GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

MEMOIR 357

GEOLOGY OF MAYO LAKE, SCOUGALE CREEK AND McQUESTEN LAKE MAP-AREAS, YUKON TERRITORY

L. H. Green

Price $3.00

Ottawa
Canada
1971

GEOLOGY OF MAYO LAKE, SCOUGALE CREEK AND McQUESTEN LAKE MAP-AREAS, YUKON TERRITORY

1,450-1970-6118

Technical Editor
R. G. BLACKADAR

Editor
D. WHITE

Printed on Georgian Offset Smooth Finish
Set in Times Roman with
20th Century captions by
THE CARSWELL PRINTING COMPANY

Artwork by CARTOGRAPHIC UNIT, GSC

FIGURE 1. The Davidson Range viewed from the abandoned mining camp at Wernecke on the west slope of Keno Hill.

GEOLOGICAL SURVEY
OF CANADA

MEMOIR 357

GEOLOGY OF MAYO LAKE, SCOUGALE CREEK AND McQUESTEN LAKE MAP-AREAS, YUKON TERRITORY (105M/15, 106D/2, 106D/3)

By
L. H. Green

DEPARTMENT OF
ENERGY, MINES AND RESOURCES
CANADA

Available by mail from Information Canada, Ottawa,
from Geological Survey of Canada, 601 Booth St., Ottawa,
and at the following Information Canada bookshops:

HALIFAX
1735 Barrington Street

MONTREAL
Æterna-Vie Building, 1182 St. Catherine Street West

OTTAWA
171 Slater Street

TORONTO
221 Yonge Street

WINNIPEG
Mall Center Building, 499 Portage Avenue

VANCOUVER
657 Granville Street

or through your bookseller

A deposit copy of this publication is also available for reference
in public libraries across Canada

Price $3.00 Cat. No. M46-357

Price subject to change without notice

Information Canada
Ottawa, 1971

PREFACE

The region described in this report is adjacent to the highly productive silver-lead properties of Keno and Galena Hills and is geologically similar to that area.

Much of the district is underlain by quartzite, phyllite and phyllitic quartzite formations that range in age from Precambrian to Mesozoic. The Keno Hill Quartzite, long considered to be Precambrian, is now known to be Early Cretaceous in age and this discovery has necessitated a re-interpretation of the geology of many parts of central Yukon.

This report synthesizes data collected during five field seasons as well as previously published work, and presents a comprehensive description of the geological framework of this interesting and potentially economically important part of Yukon Territory.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, June 20, 1968

MEMOIR 357 — Geologie der Kartenblätter Mayo Lake, Scougale Creek und McQuesten Lake (Yukonterritorium)

Von Lewis Howard Green

Das Gebiet grenzt an die bedeutenden Silber-Blei-Lagerstätten Keno und Galena Hills. Bei den Gesteinen handelt es sich hauptsächlich um Quarzit, Phyllit und phyllitischen Quarzit; sie sind präkambrischen bis mesozoischen Alters und haben zwei Verformungen durchgemacht.

МЕМУАР 357 — Геология картографированного района оз. Майо, Скугейл Крик и оз. МакКвестен территории Юкон.

Л. Х. Грин

Район этот примыкает к важному району добычи серебра и свинца гор Кино и Галина. Горные породы, в основном, кварциты, филлиты и филлитовые кварциты от докембрийского до мезозойского времени, подвергшиеся двум периодам деформаций.

CONTENTS

Illustrations

GEOLOGY OF MAYO LAKE, SCOUGALE CREEK AND McQUESTEN LAKE MAP-AREAS, YUKON TERRITORY

Abstract

The Mayo Lake, Scougale Creek and McQuesten Lake map-areas cover about 790 square miles in central Yukon Territory bounded by latitudes 63°45′ and 64°15′N and longitudes 134°30′ and 135°30′W. The area lies within Stewart Plateau, a subdivision of the Yukon Plateau.

Much of the area is underlain by quartzite, phyllitic quartzite, and phyllite that have been separated into a number of map-units believed to range from Precambrian to Mesozoic in age. The Keno Hill Quartzite, a distinctive, dark, massive quartzite, is the marker horizon for mapping. This quartzite, formerly considered of Precambrian age, is now believed to be of Early Cretaceous age on the basis of work to the west of the present area.

