium-grained rock with a speckled black-and-white-weathered surface. It is slightly gneissic but lacks compositional banding.

Under the microscope the rock is seen to consist of plagioclase (An_{28-33}) and hornblende with various amounts of biotite and quartz and minor amounts of epidote, magnetite and, locally, chlorite. The texture of the rock is hypidiomorphic equigranular. Locally, the diorite becomes slightly porphyritic; plagioclase forms the phenocrysts. Plagioclase grains tend to collect in patches with growth interference evident among the grains. Hornblende also occurs in patches of small grains regularly distributed in the rock. Several specimens of the rock from near the northern contact on the shore of Rodwalsh Lake display mortar structure. Plagioclase grains are cracked and rimmed with zones of small crushed grains; quartz is completely crushed. In some thin sections the crushing is intense but in others it is only incipient and in no section examined was the crushing so intense as to cause complete disruption of the original texture.

The diorite south of Syme Lake is a speckled weathering, fine-grained, distinctly gneissic rock with rude to distinct compositional banding. In thin section it is seen to consist of hornblende and plagioclase (An_{25}) with minor biotite, quartz, and epidote. Sulphide and sphene are accessory minerals. Locally, oligoclase occurs as porphyroblasts which have been rotated somewhat during their growth. This variety is commonly richer in hornblende than the normal diorite.

This diorite has a mosaic texture. In all sections examined, the effects of crushing were evident. The plagioclase is cracked and rimmed with fine crushed material but the crushing is not complete enough to destroy the original texture. The composition varies somewhat, with plagioclase and hornblende varying inversely in amount. Commonly hornblende forms 20 to 30 per cent of the rock and minor minerals account for less than 10 per cent of the rock.

As stated before, the diorite occurs as a sort of migmatite with Amisk hornblende-plagioclase gneiss and locally grades imperceptibly into such rocks. The alteration is first indicated by migmatite zones or the occurrence of oligoclase porphyroblasts in the amphibolite. Hornblende decreases in amount and plagioclase increases. The grain size increases slightly and the compositional banding becomes less regular.

Hornblende-Biotite Granodiorite

FIELD RELATIONS

Hornblende-biotite granodiorite occurs as bodies of batholithic dimensions in several parts of the area. The Norris Lake granite in the eastern part of Elbow Lake map-area although not a typical hornblende-biotite granodiorite is on petrographic evidence correlated with it. These rocks are younger than the diorite, but age relations with biotite granodiorite are not certainly established. The biotite granodiorite in some areas appears to cut hornblende-biotite granodiorite and in other areas grades into it. The two rock types usually occur in large, separate distinct bodies. These facts suggest that the rocks are roughly the same age. Probably the biotite granodiorite is, in part, slightly younger. Foliation in the older rocks is concordant with the contact of the granodiorite and tends to wrap around the granitic bodies. This is well illustrated in these rocks around Norris Lake. The foliation in the volcanic rocks trends north, south of the body, but sweeps east and west around the granodiorite as the contact is approached. Similarly at the north end of the granitic mass, the foliation swings parallel to the contacts. In some contact areas, the basic volcanic rocks are strongly sheared. Along parts of the contact the granodiorite is porphyritic with plagioclase phenocrysts, and is somewhat more basic close to the contact. The contact between granitic and volcanic rocks is mainly sharp with little or no granitization and no migmatite zones but south of Syme Lake, the hornblende-biotite granodiorite grades into a diorite which in turn occurs as the granitic layer in migmatites with volcanic rocks. Also north of Webb Lake, large areas of granitized rock were mapped where the granite is in contact with sedimentary and volcanic rocks. There the sedimentary, and to a lesser extent meta-volcanic, rocks grade to a grey hornblende-biotite granitic rock that is commonly porphyritic, and which in turn grades rather abruptly to the typical hornblende-biotite granodiorite.

LITHOLOGY

The hornblende-biotite granodiorite is a pink to grey weathering, fine- to medium-grained gneissic rock. Grey to greenish grey or buff feldspar, lavender coloured quartz, and locally pink microcline distinguish this rock in the hand specimen. Under the microscope it is seen to consist of oligoclase (An_{19-28}), hornblende, biotite, quartz and microcline with minor amounts of magnetite, sphene, apatite, epidote, and chlorite.

The plagioclase, which occurs as rough well-twinned laths, is partly altered to white mica and clinozoisite. Some of the grains show ill-defined zoning, which, in altered plagioclase, is marked by variation in degree of alteration. Hornblende occurs as poorly oriented grains and is pleochroic, X=yellow, Y=olive-green, Z=bluish green. Small rounded discrete grains of slighly pleochroic epidote are associated with hornblende or biotite. Sphene occurs as very small grains in or at the edge of biotite grains and, in some instances, biotite is almost completely rimmed with very small grains of sphene.

The texture is hypidiomorphic equigranular. Gneissic structure, which is obvious in the outcrop, is less obvious in thin section. Mafic minerals tend to occur in patches that are roughly aligned. Hornblende grains display a rough orientation and, in some thin sections, there is a noticeable dimensional orientation of the plagioclase.

Both field work and thin section study show that this rock actually varies in composition from diorite to a granodiorite. Locally, hornblende is present only in minor amounts and microcline forms over 10 per cent of the rock. Quartz varies inversely with hornblende but plagioclase remains fairly constant in amount. In some areas, the rock seems to be more basic near the contact, but this is not always so, as south and east of Heming Lake the rock varies in composition with no apparent relation to contact areas. Granodiorite and quartz diorite are the most abundant rock types. Point-counter analyses of typical specimens were averaged and are listed below.

Table VII

Mineral Composition of Hornblende-Biotite Granite

Minerals	Volume %
Oligoclase	57.4
Quartz	18.6
Biotite	10.1
Hornblende	10.2
Microcline	2.7
Accessories	0.6

A more or less reconnaissance thin section study of the granitized rocks substantiates evidence for granitization obtained in the field. In some thin sections the metamorphic texture of the sedimentary rocks is only slightly modified and plagioclase forms porphyroblasts that are slightly rotated. As replacement becomes more intense, the plagioclase increases in amount and becomes more sodic, the rock becomes coarser grained, and the original foliation becomes less marked. The granitized rock is often richer in biotite than is the granodiorite itself.

Biotite Granodiorite

FIELD RELATIONS

Two large batholiths of the biotite granodiorite occur in the area mapped. The larger is found in the central part of Elbow Lake map-area, and extends a short distance north into Batty Lake map-area (Robertson, 1950, *see* map), and south into Iskwasum Lake area (Stockwell, 1935, *see* map) for a distance of about 10 miles. In all, the batholith is about 30 miles long and about 10 miles wide. The second body is in the western part of Heming Lake map-area.

As has been previously stated, the biotite granodiorite is probably slightly younger than the hornblende-biotite granodiorite. It is post-Kisseynew and post-Amisk; but is cut by a younger biotite granodiorite in Heming Lake map-area.

Migmatite and granitized rocks occur at the contact between this granodiorite and volcanic or sedimentary rocks. In many places this zone is too narrow to map as a separate unit, but in other places it is up to half a mile wide. The granitized rocks are extensive west of Loonhead Lake where the granodiorite-Kisseynew contact runs across the regional strike. Other areas of granitized sediments were mapped west of North Star Lake. In the biotite granodiorite body in Heming Lake map-area, an area of very gneissic granite with numerous narrow inclusions or bands of basic rock has been mapped separately.

LITHOLOGY

For the most part the biotite granodiorite is a pink to buff weathering, fine-grained, gneissic rock with flesh coloured plagioclase, pink microcline, white quartz, and biotite visible in the hand specimen. Under the microscope, the rock is seen to consist of oligoclase (An_{11-15}), quartz microcline, and biotite with minor amounts of epidote, muscovite, magnetite, and rarely sphene. Plagioclase occurs as elongate rectangular grains which are well twinned and partly altered to white mica or kaolinite. Commonly oligoclase grains are aligned approximately parallel to the gneissosity. Some grains are zoned (core An_{20}-edge An_{15}), but the zoning is indistinct, being a gradation from the centre to the edge marked by extinction that sweeps from the core outwards. In some grains alteration is concentrated at the cores of grains. Quartz occurs as small grains with plagioclase or as patches consisting of an aggregate of smaller grains. All quartz has undulatory extinction.

Microcline occurs as irregular grains of various dimensions. It commonly embays oligoclase, and some grains contain irregular islands or remnants of plagioclase in optical continuity. Microcline, therefore, replaces oligoclase. Perthite and myrmekite occur in minor amounts wherever microcline is present in the rock in appreciable quantities. Perthite has an occurrence similar to that of microcline but there is no evidence to indicate that it replaces plagioclase. Small grains of myrmekite are commonly found near microcline grains. Also in such rocks tiny hook-shaped grains of quartz (often in optical continuity) are found near the edges of some plagioclase grains.

Small light yellow grains of epidote occur in biotite clusters. Muscovite is also associated with biotite but forms less than one per cent of the rock.

The texture of the rock is rather distinctive. Quartz tends to be concentrated in patches made up of small grains. Biotite also is collected in rough bands or elongate clusters which locally more or less wrap around plagioclase grains. The gneissic structure visible on the outcrop is marked in thin section by rough bands of biotite and alignment of clusters of biotite; regular compositional banding is not evident in thin section or for that matter on the outcrop. Oligoclase forms elongate or blocky grains. Crushing is commonly evident; oligoclase grains are cracked and rimmed with small crushed grains, and quartz is shattered. Crushing is especially evident in fault zones. In these zones where shearing is severe, muscovite is commonly developed, plagioclase becomes altered and quartz streaks out into long rods. However, no crushed microcline was seen in any thin section examined.

The mineral composition of the main mass of the rock, obtained by point-counter analysis, is given below. The rock in Elbow Lake map-area is relatively constant in composition in the central part of the batholith, although quartz, microcline, and plagioclase vary somewhat. The body in Heming Lake map-area is more variable in composition as migmatite and very gneissic zones are scattered throughout the granite. The rock is a granodiorite in composition.

