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MEMOIR 342

GEOLOGY AND MINERAL DEPOSITS OF THE CHISEL LAKE MAP-AREA, MANITOBA

Harold Williams

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PREFACE

Chisel Lake map-area forms part of the important Snow Lake mineral district in west-central Manitoba, which is currently being developed for base metals. The Chisel Lake zinc-copper mine is the largest of the recently discovered orebodies, and is now in production.

Although most geological interest in the area is related to its economic possibilities, there are also many problems of petrological, structural, and stratigraphic significance. In this report the author presents the results of a study of the origin of controversial quartz-eye gneiss (formerly quartz-eye granite), along with other metamorphic rocks and the relationships between metamorphism, deformation, igneous intrusion, and mineralization.

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

OTTAWA, February 18, 1964

MEMOIR 342 — Geologie und Mineralvorkommen im Gebiet des Chisel Lake (Manitoba).

Von H. Williams

Dieser Bericht beschreibt die präkambrischen metamorphen und eruptiven Gesteine in einem Teil des mineralreichen Snow Lake-Distrikts des westlichen Zentral-Manitobas. Es wird angenommen, dass der Quarzaugen-Gneis (in einigen angrenzenden Gebieten Quarzaugen-Granit genannt) pyroklastischen Ursprungs ist.

ТРУД 342 — Геология и месторождения полезных ископаемых района Чизел Лейк, Манитоба.

Г. Уилиамс

Этот отчет дает описание докембрийских метаморфических и изверженных пород части горно-промышленного района Сноу Лейк в западно-центральной Манитобе. Автор приписывает пирокластический генезис кварцо-очковому гнейсу (называемому кварцо-очковым гранитом в некоторых соседних районах).

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Abstract

The Chisel Lake area of northern Manitoba, comprising 10 square miles within the Churchill structural province of the Precambrian Canadian Shield, has been mapped in detail. Information is provided on the lithology, structure, relationships, and origin of the rocks. Metamorphic features of the Amisk Group are described and chemical analyses presented. Metasedimentary rocks of Amisk age have been distinguished.

Quartz-eye gneiss (formerly quartz-eye granite) is a characteristic rock type in the area. Metamorphic features of the rock do not point to an obvious origin for the parental material in most exposures, and controversy has been expressed regarding its origin and age. For the Chisel Lake area, field relationships, petrographic investigations, and chemical and micrometric analyses combine to indicate that the rock is in part, if not entirely, of pyroclastic origin. The author considers the rock to have been originally a crystal tuff. The origin of the quartzo-feldspathic rocks that are related to quartz-eye gneiss is likewise controversial; they are also considered to be of pyroclastic parentage.

The occurrence of a differentiated basic intrusion, and base-metal mineral deposits, within the metamorphic environment of the area, are of special interest.

Résumé

La région du lac Chisel dans le Nord du Manitoba, d'une superficie de 10 milles carrés, à l'intérieur de la province structurale Churchill du Bouclier précambrien, a été cartographiée à grande échelle. Dans la présente étude, l'auteur fournit des renseignements sur la lithologie, la structure, les relations et l'origine des roches. Il décrit les roches métamorphiques du groupe Amisk et donne des analyses chimiques. De plus, il différencie les roches métasédimentaires de la période Amisk.

Le gneiss à quartz oeillé (auparavant granite à quartz oeillé) est une roche type caractéristique de la région. Les caractères métamorphiques de la roche ne laissent point paraître dans la majorité des affleurements d'origine évidente des roches-mères, et il y a eu controverse sur leur origine et leur âge. Dans la région du lac Chisel, les relations établies sur le terrain, les recherches pétrographiques et les analyses micrométriques et chimiques indiquent que la roche est en partie, sinon entièrement, d'origine pyroclastique. L'auteur croit que la roche a été à l'origine un tuf cristallin. L'origine des roches à quartz et à feldspath apparentées au gneiss à quartz oeillé est aussi sujette à controverse. L'auteur croit également qu'elles sont de provenance pyroclastique.

Une venue d'intrusion basique différenciée et des gîtes de métaux communs, dans le milieu métamorphique de la région, offrent un intérêt spécial.

Chapter I

INTRODUCTION

Chisel Lake map-area lies in west-central Manitoba, from 54°49′ to 54°52′N latitude, and from 100°5′ to 100°10′W longitude. The centre of the area is about 5 miles southwest of Snow Lake and 70 miles east of Flin Flon.

Field work was carried out during the summers of 1958 and 1959. Mapping, suitable for publication, was done on a scale of 1 inch to 1,000 feet; a smaller area, surrounding the Chisel Lake orebody at the south end of Chisel Lake, was mapped in more detail (*see* Map 1180A, and Fig. 4). Field mapping was aided by the presence of cut lines that were originally used by Hudson Bay Mining and Smelting Co., Limited for geophysical work.

The area is accessible by recently constructed roads; a new spur line of the Canadian National Railways connects Chisel Lake and Optic Lake.

Acknowledgments

Sincere thanks are extended to Professor W. W. Moorhouse, of the University of Toronto, under whose guidance much of this report was prepared. Assistance was given by geologists of Hudson Bay Mining and Smelting Co., Limited and maps were supplied showing the location of cut lines and geological information from surface drilling and underground development. Student assistants were W. O. Macasey and E. Allcock in 1958, and W. D. Simmons and A. E. Kennedy in 1959.

History of Development

Gold was the metal that attracted most prospectors to this part of Manitoba prior to the discovery of economic base-metal deposits. It was discovered on the east shore of Wekusko Lake in 1914, following the early explorations of J. B. Tyrrell and Wm. McInness (Stockwell, 1937)[1]. Many other deposits were found during the next three years when the area was being studied and mapped by E. L. Bruce (1917) and

[1] Names and/or dates in parentheses are those of references listed in *Bibliography*.

F. J. Alcock (1920). At this time interest was centred in the Rex gold mine near the east shore of Wekusko Lake, which produced at intervals from 1918 to 1925 (Stockwell, 1937).

In 1941 the Nor-Acme gold deposits were discovered on the northern shore of Snow Lake, and were successfully operated by the Howe Sound Company until 1958. During this period the File Lake area was mapped by Harrison (1949), and structural studies in the Snow Lake area were made by Russell (1957). The File Lake area includes Chisel Lake.

Several important base-metal deposits were discovered in the region in 1956 by the Hudson Bay Mining and Smelting Co., Limited, the most important of which is at Chisel Lake. Other deposits are located near Ghost Lake, Stall Lake, and Osborne Lake; the last two are outside Chisel Lake map-area.

Physical Features

The map-area displays the typical hummocky surface of low relief so characteristic of this part of the Canadian Shield. Tops of hills rarely exceed elevations of 70 feet above the levels of nearby lakes, and low ridges, separated by lakes and muskeg swamps, are common. Recent mining development has materially changed much of the surroundings. Tent Lake and most of Chisel Lake have been drained, and Cup Lake, Photo Lake, and another small lake at the north-central edge of the map-area are now also dry. Forest fires during the summer of 1960 burned over much of the southern part of the map-area.

The dominant direction of ice-movement, as indicated by striae, glacial grooving, outcrop profiles, and the distribution of erratic boulders, is between south and S25°W.

Diamond drilling has shown that glacial material in places is more than 150 feet thick above the Chisel Lake orebody. It consists of coarse boulder till grading upwards to sand and mud. The thickness of each type of material is variable from place to place. The coarse lowermost fraction attains its greatest thickness over depressions within the profile of the lake bottom. The graded nature of the material suggests deposition during the waning stages of glaciation, with coarse till being covered by increasingly finer material as the ice-front retreated.

Chapter II

GENERAL GEOLOGY

The consolidated rocks of this part of Manitoba are of Precambrian age. Alcock (1920) classified all the sedimentary and volcanic rocks as the Wekusko Group. Harrison (1949) distinguished two successions in these rocks; an older group, consisting mainly of basic volcanic rocks, and a younger group, which is predominantly sedimentary. The older group was considered to be equivalent to rocks of the Amisk Group, named by Bruce (1918) in the Flin Flon district. The younger group was considered similar in some respects to Missi strata of the Flin Flon district, which unconformably overlie the Amisk rocks, but positive evidence of an unconformity between older basic volcanic rocks and Snow Group rocks was not found, and Harrison (1951a) has pointed out that Snow Group rocks grade into typical Kisseynew gneiss, whose relationships with Missi strata near Flin Flon are in dispute.

Volcanic and sedimentary rocks exposed in Chisel Lake map-area all belong to the Amisk Group. Examples of staurolite-garnet schist northwest of Tent Lake are lithologically similar to Snow Group rocks but are older, for they occur interlayered with basic volcanic rocks of the Amisk Group.

Amisk Group rocks in the map-area have been regionally metamorphosed and the degree of metamorphism varies little. Most rocks belong to either the amphibolite or albite-epidote amphibolite facies of regional metamorphism as outlined by Turner (1948). In terms of the zonal system of regional metamorphism as proposed by Harker (1939), no Amisk Group rocks are known below the almandine zone unless they have been affected by retrograde metamorphic processes. The metamorphism has obscured many critical relationships and primary features that commonly indicate definite rock origins. Chemical composition, mineralogy, and an understanding of field occurrences are the criteria used to determine the origin of rocks lacking relict features.

The metamorphosed sedimentary and volcanic rocks of the Amisk Group have been divided into seven map-units. Rocks belonging to any one unit may occur at several different stratigraphic horizons. In classifying the rocks, the goal of the author has been to apply genetic nomenclature rather than metamorphic. However, in places this was not practicable, and metamorphic nomenclature had to be used. Furthermore, in dealing with controversial quartz-feldspar rocks descriptive nomenclature is desirable.

Table of Formations

Age	Group	Map-units
PRECAMBRIAN		(9d) Meta-diorite (9c) Meta-gabbro; > 20% plagioclase (9b) Meta-gabbro; < 20% plagioclase (9a) Meta-peridotite
		Intrusive Contact
	AMISK GROUP	(8) 'Shallow intrusions'; intermediate to basic rocks, may include some flow rocks
		Intrusive Contact
		(7) Quartzo-feldspathic rocks (6) Quartz-eye gneiss (5) Metasedimentary rocks; staurolite-garnet schists (4) Amphibolite of unspecified origin (3) Basic pyroclastic rocks, with minor acidic to intermediate pyroclastic rocks (2) Massive flow rocks (1) Pillowed or amygdaloidal basalt

Amphibolites of the Amisk Group have been separated into three genetic subdivisions as follows: pillowed or amygdaloidal basalt, massive flow rocks, and basic pyroclastic rocks. Original features of these three units are generally well enough preserved to allow distinction. Where the origin of certain amphibolites was in doubt, the rocks were grouped separately into a fourth unit using metamorphic nomenclature, i.e., amphibolites of unspecified origin.

Metasedimentary rocks of the Amisk Group are in most places readily recognizable by either primary features or mineralogy, or a combination of the two.

Quartz-feldspar rocks are abundant, and occur in association with basic volcanic and metasedimentary rocks. Their origin is in dispute. The writer has mapped two types of quartz-feldspar rocks. One is a distinctive rock type containing blue or grey quartz eyes that has been described by Harrison (1949) as quartz-eye granite. Because of the proposed origin for this rock as it occurs in the map-area, the term 'granite' is undesirable and the rock is referred to in this report as quartz-eye gneiss. The distinction between the quartz-eye gneiss and the other quartz-feldspar rocks in the map-area (the latter referred to as quartzo-feldspathic rocks) is in places vague. The main criterion for separation is the presence of quartz eyes in the former and their apparent absence in the latter. Chemical, textural, structural, and mineralogical features of the quartz-feldspar rocks do not point to an obvious origin for the parental material in most exposures. The writer considers that both the quartz-eye gneiss and the related quartzo-feldspathic rocks in the map-area are mainly of pyroclastic origin and hence of Amisk age.

Two groups of basic intrusive rocks have been separated in the map-area. The first is commingled with basic volcanic rocks of the Amisk Group and has had a similar metamorphic history. The rocks in this group are considered to be shallow intrusions of Amisk age and are classified as an additional lithologic subdivision of the Amisk Group. They probably represent sills, plugs, and feeders associated with the basic volcanism. The second group of basic intrusions includes rocks of varied composition that cut all other rocks in Chisel Lake map-area. Dykes of meta-diorite cut quartz-eye gneiss west of Chisel Lake, and small plugs of dark recrystallized basic rocks are interpreted to cut shallow intrusions of the Amisk Group near Photo Lake. The most extensive occurrence of basic intrusive rocks of the second group is found bordering the western shore of Chisel Lake, where all recognized varieties are represented in the Chisel Lake intrusion.

Amisk Group

Description of Subdivisions

Pillowed or Amygdaloidal Basalt

This rock is best exposed at the north-central extremity of the map-area, where it is associated with agglomerates and quartzo-feldspathic rocks. It contains well-preserved pillows and numerous almond-shaped quartz amygdules. Amygdaloidal basalts with carbonate amygdules occur in the southeastern corner of the map-area. Southwest of Tent Lake a narrow band of black amphibolitic basalt occurs in gradational contact with quartz-eye gneiss. A few relict pillows were noted and well-formed deep red garnet is present in the southern part of this band. Along the northeastern shore of Ghost Lake, amygdaloidal basalt is surrounded by quartzo-feldspathic rocks with gradational contact relationships.