Table VIII

Volume Percentage of Biotite Granodiorite

Minerals	Volume %
Oligoclase	38.7
Quartz	39.0
Microcline	17.1
Biotite	4.9
Accessories	0.3

As noted above, granitized rock commonly occurs in the contact zones of biotite granodiorite. In the field, granodiorite grades to a more gneissic rock which in turn grades to a more basic rock displaying marked compositional banding. This last rock locally grades into a zone of migmatites and, in other places, grades into feldspathized rocks. Migmatite zones are commonly found along contacts between granodiorite and basic volcanic rocks.

In thin section, the gneissic granodiorite is similar in composition to the typical granodiorite, but has less microcline and is more variable in composition and grain size. Mafic minerals form in definite streaks and oriented clots, and compositional banding is evident. Biotite is more abundant and hornblende is locally present. Some of the granitic rock in the migmatite zones consists chiefly of quartz and plagioclase, but in other areas the granitic rock carries 15 to 20 per cent hornblende and biotite. The basic volcanic rock part of the migmatite remains unchanged. In the feldspathized rocks, commonly meta-sediments, plagioclase may form as porphyroblasts that show evidence of rotation or as grains of about the same size as the remnant minerals of the rock. Feldspathization of the rocks is marked by a coarsening of grain size and a disruption of the regularity of the compositional banding and, of course, by an increase in feldspar. Where feldspathization occurs in the basic rocks, plagioclase always forms as porphyroblasts and quartz increases in amount. Muscovite, epidote, and magnetite are minor constituents of the rock. Oligoclase varies in composition from An_{11} to An_{29}, the more basic plagioclase occurring in zones of less intense metasomatism.

The above observations indicate that during granitization there is an influx of Na_2O and SiO_2, and K_2O into volcanic rocks, and of Na_2O into meta-sedimentary rocks. Microcline is present only locally and in those places the rock is more granitic in appearance than elsewhere. Microcline seems to form late in the sequence of granitization.

The granitized rocks have a mosaic texture if even grained, although porphyroblasts of oligoclase may be present, and the rocks are gneissic to strongly banded. Locally, mortar structure is present in these rocks, with quartz and oligoclase cracked and crushed in various degrees. Contortion of foliation planes and rotation of plagioclase grains indicate that granitization was syntectonic.

Sedimentary rocks seem more susceptible to granitization because the rocks in the largest area of granitized rock, west of North Star Lake, were originally sediments although bands of unreplaced sediment occur throughout these gneisses. The only extensive areas of granitized basic rocks occur where the granite-amphibolite contact is diagonal to or across the regional strike, as west of Loonhead Lake. Such a relationship probably facilitated migration of material along foliation planes. In zones of granitized basic rocks, unreplaced remnants or inclusions are very common.

Peterson Lake Syenodiorites

FIELD RELATIONS

The Peterson Lake complex varies in composition from diorite to syenodiorite to syenite. The rocks are found west, northwest, and south of Peterson Lake in Heming Lake map-area. The large body west of Peterson Lake extends south into Cranberry Portage map-area.

The Peterson Lake syenodiorites cut the hornblende-biotite granodiorite and biotite granodiorite and are, therefore, younger. They are cut by the pink biotite granodiorite.

Contact relations with the basic volcanic rocks are obscured by faulting, as south of Peterson Lake diorite and meta-volcanics are in fault contact. Diorite dykes are found in the hornblende-biotite granodiorite in their contact zones.

LITHOLOGY

The Peterson Lake complex varies considerably in composition and texture. The most abundant types in the area mapped are diorite and syenodiorite; however, in Cranberry Portage map-area, syenite is also found.[1] The rock is commonly porphyritic with plagioclase as phenocrysts and is black and buff weathering, fine to medium grained, and distinctly gneissic. Bluish maroon plagioclase laths, hornblende, and biotite are visible in the hand specimen.

Under the microscope the rock was seen to consist essentially of plagioclase and hornblende with various amounts of biotite and microcline

[1] T. Podolsky, personal communication.

and minor amounts of quartz, titanite, epidote, iron oxide and apatite. Plagioclase is in well-twinned (carlsbad twinning common), roughly oriented laths that vary in composition from oligoclase (An_{23}) to andesine (An_{35}). The more basic plagioclase is found in dioritic phases. Some grains are almost entirely altered to sericite but most of the feldspar is fresh. Some laths are bent but there is no evidence of crushing.

Poorly oriented, stubby grains of hornblende tend to concentrate in patches in the rock. Pleochroism is commonly X=greenish yellow, Y=olive-green, Z=grass-green. In some grains, however, areas of hornblende occur where the pleochroism is X=yellow, Y=green, Z=brownish green. The brown hornblende occurs in cores of large grains and grades to the green hornblende. Pyroxene is found as small grains in the cores of hornblende grains, either green or brown; it is monoclinic and either augite or diopside. Not enough of the mineral was present for an accurate determination. The above relations indicate that at least some, and probably all of the hornblende is secondary. The green hornblende is definitely secondary after brown hornblende. Brown hornblende, in some places at least, is secondary after pyroxene.

Biotite occurs as books associated with hornblende and forms no more than 5 per cent of the rock. It is invariably associated with sphene. Microcline, where it occurs, is in irregularly shaped, altered grains. No evidence was obtained concerning its relations to plagioclase. Rounded epidote grains are scattered throughout the rock. The rock is colourless to deep yellow, which suggests that it is relatively iron-rich. Small grains of sphene occur as inclusions in or at grain boundaries of hornblende and biotite.

The texture as a rule is hypidiomorphic equigranular. Locally, the rocks are porphyritic with plagioclase as well-oriented laths; in such rocks the texture is almost ophitic.

Variations in composition are apparent in hand specimen and more so in thin section. Quartz varies in amount from zero to 10 per cent. Biotite may be absent or present in amounts up to 5 per cent. Microcline varies from zero to about 10 per cent in the rocks examined. Plagioclase is always the most abundant constituent forming up to 60 per cent of the rock.

Pink Biotite Granodiorite

FIELD RELATIONS

The pink biotite granodiorite is the youngest plutonic rock in the area mapped. Dykes of this rock are found in hornblende-biotite granodiorite, biotite granodiorite, and the Peterson Lake syenodiorite. The largest body mapped lies east and south of Heming Lake in Heming Lake map-area and extends east into Elbow Lake area. It is present east and south of Peterson Lake and smaller bodies occur west of the railroad track in the south part of Heming Lake map-area.

There are no granitized rocks associated with the granodiorite and the granodiorite is not everywhere concordant with surrounding rocks. North of Peterson Lake, the gneissosity of the granodiorite, which is parallel to the contact, cuts obliquely across the gneissosity in the hornblende-biotite granodiorite. Similar discordant relations are found east of Separation Creek. Fifty per cent of some outcrops of older rocks near the contacts consist of dykes of granodiorite that are slightly finer grained than the main mass. Such dykes are most abundant in the granitic rocks, and basic volcanic rocks in contact with the granodiorite contain only a few dykes. There is little evidence of contact metamorphism in the basic rocks at the granodiorite contact. Locally, the rocks have a baked appearance, but thin section study reveals no hornfels texture of appreciable change in metamorphic grade.

The granodiorite is itself cut by dykes of finer grained rock which in hand specimen and thin section appears to be a fine-grained equivalent of the granodiorite.

LITHOLOGY

The granodiorite is a pink to reddish weathering, fine- to medium-grained, equigranular, slightly gneissic to massive rock. Pink to reddish feldspars, white rounded quartz grains, and biotite are visible in hand specimen. In thin section, the rock is seen to consist of plagioclase, microcline, perthite, quartz, and biotite with minor amounts of chlorite, epidote, white mica, hornblende, and iron oxide.

Plagioclase is oligoclase (An_{12-16}) and occurs as fresh, well-twinned, rectangular grains which form in clusters with small grains of quartz filling the interstices. A few grains are roughly zoned. Quartz occurs as rounded grains consisting of an aggregate of small grains all of which exhibit undulatory extinction.

Microcline occurs in various amounts as blocky to irregularly shaped grains and replaces oligoclase in all sections examined. It embays plagioclase; some embayments seem controlled by twinning in the oligoclase. Small grains or islands of oligoclase, all optically parallel, are found in grains of microcline. Perthites are common in rocks rich in microcline and consist of coarse blobs, irregularly shaped grains, and hook-shaped masses of sodic plagioclase in the potash feldspar. Biotite is found in quantities less than 5 per cent and occurs as small books which are roughly oriented.

Faint yellowish green to grass-green chlorite is an alteration product of biotite and in some areas, the alteration is almost complete. Muscovite is locally present, closely associated with biotite, and epidote occurs as discrete grains usually with biotite.

The rock in hand specimen is faintly gneissic to almost massive. In thin sections of gneissic rock, feldspars are roughly aligned and in some outcrops, quartz aggregates are aligned. Locally, particularly in fault zones, the rock is crushed; quartz may be completely crushed whereas oligoclase is rimmed with crushed grains and seems to resist crushing more than does quartz. In some thin sections crushing is very intense in narrow elongate zones whereas, in the remaining part of the thin section, it is only incipient.

The composition of the rock is that of a granodiorite. The chief variation in composition is in the amount of microcline, which may vary from 2 to 25 per cent of the rock. An average of four point-counter analyses is given in the following table.

Table IX

Mineral Composition of Pink Biotite Granodiorite

Minerals	Volume %
Oligoclase	43.1
Quartz	33.1
Microcline	18.2
Biotite	4.4
Accessories	1.2

Regional Distribution of Granitic Rocks

Table X shows sequence of granitic rocks and their distribution in the area between Flin Flon and Wekusko Lake, some 50 miles east of Flin Flon. The information is based on the author's mapping in the Elbow-Heming Lakes area, from published works of the Geological Survey of Canada, from personal observations in areas surrounding the map-area, and from conversations with some of the authors of the publications referred to above. The correlations are, therefore, tentative and will no doubt be modified as more work is done in the region.

Few changes were made in the original workers' sequence of granitic rocks. However, some authors grouped all granitic rocks together; in such areas the various granites were separated on the chart on the basis of their published descriptions. In the Weldon Bay area, Kalliokoski (1952) has separated the granitic rocks into groups that correspond petrographically to the division made by the author and by Podolsky (1951), but his age relations differ in many respects. For the purposes of the chart, his sequence of granites is altered to correspond to those in adjoining areas to avoid confusion and the reader is referred to Kalliokoski's publication for his analysis of the relations between the various granites.

Some interesting facts are emphasized by a study of the chart. Firstly, the quartz-eye granite and the basic intrusions are widely distributed in this area of Manitoba. They are known to occur in Saskatchewan and throughout the area from Flin Flon to Wekusko Lake. A study of the various maps shows that the quartz-eye granite does not outcrop in the Kisseynew rocks or, in fact, near the Kisseynew-Amisk contact. The large masses of this rock type commonly are at least 7 or 8 miles south of the contact.

Kisseynew granodiorites are distributed throughout the Kisseynew complex. Age relations between this and other granites in the area are not certainly known.

Of chief interest is the regional distribution of granites younger than quartz-eye granite. In the east, in the Crowduck Bay area (*see* Table X), rocks corresponding to the biotite granodiorite and hornblende-biotite granite are present. Farther west, in File Lake area, biotite granodiorite and to a lesser extent hornblende-biotite granodiorite form the major granitic intrusions. The same is true in Elbow Lake map-area except in the extreme western part. There and in the Heming Lake, Cranberry Portage and Weldon Bay map-areas, the rocks correlating with pink biotite granodiorite, Peterson Lake diorite and syenodiorite, and diorite make their appearance. In other words, the younger granitic rocks are, as far as can now be determined, confined to the western part of the area whereas the older rocks are found in all parts of the area. Study of maps of the area reveals that the older granites in the east occur in very large batholiths (*see* File Lake and Elbow Lake map-sheets), whereas in the western section all granitic rocks form smaller bodies and areas underlain by volcanic and sedimentary rocks are, therefore, larger.

The diversity of both type and age of granitic rocks, more extensive areas of volcanic rocks, and the occurrence of young Missi sediments in the western part of the area give the impression, to the author at least, that the rocks exposed in the Flin Flon area are from a higher crustal level than those exposed in the east.

Origin of Granites

The various granites are considered to be related to one period of orogeny although they are of different ages. The petrogenesis of the

Table X
Regional Correlation of Granitic Rocks

Elbow-Heming Lakes Area *McGlynn 1959*	Flin Flon Area *Stockwell 1946*	Mikanagan Lake Area. *Bateman, Harrison 1945*	Athapapuskow Lake Area *Buckham 1944*	Weldon Bay Area *Kalliokoski 1952*	Cranberry Portage Area *Podolsky 1951*	File Lake Area *Harrison 1949*	Crowduck Bay Area *Frarey 1948*
pink biotite granodiorite	Kaminis granite	albite granite, massive granodiorite	granite, granodiorite (includes biotite granite, hornblende granite, hornblende-biotite granite)	Alaskite granodiorite, diorite, gabbro	pink biotite, granite	pink microcline-rich granite (? in Harrison's report included with granites below)	biotite granite, quartz diorite, granodiorite
Peterson Lake syenodiorite	Boundary intrusions	hornblende diorite, diorite porphyry, quartz feldspar porphyry?			syenite gneiss and syenodiorite		
biotite granodiorite	granite, granodiorite, quartz diorite	granodiorite gneiss, porphyritic granodiorite gneiss		biotite granodiorite, hornblende granodiorite, quartz diorite, hornblende diorite	quartz diorite, biotite-hornblende diorite, granodiorite	biotite granite (includes biotite-hornblende granites)	
hornblende-biotite granodiorite							
diorite					porphyritic diorite		
Kisseynew granodiorite	not present	albite granite and granodiorite	not present	Alaskitic granodiorite	not present	granodiorite (in Harrison's report included with above)	granodiorite (included with above by Frarey)
'quartz-eye' granite	Cliff Lake granite porphyry	'quartz-eye' granodiorite?	'quartz-eye' granite	Alberts Lake granodiorite (in part 'quartz-eye' granite)	epidote-biotite granite gneiss	'quartz-eye' granite	'quartz-eye' granite
basic intrusions		basic intrusions of varying composition	basic intrusions of varying composition	?	hornblende gabbro	basic intrusions of varying composition	

hornblende-biotite granodiorite and of the biotite granodiorite, which are probably closely related in time and which form the bulk of the granites, are considered together.

Both granites form large masses that display for the most part conformable relations with the country rock. Gneissosity in granites is parallel to the regional foliation. Locally, as west of Loonhead Lake, the contact is at right angles to the structure in the hornblende-plagioclase gneisses of Kisseynew age; however, the contact area is there marked by a zone of granitization and extensive areas of migmatites. Rather large elongate masses of the older gneiss are common in the granites and in some places are a considerable distance from the main granite-amphibolite contact. Yet the foliation in these inclusions is parallel to the regional foliation and also to gneissosity in the granitic rocks. Granitized rocks and migmatite zones are common in the contact zones. In the biotite granodiorite around Wapun Lake, a large area of granitized rocks with numerous amphibolite inclusions grades both to amphibolite or meta-sediment and to granite. In areas where the granite contact is parallel to regional foliation the contact zone of hybrid rock is usually narrow, in some places a matter of a few feet.

The granitized rocks are characterized by a mosaic of crystalloblastic grains. The granites are gneissic throughout but their texture differs in detail from the granitized gneisses. Plagioclase is the most abundant mineral and forms rough laths that tend to cluster together. Biotite occurs in clusters of small books which are oriented. The texture is not a truly igneous texture nor is it typical of metamorphic rocks.

The hornblende-biotite granodiorite varies in composition from a diorite to a granodiorite. The variations in composition, in some places, bear no relation to the contacts of the granite and in many there is no predictable zoning from basic rock at the contact to acidic rock in the central zones of large masses.

The present mineral assemblage in both rocks is one that is stable at temperatures of the epidote amphibolite and amphibolite facies of metamorphism. This fact has an important bearing on the origin of the rock because it indicates that if the rock is magmatic it has been recrystallized. It is significant that the stability conditions of the minerals in the granites are equivalent to those of the mineral assemblages in the older rocks.

In the light of recent investigation (Bowen and Tuttle, 1950; Laves, 1952) the feldspar relations in the biotite granodiorite are particularly significant. Ignoring for the moment the effect of lime on the system, a magma of composition necessary to produce the granodiorite should at high temperatures permit crystallization of only one feldspar. At lower temperatures

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the feldspar should unmix to two feldspars, a potash-rich and a soda-rich. If the unmixing is complete, microcline and plagioclase will result. Presence of large amounts of water will depress the liquidus curve possibly to the extent where two feldspars may crystallize simultaneously. Addition of lime to the system in amounts over one per cent will probably, according to Tuttle (1952), change the course of crystallization in such a way that at first a plagioclase will crystallize using up the lime, then a homogeneous potash soda feldspar will crystallize which must again unmix at lower temperatures. From these considerations, we see that even with lime or excess water in the system, microcline and plagioclase must result by unmixing or must crystallize together. The temperature of unmixing is in the range 550 to 600 degrees. Microcline in the biotite granodiorite replaces plagioclase. If the evidence of this replacement is accepted, then microcline is later than plagioclase and not contemporaneous with it. Also a replacement relationship cannot be explained by unmixing from homogeneous feldspar. These facts seem to indicate an origin other than magmatic for the granite. At least if the rock has crystallized from a magma then at some later time microcline was formed. If the rock crystallized from a magma the minimum temperature was somewhere above 600 degrees. This temperature is higher than temperatures at which minerals in the metamorphic rocks, even at the contacts, were stabilized. Perthites in the granodiorite contain very minor amounts of albite in the form of tiny rods or blobs which, assuming complete exsolution, also indicate lower temperature, about 400 degrees (Laves, 1950).

An evaluation of the evidence is difficult to make. The mineral assemblage of the granitic rocks and the feldspar relationships suggest a non-magnetic origin. Structural relations are inconclusive in some ways because local discordance is evident but, in some places, rocks grade along strike into granites. Also, undisturbed bodies of meta-volcanic rocks occur within the granite at considerable distances from the contact, suggesting absence of structural disruption during the formation of the granite. On the whole, the evidence indicates a metasomatic origin for the hornblende-biotite granodiorite and biotite granodiorite.

These granitic rocks are of slightly different age and were probably formed by the same process. The biotite granodiorite, which is thought to be the younger of the two, represents the end product of the granitization process. Granodiorite was also the final product of granitization in the Kisseynew.

The Peterson Lake syenodiorite differs in many respects from the rocks mentioned above. The present mineral composition puts the rock into the amphibolite facies of metamorphism, but cores of pyroxene in hornblende indicate that a higher temperature assemblage was once stable. South of the area mapped the same rock contains labradorite, feldspar, and pyroxene.[1] In the same area volcanic rocks along the contact of the rock have been metamorphosed to pyroxene hornfels. The syenodiorites were in fault contact with volcanic rocks in the area mapped. The Peterson Lake mass is gneissic, with feldspar laths aligned to outline the gneissosity, and in some areas the texture is almost ophitic. The syenodiorites are for the most part concordant with the regional structure, but crosscutting dykes of it occur in the older granites. Contact metamorphism and evidence of a former high temperature mineral assemblage indicate that syenodiorite has formed at high temperatures. The mineral assemblage in the surrounding rocks (epidote amphibolite facies) represents a lower temperature assemblage. These relations indicate a magmatic origin. Whether a magma or a semi-solid mush was intruded is unknown but the ophitic texture indicates intrusion of magma. After consolidation of magma, pyroxene was converted to brown hornblende which in turn formed green hornblende. Epidote developed during these post-consolidation changes, which took place at temperatures equivalent to those prevailing in the older rocks, indicating that the syenodiorite, if magmatic, was intruded during the regional metamorphism.