Lithology

Pillowed or amygdaloidal basalts are represented by fine- to medium-grained black amphibolites. They generally have a lineation produced through the alignment of prismatic amphibole crystals. The major constituents of the rocks in their relative order of abundance are amphibole, plagioclase, biotite, quartz, epidote, garnet, and calcite. Minor constituents include chlorite and magnetite, and accessory minerals are apatite, muscovite, pyrite, sphene, and leucoxene. The rocks have a crystalloblastic texture, with crystals of amphibole separated by granular plagioclase and quartz with sutured boundaries. Thin quartz veins that commonly cut the rocks are seen in thin section to consist of serrated, strained quartz crystals with some epidote, amphibole, and apatite.

Amphibole crystals in the basalts vary in form and size. Generally they are prismatic, and less commonly they are acicular or equidimensional. Most of the crystals are about the same size, but in some places large poikilitic porphyroblasts occur, and in others there is a gradation from small to large crystals, which produces a seriate texture. The amphibole varies from dark green to black in hand specimen and shows corresponding variations in thin section, where it is generally pale green, but in some sections deep green to blue. In places the amphibole is bleached, showing gradations from deep green to colourless, with bleached material surrounding the more highly coloured. Calculations made from chemical compositional data of the basalts (Table I) suggest that the amphibole is an actinolitic-hornblende rich in soda.

Plagioclase in the basaltic rocks is variable in composition. Generally it is intermediate to sodic andesine, but oligoclase (Ab_{77}) and calcic andesine (Ab_{61}) occur locally. It occurs as interstitial anhedral crystals and large ragged porphyroblasts containing quartz inclusions. It is generally clear, but in places is impregnated with a white scaly alteration. Locally, where the rocks have been sheared, the plagioclase has a lower anorthite content than is common and has epidote associated with it.

Biotite in the amphibolitic basalts is in part derived from amphibole, but also occurs as distinct crystals surrounded by quartz or feldspar. Epidote occurs as finely distributed crystals throughout the groundmass or as well-formed lath-shaped crystals in amygdules. Most of the epidote has the optical properties of clinozoisite. Quartz occurs interstitially intergrown with plagioclase, as a vesicule filling, and in lenticles and thin veinlets throughout the rocks.

Quantitative mineralogical variations in the basalts indicate chemical compositional changes that appear to be haphazard in their distribution. Available petrographic and mineralogical data suggest that the compositional variations occurred either as deuteric effects following crystallization or as a result of regional metamorphism. Compositional variations are noticeable in outcrops of amphibolitized amygdaloidal lava on the northeast shore of Ghost Lake. Outcrops there contain thin discontinuous stringers of quartz-rich material and in places quartz comprises more than 30 per cent of the rock, suggesting an enrichment in silica.

Chemical Analyses

Three specimens of amphibolite, in places showing relict pillows, were collected about 1,000 feet south of Horseshoe Lake for rapid-method analyses. The samples consisted of 2 to 3 pounds of fresh material collected several inches below the weathered surface. The specimens were black, medium-grained amphibolite, and as far as could be determined from field observation, were not altered in any way. The results of the analyses are shown in Table I, together with analyses of basalts for purposes of comparison.

The three analyzed rocks are richer in soda than average basalt, and apart from a rather high alumina content they otherwise closely approach spilite in composition. They also differ from average basalt in that they are richer in silica, alumina, and alkalis, and are deficient in iron, titanium, magnesium, and calcium. Unlike tholeiitic basalt, they contain no normative quartz and up to 14 per cent normative olivine. In this respect they more closely approach the undersaturated oceanic olivine basalts.

In general, spilites are characterized by the presence of a highly sodic plagioclase (albite or oligoclase), and augite or its altered equivalent (actinolite, chlorite, epidote, etc.). The chemical similarity of the three amphibolitized basalts in Chisel Lake map-area to rocks of spilitic parentage is not reflected by their mineral composition (*see*

Table I

Composition of Amygdaloidal and/or Pillowed Basalt, with added analyses for comparative purposes

Oxide	1 (Wf-1649)	2 (Wf-1651)	3 (Wf-1653)	4	5	6	7	8
SiO_2	53.8	52.2	53.8	53.3	53.15	51.22	50.61	49.58
TiO_2	0.7	0.8	0.7	0.7	1.50	3.32	1.91	3.17
Al_2O_3	15.8	17.6	16.0	16.5	14.39	13.66	13.58	13.19
Fe_2O_3	2.1	0.4	2.1	1.5	1.28	2.84	3.19	2.40
FeO	8.99	10.44	8.95	9.5	9.33	9.20	9.92	9.49
MnO	0.2	0.2	0.2	0.2	0.14	0.25	0.16	0.12
MgO	4.8	4.8	3.9	4.5	4.74	4.55	5.46	8.30
CaO	7.7	6.5	6.6	6.9	7.04	6.89	9.45	10.69
Na_2O	4.2	4.8	5.2	4.7	4.58	4.93	2.60	2.25
K_2O	1.0	0.6	1.1	0.9	1.01	0.75	0.72	0.55
H_2O+	0.91	1.10	0.96	1.00	2.02	1.88	2.13	—
H_2O-					0.19			—
P_2O_5	0.2	0.1	0.1	0.1	0.19	0.29	0.39	0.26
CO_2	0.31	0.18	0.99	0.5	0.10	0.94	—	—
Total	100.7	99.7	100.6	100.3	99.66	100.72	100.12	100.00

1, 2, 3. Amphibolite of basalt origin. Analyses by the Geological Survey of Canada using the rapid methods. Analyst: U. ter Haar Romeny.

4. Average of 1, 2, and 3.

5. Spilite, somewhat high in potash, eastern Oregon; J. Gilluly, *Am. J. Sci.*, vol. 29, p. 235, No. 8, 1935, *after* Turner and Verhoogen 1951, p. 204.

6. Average spilite, 19 analyses: 3 from England, 7 from New South Wales, 5 from Kiruna, Sweden, 4 from Karelia, Finland; N. Sundius, *Geol. Mag.*, vol. 67, p. 9, 1930, *after* Turner and Verhoogen 1951, p. 204.

7. Average of 11 Deccan basalts; H.S. Washington, Deccan traps and other plateau basalts, *J. Geol.*, vol. 33, p. 797, No. 1, 1922, *after* Turner and Verhoogen 1951, p. 180.

8. Average (water-free) of 11 basalts Hawaiian Islands; R. A. Daly, *Bull. Geol. Soc. Amer.*, vol. 55, p. 1365, 1944, *after* Turner and Verhoogen 1951, p. 180.

Table II) as determined by micrometric analyses. Rather the minerals present constitute a metamorphic assemblage that is stable under the conditions of the amphibolite facies of regional metamorphism. The initial mineral composition of the rocks is not known, and no relict textural features have been preserved.

Apart from amphibole and biotite, the mineralogy of the chemically analyzed basalts is fairly well understood. It is, therefore, possible to calculate approximately the composition of the amphibole in each chemically analyzed rock from a knowledge of the mineral proportions and the oxides present in the whole rock analyses. Amphibole compositions calculated in this way are listed in Table III for each of the three chemically analyzed specimens of Table I. The calculated amphibole compositions can only be regarded as rough approximations, but they suffice to indicate that the amphibole present has chemical characteristics of both actinolite and hornblende. It is richer in silica and magnesium than hornblende, and contains more alumina and iron than actinolite. It is therefore regarded as actinolitic hornblende. The soda content of the amphibole is relatively high.

Table II

Modal and Normative Mineral Constituents of Three Amygdaloidal and/or Pillowed Basalts of Chisel Lake Map-area

Mode (Wt. %)	Wf-1649	Wf-1651	Wf-1653
Amphibole	55.3	60.9	46.6
Plagioclase (Ab_{70})	29.9	33.4	34.6
Biotite	14.8	5.4	17.9
Quartz	—	0.3	—
Clinozoisite	—	—	—
Magnetite	—	—	0.5
Carbonate	—	—	0.4
Total	100.00	100.00	100.00

Norm. (Wt. %)	Wf-1649	Wf-1651	Wf-1653
Orthoclase	6.12	3.34	6.67
Albite	35.63	40.35	44.01
Anorthite	21.13	25.02	16.96
Diopside	12.03	4.42	7.21
Hypersthene	18.40	8.55	12.00
Olivine	1.17	14.23	5.91
Magnetite	3.02	0.70	3.02
Ilmenite	1.37	1.52	1.37
Apatite	0.34	0.34	0.34
Calcite	0.70	0.40	2.30
Total	99.91	98.87	99.79

Classification according to C.I.P.W. system:
Wf-1649—Class 2, order 5, rang 4, subrang 3.
Wf-1651 and Wf-1653—Class 2, order 5, rang 3, subrang 5.

Table III

Composition of Amphibole in Three Amphibolites of Basalt Origin, Chisel Lake Map-area

Oxide	1	2	3	4
SiO_2	54.5	49.4	55.7	53.2
Al_2O_3	10.6	14.1	9.3	11.3
Fe_2O_3	3.2	0.5	3.8	2.5
FeO	11.2	15.7	11.8	12.9
MnO	0.4	0.3	0.4	0.4
MgO	6.3	7.2	4.9	6.1
CaO	10.6	7.5	9.5	9.2
Na_2O	2.5	3.8	3.8	3.4
H_2O	0.7	1.5	0.8	1.0
Total	100.0	100.0	100.0	100.0

Calculated amphibole composition:
1. From sample Wf-1649 (Table I)
2. From sample Wf-1651 (Table I)
3. From sample Wf-1653 (Table I)
4. Average of columns 1, 2, and 3.

Massive Flow Rocks

These rocks occur mainly east and southeast of Chisel Lake in folded structures with basic pyroclastic rocks. A few smaller patches east of Ghost Lake are surrounded by quartzo-feldspathic rocks. Absence of primary features and their massive nature in outcrop caused some concern regarding their origin in the initial stages of field mapping, but the massive flow rocks are everywhere conformable with layered pyroclastic rocks. Contacts southeast of Chisel Lake have a relatively smooth planar aspect, and southeast of Lost Lake a few quartz amygdules were noted on a weathered surface. These features, combined with the geometry of outcrop pattern, are interpreted to indicate an extrusive origin for the massive flow rocks.

Lithology

The massive flow rocks weather to various shades of grey, and are lighter coloured and appear more siliceous than the basalts. Their composition probably approaches that of andesite. Garnet and magnetite can be identified on the weathered surfaces of most exposures and locally elongate yellowish green nodules containing much epidote are present, which give the rocks a pyroclastic appearance. The massive flow rocks have a consistent mineral composition and generally contain at least 10 per cent quartz. The following minerals, in order of decreasing abundance, were identified: amphibole, plagioclase, quartz, biotite, epidote, calcite, garnet, and magnetite. Accessory minerals are sphene, chlorite, apatite, pyrite, and pyrrhotite.

As seen in thin section the texture is crystalloblastic. The amphibole is mainly optically similar to that of the basaltic flows of map-unit 1, but is more equidimensional and has ragged edges. The plagioclase is an intermediate to sodic andesine with little or no polysynthetic twinning, has crenulated borders, and is intergrown with quartz in a mosaic pattern. Some larger anhedral crystals of plagioclase contain inclusions of quartz; in places quartz appears to replace plagioclase.

On the eastern shore of Chisel Lake, a massive amphibolite of flow origin has been altered to coarse-grained pseudodiorite. The alteration is localized along cracks and fissures. Amphibole porphyroblasts up to a quarter of an inch in diameter have been developed in the amphibolite, marginal to the breaks. The pseudodiorite is massive, with a rough granular weathered surface. Its composition is not obviously different from the amphibolite from which it was derived. However, it appears that in places quartzo-feldspathic material has been introduced.

Basic Pyroclastic Rocks

Pyroclastic rocks within the map-area consist of agglomerates, tuffs, and finer ash deposits. No attempt was made to separate these three rock types in the field. Coarse varieties are easily recognized, but primary textures of fine-grained pyroclastic material have been destroyed by metamorphic recrystallization, and they can only be distinguished from metamorphosed flows by the presence or absence of bedding. The best examples of agglomerate are found: southeast of a small drained lake at the north-central edge of the map-area; northwest from the northern end of Chisel Lake; and in the southeastern corner of the map-area. Finer grained pyroclastic deposits are well represented along the northeast and southeast shore of Ghost Lake and along the east shore of Chisel Lake.

Lithology

The agglomerates are made up of fragments that are generally less than a foot in diameter, although, locally, fragments or amygdaloidal bombs up to 3 feet in diameter are present. The clastic material is poorly sorted, and bedding is not conspicuous. Fragments consist of dark amphibolite and rounded bombs of amygdaloidal lava, with white-weathering siliceous volcanic fragments dominant in places. The matrix of the rocks is fine- to medium-grained, dark green to black amphibolite. In places where deformation has not been intense, siliceous white-weathering fragments are angular, whereas the basic ones are subangular or round. This suggests that the former were derived from the walls of a volcanic vent and represent accidental lithic debris. In other places, structural deformation has produced elongate fragments with a length to width ratio of 15:1.