The pink biotite granodiorite is the youngest rock in the region. Contacts are sharp with no associated granitization. Country rocks are locally baked in appearance yet there is little or no evidence of contact metamorphism. The rock is slightly gneissic to almost massive, with only the faintest alignment of feldspar visible in most outcrops. The granodiorite locally displays discordant relations to regional structure. The mineral assemblage indicates that the minerals formed at a temperature corresponding to that of epidote amphibolite or amphibolite facies of metamorphism. Dykes of the rock are very numerous in all contact areas.

The microcline-plagioclase relationships are essentially the same as those in biotite granodiorite and, therefore, the same reasoning applies in both cases. Perthites, however, differ from those in the biotite granodiorite. Perthite is more abundant in the rock and consists of about 40 per cent exsolved albite. Such a perthite, is, according to Tuttle (1952) "evidence per se of high temperatures and suggests a magmatic history for the rocks concerned". According to Laves (1950), however, the temperature of such a combination in deep seated rocks is about 550 to 600 degrees. Such temperatures are possibly at the very lowest limit of magma.

[1] T. Podolsky, personal communication.

The evidence, therefore, is conflicting. Certain features of the granite such as structural relations, contact relations, numerous dykes of these rocks, lack of associated granitized rocks, all indicate a magmatic origin. The stability relations of the present mineral assemblage and microcline-plagioclase relationships however point to a non-magmatic origin. Perthites suggest a high temperature and, according to Tuttle, a magmatic history. If a magmatic history is assumed, the temperature relations indicated by the present mineral composition could be explained by recrystallization. Because the granodiorite is intruded by dykes of a finer grained granodiorite it is, therefore, possible that at the time of this intrusion potash was introduced, thus accounting for the feldspar relations and for other mineral changes. A metasomatic history is suggested by present mineral stabilities and for feldspar relationships, but metasomatism fails to account for the perthites unless one postulates a replacement origin of the perthites. This necessitates a complex process in which potash feldspar replaced plagioclase and then albite replaced some of the potash feldspar. With such conflicting lines of evidence, one can only balance the various facts and suggest possible origins. The facts that the syenodiorite is probably of magmatic origin and that the pink granodiorite is later than the syenodiorite and geographically related to it in the general region, suggest that the two may be related and have a common magmatic origin.

In summary, then, the hornblende-biotite granodiorite and biotite granodiorite are considered to have been formed by a metasomatic process. The Peterson Lake syenodiorite is considered to be of magmatic origin and it is suggested that the pink biotite granodiorite is also of magmatic origin. The latter granites have been recrystallized at sub-magmatic temperatures during which epidote and oligoclase, or andesine in the syenodiorite, were stabilized. In the syenodiorite, pyroxene was converted to hornblende at this time.

It is evident that during granitization sodium and silica are first introduced; potash is later in the sequence and seems less mobile. Only where granitization is complete is microcline at all abundant. The final product of granitization in the area seems to be a granodiorite. It is interesting to note that similar relations (especially concerning the mobility of potash) were found in the Beaverlodge area by Christie (1953).

Overburden

Glacial deposits consisting of sand, gravel, clay and boulders cover considerable areas of the Elbow-Heming Lakes area. The common deposit is a mixture of sand and clay that possibly represents lake deposits. A large area of such material is found in the northeast corner of Elbow Lake map-area, and a smaller area lies in the northern part of Heming Lake map-area.

A flat, wide sand-plain occurs east of North Star Lake. The sand is fine, even grained, and probably results from glacial outwash. Fairly large areas of similar material occur southwest and north of Heming Lake and east of Fay Lake. Gravel beds occur in these sand deposits near Heming Lake and just southeast of Fay Lake. The gravel near Heming Lake has been used for railway construction. Such gravel deposits are not extensive and are not high quality gravel.

Glacial boulders are scattered about the rock surfaces and on other glacial deposits. A few boulders of Ordovician limestone were noted in the area between North Star and Preaston Lakes. These rocks consist of a buff weathering, fine-grained dolomite.

Outcrops, particularly on hill tops, have been striated and, locally, polished by glaciers; the direction of movement indicated by the strike of striations is roughly 20 degrees west of south.

CHAPTER III

METAMORPHISM

All the volcanic and sedimentary rocks, basic intrusions, and some of the granitic rocks in the map-area have been metamorphosed. The alteration, involving as it does recrystallization accompanied in some cases by crushing and orientation of newly formed minerals, is the result of high temperatures and pressure or shearing stress. The bulk chemical composition of the rocks is not changed to any great extent during the metamorphism; however, in the vicinity of granitic rocks, the process is accompanied by addition of material which tends to convert the rocks to granites, a process known as granitization.

The degree of metamorphism varies within the map-area and in a general way the variation follows a regional pattern. The rocks in the northern part of the area are more intensely metamorphosed than those in the south. However, during the field mapping and subsequent laboratory studies it was not possible precisely to define or to outline on a map the various zones of metamorphism.

Metamorphism of the Amisk Basic Volcanic Rocks

The following assemblages are found in the basic volcanic rocks in the east half of the Elbow Lake map-area:

1. Hornblende-plagioclase (An_{15-30})-quartz-biotite
2. Hornblende-plagioclase (An_{15-30})-epidote-quartz-biotite
3. Hornblende-plagioclase (An_{30-60})-quartz-biotite
4. Hornblende-plagioclase (An_{30-65})-epidote-quartz-biotite
5. Hornblende-plagioclase (An_{30-65})-garnet-quartz-biotite
6. Hornblende-plagioclase (An_{30-65})-diopside-quartz.

The base of the amphibolite facies is set at a plagioclase composition of An_{30} (Ramberg, 1949) and (Barth, 1952) so the above assemblages belong to the epidote amphibolite, and amphibolite facies. According to Turner's classification (Turner, 1948), which with the above-mentioned refinement is used in this text, the following subfacies of the amphibolite facies are present: staurolite-kyanite, sillimanite-almandine and almandine-diopside, or hornblende.

The distribution of these assemblages follows a regional pattern but there is no gradual increase in grade which enables one to draw an isograd line on the map. In general, however, the volcanic rocks around Sewell Lake contain plagioclase in the range An_{14} to An_{32} and epidote is common in these rocks. Around North Star Lake, the plagioclase is in the range An_{22}-An_{36}, but north of North Star Lake, the plagioclase range is An_{26}-An_{65}. Epidote is more abundant in the south than in the north. Hornblende also varies from south to north for as the plagioclase becomes more calcic, the colour of the hornblende becomes more intense. Quartz varies in amount but its distribution is erratic and bears no relation to intensity of metamorphism. About half-way between North Star Lake and Loonhead Lake, garnet appears in the basic rocks. It is commonly associated with plagioclase more calcic than An_{30} and commonly between An_{35} and An_{45}, but it does occur with plagioclase as sodic as An_{25}. In the area of volcanic rocks south of Loonhead Lake, the presence of garnet is in part controlled by original composition of the rocks because garnetiferous bands are enclosed in hornblende-plagioclase gneiss having no garnet and they contain more plagioclase and quartz than do the garnet-free bands. Biotite and sphene are erratically distributed throughout the amphibolites but never occur in quantities more than one or two per cent. Sphene occurs as inclusions in or at grain boundaries of hornblende. The presence of biotite and sphene cannot be correlated with relative amounts of essential minerals on the basis of available information.

Like other features of these rocks, there is considerable variation in texture which, in a general way, fits into a regional pattern. In the south, around Sewell and Preaston Lakes, the rocks are fine grained. Hornblende is well oriented; but only locally is hornblende collected into bands to form a compositionally banded rock. Farther north, around North Star Lake, a rough banding is evident in thin section although less obvious in the outcrop. Between North Star and Loonhead Lakes banding becomes more obvious and is easily visible in outcrop unless obscured by later faulting and associated shearing of the rocks. The banded rocks are coarser grained than rocks farther south. In this region of banded rocks, hornblende is well oriented and collected in distinct bands which alternate with plagioclase-quartz bands. The twinning of the feldspar varies also; in fine-grained rocks, plagioclase is poorly twinned and, with quartz, forms a mosaic of fine grains which are much smaller than hornblende grains. In the better foliated and coarser grained rocks, the plagioclase in the mosaic increases in grain size and begins to develop twinning; the feldspar and quartz form in rough lens-like patches in the rock. Finally, in still coarser grained and well-foliated rocks, the plagioclase is well twinned (albite and less commonly pericline) and forms blocky grains in mosaic with rounded grains of quartz. Locally, plagioclase forms porphyroblasts around which foliation 'swirls' to indicate that they were rotated during their growth.

The above results, based on detailed studies in the east half of Elbow Lake map-area, are corroborated by a less detailed study of the basic volcanic rocks in other parts of the area mapped.

The rocks around Elbow Lake contain an assemblage of epidote-actinolite-albite to oligoclase-quartz. The rocks are somewhat schistose. Thus, most of the rocks around Elbow Lake that have escaped later metamorphism are of the epidote amphibolite facies. Locally, rocks of the amphibolite facies are present. As previously described, rocks of greenschist facies (chloritic schists) occur around Elbow Lake. These rocks are confined to shear zones and are common in this area because of extensive faulting.

North of Elbow Lake, around Webb Lake, the rocks are of the amphibolite facies with the typical assemblage of hornblende, plagioclase (An_{25-40}) and quartz. Epidote is locally present. North of Webb Lake, compositional banding with attendant coarsening of grain size is evident. All the basic volcanic rocks around Syme, Fay, Rodwalsh, and Saddle Lakes are of the amphibolite facies and epidote is locally present. Garnet occurs in rocks along the shores of Fay and Syme Lakes and plagioclase is calcic (An_{30-40}). The rocks are compositionally banded except where intensely sheared. Around Vamp Lake, south of Syme Lake compositional banding is not evident in hand specimen but can be seen in thin section. Plagioclase is oligoclase-andesine from An_{20}-An_{35}. These rocks are of slightly lower grade than those to the north.

Metamorphism of the Amisk Sedimentary Rocks

The following mineral assemblages were recognized in the Amisk sediments:

1. Plagioclase (An_{20-42})-biotite-quartz
2. Plagioclase (An_{15-35})-biotite-muscovite-quartz
3. Plagioclase (An_{22-38})-biotite-muscovite-garnet-quartz
4. Plagioclase (An_{28-38})-biotite-muscovite-microcline-quartz
5. Plagioclase (An_{16-25})-biotite-staurolite-garnet-quartz
6. Plagioclase (An_{25-38})-biotite-hornblende-garnet-quartz.

According to Turner's classification (1948), these assemblages are typical of the staurolite-kyanite subfacies of the amphibolite facies. The microcline-bearing assemblage is due to an excess of K_2O. According to Turner (1948, p. 84), microcline is stable if $\frac{CaO+K_2O+Na_2O}{Al_2O_3}>1$.

Epidote occurs locally but cannot be correlated with any of the above assemblages or with plagioclase of any compositional range. Sphene is also locally present but is not distinctive of any particular assemblage. Where these rocks are granitized, however, sphene is almost always developed.

Muscovite is, in part, a mineral of a stable assemblage but where these rocks are sheared, muscovite increases in amount until locally it is more abundant than biotite. The same relationship was noted in the biotite gneiss of the Kisseynew.

The hornblende-bearing assemblage is restricted to a narrow strip along the eastern contact area of the meta-sediments. Its presence probably is related to an original difference in composition and not to grade of metamorphism. The hornblende is well oriented and poikilitic, growing around and including quartz grains. It does not exceed more than about 2 per cent of the rock.

The microcline-bearing rocks are restricted to the area west and a little north of North Star Lake where they occur near an area of granitized rocks. However, there is no structural or textural evidence of introduction of potash to account for the presence of microcline. In thin section, microcline has all the appearances of a mineral in equilibrium with other minerals present.

It is evident that the biotite gneisses of the Amisk group are metamorphosed to the same degree as are the volcanic rocks in the area. However, in these sedimentary rocks, there is less obvious evidence for an increase of metamorphism from south to north, the only change being a general coarsening of grain size from south to north. As the grain size increases, the plagioclase also becomes well twinned and compositional banding becomes evident in the rock.

Metamorphism of the Basic Intrusions

The grade of metamorphism of the basic intrusions seems to be lower than that of the surrounding basic volcanic rocks. The typical mineral assemblage in the meta-gabbros around Sewell Lake is blue-green amphibole, plagioclase (An_{15}), quartz, and epidote. This assemblage belongs to the epidote amphibolite facies. The meta-gabbro east of Preaston Lake has the assemblage tremolite-epidote (Fe poor)-chlorite. The assemblage in the body of basic rock south of Loonhead Lake is actinolite-chlorite-plagioclase (An_{40}?). The plagioclase of this rock is possibly out of equilibrium with the other minerals. The last two assemblages are difficult to place in the facies scheme. They may be part of the greenschist facies with the lack of talc being explained by deficiency in SiO_2. Also it is possible that they belong to the epidote amphibolite facies. The absence of feldspar makes precise classification difficult.

These assemblages show that the rocks are of a lower metamorphic grade than the meta-volcanic rocks in which they are found. This is particularly true of the tremolite-bearing rocks near Loonhead Lake for the Amisk rocks around this body rank high in the amphibolite facies. The stable mineral in the amphibolite facies for a rock of this composition is anthophyllite and it is not present in the basic intrusion. In the latter case, the Fe-Mg ratio in the rock may be the controlling factor. Another explanation may be the lack of schistosity in these rocks. It has been noted elsewhere that these rocks are massive to slightly schistose. The Amisk volcanic rocks are well foliated. It seems that the basic intrusions, probably because they were originally massive and medium grained (during regional deformation), resisted the forces imposed upon the rocks in the area. This lack of penetrative movement in the basic intrusions possibly accounts for the lower degree of metamorphism relative to the surrounding rocks. The absence of penetrative movement would hinder conduction of heat and solutions and, in this way, slow the processes of metamorphism.

Certain primary features in these rocks have survived metamorphism. For example, pyroxene remnants occur in the body near Loonhead Lake and very long rods of apatite and magnetite with altered ilmenite in grid structure occur in the meta-gabbro around Sewell Lake. These features or remnants must be due to lack of strong deformation.

Metamorphism of the Kisseynew Rocks

The following mineral assemblages have been recognized in the biotite gneisses:

1. Plagioclase-biotite-almandine-quartz
2. Plagioclase-biotite-hornblende-quartz
3. Plagioclase-biotite-quartz.

The mineral assemblages found in the hornblende-plagioclase gneisses are:

1. Plagioclase-hornblende-quartz
2. Plagioclase-hornblende-quartz-almandine.

The rocks of the Kisseynew are, therefore, of the amphibolite facies, commonly staurolite-kyanite subfacies. The rocks almost invariably are compositionally banded. Feldspar is well twinned and forms a mosaic with quartz. These rocks are similar in metamorphic grade to rocks of the Amisk which occur in the north half of the area. There is complete overlap in mineral composition and the textures of the Kisseynew rocks are exactly reproduced in Amisk rocks of similar grade. For a very detailed study of the metamorphism of Kisseynew rocks the reader is referred to Robertson (1953); the author essentially agrees with Robertson's findings.

Regional Considerations

As previously mentioned, there is a general increase in grade of metamorphism from south to north in Elbow Lake area. However, it must be emphasized that there are many exceptions and the gradation is statistical, especially in the east half of the area. The gradation is from epidote amphibolite to amphibolite facies. Harrison (1949) found a similar increase in grade in File Lake area in pelitic rocks. His sequence is biotite schists, garnetiferous biotite schists, garnetiferous staurolite schists, sillimanite-bearing gneisses. It is notable that, according to Turner, the last three rocks are typical of the staurolite-kyanite and sillimanite-almandine subfacies of the amphibolite facies. The first assemblage is possibly equivalent to the epidote amphibolite facies. It is evident, therefore, that the grade of metamorphism is about the same in both areas. Rocks in Weldon Bay area (Kalliokoski, 1952) seem to be of the epidote amphibolite and amphibolite facies. A parallel increase was found in the Missi sediments near Flin Flon by Ambrose (1936). However, rocks of the amphibolite facies are found in Cranberry Portage area[1] (Podolsky, 1951) which is south of the Elbow Lake area. Rocks in the Kisseynew belong to the amphibolite facies wherever studied.

In general, it can be concluded that rocks in Flin Flon-Snow Lake region of Manitoba are, for the most part, metamorphosed to the epidote amphibolite and amphibolite facies and the intensity of metamorphism increases from south to north. Locally, rocks of the greenschist facies are found, but in Elbow Lake map-area such rocks are correlated with shear zones and are considered to be the result of retrogressive metamorphism.

[1] T. Podolsky, personal communication.

CHAPTER IV

STRUCTURAL GEOLOGY

The general trend of the folded structures in most of the area is north; however, folds in the Kisseynew rocks trend northeast to east. The folds in the east part of Elbow Lake area plunge north but the plunge of those in the vicinity of Elbow Lake is uncertain. Folds in the Kisseynew contact area plunge northeast to east.

Direction and plunge of both linear elements and drag-folds are shown on the map. Lineation is marked by alignment of elongate amphibole grains, elongation and alignment of clots of minerals and small crenulations in planes of foliation. In the volcanic rocks around Elbow Lake, the lineation, where developed, seems to be inconsistent and of little use in deciphering the structure. Some lineation is related to faults and is of no significance in determining the plunge or geometry of folds. Drag-folds also are related both to folding and to faulting. Some, therefore, plunge parallel to the major folds, others are related to movements occurring in areas of intensely sheared rocks in fault zones. The latter drag-folds are useful in determining the relative direction of movement along the faults.

In almost all areas mapped, primary structures, such as crossbedding, grain gradation, or pillow lavas, have been completely destroyed making top determination impossible. Pillow lavas occur around Elbow Lake but the rocks are sheared and individual pillows stretched so that top determinations are at best unreliable. Thus, in areas of basic volcanic rocks with no marker horizons the structure is unknown except in a general way. Foliation and gneissosity, as far as can be determined, are parallel to original structures in both sedimentary and volcanic rocks such as compositionally distinctive bands of sedimentary rocks, contacts between different rock types and between sedimentary and volcanic rocks, and bands of pillow lava. This is generally true for schistosity except where it is induced by shearing in some fault zones. Fault or shear zones are commonly parallel to regional structural trends but several cross-faults are known.

Folds

In the volcanic rocks around Elbow Lake, the regional strike trends a little east of north. Dips are commonly between 75 and 90 degrees but a few are around 50 degrees. Lack of primary structures in Amisk lavas makes it difficult to decipher the structure. Scattered top determinations on altered pillow lavas on the shores of Elbow Lake suggest that the basin of the lake may be a syncline, a structure that is complicated by smaller folds and faults. The volcanic rocks wrap around the north end of a large mass of quartz-eye granite located east of Grass River, possibly indicating a syncline which, according to lineation, plunges steeply south.

West of the south end of Elbow Lake, the basic lavas north of the mass of hornblende-biotite granodiorite form a sharp flexure. Lineations plunge 65 degrees south, dips are 75 to 90 degrees and direction of dip is both north and south. This structure probably represents a flexure formed during the formation of the granite. A similar structure occurs in the Amisk rocks west of the north end of Elbow Lake.

North of Webb Lake in the west half of Elbow Lake map-area, the basic lavas extend north into Batty Lake map-area as part of the southeast limb of an anticline which trends northeast and plunges in the same direction (Robertson, 1950). The band of volcanic rock in the northwest corner of Elbow Lake map-area possibly represents a nose of an anticline trending northeast and plunging in the same direction. Lack of top determinations and the steep dips, however, make it impossible to be certain of this interpretation. The structure south of Syme Lake probably also is anticlinal.