Rocks classified as tuffs are characterized by fragments one quarter to one inch in diameter. The fragments cannot always be recognized on a fresh fracture, but are distinct on a weathered surface. Bedding is well developed and beds vary in thickness from a few inches to tens of feet; some beds can be traced along strike for several hundreds of feet. Ash deposits are recognized by their finely laminated nature. Some beds are grey weathering and less than an inch thick, whereas others are as much as 2 to 3 feet thick.

Metamorphic minerals and textures of the basic pyroclastic rocks are for the most part similar to those in amphibolites of flow origin. Little information is available on the composition of the basic pyroclastic rocks, but if the mafic metamorphic minerals present are compositionally similar to those found in the amygdaloidal basalts, then quantitative mineralogical data suggest that in places the rocks are of equivalent composition. Generally, the basic pyroclastic rocks contain more quartz than the basic flows and are thus more intermediate in composition.

Amphibolites of Unspecified Origin

These rocks occur in a northwest-trending band southwest of Tent Lake and as discontinuous lenses to the north in contact with quartz-eye gneiss. They are considered to be largely derived from pyroclastic material. The rocks are highly deformed, are in some places exceedingly garnetiferous, and in others show banding, which is the result of metamorphic differentiation. Weathered surfaces commonly exhibit an inhomogeneity of mineral distribution; this feature is also prominent in some thin sections. In a few places definite fragments were identified. Most of these rocks are mineralogically similar to pyroclastic rocks as previously described; others are more homogeneous and may be of flow origin. It is possible that some siliceous highly garnetiferous types are of sedimentary origin.

Metasedimentary Rocks

Metasedimentary rocks are rare within the Amisk Group. Their main occurrence within the map-area is as a band outcropping along the shore of Tent Lake and extending towards the northwest. A small patch is present near the junction of Chisel and Tent Lakes, and staurolite-bearing siliceous rocks occur along the foot-wall and hanging-wall of the Chisel Lake orebody. The best exposures of metasedimentary rocks are along the shoreline of Tent Lake below the former water level.

Lithology

The metasedimentary rocks are represented by coarsely crystalline staurolite garnet biotite schists. Other minerals present include quartz, plagioclase (oligoclase), chlorite, muscovite, with accessory magnetite, apatite, zircon, and sulphides. Sillimanite, traceable into biotite, was identified in one specimen collected northwest of Tent Lake, and kyanite and andalusite are sparingly known from the metasedimentary rocks bordering the Chisel Lake orebody. Typically the rocks have a well-developed schistosity resulting from the parallelism of micaceous minerals. In places lenticular gneissic banding has resulted from the segregation of garnet into thin lenticles, which are commonly drag-folded. Garnets commonly exceed half an inch in diameter and staurolite crystals up to 2 inches long have been seen. Northwest of Tent Lake the metasedimentary rocks are more highly deformed and schistosity is well developed. Micaceous minerals are arranged in parallel sheets, but prismatic staurolite crystals commonly cross the schistosity at high angles. Elsewhere staurolite occurs in eyes elongated parallel to the schistosity. Exposures along the shore of Tent Lake contain subangular and poorly sorted fragments of fine-grained acidic to intermediate volcanic rocks.

In thin section staurolite and garnet crystals are seen to contain numerous quartz inclusions; in fact some staurolite crystals contain more included material than host mineral. This suggests that the crystals grew along grain boundaries and interstitial areas, enclosing many quartz grains during growth. Elsewhere staurolite appears to be pseudomorphous after biotite.

In some places, aureoles or lenticular areas of material markedly deficient in the iron-bearing minerals surround garnet porphyroblasts. Thus many of the rocks are blotched by white patches of quartz and feldspar, which generally measure one quarter to one half inch in diameter. The cores of these blotches contain crystals of garnet, and in a few places well-formed magnetite crystals.

Garnet collected from metasedimentary rocks forming the hanging-wall of the Chisel Lake orebody has a cell-edge dimension of $11.546 \pm .005$ angstrom units, and a specific gravity of $4.00 \pm .02$, as reported by J. L. Jambour, of the Geological Survey of Canada. The index of refraction is $1.805 \pm .004$. Spectrographic analysis shows that the major constituents are iron, silicon, and aluminum, with minor amounts of magnesium, and a trace of calcium, manganese, and titanium. These properties are very close to those of almandine (Stockwell, 1927).

Quartz-Eye Gneiss

Throughout northern Manitoba and parts of eastern Saskatchewan, quartz-bearing rocks, referred to as 'quartz-eye granite,' have been reported from Flin Flon eastward to Wekusko Lake, a distance of some 100 miles. The origin of the rocks as they occur in some places is in dispute. An intrusive magmatic origin has been suggested or implied by most authors, e.g., Bruce (1918), Alcock (1920), Stockwell (1935, 1937), Tanton (1941), Harrison (1949), Frarey (1949), Podolsky (1951), Kalliokoski (1952), and McGlynn (1959).

Stockwell (1937) has described dykes and apophyses of 'quartz-eye granite' that cut the country rocks, clearly indicating a magmatic origin. However, in Chisel Lake map-area, field relationships of 'quartz-eye granite,' here called quartz-eye gneiss, are vague. Harrison (1949) regarded the rocks as intrusive, but where the same outcrops were studied by Russell (1957) he favoured a sedimentary origin. The writer's studies suggest that throughout northern Manitoba rocks of different origin have been included under the term 'quartz-eye granite,' and that in Chisel Lake map-area the rocks are metamorphosed crystal tuffs.

Nature of Field Occurrence

The main occurrences of quartz-eye gneiss partly within or near Chisel Lake map-area are shown in Figure 1. One large U-shaped mass and two smaller conformable bodies form part of the Threehouse syncline (Harrison, 1949), which is a regional structure that includes and surrounds Chisel Lake map-area. On the western limb of the Threehouse syncline much of the larger mass is exposed in Chisel Lake map-area. Part of a smaller mass also outcrops within the northern part of the map-area.

Quartz-eye gneiss and amphibolitic basalt of map-unit 1 are commingled where they are in contact, southwest of Tent Lake. At right angles to the strike, the irregular contact zone is several tens of feet wide. Farther within the quartz-eye gneisses west of Chisel Lake, conformable intercalations of amphibolite occur, varying in area from 20 to more than 200 square feet. Some of the amphibolitic intercalations are gradational into the surrounding rocks and in places their boundary is marked by a biotite-rich zone. They are most abundant in the northwestern part of the map-area.

Harrison (1949) has indicated that 'quartz-eye granite' masses are generally schistose or gneissic in the marginal zones, whereas in the central part of larger 'intrusions' much of the rock is massive. Russell (1957) also noted similar variations in the rocks exposed between Anderson Lake and Berry Creek (Fig. 1). This generalization also applies, in part, to 'quartz-eye granite' of Elbow Lake map-area (McGlynn, 1959). However, within Chisel Lake map-area, the rock is everywhere seen to display a mild foliation and/or lineation, with the lineation located within the plane of the foliation where the two occur together. Linear elements include streaks of mafic minerals and elongate quartz eyes. In the map-area, foliation and lineation are secondary structures and bear no relationship to the shape of quartz-eye gneiss bodies. The structures persist across contacts and parallel secondary fabrics in the surrounding country rocks.

Quartz-eye gneiss with numerous and distinct quartz eyes occurs northwest of Photo Lake. One exposure in this area has a distinctly layered structure resembling bedding. The layers range from 6 inches to more than 5 feet in exposed thickness and result from mineralogical and colour variations.

Mineralogy and Texture

Quartz-eye gneiss in the map-area displays variations in texture and mineral composition. Compositional variations are haphazard and apparently bear no relationship to other properties of the rock. Textural variations depend upon the amount of shearing to which the rocks were subjected during metamorphism. The more schistose varieties, common in the main mass west of Chisel Lake, are marked by an

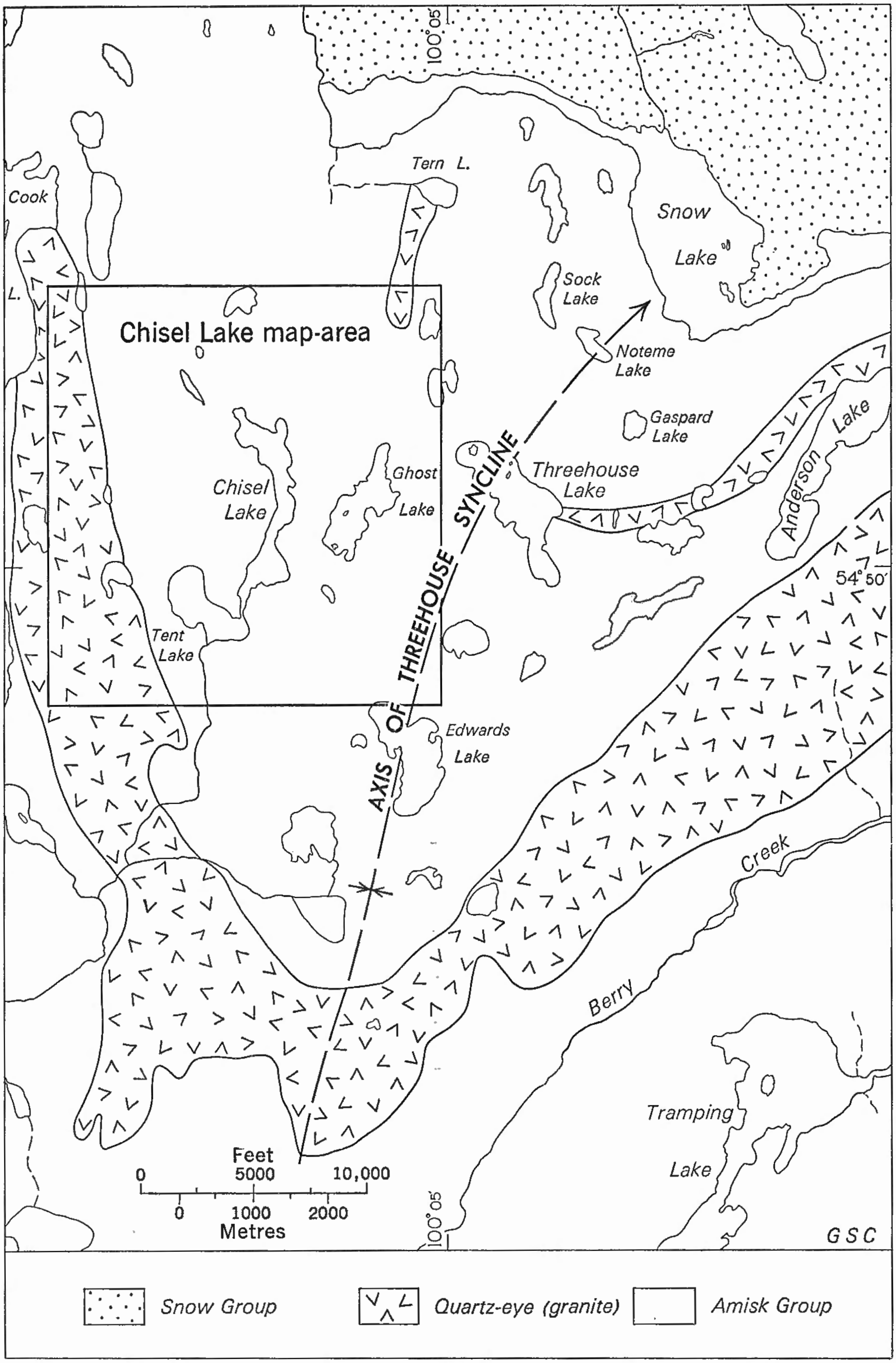

FIGURE 1. Regional geology and structure around Chisel Lake map-area.

equigranular crystalloblastic texture with porphyritic tendencies. Elsewhere, as northwest of Photo Lake, less schistose samples are porphyritic with distinct quartz eyes.

The rocks consist mainly of quartz and sodic plagioclase, generally oligoclase, which together account for more than 80 per cent. Mafic minerals are biotite and hornblende, and minor constituents are potash feldspar, epidote, muscovite, and garnet. Accessory minerals are apatite, pyrite, pyrrhotite, sphene, leucoxene, and zircon.

The most characteristic feature of less-deformed varieties of quartz-eye gneiss is a porphyritic texture accentuated by grey or blue quartz eyes. These are set in a fine-grained grey to pink matrix and range from one sixteenth to one quarter inch in diameter. In thin section the quartz eyes are seen to consist of one or more large quartz crystals, which are generally almond-shaped and show undulose extinction. In places the quartz crystals have one or more straight and sharp boundaries, and locally display groundmass-filled embayments. The original features of the groundmass have been destroyed by recrystallization. The groundmass now consists of a mosaic of quartz and feldspar. Mineral distribution and grain size are variable throughout most thin sections, and locally quartz eyes are surrounded or partly enclosed by a mosaic of fine-grained quartz and feldspar that appears different from that in the overall groundmass.