The Amisk rocks in the east half of Elbow Lake map-area are tightly folded. Dips are steep and predominantly to the east, and the regional strike is northerly. Folds mapped southwest of Loonhead Lake trend north and plunge northerly. Lineations measured on hornblende grains and biotite clots plunge 20 degrees and strike slightly east of north. Plunge of the folds as determined by the method outlined by Stockwell (1950) is about 25 degrees east of north and the strike of the fold axis determined by the same method is east of north. The folds are overturned to the west. The fold axes shown on the map are actually the surface trace of the axial plane of the folds. The folds are reflected in the granitized rocks that outcrop south of them, as shown on the map. The detailed structure of the metamorphosed basic lavas in this area is unknown; steep dips are the rule in the lavas but they are probably less tightly folded than the sedimentary and younger volcanic rocks.

In summary, then, in the east half of Elbow Lake area the Amisk sedimentary and younger volcanic rocks are tightly folded; the folds are overturned somewhat to the west and plunge east of north. Faulting in the area complicates the structure. The amount of overturning seems to vary and, probably, the trend varies along the length of the folds. Lack of primary structures makes it impossible to decipher in any detail the structure of the older Amisk volcanic rocks in this area.

The Loonhead dome situated in the northeast corner of Elbow Lake map-area trends in an easterly direction and plunges to the east at about 15 degrees. Both Amisk and Kisseynew rocks are involved in the structure. A synclinal fold west of Dow Lake plunges to the north and the axial plane trends east of north. West of Wood Lake, an anticline plunges about 20 degrees northeast and trends about east of north. The nose of this fold is in Batty Lake map-area (Robertson, 1950). South of Dow Lake, a small anticline and a syncline deform the Kisseynew amphibolites. They trend in an easterly direction and plunge to the east and probably represent minor folds in the limbs of a major structure. The folding around Wood, Dow, and Loonhead Lakes in the Kisseynew rocks is complex. The folds mentioned above are obvious but do not account for the structure of all the rocks exposed. South of Wood and Dow Lakes, the rocks dip east at about 40 degrees but towards the biotite granodiorite the dip tends to steepen somewhat. Lineations strike east of north and plunge at about 25 degrees. All of these folds are along the north border of the sheet. It is postulated that the rocks south of the above-mentioned lakes are tightly compressed into folds that trend east of north and plunge in the same direction and which are markedly overturned to the west. The small folds represent minor folds in this structure. The picture is complicated by the Loonhead Lake dome, a structure that may be of a different origin and not directly related to the regional structure for it seems to disrupt regional trends. The rock type of the core of the dome is unknown. Islands in the lake are underlain by amphibolites, and granitic rock is exposed on a peninsula along the north shore of the lake. It is possible, therefore, that the core consists of granitic rock but evidence for this conclusion is scanty.

The structure of the rocks in the northern part of Heming Lake map-area is not at all obvious in the map accompanying this report. Reference must be made to the map-area north of the Heming Lake sheet (Bateman and Harrison, 1946). The folds in the Kisseynew in the south part of Sherridon map-area trend east-west, are recumbent, overturned to the south, and plunge east at about 30 degrees (Kalliokoski, 1953). Lineations and small drag-folds plunge east at about 30 degrees. The Kisseynew and Amisk rocks of the north end of Heming Lake area occur at the crest of a number of these folds and, therefore, they appear to trend in an east-west direction. Also a major fault in the area distorts the original foliation.

Faults

Faults are numerous in areas underlain by volcanic and sedimentary rocks but also occur on the granitic rocks. Three directions of faulting are recognized: namely, east of north, west of north, and east.

Faults striking east of north and west of north probably are of the same age and origin, as where they join, one is not displaced by the other. The faults striking east occur mainly along the contact of the Kisseynew and Amisk strata and probably are older than the northerly trending faults.

Faults trending east or west of north are by far the most abundant in the map-area. Evidence of direction and amount of displacement is difficult to obtain as most faults parallel the strike of the formations. Displacement of meta-pyroxenite contacts south of Loonhead Lake and the orientation of drag-folds, slickensides and lineations in the shear zones, however, indicate that many of the northerly trending faults have right-hand displacement. Minor structures on islands in Elbow Lake give conflicting evidence and suggest chiefly horizontal movement both to the north and south. The northeast-trending faults in the basic lavas at the south border of Heming Lake map-area have left-hand displacement.

All faults are marked by zones of intense shearing. Commonly, in volcanic rocks, chlorite and epidote are developed, whereas in biotite gneiss and granite, white mica occurs in the sheared rocks. In the latter rocks, a sericite schist marks zones of intense shearing. Crenulation and drag-folding of the shear planes are common. Mylonites occur along the fault near the entrance of Grass River into Elbow Lake. Crushed quartz and feldspar occur along fault zones in granite and to a lesser extent in volcanic rocks. The width of such alteration zones varies for some unestablished reason. Almost all rocks exposed on islands and along the shores of Elbow Lake are chloritic schists, presumably marking a broad zone of altered sheared rocks. The same is true to a lesser extent along faults in the volcanic rocks south of Peterson Lake in Heming Lake map-area, but south of Loonhead Lake and North Star Lake the faults in the volcanic rocks have altered zones, as little as a few feet wide.

Some faults seem to be localized along contacts between volcanic rocks and intrusions. Thus the fault that extends along Webb Creek follows or is near the granite-basic lava contact. Other examples are faults near the basic intrusion just south of Loonhead Lake, the fault in the east branch of the Grass River, and faults in the basic lavas around Vamp and Paton Lakes. The intrusive rocks probably act as buffers around which the older less homogeneous rocks are sheared.

The northeast-trending fault that extends southwest from the long arm of Vamp Lake is a continuation of the Vamp Creek fault mapped by Kalliokoski (1953). Its total length is about 16 miles. No evidence for direction or amount of displacement was obtained by Kalliokoski or the present author.

The Kisseynew-Amisk Lineament

Kalliokoski (1949) and Harrison (1951b) have postulated that a fault extends along the Kisseynew-Amisk contact. Robertson (1951), however, considered that the lineament marks, for part of its length at least, a conformable contact between the two rock-units.

The Kisseynew-Amisk lineament occurs in two parts of the area mapped by the author, namely, in the northeast corner of Elbow Lake map-area around Loonhead Lake and in the north part of Heming Lake map-area around Fay and Syme Lakes.

The lineament around Loonhead Lake marks the position of a fault that runs along the south shore of Loonhead Lake and swings northwest, as shown on the map. It is a continuation of a fault mapped by Harrison (1949) in File Lake map-area. Schist zones, numerous quartz veins, mineralized zones and, in thin section, crushing of quartz and plagioclase in nearby rocks are all evidence for the fault. The minor structures and dips of schistosity to the south at moderate to high angles indicate thrusting from the south. However, some related drag-folds plunge steeply and indicate horizontal movement. It is possible that there was more than one type of movement on the fault. This fault terminates against a second fault which trends in an easterly direction. Again, schist zones, mineralized zones and crushing indicate faulting. Minor structures indicate horizontal, right-hand movement. This fault abuts against granite gneiss to the west and is lost in drift-covered area to the east. West of this area, south and west of Dow Lake, there is no evidence of the lineament or of faulting. The contact between Kisseynew gneisses and the biotite granodiorite is a normal one.

In the northern part of Heming Lake map-area, the structure is very complex. The rocks are highly sheared and cut by several faults. The northernmost fault on the map is in Kisseynew gneisses and swings northeast into Batty Lake map-area near longitude 101 degrees. To the west it either dies out in an area of sparse outcrops or swings northward into Sherridon map-area. A fault is mapped in the Sherridon area that is approximately in line with a presumed northward extension of this fault (Bateman and Harrison, 1946). A second fault south of the first, extends from the west border of the map-area through Syme and Fay Lakes almost to the east border of the area where it and some branches terminate against a mass of hornblende-biotite granite. The south fault follows in part, the Kisseynew-Amisk contact but is mostly in the Amisk rocks. It marks the eastward extension of a fault mapped by Kalliokoski (1949) in Weldon Bay map-area which is along the Kisseynew-Amisk contact in that area.

Kalliokoski (1953) and Harrison (1951b) proposed that this fault extends westward at least to the Saskatchewan-Manitoba provincial border, a distance of some 30 miles. Several minor faults occur between the major faults with the result that the rocks north of Syme and Fay Lakes are intensely schistose.

In Syme-Fay Lakes section, crushing is evident in all the rocks associated with the faults. Muscovite is developed in the biotite gneisses and granitized rocks and, locally, quartz tends to be oriented dimensionally, and optically, parallel to the muscovite orientation.

Most drag-folds associated with these faults plunge about 60 degrees to the east and strike about east-west. They indicate that the north side moved up and eastwards. A few drag-folds were mapped that plunge east at about 30 degrees; still other drag-folds, commonly associated with the smaller faults, plunge steeply to the east, indicating almost horizontal movement. Two sets of lineations were mapped in the area, both striking about east-west. However, one set plunges east at 25 to 35 degrees whereas the other set plunges east at 50 to 65 degrees. Both lineations were locally discernible on the same shear surface and both were due to alignment of mineral grains. In some outcrops the steeper predominates, but in other outcrops the shallower one was dominant. The above facts can be explained in several ways. It is possible that there were two periods of movement on the faults, the movement sense being the same but direction of movement, different. It is more probable, however, that the more gently plunging set of lineations and drag-folds is related to folding because they are concordant with folds in Kisseynew of Sherridon map-area which plunge at about 30 degrees to the east (Kalliokoski, 1953). It is probable therefore, that the faults mark a high angle thrust, for the rocks dip steeply north, and that the north side moved up and to the east. Robertson (1951) stated that in the Batty Lake area the northern fault is normal with the north side down. However, the study of numerous minor structures in this area gives no evidence for such a conclusion and Kalliokoski's determinations to the west (1953) agree with those of the author.

Thus, faulting does occur along the Kisseynew-Amisk contact in the area mapped by the author, but in the east part of the area, around Loonhead Lake, direction of movement along the fault differs from that on the faults around Fay and Syme Lakes. Also in Fay-Syme Lakes area the several faults are *en échelon* and none is confined to the Kisseynew-Amisk contact.

Evidence of a fault along the whole length of the Kisseynew-Amisk contact as listed by Harrison is as follows (Harrison, 1951b, p. 144): (1) contact marked by persistent lineament, (2) abrupt change in degree of metamorphism near the contact, (3) discordance between regional structures of Amisk and Kisseynew strata, (4) types of mineral deposits are different on different sides of the fault, (5) heavy shearing occurs in several places along the lineament.

Point (4) is based on the fact that pyrrhotite seems more abundant north of the lineament whereas pyrite is more abundant south of the lineament. However, there are many exceptions to this rule; for example, sulphide deposits on Fay Lake, Vamp Lake and in the volcanic rocks south of Peterson Lake all contain considerable quantities of pyrrhotite. Also fewer orebodies and prospects occur north of the lineament than in the south. Point (1), the persistent lineament can be related to faulting which occurs in the contact area and, in some cases, to the different chemical character of the rocks exposed along the contact, thus making for differing rates of erosion. Point (5), heavy shearing in various places along the contact is related to faults which are known to exist in the contact area. Point (2), abrupt change in metamorphism near the contact is not always evident. The rocks around Fay and Syme Lakes are all of the same grade of metamorphism whether they are of Kisseynew or Amisk age. The same is true in Loonhead Lake area. In fact, 3 miles southwest of Loonhead Lake, amphibolites of the Amisk series are of the same grade of metamorphism and same degree of recrystallization as Kisseynew amphibolites. Therefore, the change in grade of metamorphism, although locally apparent is not evident throughout the area. Point (3), discordance between regional structures in the two rock-units is evident in several places in the area and is caused by faults that are known to exist, but both Robertson (1951) and the author have mapped areas where no such discordance exists.

The foregoing facts indicate that a fault zone along the Kisseynew-Amisk contact is not necessary or proven especially as two rock types are found in contact where no fault occurs. The lineament is discontinuous, a feature apparently caused by granitic masses. A significant fact is that in various areas along the lineament workers have found differing movement sense on faults occurring in the contact area. Around Snow Lake minor structures indicate normal faulting; around Loonhead Lake they indicate thrusting from the south and possibly horizontal movement; in Fay-Syme Lakes area and Weldon Bay area they indicate thrusting from the north. This contradictory evidence suggests the possibility that the Kisseynew-Amisk contact area marks a zone of faulting but no one fault or fault system.

In summary, then, it can be stated that faults are present in the Kisseynew-Amisk contact area; that the faults are probably of about the same age; and that the Kisseynew and Amisk are not in fault contact along their whole length.

Summary of the Geological History of the Area

The geological history of the area is complex and is interpreted as follows. While Amisk basic lavas and tuffs, the oldest rocks in the area, were accumulating, local areas of sedimentation formed and, later, a geosyncline began to develop. The Kisseynew sedimentary rocks were in part conformable on the Amisk, but probably locally were unconformable. As sedimentation continued, Amisk rocks in the marginal areas of the geosyncline and especially at some distance from the margins were probably deformed, locally at least. Intrusions of basic and ultrabasic rocks, and possibly quartz-eye granite were probably synchronous with this deformation in the marginal areas and with sedimentation in the geosyncline. Finally, a major orogeny affected rocks of both Kisseynew and Amisk age. Kisseynew rocks were complexly folded, metamorphosed and granitized. Amisk rocks were regionally metamorphosed. Temperatures were lower in parts of the Amisk due in part to the fact that they were structurally higher in the crust and in part to less intense deformation. Amisk rocks in or near the Kisseynew sediments were exposed to the same conditions as the Kisseynew rocks and underwent the same alteration. In a somewhat later phase of the orogeny, granites were formed in the Amisk rocks and locally in the Kisseynew rocks. In this phase, the Amisk folding was intensified and locally metamorphic grade was increased. Probably towards the end of this period of orogeny, faulting occurred in the Amisk contact area. Movements along these faults were complex and probably several types of movement occurred along single faults.

At the same time faults were formed that apparently were concentrated in the Amisk rocks. Along these faults, the rocks have undergone retrogressive metamorphism. It is possible that at some later date a broad regional warping affected the rocks of the region. There is slight evidence that rocks in the Flin Flon area represent a higher crustal level than rocks to the east.

The above picture is an over-simplified interpretation, but in the author's opinion best accounts for the facts as they are now known. The geology illustrates the effect of structural environment on the character of the rocks. Differences in the intensity of metamorphism, character of deformation, and origin of granite, all appear to be dependent on the structural level, and on the position with respect to the main geosyncline.

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CHAPTER V

MINERAL DEPOSITS

Two general types of mineral deposits are known in the area. One type consists of quartz veins containing minor amounts of sulphides and gold, the second consists of sulphide deposits with small amounts of quartz carrying minor gold and, in some deposits, copper and zinc. Some sulphide deposits are reported to carry nickel.

Quartz veins are scattered through the basic volcanic rocks but are most abundant near Elbow and North Star Lakes. They occur in shear zones and many such are parallel with the schistosity, although a few cross the strike of the enclosing volcanic formations. Many of the shear zones are exposed only from 300 to 500 feet along their strike, whereas others are exposed at intervals for several thousand feet. The shear zones, parallel and close to large faults, are most abundant in volcanic rocks that are highly faulted, as those around Elbow Lake. The rocks in the shear zones are commonly altered to chlorite or chlorite-carbonate schist.

Quartz occurs in lenses, pods, branching veins, or regular veins in the shear zones. The veins, or vein complexes, vary in width from a few inches to about 12 feet and are up to about 1,000 feet long although many are only 200 or 300 feet long. They do not occupy the full length of most shear zones. The quartz is fine to medium grained and milk-white to greyish. Inclusions of country rock and locally a brownish carbonate, probably iron-bearing, are present in some veins. Sulphides form less than 5 per cent of the quartz and included country rock. Pyrite is the most common sulphide but chalcopyrite, sphalerite, galena, arsenopyrite, and pyrrhotite also are present. Visible gold occurs in fractures in quartz, with sulphides, and along contacts of quartz and country rock.

The deposits are commonly near small bodies of quartz-eye granite or dykes of quartz-feldspar porphyry. Such relations suggest that the effect of shearing on rocks of varying competency to some extent controls the localization of shear zones and their contained quartz veins.

Sulphide deposits occur in schistose basic lavas, especially in local shear zones in highly faulted volcanic rocks near younger gabbroic rocks, and in sedimentary rocks. There are many exceptions. They occur around the north end of Elbow Lake, around Loonhead, Webb, Fay, Syme and Peterson Lakes replacing schist. There they consist of sulphides occurring as disseminated grains and solid masses. The amount of sulphide in the schist varies considerably in individual deposits but commonly masses of solid sulphide are found in the central parts of the deposits. The sulphide zones are up to 50 feet wide and may be several hundred feet long. Some deposits contain essentially pyrite or pyrrhotite, whereas other deposits carry both sulphides. Chalcopyrite and sphalerite occur locally in these deposits and more rarely are found in considerable quantities. Where observed by the author, chalcopyrite is localized in stringers, veinlets, or irregular patches in the other sulphides, usually in parts of the deposit consisting of pure sulphide. The amount of gold is usually low; nickel is reported from some of them. Narrow quartz veins, stringers, or lenses appear locally in the sulphide masses; they carry disseminated sulphides and, rarely, gold.

Most of the deposits in the area were described in detail by Stockwell (1935). Only those that have received attention in recent years are mentioned in this report.

Deposits

The Century Mine

The Century Mine, previously known as Webb and Garbutt claims (Stockwell, 1935, p. 29), is situated on a large island in the northern part of Elbow Lake. In the 1940s the shaft was enlarged and deepened to 500 feet; drifting and crosscutting were done at 125 and 250 feet depth and some gold was produced. Camp buildings, a small mill, and assay office were erected on the property but the operation ceased in 1947. In the spring of 1951, 5,675 feet of diamond drilling were completed in six holes to cut the deposits from 600 to 1,100 feet vertically below the surface.

The deposits occur in schistose basic lavas, some of which are pillowed. The lavas are invaded by small bodies and dykes of quartz-feldspar porphyry that are strongly sheared and mineralized. Several strike faults traverse the island. The schistosity in the vicinity of the veins strikes north 15 degrees and dips 80 degrees east. The outcrops of the veins are covered by a dump and by buildings and were not observed but, according to Stockwell (1935, p. 29), occur as lenses and branching veins in both lavas and sheared porphyry. Their position may be in part controlled by a dyke of porphyry. Quartz is the abundant mineral in the veins along with carbonate and altered inclusions of wall-rock. Pyrite and minor chalcopyrite occur in the veins and the wall-rocks, and visible gold was observed in quartz, commonly at contacts of altered wall-rock and quartz. Stockwell reported the vein complex as up to 10 feet wide and exposed at intervals for several hundred feet along the strike.

A second deposit, the Bow vein (Stockwell, 1935), 700 feet northwest of the zone described above has been explored by surface trenches and diamond drill-holes. This vein which is located in schistose basic lavas is about 250 feet long with an average width of 2 feet. It strikes a little east of north and is steep dipping. Mineralization is the same as that described above. Stockwell (1935, p. 29) reported that samples taken across 5 feet of quartz at four locations along the vein assayed, respectively, 0.60, 1.20, 0.28, 0.34 ounce of gold a ton.

Vanderberg Group

The Vanderberg group of claims is situated on the west side of Elbow Lake near the north end. It was formerly known as the Apex Nos. 1, 2 and 3 and the Bell claims. In recent years a few diamond drill-holes have been completed, most of them for assessment work. The main showings are located on the Apex No. 1 and Bell claims.

The rocks exposed on the property are chiefly basic lava flows with small bodies of meta-diorite but in the northern part of the group rhyolite is abundant. These rocks are intruded by small bodies of quartz-eye granite and dykes of acidic porphyry cut the basic lavas and meta-diorite.

Regional schistosity strikes about east and dips steeply both to the north and south. The rocks are cut by north-trending faults marked by chloritic shear zones.