Chemical Composition

Chemical analyses were made of four specimens of quartz-eye gneiss collected near Horseshoe Lake, and one sample collected northwest of Photo Lake (*see* Table IV). Micrometric analyses were made on ten samples (*see* Table V). The variations in chemical composition are apparent from a study of these analyses. One striking

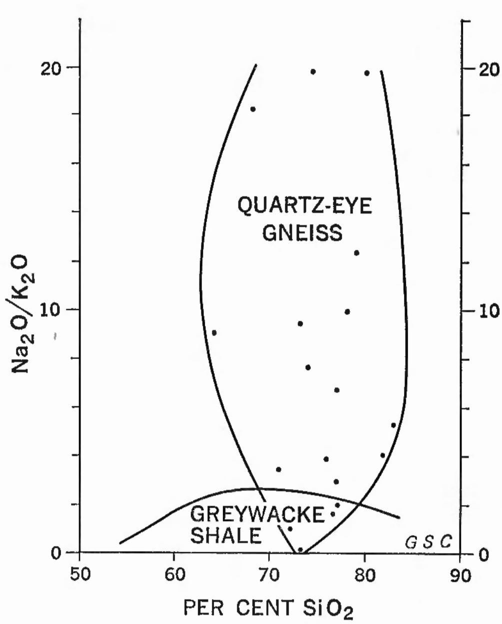

FIGURE 2. Comparison of soda/potash ratio in clastic sedimentary rocks and quartz-eye gneiss.

feature is the excess of soda over potash; also the silica content is high in some specimens. However, analogues for most analyses can be found among igneous rock compositions (Washington, 1917).

Micrometric analysis has indicated the presence of sedimentary rocks within the main body of quartz-eye gneiss west of Tent Lake. The micrometric analysis for sample Wf-29 (Table V) shows most of the chemical characteristics of an argillaceous sediment (Bastin, 1909). However, the simple recrystallization of sedimentary rocks will not produce typical quartz-eye gneiss. The high soda/potash ratio is particularly incongruous, as is illustrated on Figure 2, which shows a comparison of the soda/potash ratio in common clastic sedimentary rock compositions as listed by Pettijohn (1951) and compositions of quartz-eye gneiss in Chisel Lake map-area. Texture and mineralogy are also contrary to a sedimentary origin for most of the rocks.

Table IV

Chemical Analyses of Quartz-Eye Gneiss

Oxide	Wf-1655	Wf-1656	Wf-1657	Wf-1658	Wf-1659
SiO_2	74.4	77.3	77.3	77.0	72.5
TiO_2	0.2	0.2	0.1	0.1	0.2
Al_2O_3	11.8	10.7	10.9	11.6	10.9
Fe_2O_3	0.7	0.4	0.6	0.2	0.4
FeO	1.35	3.21	2.98	2.36	5.36
MnO	0.0	0.0	0.0	0.0	0.1
MgO	0.5	0.8	0.9	0.3	1.0
CaO	2.8	1.2	0.6	0.8	2.4
Na_2O	4.6	4.1	3.6	3.8	2.2
K_2O	0.6	0.4	1.9	2.3	2.1
H_2O	0.38	0.53	0.64	0.44	0.98
P_2O_5	0.0	0.0	0.0	0.0	0.0
CO_2	1.34	0.19	0.31	0.03	0.51
Total	98.7	99.0	99.8	98.9	98.7

Wf-1655 Collected 1,000 feet southeast of Horseshoe Lake, 7 feet from basalt contact.
Wf-1656 Collected 1,000 feet southeast of Horseshoe Lake, 57 feet from basalt contact.
Wf-1657 Collected 1,000 feet southeast of Horseshoe Lake, 165 feet from basalt contact.
Wf-1658 Collected 1,000 feet southeast of Horseshoe Lake, 300 feet from basalt contact.
Wf-1659 Collected 1,500 feet west of the northern end of Photo Lake.
Analyst: U. ter Haar Romeny, Geological Survey of Canada.

Origin

The available data suggest to the author that the quartz-eye gneiss in the map-area is essentially of pyroclastic origin and is a metamorphosed crystal tuff. The tuff could contain intrusive porphyry of similar mineralogy and texture, along with sedimentary and amphibolite intercalations, but intrusive porphyry, if present, is thought to be of minor importance. A pyroclastic origin is based upon the following features:

(a) Structure–The occurrence of U-shaped bodies of quartz-eye gneisses in the Threehouse syncline (Fig. 1) suggests that their positions are structurally controlled. They are concordant with rocks of the Amisk Group and are probably stratigraphic units. Foliation and lineation in quartz-eye gneisses of

Table V

Micrometric Analyses of Quartz-Eye Gneiss

Wt. %	Wf-2	Wf-20	Wf-22	Wf-29	Wf-30	Wf-316	Wf-354	Wf-373	Wf-1200	Wf-1607	Y
Mineral											
Quartz	57.3	55.2	41.4	55.6	44.2	20.3	37.6	33.6	46.6	32.2	
Plagioclase	34.6	35.8	49.4	5.3	48.7	38.0	54.7	50.5	48.7	46.7	
Biotite	2.3	3.5	0.1	13.4	0.0	4.4	0.0	13.8	0.0	6.3	
Muscovite	4.0	4.8	6.4	20.6	3.7	0.0	0.4	0.0	1.2	0.0	
Chlorite	0.9	0.2	1.6	0.0	2.5	0.0	7.1	0.0	0.8	0.0	
Garnet	0.0	0.3	0.0	0.6	0.0	0.9	0.0	0.3	0.0	0.6	
Carbonate	0.7	0.2	0.0	0.0	0.1	0.0	0.1	0.2	1.3	0.0	
Clinozoisite	0.1	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0	
Apatite	0.1	0.0	0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.2	
Magnetite	0.0	0.0	1.1	4.5	0.4	0.7	0.0	0.0	0.0	1.7	
Actinolite						34.7	0.0	1.6	0.8	12.3	
Leucoxene						0.0	0.0	0.0	0.2	0.0	
Oxide											
SiO_2	82.90	81.77	77.18	73.20	79.37	64.10	74.00	70.70	80.40	72.92	76.8
TiO_2	0.08	0.15	0.00	0.57	0.00	0.15	0.00	0.60	0.00	0.26	0.1
Al_2O_3	9.51	10.86	13.36	11.62	12.17	14.30	14.50	15.00	11.16	12.25	11.9
Fe_2O_3	0.03	0.06	0.69	3.33	0.33	1.80	0.00	0.30	0.02	1.58	0.4
FeO	0.67	0.78	0.65	4.18	0.72	6.20	1.64	3.10	0.34	3.64	2.4
MnO	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.0
MgO	0.38	0.32	0.29	1.20	0.48	2.40	1.30	1.45	0.26	1.30	0.7
CaO	1.21	1.30	1.16	0.30	0.92	6.12	3.00	2.55	1.83	1.67	1.7
Na_2O	3.59	3.47	5.13	0.48	5.28	3.60	4.70	4.40	5.20	5.42	4.3
K_2O	0.68	0.87	0.76	3.63	0.42	0.40	0.05	1.30	0.11	0.57	0.9
H_2O	0.64	0.42	0.78	1.48	0.31	0.49	0.81	0.50	0.11	0.32	0.5
P_2O_5						0.40	0.00	0.00	0.00	0.00	0.0
CO_2	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.57	0.00	0.3
F						0.04	0.00	0.00	0.00	0.02	0.0

Wf-2	Collected 2,000 feet west of Horseshoe Lake.
Wf-20	Collected 1,000 feet southeast of small lake in southwest corner of area.
Wf-22	Collected 500 feet east of small lake in southwest corner of the area.
Wf-29	Collected 2,250 feet west of small lake in southwest corner of the area. This rock has the chemical characteristics of a sediment.
Wf-30	Collected 2,500 feet west of small lake in southwest corner of the area. This rock has a micrographic texture.
Wf-316	Collected 2,500 feet southwest of small lake in northwest corner of the area. This is a rather basic phase hardly typical of the rock type.
Wf-354	Collected 2,500 feet southeast of small lake in the northwest corner of the area.
Wf-373	Collected 2,000 feet southwest of small lake in the northwest corner of the area.
Wf-1200	Collected 700 feet southeast of Horseshoe Lake near the basalt contact.
Wf-1607	Collected 1,400 feet west of the northern corner of Photo Lake.
Y	Average quartz-eye gneiss omitting samples 316 and 29.

the map-area parallel secondary structures in surrounding country rocks and are geometrically, if not genetically, related to the Threehouse syncline.

(b) Texture–Slightly deformed quartz-eyes with sharp outlines or embayed boundaries are typical of phenocrysts in volcanic rocks, e.g., dacitic flows or pyroclastic equivalents. Irregular mineral distribution, variable grain size, patchy textures, and layered outcrops with porphyritic texture, all indicate inhomogeneity of the rocks and point to a pyroclastic rather than to an intrusive or sedimentary origin.

(c) Composition–The lithological inhomogeneity of the rocks is supported by variability in chemical compositions. An igneous extrusive origin is compatible with most analyses.

In the Cross Lake map-area of northern Manitoba, Bell (1962) has mapped quartz-eye-bearing rocks that are lithologically similar to quartz-eye gneiss in Chisel Lake map-area, but are less metamorphosed. In places the former contain poorly sorted white volcanic fragments set in a quartz-eye-bearing matrix, indicating a definite extrusive fragmental origin.

A pyroclastic origin for quartz-eye gneiss in Chisel Lake map-area relates structure, texture, and composition with occurrences of the rocks in the field, and dates the rocks as being of Amisk age and part of the Amisk Group. The author feels that throughout northern Manitoba rocks of various origins have been named 'quartz-eye granite' because of their contained quartz-eyes. Many of these rocks are mineralogically unlike granite or granodiorite, as potash feldspar is generally absent. Moreover, use of the term granite is particularly undesirable where origin is in doubt.

Quartzo-Feldspathic Rocks

In Chisel Lake map-area, quartzo-feldspathic rocks occur in association with basic volcanic rocks of the Amisk Group. Locally, relict fragments typical of pyroclastic deposits are displayed, but in most exposures metamorphic features have obscured original textures. Where a definite pyroclastic fragmental origin was apparent in the field, the rocks were grouped with basic pyroclastic rocks of map-unit 3; elsewhere they were mapped separately as quartzo-feldspathic rocks of map-unit 7.

Distribution of the quartzo-feldspathic rocks among Amisk basic volcanic rocks is most irregular, and northeast of Ghost Lake these rocks surround amphibolitized amygdaloidal lava. Contacts are generally gradational.

Lithology

Quartzo-feldspathic rocks are fine- to medium-grained and weather dull grey or various shades of pink. They are mineralogically similar to quartz-eye gneiss and consist essentially of quartz and sodic plagioclase with lesser amounts of amphibole, biotite, garnet, epidote, potash feldspar, and chlorite. Mafic minerals, particularly hornblende, are more abundant than in quartz-eye gneiss, and these are aligned in places, producing secondary foliation and lineation. The rocks have a granoblastic texture, which is characterized by relatively even-sized and closely fitting anhedral grains. Locally, quartz and hornblende occur in larger crystals and the granoblastic texture grades into a porphyroblastic one. Rarely are the constituent minerals distributed uniformly throughout the rocks. This is apparent on weathered surfaces that show sugary, elongate patches that are mineralogically distinct from the surrounding matrix. In a general way the metamorphic texture of quartzo-feldspathic rocks is similar to that of the matrix of porphyritic quartz-eye gneiss.

Chemical Composition

Chemical compositions of ten quartzo-feldspathic rocks, recast from micrometric analyses, are listed in Table VI. The analyses show that, in most samples analyzed, the rocks are less siliceous than quartz-eye gneiss, but have similar chemical characteristics, i.e., excess of soda over potash, and lime over magnesia. Like quartz-eye gneiss, compositions are variable and one analysis, Wf-1312, has the compositional properties of a sedimentary rock (Bastin, 1909). The calculated analysis of sample Wf-1606 is similar to some examples of quartz-eye gneiss in that it is rich in silica.

Origin

The following observations suggest that the quartzo-feldspathic rocks and quartz-eye gneisses in the map-area are related in time and space:

(a) the rock types are virtually inseparable where occurring in contact;

(b) both have similar chemical and mineralogical characteristics; and

(c) they occur among basic volcanic rocks of the Amisk Group.

Field observations on weathered outcrop surfaces of quartzo-feldspathic rocks indicate that some of the rocks are of pyroclastic fragmental origin. Others can be traced into siliceous agglomerates and tuffs mapped as part of the Amisk Group. Thin sections from outcrops that are not particularly informative show patchy textures and irregular distribution of mafic minerals supporting a fragmental origin. The author therefore considers these rocks to be mainly siliceous pyroclastic deposits, i.e., lithic tuffs and agglomerates, with original features largely obliterated by metamorphism.