Quartz forms veins, stringers, and lenses in shear zones and these zones of mixed quartz and schist vary in width from a few inches up to 15 feet. The exposed length of the vein complex is about 200 feet on the old Bell claim and about 175 feet on the Apex No. 1 claim. The quartz is fine to medium grained, white to bluish grey and locally contains brown iron carbonate and feldspar. Pyrite is present in the wall-rocks and in the quartz vein. In quartz, pyrite commonly occurs along grain boundaries, in small fractures in quartz, or at the contact of quartz and inclusions of country rock and forms less than 5 per cent of the vein material. Minor amounts of chalcopyrite are erratically distributed in the vein, commonly in or near pyrite grains.

Stockwell reported a channel sample taken across the vein and schist for a total length of 14 feet, assayed 0.24 ounce of gold a ton and a chip sample assayed 0.40 ounce gold a ton (1935, pp. 17 and 18). The gold seems to be spottily distributed in the veins.

Elbow Lake Property

The Elbow Lake property is situated on the west shore of Elbow Lake south of Webb Creek. Stockwell referred to the property as the Gunwar group (1935, p. 20). In recent years the deposits have been diamond drilled and some surface work has been done.

The rocks in the area are chiefly basic volcanic rocks with minor amounts of rhyolite. These rocks are invaded by meta-diorite and cut by dykes of rhyolite and quartz-feldspar porphyry, many of which trend about northeast. All the rocks are intruded by large bodies of hornblende-biotite quartz diorite.

Schistosity in the lavas trends nearly northeast and dips between 60 and 70 degrees southeast. The lavas are cut by shear zones, some of which strike about north whereas others strike nearly east. The east-striking shear zones tend to parallel dykes of acidic rock.

The quartz occurs in the shear zones as veins, branching veins and discontinuous lenses. The most important veins trend easterly and two of them have been explored by many trenches and two shallow shafts.

The easterly of these veins is 200 to possibly 300 feet long and from a foot to 3 feet wide, although locally it is up to 5 feet wide. The second vein or zone of quartz lenses and sheared rock, is several hundred feet to the west and has similar dimensions.

The quartz in the veins is medium grained, white to grey, and forms over 95 per cent of the vein material. Brown carbonate and, locally, feldspar occur with the quartz. The quartz and sheared wall-rock contain pyrite. Chalcopyrite and sphalerite occur in the quartz. The veins locally carry coarse gold but no information is available concerning their average gold content, although in the past some gold was produced by small high grading operations.

Ding How Property

The Ding How property is on a small island in the southeast part of Elbow Lake. Some years ago a shaft was sunk on a quartz vein to a reported depth of 40 feet.

Rocks on the island are chloritic schists which strike N30°E and dip close to vertical both to east and west. Locally, cleavage planes are crinkled and drag-folded.

The outcrops of the deposit are now covered by a dump and the shaft is full of water. Stockwell (1935, p. 36) reported two quartz veins in a shear zone trending N30°E. One extends 90 feet northeast of the shaft; the second vein lies to the northeast of the first and is about 150 feet long. The veins vary in width up to 2½ feet. In the shaft, two veins, a foot and 1.5 feet wide, are exposed. They are reported to continue to the bottom of the shaft. Sheared country rock near to and included in the veins carries pyrite.

Examination of material on the dump and from exposed veins shows that fine- to medium-grained, white to grey quartz is the essential gangue mineral. Locally, a brown carbonate is present. The quartz contains about 1 per cent pyrite and minor chalcopyrite and sphalerite. Gold was observed in several specimens where it commonly occurs in quartz near small altered inclusions of country rock.

Webb Property

The Webb property is on the west shore of a small lake southwest of Webb Lake. The rocks in the vicinity are highly altered lavas in the contact zone of a large body of granitic rock lying to the west. The lava is highly sheared along a north-trending fault.

A zone of lava, partly replaced by sulphide is about 30 feet wide and is exposed 100 to 200 feet along the strike. Locally, the replacement is almost complex resulting in small bodies of massive sulphide. Fine-grained pyrite and pyrrhotite occur but pyrite is the more abundant. Minor amounts of chalcopyrite were observed and a vein an inch wide of almost pure chalcopyrite is exposed in one trench. Small quartz veins or lenses are scattered throughout the sulphide zone. The average gold and copper content is reported to be low.

Parres Property

The Parres property is a gold prospect at the northeast end of a small lake in the northwest corner of Elbow Lake map-area. Part of the showing is on a small island in the lake, which was not examined. The property was staked in 1950 and trenching, stripping and diamond drilling have since been completed, but the author does not know the results.

The rocks in the vicinity of the deposit are metamorphosed lavas locally converted to banded gneisses and containing narrow layers of sedimentary rock. These rocks are cut by a body of hornblende-biotite granodiorite. The foliation of the lavas strikes north to west of north and dips steeply. Small shear zones cut the basic lavas, and quartz veins and lenses in one of these are reported by the owners to carry gold.

Kay Lake Property

Kay Lake property is situated at the south end of a small lake south of Peterson Lake near the south boundary of Heming Lake map-area. During the period 1950-52 the deposit was explored by sixteen regularly spaced trenches and diamond drill-holes.

The rocks about the prospect are altered basic lavas cut by syenodiorite and pink biotite granodiorite. The lavas are faulted and sheared to chloritic schists. The schistosity, faults, and shear zones strike northeast and dip nearly vertically.

The deposit consists of two quartz veins in a shear zone, exposed for a length of about 1,300 feet. One vein is exposed at intervals along the full length of the zone, and the second vein about 3 feet to the north of the first is exposed along a part of the length. The whole zone varies in width from about 3 feet to a maximum of 15 feet.

Quartz is medium to fine grained, varies in colour from milk-white to bluish grey, and has been fractured so that it breaks in rough rhombs. Pyrite, chalcopyrite and galena occur in fractures and seams in the quartz and are most abundant in the bluish grey quartz. Most of the galena is in a 300-foot length of the vein south of a point about 300 feet from the north-east end of the deposit. Sulphides are estimated to form about 1 per cent of the vein material. Pyrite is present in the schists adjoining the veins. No information concerning the average gold content of the deposit is available.

Vamp Lake Property

The Vamp Lake property is on the large island in the north part of Vamp Lake and is held by Lee Gordon Mines Limited. This company has carried out surface exploration, magnetometer and electromagnetic surveys and completed some diamond drilling with both X-ray and heavy drills.

The rocks in the vicinity of the deposit consist of basic lavas altered to hornblende gneiss and some rhyolite that may be either intrusive or extrusive. A small mass of gneissic granite occurs in the western part of the island. The foliation strikes about N35°E and dips vertically or steeply to the southeast.

The gneisses are cut by a fault paralleling the foliation, and the formation on the east side of the fault probably moved north an unknown amount with respect to that on the west side. The fault probably is a northward extension of the fault on the mainland to the south.

Much of the basic rock of the island contains pyrite in amounts up to 3 per cent. The main sulphide bodies, however, occur as lenses in the fault zone where they consist of fine- to medium-grained pyrite with some pyrrhotite, chalcopyrite, and minor sphalerite. The company reports copper, zinc and gold in the deposit.

Some work has been done on a prospect on the mainland southwest along the projected strike of the main showing. There a deposit similar to that on the island is exposed, but details concerning its size and average grade are not available. Some copper and zinc are reported.

Redwin Property

The Redwin property is situated on Fay Lake in the northern part of Heming Lake map-area. In the past, surface work, diamond drilling and an electromagnetic survey have been undertaken.

Bedrock consists of metamorphosed basic lavas intruded by rhyolite and feldspar porphyry and, a short distance south of the deposit, both groups are intruded by hornblende-biotite quartz diorite. The foliation trends east and dips from 60 to 80 degrees north. The lavas are cut by schist zones trending parallel to, and probably contemporaneous with major east-trending faults that pass a short distance north of the deposit.

The deposits consist of sulphide bodies and quartz veins in the schist zones. The schist is partly replaced by sulphides and locally the replacement is complete resulting in lens-shaped bodies of massive pyrrhotite and pyrite. The quartz occurs in narrow veins, lenses, and pods in the sheared, sulphide-bearing rock. Pyrite and pyrrhotite are present in varying proportions. In general, pyrite is more abundant than pyrrhotite in partly replaced rock but in massive bodies pyrrhotite is more abundant. Minor amounts of chalcopyrite occur in quartz veins and in the sulphide-rich zones. Quartz veins apparently contain most of the gold that has been reported. The average copper content and the distribution of copper in the deposit were not determined.

Sulphide and quartz bodies are known to extend for a total length of 600 feet along strike but for 200 feet of this length, outcrops are sparse. The strike of the foliation suggests that the two main outcrops represent separate bodies, each about 200 feet long. Individual sulphide zones are up to 20 feet wide, and the quartz veins within the sulphide zones are up to about a foot wide and seldom more than 50 feet long.

Fay Lake Property

The Fay Lake property is situated between Fay Lake and the railroad just north of Mile 29. Surface work has been done on the showing and in September 1952 geophysical work was in progress.

The deposit is in hornblende-plagioclase gneiss intruded by bodies of rhyolite porphyry. The foliation strikes about east and dips steeply to the north. Lineation plunges east at about 30 degrees. The gneiss is sheared locally and such schist zones probably are related in origin to some of the major faults nearby.

Quartz occurs in schist zones as veins, lenses, and pods. In one trench, two veins are separated by about 10 feet of altered and sheared gneiss. In a second trench about 75 feet along the strike from the first, only one vein is present. The veins are 2 feet wide at places and their known length is about 100 feet. The quartz is fine to medium grained, white to grey, and at places contains up to 3 per cent combined pyrite, arsenopyrite, galena, and chalcopyrite. The wall-rock carries pyrite, arsenopyrite and gold; grab samples are reported by the owners to assay 0.23 ounce gold a ton.

Other Deposits

In the interval 1915 to 1950 certain parts of the area were prospected and the mineral discoveries were explored. Many of the pits and trenches then made are caved or the sulphides oxidized, so that little information about these deposits can be obtained from a study of their present outcrops. Details of many of these discoveries are published in reports of the Geological Survey of Canada during this period: Bruce, 1918; Armstrong, 1922; Wright, 1930; Stockwell, 1935; and Harrison, 1949.

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