Harrison (1949) considered the quartzo-feldspathic rocks of the map-area to be granitized equivalents of the Amisk Group, and produced through metasomatic action of quartz-eye 'granite.' Gradational relationships between quartz-eye gneiss and quartzo-feldspathic rocks, between quartzo-feldspathic rocks and basic volcanic rocks of the Amisk Group, and the irregular and haphazard-appearing distribution of the quartzo-feldspathic rocks among Amisk basic volcanic rocks all agree with such an hypothesis. If the quartzo-feldspathic rocks represent original silicic pyroclastic deposits, the gradational features must be explained by intermingling of rock types at the time of deposition or migration and rearrangement of constituents during regional metamorphism. Their haphazard distribution must also be explained as primary, complicated by tight folding.

The Amisk is the oldest group of rocks in the region. Basic agglomerates of the group contain angular siliceous fragments that are apparently of volcanic origin and represent accidental lithic debris incorporated with the basic volcanic material at the time of deposition. Their presence shows that siliceous volcanic rocks existed during some periods of Amisk volcanism, and supports the author's view that metamorphosed quartzo-feldspathic rocks of the map-area are an integral part of the Amisk Group and represent original siliceous volcanic rocks.

Table VI

Micrometric Analyses of Quartzo-Feldspathic Rocks

Wt. %	Wf-780	Wf-807	Wf-1054b	Wf-1060a	Wf-1211	Wf-1298	Wf-1312	Wf-1525	Wf-1558	Wf-1606
Mineral										
Quartz	39.2	34.0	38.0	42.3	20.6	29.8	38.7	31.1	30.8	52.1
Plagioclase	21.2	50.3	16.8	0.0	61.4	47.5	23.3	47.2	14.2	41.4
Biotite	15.3	9.6	17.6	6.5	2.5	16.8	28.8	11.5	28.8	0.8
Clinozoisite	20.4	0.4	24.2	51.2	0.0	3.0	0.1	0.0	19.8	0.0
Garnet	3.3	1.9	0.8	0.0	1.1	1.8	0.2	0.0	1.2	0.0
Muscovite	0.6	2.1	2.6	0.0	0.0	0.0	1.7	4.4	5.2	1.0
Magnetite	0.0	1.7	0.0	0.0	0.6	1.1	0.2	0.0	0.0	0.2
Amphibole	0.0	0.0	0.0	0.0	13.8	0.0	0.0	0.6	0.0	2.2
Chlorite						0.0	6.2	4.9	0.0	1.0
Carbonate						0.0	0.6	0.1	0.0	1.3
Sphene						0.0	0.1	0.0	0.0	0.0
Apatite						0.0	0.1	0.0	0.0	0.0
Pyrite						0.0	0.0	0.2	0.0	0.0
Oxide										
SiO_2	66.71	69.30	65.07	65.00	66.73	68.20	64.80	67.83	60.10	81.14
TiO_2	0.67	0.42	0.70	0.27	0.10	0.71	1.22	0.48	1.24	0.04
Al_2O_3	15.65	15.95	16.40	18.40	17.63	14.60	13.50	16.42	17.45	10.10
Fe_2O_3	0.27	1.38	0.30	0.11	0.62	0.98	0.62	0.22	0.51	0.20
FeO	4.44	3.20	3.60	1.24	2.94	4.45	6.97	3.48	6.20	0.78
MnO	0.02	0.01	0.02	0.00	0.04	0.02	0.03	0.01	0.03	0.00
MgO	1.39	0.89	1.56	0.57	1.07	1.53	3.76	2.05	2.65	0.41
CaO	7.14	3.80	8.04	12.62	5.28	2.91	2.91	3.13	6.00	2.21
Na_2O	1.68	3.80	1.40	0.01	5.15	4.42	1.36	3.84	1.11	4.17
K_2O	1.44	0.90	1.88	0.55	0.22	1.53	2.85	1.56	3.27	0.21
H_2O	0.55	0.35	1.03	1.22	0.22	0.60	1.63	0.95	1.35	0.17
CO_2						0.00	0.26	0.00	0.00	0.57
F	0.04	0.00	0.00	0.01	0.00	0.05	0.09	0.03	0.09	0.00

Wf-780 Collected 4,000 feet west of Photo Lake.
Wf-807 Collected 3,500 feet west of the southern end of Photo Lake.
Wf-1054b Collected 3,000 feet west of Cup Lake.
Wf-1060a Collected 2,250 feet west of Cup Lake along the transmission line from Chisel Lake.
Wf-1211 Collected 1,000 feet southwest of Cup Lake.
Wf-1298 Collected 2,400 feet east of the northern end of Ghost Lake.
Wf-1312 Collected 500 feet east of the extreme eastern shore of Tent Lake.
Wf-1525 Collected from the extreme southeast corner of the Chisel Lake map-area.
Wf-1558 Collected 2,300 feet southeast of the extreme southern end of Ghost Lake.
Wf-1606 Collected 1,800 feet west of central Photo Lake. This rock is gradational into 'quartz-eye granite.'

Shallow Intrusions (Amisk Group)

Amphibolites, which are considered to be of intrusive origin, occur northeast of Chisel Lake, southeast of Ghost Lake, and near Photo Lake. The rocks are similar in mineralogy and degree of metamorphism to basalts and basic pyroclastic rocks of the Amisk Group but they are distributed irregularly throughout the volcanic rocks and definitely truncate bedding in basic pyroclastic rocks of map-unit 3. They are therefore considered to be basic intrusions, probably representing sills, plugs, and feeders associated with Amisk basic volcanism.

The rocks are black or dark green and generally massive, although locally a secondary lineation is apparent. They are medium- to coarse-grained and commonly exhibit a porphyroblastic texture, which results through the development of either large amphibole metacrysts or clumps of ragged plagioclase metacrysts. The rocks consist of amphibole and intermediate plagioclase in roughly equal amounts along with quartz, epidote, or clinozoisite, and in examples north of Chisel Lake biotite and garnet are common.

Structure

Amisk Group rocks of the map-area are structurally situated on the western limb of the Threehouse syncline (Harrison, 1949), which is a major structure including folded rocks of both the Amisk and younger Snow Groups. About 30,000 feet of volcanic rocks are exposed along the axial plane of the Threehouse syncline south from Snow Lake (Fig. 1). Chisel Lake map-area includes only part of the southern portion of this volcanic assemblage. Within the map-area, the outcrop pattern of sedimentary and volcanic rocks generally conforms to the regional arcuate pattern of the Threehouse syncline, trending between northwest and north. Secondary structural features displayed by the Amisk Group rocks, such as lineation and schistosity, are geometrically related to the Threehouse syncline.

Local structures in the layered rocks can be deciphered in only a few places. Top determinations can rarely be made, and continuity in layered rocks is commonly truncated by intrusions or obscured by the occurrence of unbedded, irregularly distributed quartzo-feldspathic rocks of map-unit 7.

Folds

Three minor folds are recognized in the map-area. The best displayed one is southwest of Lost Lake, where the outcrop pattern and secondary northwest-plunging lineation suggest a northwest-plunging synclinal structure overturned to the northeast. The fold pattern is accentuated by a V-shaped massive flow, which is greatly thickened at the nose of the structure. Schistosity parallels the axial plane and bedding along the limbs, but crosses the bedding at high angles near the nose.

On the eastern shore of Chisel Lake, opposite the southern end of Ghost Lake, another distinct fold pattern can be detected. This fold is evident from the attitudes of bedded pyroclastic rocks near the eastern shore of Chisel Lake. The pyroclastic rocks form the east limb and part of the nose of a syncline that plunges north. The axis of the syncline lies to the west beneath Chisel Lake, and the western limb is truncated by the intrusion that outcrops along the western shore of the lake. Schistosity is parallel to bedding along the eastern limb of the fold, but crosses bedding at high angles near the nose. Drag-folds are common. Their axes parallel that of the major structure. Elongate fragments in coarse pyroclastic beds are also aligned in the direction of the fold axis. The plunge of the linear elements is generally 20 degrees to the northeast.

At the north-central extremity of the map-area, the western limb of a northeasterly plunging syncline is exposed. This structure, although distinct southwest of the synclinal axis, could not be traced to the east where abundant quartzo-feldspathic rocks occur commingled with the basic pyroclastic rocks and flows.

Faults

Faults are not a prominent structural feature in the map-area. The only fault observed occurs along the western boundary of the Chisel Lake intrusion in the northwest corner of the area. This is a continuation of the Varnson Lake fault mapped by Harrison (1949) to the north. The fault is marked by shearing over a few tens of feet and rocks exposed along the fault zone are brecciated and carbonatized. Schistosity produced by the fault strikes north and dips steeply east.

A northwest-trending fault has been inferred in the low, swampy ground between Lost Lake and the southern end of Chisel Lake, because rocks exposed on each side of the presumed fault are structurally discontinuous. South of Lost Lake the bedding in pyroclastic rocks strikes northwest and dips steeply northeast, whereas north of the lake, bedding strikes north and dips moderately to the west. This inferred fault is of interest, as its northwest extension is near the Chisel Lake ore zone.

Metamorphic Fabrics

Several secondary fabrics have been recognized in metamorphic rocks of the map-area. These are:

(a) a regional northeast-trending schistosity that dips steeply southeast;

(b) a regional lineation that plunges northeast and is located within the plane of the regional schistosity;

(c) schistosity that parallels bedding or outcrop pattern; and

(d) gneissic banding that follows the outcrop pattern of layered rocks. This banding results in places through preservation of primary features within the rock, in others it is the result of metamorphic differentiation.

Most rocks show only one of these secondary fabrics, but examples were noted where three fabrics could be detected in one outcrop. The attitudes of the planar features and the direction and amount of plunge of linear elements are shown on the geological map accompanying this report. Linear elements include: the alignment of prismatic minerals; elongate segregations of flaky minerals; the elongation of fragments in pyroclastic rocks; the elongation of amygdules or pillows in flow rocks; and the axes of drag-folds in deformed rocks. In general, all these linear elements lie in the same direction and plunge in the same sense as the regional structure of the Threehouse syncline. Deviations occur only where lineation is controlled by smaller folds.

Relationships among gneissic banding, lineation, and schistosity are well exposed west of the northern end of Tent Lake. Metasedimentary rocks there show a gneissic banding accompanied by a lineation that crosses the banding at high angles. The banding represents relict bedding and the lineation is produced by drawn-out clots of biotite. Where the biotite flakes in the elongate clots are in parallel position they also produce a schistosity that varies in intensity with the amount of biotite present. Farther north within the same band of metasedimentary rocks, schistosity is parallel to gneissosity and outcrop pattern.

Banding that is considered to be the result of metamorphic differentiation occurs in some of the amphibolites in the map-area. Its metamorphic origin is apparent, because the rocks in which it is present can be traced into massive flows. Harrison (1949) has noted similar banding. The bands within amphibolites are uniformly thin, rarely more than 2 inches thick, and are not continuous for more than 20 feet along strike. Light and dark bands consist of the same mineral varieties but differ in the amount of these minerals. The proportion of light to dark bands does not vary greatly, and there is no indication that the bulk composition of the rock has been changed. A similar banding was noted within garnetiferous amphibolites southwest of Tent Lake. There bands result from the concentration of garnet into definite layers, generally less than an inch wide and continuous for several feet. Individual garnet layers are bordered by thin irregular quartz-plagioclase zones that have been impoverished in mafic constituents. The impoverished zones grade outwards into adjacent, more basic rock. Garnet porphyroblasts occurring elsewhere throughout the rock are also surrounded by circular light coloured aureoles.

Relationship of Metamorphic Fabrics to the Threehouse Syncline

The strike of regional schistosity and the direction of regional lineation are approximately parallel to the axis of the Threehouse syncline as interpreted by Harrison (1949). This geometrical relationship indicates that the rock fabrics and the syncline were formed contemporaneously. The regional schistosity may be regarded as axial-plane cleavage, and the regional lineation as a 'b' lineation. The lineation plunges in the same sense as the fold axis, but it is not known if the amount of plunge of the axis of the syncline, and of the apparently related lineation, are the same numerically. The plunge of the lineation is generally about 20 degrees—rarely does it exceed 30 degrees. If the regional fold has the same plunge, it is a gently plunging structure with steeply dipping limbs.

Textural evidence suggests that metamorphic recrystallization and deformation were contemporaneous. This is indicated by the elongation and alignment certain minerals have acquired during crystalloblastic growth. Rocks that were originally massive and homogeneous, e.g., basalt, are now characterized by directional fabrics, geometrically related to folds in the map-area. In places where movement outlasted crystalloblastic growth, metamorphic minerals have been broken or crushed, whereas in other places all cataclastic features have been healed by recrystallization. Thus one continuous major process of combined deformation and recrystallization is indicated.

Intrusive Rocks

Four types of intrusive rocks, which are younger than the Amisk Group, are recognized in the map-area. All have been metamorphosed resulting in almost complete destruction of original textures and minerals, but locally relict features are preserved. The four types are: meta-peridotite, two varieties of meta-gabbro, and meta-diorite. A small plug of meta-peridotite intrudes metasedimentary rocks of the Amisk Group northwest of Tent Lake and small bodies of meta-gabbro and meta-diorite are common throughout the map-area. The most extensive occurrence of basic intrusive rocks is in the Chisel Lake intrusion where all four types are represented.

The distinction between meta-gabbros of map-units 9b and 9c and the distinction between meta-diorite of map-unit 9d from shallow basic intrusions of the Amisk Group are relatively clear in most places. Texture and mineralogy are usually sufficient for distinction but structure, appearance in outcrop, and intensity of metamorphic alteration are also helpful.

Chisel Lake Intrusion

General Description and Form

In the central part of the map-area, the Chisel Lake intrusion outcrop has the outline of a teardrop that bulges towards the southeast. The intrusion is 5,800 feet in maximum width, 15,000 feet long in the map-area; surface exposures continue northward beyond the map-area for 17,000 feet. Four rock types are represented in the intrusion and are exposed in a concentric outcrop pattern. They are arranged in order of increasing acidity from the outside towards the centre of the intrusion, with meta-peridotite forming the outer zone, followed inward by meta-gabbros, and by meta-diorite. An exception to this concentrically zoned pattern is evident in the northwest corner of the map-area, where outcrops of meta-peridotite are surrounded by meta-diorite. There the meta-peridotite is highly sheared and the reverse relationship is probably the result of faulting.

Smooth planar contacts are exposed between meta-peridotite and meta-gabbro in two places. North of Tent Lake on the southwest side of the intrusion, the contact strikes northwest and dips 60°NE; on the western shore of Chisel Lake along the northeast side of the intrusion, it strikes northwest and dips 33°SW. These attitudes indicate a basin-shaped intrusion.

Rhythmic layering is not common, but locally a vaguely developed banding appears in the meta-gabbros. It is best exposed on the western shore of Chisel Lake, where green or greyish white bands are a few inches thick and continuous over several tens of feet. Attitudes of the bands conform with a basin-shape for the intrusion.

Irregular patches of barren quartz occur within meta-diorite at the centre of the intrusion. The quartz patches range in size from 20 to 400 square feet and are strikingly apparent in contrast to the surrounding melanocratic rocks. Their localized occurrence within the meta-diorite and their marked absence elsewhere suggest that the quartz patches are genetically related to the meta-diorite. Also within the meta-diorite along the central axis of the intrusion, roof pendants of Amisk Group pyroclastic rocks are preserved. Their presence indicates that the present erosional surface lies near the roof of the intrusion.

Nature of Contacts

Contacts between meta-peridotite and overlying meta-gabbro within the intrusion are relatively sharp in general appearance but gradational in detail. At the contacts, 3 or 4 feet of reddish green rock separates typical meta-peridotite from meta-gabbro in map-unit 9b, and displays features typical of both rock types. It is characterized by dark spots that are rich in magnetite and which represent relict olivine crystals. Locally the meta-peridotite has a planar fissility, which parallels its contacts with meta-gabbro but the gradational contact rock and meta-gabbro are massive.

Meta-gabbro of map-unit 9b consists essentially of green metamorphic amphibole near its contacts with meta-peridotite. The meta-gabbro forms a thin zone, not exceeding 300 feet in exposed thickness, and locally it is absent. Towards the centre of the intrusion, the amount of amphibole in the meta-gabbro decreases and the rock becomes richer in plagioclase and epidote, eventually grading into more feldspar-rich meta-gabbro of map-unit 9c. Farther inward meta-gabbro of map-unit 9c grades into meta-diorite. The gradation is marked by a gradual colour change in the rock types caused by the contained amphibole, which changes from green to black.

The contact between meta-peridotite of the intrusion and surrounding country rocks is exposed in only one locality—southeast of a small elongate lake northwest of Chisel Lake. There meta-peridotite is in contact with pyroclastic rocks of the Amisk Group. The contact is marked by extensive shearing and original features have been destroyed. The meta-peridotite is represented by a soft and crumbly greenschist. Elsewhere near the margins of the intrusion there is no evidence of a chilled zone, and the border rock is typical meta-peridotite.

Lithology of Rock Types

Meta-peridotite

This rock is fine- to medium-grained, massive, and weathers reddish brown. Commonly outcrop surfaces display thin discontinuous grooves or small pits about ¼ inch in diameter. In a few places the rock has been sheared or fractured and contains fibrous serpentine. The serpentine is of local occurrence and is hard, splintery, and of a poor economic grade. Fractures filled with hematite are known in one locality on the western shore of Chisel Lake.

Mineralogically, meta-peridotite consists of tremolite, green or colourless serpentine, chlorite, olivine, magnetite, and rusty iron stain, with accessory pyrrhotite and pyrite. Many thin sections show various amounts of yellowish alteration with indeterminable optical properties. Where the rock has been sheared, particularly in the northern extremity of the map-area, calcite is abundant. Apatite and anthophyllite were identified in one calcite-rich specimen.

Meta-peridotite displays a combination of relict igneous texture and metamorphic crystalloblastic texture. The main relict feature is granular mosaic intergrowths consisting almost entirely of serpentine pseudomorphous after olivine. In places small cores of olivine still exist within larger grains of completely altered material. Elsewhere relict granular texture appears in various stages of destruction owing to the crystalloblastic growth of prismatic or acicular tremolite crystals, which are arranged in decussate pattern. Magnetite occurs as distinct grains and fine dusty material with the latter surrounding or impregnating relict olivine crystals. Rusty iron stain is responsible for the reddish brown colour of the rock.

Meta-gabbros

The two types of meta-gabbro distinguished within the Chisel Lake intrusion are medium to coarse grained and massive. The rocks are lithologically similar, differing only in the amount of the constituent minerals. Meta-gabbro of map-unit 9b, which occurs in contact with meta-peridotite, rarely contains more than 20 per cent plagioclase and consists mainly of amphibole, with minor amounts of clinozoisite, serpentine, magnetite, and chlorite. The meta-gabbro of map-unit 9c contains more plagioclase and considerably more clinozoisite. Both rock types are recrystallized and the mineral constituents are secondary. Amphibole occurs in equidimensional pale green metacrysts, which are crushed along the borders producing mortar texture. Fine-grained amphibole, plagioclase of intermediate compositions, and clinozoisite occur as interstitial anhedral grains between the larger amphibole metacrysts. Talc and calcite are abundant in a few places where the rocks have been sheared.

Igneous textures have been largely destroyed by recrystallization and shearing, but locally relict ophitic texture is preserved in the meta-gabbro of map-unit 9c. It is portrayed by deep rectangular embayments in amphibole metacrysts. The embayments are filled with fine-grained clinozoisite and are thought to represent the outlines of former plagioclase lath-shaped crystals intergrown with original pyroxene crystals.

Meta-diorite

This is the most acidic member of the intrusion and is distinguished from meta-gabbros in the field because of its darker colour and its quartz content. The rock is medium to coarse grained and massive in outcrop. In thin section it is seen to consist of green amphibole, plagioclase, quartz, and magnetite. Accessory minerals are calcite, apatite, pyrite, clinozoisite, and sphene. The amphibole is more highly coloured and less deformed than that in the meta-gabbros and occurs as large crystals, which have inclusions of quartz and plagioclase. Plagioclase occurs as interstitial anhedral grains for the most part, but in a few places it is subhedral with polysynthetic twinning and continuous zoning. These features suggest that the subhedral crystals are primary. Magnetite and quartz are characteristic minerals in meta-diorite but are virtually absent in the meta-gabbros.

Composition of Rock Types

Standard chemical analyses, made on each of the four rock types represented in the Chisel Lake intrusion, and semi-quantitative spectrographic analyses for several minor elements, are listed in Table VII. Micrometric modal analyses and calculated normative minerals for each chemically analyzed rock are listed in Table VIII.

Table VII

Compositions of Rock Types in Chisel Lake Intrusion

Oxide	Wf-1645	Wf-1646	Wf-1647	Wf-1648
SiO_2	38.13	47.96	48.73	49.95
TiO_2	0.28	0.46	0.54	1.55
Al_2O_3	3.72	13.67	13.51	13.55
Fe_2O_3	8.65	0.93	1.39	2.50
FeO	5.33	6.83	6.27	13.23
MnO	0.15	0.13	0.15	0.23
MgO	30.64	13.41	11.64	5.66
CaO	2.15	13.83	15.13	9.43
Na_2O	0.08	1.04	0.79	2.33
K_2O	0.02	0.12	0.11	0.20
H_2O +	9.01	0.49	0.71	0.97
H_2O −	0.59	0.05	0.43	0.03
P_2O_5	0.04	0.05	0.05	0.14
CO_2	0.06	0.34	0.00	0.05
Cr_2O_4	0.58	0.16	0.09	NF
NiO	0.07	tr.	tr.	NF
Total	99.50	99.47	99.54	99.82

Analyst: S. Courville, Geological Survey of Canada

Semi-quantitative Spectrographic Analyses

Ba	C	B	B	B	A = .1 —1%
Co	C	C	C	C	B = .01—.1%
Cu	C	C	C	C	C = below .01%
Sc	—	B	B	B	
Sr	—	C	C	B	
V	C	B	B	B	
Zn	—	—	—	.02	
Zr	—	—	—	C	

Analyst: W. H. Champ, Geological Survey of Canada

Wf-1645 Meta-peridotite collected 2,500 feet southeast from the extreme northern end of Chisel Lake at the western shore of the lake. East-west section 52 north with reference to geophysical grid lines within the area.

Wf-1646—Meta-gabbro collected 934 feet directly west of 1645.

Wf-1647—Meta-gabbro collected 1,268 feet directly west of 1645.

Wf-1648—Meta-diorite collected 2,015 feet directly west of 1645.

Table VIII

Normative and Modal Minerals in Members of Chisel Lake Intrusion

Mode (Wt. %)	Wf-1645	Wf-1646	Wf-1647	Wf-1648
Amphibole	27.7	88.0	56.1	77.7
Plagioclase	0.0	10.0	11.4	12.6
Clinozoisite	0.0	1.0	31.3	0.0
Serpentine	32.5	0.0	0.0	0.0
Chlorite	15.0	0.0	0.0	0.0
Quartz	0.0	0.0	0.0	4.2
Magnetite	17.7	0.0	0.0	5.5
Iron stain	7.1	0.0	0.0	0.0
Sphene	0.0	1.0	1.2	0.0
Total	100.0	100.0	100.0	100.0

Norm. (Wt. %)	Wf-1645	Wf-1646	Wf-1647	Wf-1648
Quartz	0.00	0.00	0.00	2.94
Orthoclase	0.00	0.56	0.56	1.11
Albite	1.05	8.38	6.81	19.39
Anorthite	9.45	32.53	32.80	25.85
Diopside	0.86	27.12	33.82	16.73
Hypersthene	31.93	15.00	17.36	25.65
Olivine	32.38	11.94	3.82	0.00
Magnetite	12.53	1.39	2.09	3.71
Chromite	0.96	0.24	0.24	0.00
Ilmenite	0.61	0.91	0.91	2.89
Calcite	0.00	0.70	0.00	0.00
Apatite	0.00	0.00	0.00	0.34
Total	89.77	98.77	98.41	98.61

Classification according to C.I.P.W. system:
Wf-1645—Class 5, not represented by order, rang 1, section 1, subrang 1.
Wf-1646—Class 3, order 5, rang 5, not represented by subrang.
Wf-1647—Class 3, order 5, rang 5, not represented by subrang.
Wf-1648—Class 3, order 5, rang 4, subrang 3.

Origin and History of Rock Types

The descriptions of the rock types, their close association in the field, the gradational changes distinguishing the successive members, and the nature of the contacts all indicate that this assemblage is one petrological unit derived from a common magma. The apparent basin-shape of the intrusion, concentric outcrop pattern, and increasing acidity of constituent rock members towards the centre further suggest that the rock types originated by some form of gravitative crystallization differentiation.

Figure 3 is a variation diagram representing the quantitative changes in the constituent oxides of the rocks during differentiation. The significant variations are the increase in alkalis, lime, and ferrous iron; the marked decrease in magnesium; and the variation in the amount of alumina. The changes are characteristic of igneous rock series ranging from ultrabasic to intermediate in composition.

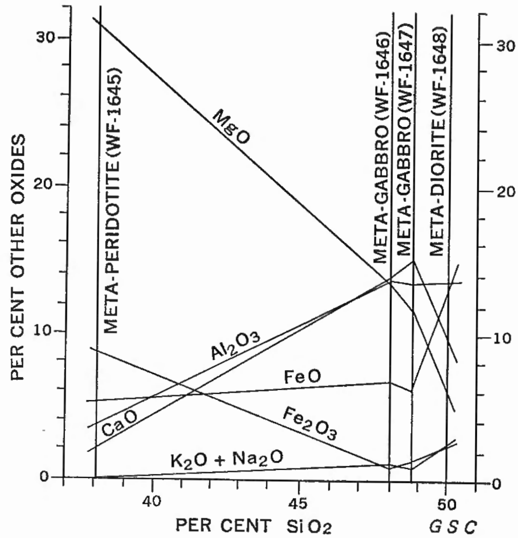

FIGURE 3. Variation diagram representing the quantitative changes in constituent oxides during crystallization of the Chisel Lake intrusion.

The Chisel Lake intrusion, if classified according to the scheme of Smith (1958), forms an intermediate member in the ultrabasic and gabbroic layered pluton series, and combines features considered typical of gabbroic layered plutons with those typical of ultrabasic plutons of orogenic belts.

The Chisel Lake intrusion and related intrusive rocks of the map-area have been metamorphosed and granulated, but the local preservation of relict textures and minerals, particularly in meta-peridotite, suggests that the rocks are younger than the regional metamorphism that changed Amisk Group rocks into crystalline schists and gneisses. The younger intrusive rocks are massive and have not apparently been affected by the penetrating forces that accompanied regional metamorphism and produced secondary lineation and foliation in the country rocks. Mortar structures in younger intrusions are conspicuous, but these have resulted through granulation, which postdates metamorphism, as it is the metamorphic minerals that are granulated.

Harrison (1949) has interpreted basic intrusions of the regional area as earlier than the metamorphism that transformed rocks of the Snow Group into typical Kisseynew gneisses. This suggests that the younger intrusive rocks of the map-area are older than the regional metamorphism that affected the country rocks. Possibly the basic intrusive rocks were emplaced during the waning stages of regional metamorphism, sharing only in that part of the process that postdated their intrusion.

Chapter III

MINERAL DEPOSITS

Two base-metal orebodies owned by Hudson Bay Mining and Smelting Co., Limited occur in the map-area. The larger, the Chisel Lake orebody, is directly below the southern end of Chisel Lake. The smaller, or Ghost Lake orebody, is 2,000 feet northeast of Lost Lake and is 4,000 feet east of the Chisel Lake orebody. Tonnages and ore grades of these deposits are listed in Table IX.

The map-area was closely prospected in the past, and the ground enclosing the orebodies has changed ownership many times. There is little surface indication of economic sulphide concentrations below Chisel Lake, and previous interest in the area centred around two small mineralized quartz zones (Harrison, 1949). One of these is on the southeast shore of Chisel Lake and is approximately along strike from the present orebody; the other is about a quarter of a mile farther south. Both are thin veins and small stockworks of quartz, and contain irregularly distributed pyrite. Economic sulphide deposits were discovered in the area in 1956 by ground electromagnetic surveys, followed by diamond drilling of obtained anomalies. Production at Chisel Lake began during the summer of 1960 at a proposed rate of 1,000 tons per day. The ore is taken directly to Flin Flon by rail for milling and smelting.

Most of the writer's observations and interpretations of the ore deposits are based on data collected from surface mapping, and from diamond-drill records kindly supplied by Hudson Bay Mining Company. Two short visits underground were made at Chisel Lake in 1959.

The presence of a manganese-rich coating was revealed on rocks surrounding Chisel Lake subsequent to its drainage. The coating is one eighth to one quarter inch thick, and varies in colour from steel-blue to dark brown. It is colloform with an amorphous appearance, and bears no relationship to the rocks that it covers. The coating contains an average of about 1,000 ppm of zinc as determined colorimetrically from samples collected systematically around the lake shore. No obvious relationship exists between the distribution of zinc values in the coating and the position of the Chisel Lake orebody. Results of the analyses are on file with the Geological Survey of Canada in Ottawa.

Table IX

Tonnages and Ore Grades, Chisel Lake and Ghost Lake Orebodies[1]

Orebody	Tonnage	Au oz/ton	Ag oz/ton	Cu %	Zn %	Pb %
Chisel Lake	3,832,400	0.066	1.96	0.42	11.0	0.91
Ghost Lake	260,700	0.013	1.14	1.42	11.6	0.7

[1] Figures from Hudson Bay Mining and Smelting Co., Limited, Annual Report 1956.

Chisel Lake Orebody

The Chisel Lake orebody occurs in metasedimentary and volcanic rocks of the Amisk Group. The foot-wall and hanging-wall rocks are garnetiferous biotite schists, which commonly contain staurolite and minor amounts of kyanite and andalusite. These are followed outward from the ore zone on the hanging-wall side by garnetiferous amphibolites that are lithologically similar to massive flows of map-unit 2. Considerable vein material or gangue, which consists mainly of actinolite, tremolite, dolomite, and chlorite, accompanies the sulphide minerals. The highest grade zinc-copper-lead ores are found in this gangue material, although disseminated minerals and sulphide veins also occur in siliceous schists of the hanging-wall and foot-wall.

Structure

The mineralized zone is somewhat irregularly shaped. It strikes northwest and dips towards the northeast at roughly 45 degrees, with the southeast end of the orebody raking steeply towards the northwest. Projections of the mineralized zone to the surface are shown on the map and Figure 4 accompanying this report. The sulphide minerals and host rocks are bounded by basic intrusive rocks to the northwest; to the southeast along strike the underground geology cannot be exactly fitted to surface exposures. Staurolite-bearing rocks, which are so characteristic of the ore zone, are not represented along the lake shore, although staurolite was found sparingly in one place and a thin pyritiferous vein in another. The staurolite-bearing rocks of the mineralized zone are interpreted as a metasedimentary intercalation among pyroclastic rocks of the Amisk Group as exposed on the southeast shore of Chisel Lake. The position of garnetiferous amphibolites in the hanging-wall of the orebody, relative to surface exposures of similar rocks, is indefinite.

A fault has been inferred lying almost parallel to the ore zone between Chisel and Lost Lakes. Structural discontinuity is pronounced across this inferred fault and both primary features (such as bedding) and secondary structures (cleavage and lineation) are discontinuous across it. The orebody is on the southwest side of the presumed fault. As the fault does not apparently intersect the northeast-dipping orebody at depth, it may likewise dip northeast, with the orebody on its foot-wall side.

The orebody is also approximately coincident with the axial plane of the northwesterly plunging overturned syncline to the southeast of Chisel Lake. The mineralized zone strikes parallel to secondary structures in the layered rocks and the rake of the southeast end of the orebody towards the northwest is in the same direction and sense as the plunge of lineation associated with the fold. The strike of the axial plane of this small fold at Chisel Lake makes an angle of about 90 degrees with the strike of the axial plane of the regional Threehouse syncline. The syncline containing the mineral-

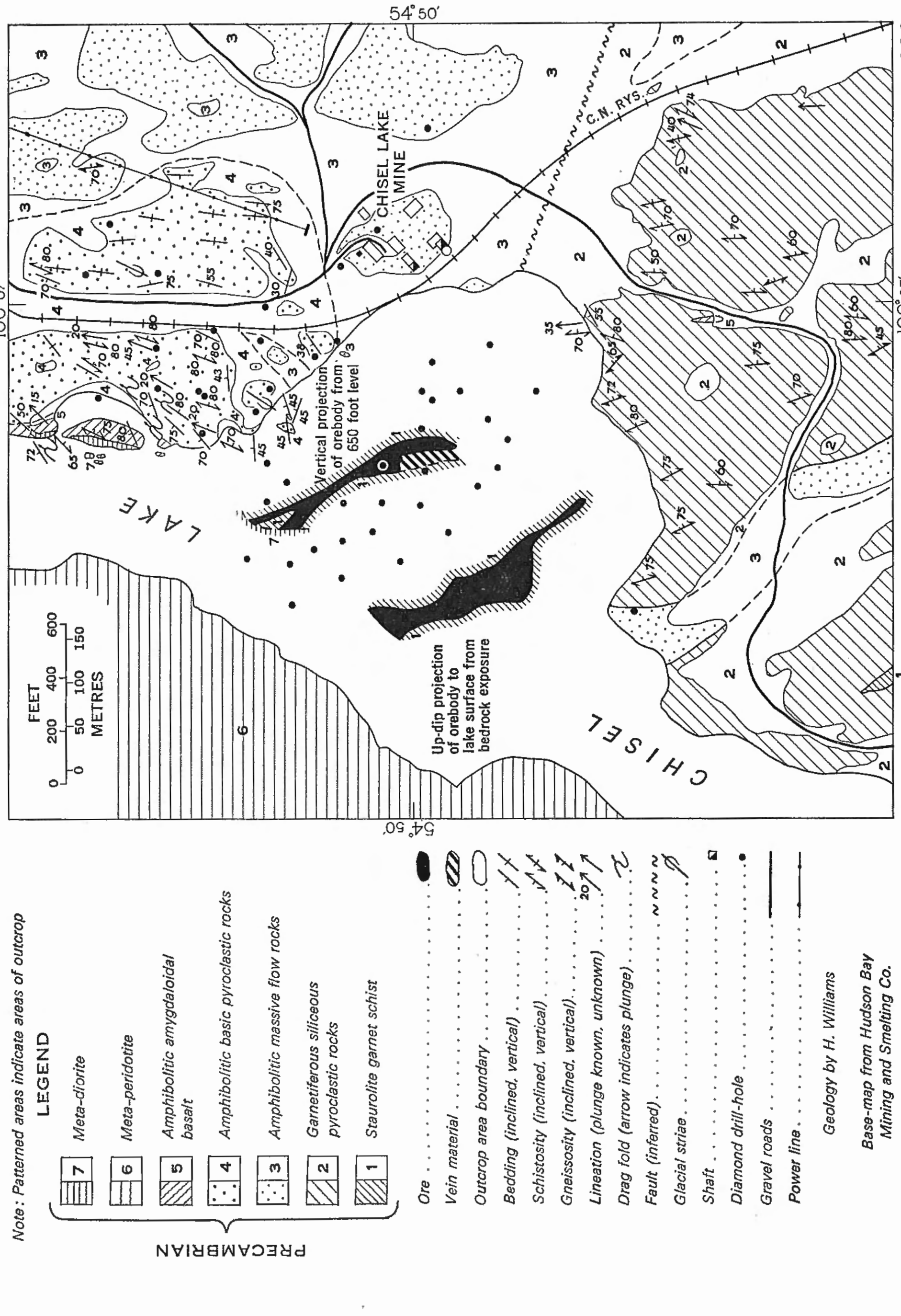

FIGURE 4. Geology, Chisel Lake mine area.

ized zone is therefore a small cross-fold within the much larger Threehouse syncline.

The role of folds or faults with regard to localization of ore cannot be properly assessed with the information at hand; however, these structures may be controlling factors determining the position of the orebody.

Mineralogy

The principal sulphides in the Chisel Lake orebody in order of decreasing abundance are: sphalerite, pyrite, pyrrhotite, chalcopyrite, galena, and arsenopyrite. In addition Bence and Coleman (1963) have reported gudmundite, marcasite, meneghinite, tetrahedrite, a bournonite-seligmannite solid solution, and native gold. Most of the ores have a granular texture, and are medium to coarse grained and massive. The texture is produced by an even distribution of subhedral to euhedral pyrite crystals surrounded by a matrix of black sphalerite or other sulphide minerals.

It appears that shearing and granulation were operative during much of the time interval of ore deposition. Gangue material in the mineralized zone is extremely sheared in places, and pyrite crystals are commonly brecciated and broken. Mortar structures are commonly healed by the later deposition of pyrrhotite, sphalerite, chalcopyrite, or galena. In addition, later minerals in the depositional sequence, such as galena, display cleavage traces that are curved or broken, suggesting a stress environment.

Temperature of Deposition

One specimen of black, coarse-grained sphalerite was chemically analyzed for its iron content by the Geological Survey of Canada. Homogeneous cleavage fragments, uncontaminated by other sulphides, were used for the analysis. No pyrrhotite was present in the sample. The FeS content of the sample, assuming the total iron as being of the ferrous variety, is 13.82 weight per cent, which is equivalent to 15.11 molecular per cent. Using the information from Kullerud (1953) as compiled by F. G. Smith (pers. com.), the FeS content indicates a minimum temperature of deposition of 500°C. This value increases with pressure at the time of deposition by about 25°C per 1,000 bars.

More complete geothermometry studies of the orebody were made by Bence and Coleman (1963) using the sphalerite geothermometer of Kullerud (1953) and the pyrrhotite geothermometer of Arnold (1962). Their results show that minimum temperatures of formation determined from 14 samples using the sphalerite geothermometer range from 275 to 425°C. Bence and Coleman have interpreted the distribution of values to indicate temperature zonation within the orebody during sphalerite deposition, whereby highest temperatures occurred near its centre, decreasing towards the margins. Pyrrhotite geothermometry on two of the samples yielded temperatures of 510 and 515°C. The pyrrhotite was regarded as having formed earlier than sphalerite at higher temperatures, and the authors add that early formation of pyrrhotite is also supported by textural evidence. If the textural evidence is conclusive and pyrrhotite and sphalerite are not coeval, then the range in temperature indicated by the sphalerite geothermometer may also be interpreted to mean that the amount of available iron varied from place to place within the orebody during sphalerite crystallization, and that the variations in minimum temperatures are more apparent than real.

Vein Material

Vein material or gangue, which occurs with the sulphides in the mineralized zone, is of variable mineral composition and texture. Minerals recognized, in decreasing order of abundance, are actinolite, dolomite, tremolite, chlorite, biotite, quartz, muscovite, and talc; with minor amounts of gahnite, apatite, tourmaline, epidote, sphene, and serpentine. In places, coarse-grained massive rocks consisting mainly of green prisms of actinolite grade into medium-grained granular varieties composed of dolomite and tremolite, or schistose rocks made up of chlorite and biotite, or tremolite and talc. Some of the gangue minerals accompany the sulphides where they occur in discordant veins in the country rock. Actinolite and dolomite were seen in a few veins, and quartz and minor amounts of gahnite are common in most.

Sulphides commonly occur interstitially to silicate minerals of the gangue, but in places appear to replace the silicates. The sulphides are also thought to replace dolomite. Galena occurs not only in angular areas between actinolite crystals, suggesting cavity filling, but also as streaks and bands parallel to cleavage, suggesting replacement. Similar textural relations are displayed between sphalerite and chlorite. Pyrite was not found to occur interstitially among silicate gangue minerals, probably because of its greater tendency to form euhedral crystals. Sulphides in specimens of mixed dolomite and lime silicates appear to be more intimately associated with the silicates.

The origin of the vein material or gangue is in doubt. It predates the sulphide minerals and appears to have been introduced, especially in places where actinolite or dolomite accompany sulphides in veins, but much of the mixed lime silicate and carbonate material could be primary and represent metamorphosed limy sedimentary rocks.

Host Rocks

Metasedimentary rocks bordering the ore zone have been altered in comparison with similar rocks elsewhere in the map-area. They consist of quartz, sodic plagioclase, biotite, chlorite, garnet, staurolite, sericite, kyanite, and andalusite. Accessory minerals are carbonate, epidote, apatite, gahnite, and the various sulphides of the ore deposit. The most conspicuous alterations are the development of sericite along shear surfaces and an apparent introduction of silica. Staurolite found in the rocks has two distinct modes of occurrence: as shadowy, extremely poikilitic, anhedral crystals, and as sharply bounded euhedral crystals. Otherwise, textures are for the most part similar to metamorphic textures of other metasedimentary rocks in the map-area. Gahnite is a common accessory in rocks near the ore zone, though it is unknown elsewhere. Like staurolite, it occurs either as extremely poikilitic anhedral crystals or as sharply bounded euhedral ones.

Sulphides found in the metamorphic wall-rocks of the orebody occur in veins or are disseminated interstitially among the silicate minerals. They are most abundant in specimens rich in biotite and sericite and are associated with these minerals. In a few places staurolite crystals were observed surrounded by massive pyrite.

Metamorphism

Metamorphosed sedimentary rocks that border the mineralized zone on both sides display metamorphic mineral associations different from vein material that accompanies the sulphides. The metasedimentary rocks belong to the staurolite-kyanite subdivision of the amphibolite facies (Turner, 1948), whereas associations of chlorite and biotite or talc in the vein material of the ore zone are typical of the greenschist facies. The metamorphosed sedimentary rocks bordering the orebody have been altered, presumably during ore formation, suggesting that regional metamorphism predated sulphide deposition.

It is not known whether the vein material accompanying the sulphides originated before or after regional metamorphism of the country rocks. Minerals present in the vein material, which are typical of the greenschist facies, may have formed through retrogressive metamorphism of earlier amphibolite facies mineral assemblages. Vein materials such as tremolite or actinolite appear to be stable in association with chlorite, biotite, or talc, and in places well-formed decussate prisms of actinolite are embedded in a chloritic matrix and there is nothing to suggest that actinolite and chlorite did not originate together.

Schistose vein material and sulphide minerals are terminated by meta-diorite at the northwest end of the mineralized zone. The meta-diorite exposed underground is probably continuous with outcrops of similar rock to the northeast along the east shore of Chisel Lake, and all are probably related to the nearby Chisel Lake intrusion. The meta-diorite, which terminates the orebody, has a fine-grained border-zone several feet thick, and contains small amounts of sulphides, which diminish away from the contact. The contact appears to be intrusive and suggests that the younger basic intrusions postdate sulphide deposition.

Summary

The Chisel Lake base-metal orebody is a high temperature, epigenetic deposit, which originated subsequent to high-grade regional metamorphism that affected surrounding rocks of the Amisk Group. The orebody bears no apparent relationship to nearby basic intrusive rocks, and its position probably relates to structural control. The general position of the deposit seems related to cross-folding; but if regional metamorphism and folding are coeval, as earlier suggested in this report, then the local distribution of ore and vein material, and textures and mineral facies of the vein material, are all mainly a consequence of later deformation and metamorphism. Faulting, which postdates folding, may have played an important role in localizing the orebody.

The occurrence of sulphide ores in moderately high-grade metamorphic rocks furnishes incentive for prospecting in metamorphic terranes that have frequently been ignored.

Ghost Lake Orebody

Only limited information on the Ghost Lake orebody is available from diamond-drill records. Many similarities exist between it and the Chisel Lake orebody, which suggest that the ore in both had a common origin and was localized by similar processes.

The shape of the Ghost Lake orebody is roughly similar to that of the Chisel Lake body. It has an irregular planar disposition, striking northwest and dipping towards the northeast. Both orebodies are therefore orientated in the same direction and dip in the same sense. The Ghost Lake orebody is north of the inferred fault that extends from Lost Lake to Chisel Lake.

All the common sulphides found at Chisel Lake are represented in the Ghost Lake orebody. Much of the gangue or vein material is also represented, as is apparent from frequent references to chlorite biotite schist, hornblende schist, and carbonate in the drill logs. Sericite is plentiful in the mineralized zone. The hanging-wall rocks are typical of the Amisk pyroclastic rocks and older shallow intrusions of map-unit 8. The foot-wall rocks in places contain staurolite, a mineral not observed at the surface, which suggests that metasedimentary rocks are intercalated with the Amisk volcanic rocks in this deposit as they are at Chisel Lake.

SELECTED BIBLIOGRAPHY

Alcock, F. J.
1920: Reed-Wekusko map-area, northern Manitoba; *Geol. Surv. Can.*, Mem. 119.

Armstrong, J. E.
1941: Wekusko, Manitoba; *Geol. Surv. Can.*, Map 665A.

Arnold, R. G.
1962: Equilibrium relations between pyrrhotite and pyrite from 325° to 743°C; *Econ. Geol.*, vol. 57, pp. 72-90.

Barton, P. B., and Kullerud, G.
1957: Preliminary report on the system FeS-ZnS-S, and implications regarding the use of the sphalerite geothermometer; *Bull. Geol. Soc. Amer.*, vol. 68, p. 1699.

Bastin, E. S.
1909: Chemical composition as a criterion in identifying metamorphosed sediments; *J. Geol.*, vol. 17, pp. 445-472.
1913: Chemical composition as a criterion in identifying metamorphosed sediments; *J. Geol.*, vol. 21, pp. 193-201.

Bateman, J. D., and Harrison, J. M.
1945: Mikanagan Lake, Manitoba; *Geol. Surv. Can.*, Map 832A.
1946: Sherridon, Manitoba; *Geol. Surv. Can.*, Map 862A.

Bell, C. K.
1962: Cross Lake map-area, Manitoba; *Geol. Surv. Can.*, Paper 61-22.

Bence, A. E., and Coleman, L. C.
1963: Temperatures of formation of the Chisel Lake sulphide deposit, Snow Lake, Manitoba; *Can. Mineralogist*, vol. 7, pt. 4.

Bowen, N. L.
1956: The evolution of the igneous rocks; New York, Dover Publications, Inc.

Bruce, E. L.
1917: Schist Lake and Wekusko Lake area, northern Manitoba; *Geol. Surv. Can.*, Sum. Rept. 1916, pp. 159-169.
1918: Amisk-Athapapuskow Lakes district; *Geol. Surv. Can.*, Mem. 105.
1919: District lying between Reed Lake and Elbow Lake, Manitoba; *Geol. Surv. Can.*, Sum. Rept., pt. D, pp. 2-5.

Byers, A. R.
1954: Geology of Wildnest and Amisk Lake area, Manitoba; *Precambrian*, vol. 57, No. 5.
1959: Base-metal mineralization associated with pegmatite, northern Saskatchewan; *Proc. Geol. Assoc. Can.*, vol. 2.

Byers, A. R., and Dahlstrom, C. D. A.
1954: Geology and mineral deposits of the Amisk-Wildnest Lakes area, Saskatchewan; *Sask. Dept. Min. Res.*, Geology Br., Rept. 14.

Cross, C. W., *et al.*
1903: Quantitative classification of igneous rocks; Chicago, Univ. Chicago Press.

Frarey, M. J.
1949: Crowduck Bay, Manitoba; *Geol. Surv. Can.*, Map 987A.

Grout, F. F.
1926: The use of calculations in petrology; *J. Geol.*, vol. 34, pp. 512-558.
1941: Formation of igneous-looking rocks by metasomatism; a critical review and suggested research; *Bull. Geol. Soc. Amer.*, vol. 52, pp. 1525-1576.

Harker, A.
1939: Metamorphism; London, Methuen.

Harrison, J. M.
1949: Geology and mineral deposits of File-Tramping Lakes area, Manitoba; *Geol. Surv. Can.*, Mem. 250.
1951a: Precambrian correlation and nomenclature, and problems of the Kisseynew gneisses in Manitoba; *Geol. Surv. Can.*, Bull. 20.
1951b: Possible major structural control of ore deposits in the Flin Flon-Snow Lake mineral belt, Manitoba; *Trans. Can. Inst. Min. Met.*, vol. 54, pp. 4-8.

Johannsen, A.
1931: A descriptive petrography of the igneous rocks; Chicago, Univ. Chicago Press, Vol. 1.

Kalliokoski, J.
1952: Weldon Bay map-area, Manitoba; *Geol. Surv. Can.*, Mem. 270.
1953: Interpretations of the structural geology of the Sherridon-Flin Flon region, Manitoba; *Geol. Surv. Can.*, Bull. 25.

Kullerud, G.
1953: The FeS-ZnS system. A geological thermometer; *Norske Geologisk Tidsskrift*, vol. 32, pp. 61-147.

Larsen, E. S.
1931: Composition of the alkali amphiboles; *Am. Mineralogist*, vol. 16, pp. 140-144.

Loudon, J. R.
1960: The origin of the porphyry and porphyry-like rocks of Elbow, New Brunswick; *Univ. Toronto*, unpubl. Ph.D. thesis.

McGlynn, J. C.
1959: Elbow-Heming Lakes area, Manitoba; *Geol. Surv. Can.*, Mem. 305.

Moorhouse, W. W.
1941: Geology of the zinc-lead deposit on Calumet Island, Quebec; *Bull. Geol. Soc. Amer.*, vol. 52, pp. 601-632.

Pettijohn, F. J.
1956: Sedimentary rocks; New York, Harper and Brothers.

Podolsky, T.
1951: Cranberry Portage (east half), Manitoba; *Geol. Surv. Can.*, Paper 51-17.

Poldervaart, A.
1953: Metamorphism of basaltic rocks; a review; *Bull. Geol. Soc. Amer.*, vol. 64, pp. 259-274.

Poldervaart, A., and Taubeneck, W. H.
1960: Layered intrusions; *Internat. Geol. Congress*, Rept. Twenty-First Session, Norden, Pt. 13.

Robertson, D. S.
1953: Batty Lake map-area, Manitoba; *Geol. Surv. Can.*, Mem. 271.

Russell, G. A.
1957: Structural studies of the Snow Lake-Herb Lake area, Manitoba; *Man. Mines Br.*, Publ. 55-3.

Smith, C. H.
1958: Bay of Islands igneous complex, western Newfoundland; *Geol. Surv. Can.*, Mem. 290.

Stockwell, C. H.
1927: An X-ray study of the garnet group; *Am. Mineralogist*, vol. 12, pp. 327-344.
1935: Gold deposits of Elbow-Morton area, Manitoba; *Geol. Surv. Can.*, Mem. 186.
1937: Gold deposits of Herb Lake area, northern Manitoba; *Geol. Surv. Can.*, Mem. 208.
1946: Flin Flon-Mandy area, Manitoba and Saskatchewan; *Geol. Surv. Can.*, Paper 46-14.

Tanton, T. L.
1941: Schist Lake, Saskatchewan and Manitoba; *Geol. Surv. Can.*, Map 633A.

Turner, F. J.
1948: Mineralogical and structural evolution of the metamorphic rocks; *Geol. Soc. Amer.*, Mem. 30.

Turner, F. J., and Verhoogen, J.
1951: Igneous and metamorphic petrology; McGraw Hill Book Co. Inc.

Tuttle, O. F., and Bowen, N. L.
1958: Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O; *Geol. Soc. Amer.*, Mem. 74.

Walton, M.
1955: The emplacement of granite; *Am. J. Sci.*, vol. 253, p. 1.

Washington, H. S.
1917: Chemical analyses of igneous rocks; *U.S. Geol. Surv.*, Prof. Paper 99.

Williams, H.
1961: A petrographic study of the metamorphic rocks of the Chisel Lake area, northern Manitoba; *Univ. Toronto*, unpubl. Ph.D. thesis.

Wright, J. F.
1932: Oxford House area, Manitoba; *Geol. Surv. Can.*, Sum. Rept. 1931, pt. C, pp. 1-25.

Yoder, H. S.
1952: The MgO-Al_2O_3-SiO_2-H_2O system and the related metamorphic facies; *Am. J. Sci.*, Bowen vol., pt. 2, pp. 569-627.

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