The Keno Hill Quartzite and the underlying Lower Schist have been intruded by numerous sills of diorite and gabbro, now extensively altered to secondary minerals. These sills, locally referred to as greenstone, are believed to have been intruded prior to and possibly also in the early stages of an older deformation. Fold-like terminations of a number of greenstone bodies are described. Granitic rocks of probable Late Cretaceous age intrude older sedimentary rocks.

Two periods of folding and faulting are believed to have affected rocks of the area, (1) an older deformation that may have begun by the thrusting of Precambrian rocks on Mesozoic rocks followed by extensive northward movement with the production of complex folds, both small- and large-scale, and pervasive development of foliation; and (2) a younger deformation marked by open folding, the formation of wrinkle lineation and possible rotation of earlier formed fold axes. Late faulting may be the final phase of this deformation.

The area lies adjacent to and is underlain by the same rocks as the highly productive Keno and Galena Hills silver camp. A number of silver-lead showings have been explored within the area, but those discovered to date lack the high silver values of the main camp.

Résumé

Les régions du lac Mayo, de Scougale Creek et du lac McQuesten couvrent environ 790 milles carrés, au centre du Yukon, limités par les latitudes 63°45′ et 64°15′N et les longitudes 134°30′ et 135°30′W. La région entière se trouve dans le plateau Stewart, qui fait partie du plateau du Yukon.

La plus grande partie de la région est sous-jacente à du quartzite, du quartzite phylliteux, et de la phyllite qui ont été répartis en un certain nombre d'unités, et qui pourraient s'échelonner du Précambrien au Mésozoïque. Le quartzite de Keno Hill, très particulier, sombre, massif, est la couche repère de l'horizon de la carte. Ce quartzite, que l'on pensait dater du Précambrien, est maintenant considéré comme datant du début du Crétacé, d'après des travaux effectués à l'ouest de la présente région.

De nombreux filons-couches de diorite et de gabbro, à présent profondément altérés, transformés en minéraux secondaires, ont pénétré dans le quartzite de Keno Hill et dans le schiste inférieur qui lui est sous-jacent. Ces filons-couches, que l'on désigne dans la région sous le nom de roche verte, auraient fait intrusion antérieurement à une déformation plus ancienne, et peut-être également au cours des premières étapes de cette déformation. Les terminaisons en plis d'un certain nombre de massifs de roche verte sont décrites. Des roches granitiques, datant probablement de la fin du Crétacé, font intrusion dans des roches sédimentaires plus anciennes.

On pense que deux périodes de plissement et de faille ont agi sur les roches de la région: 1) une première déformation qui a pu commencer par le rejet des roches précambriennes sur les roches mésozoïques, suivi par un important mouvement en direction du nord, accompagné de la formation de plis complexes, de faible et de grande taille, et de la constitution d'une structure feuilletée, et 2) une déformation postérieure caractérisée par des plissements ouverts, par la formation d'une linéation ridée, ainsi que par la rotation possible des anciens axes de plissement. La formation tardive de failles peut être la phase finale de cette déformation.

Sous-jacentes et adjacentes à la région se trouvent des roches semblables à celles des très riches gîtes d'argent des collines Keno et Galena. Un certain nombre d'affleurements d'argent-plomb ont été explorés dans la région, mais ceux que l'on a découverts jusqu'à présent n'ont pas la forte teneur en argent du filon principal.

INTRODUCTION

The region described in this report occupies about 790 square miles in Mayo district, Yukon Territory. The only inhabitant of the area at the time of the mapping was the late Mr. S. Arbutina who was living at Wilson's Cabin and doing a limited amount of trapping. Several abandoned traplines lie partly or entirely within the area, but they have not been worked recently and the roofs of most of the cabins have collapsed.

The area lies to the east and north of the village of Keno Hill,[1] and may be reached by trails from Keno Hill and by a branch road to the west end of Mayo Lake. Mayo Landing is the main supply point for the area. A good gravel road runs from Whitehorse to Mayo, and north of Mayo a network of roads extends to the communities of Keno Hill, Wernecke, Elsa and Calumet, and to Mayo and Hanson Lakes. Many of the lakes in the northern part of the area are suitable for aircraft, and this part of the area is most easily serviced by aircraft operating from Mayo. Good helicopter landing sites are plentiful and the entire area is within easy range for a machine operating from the vicinity of the village of Keno Hill.

Canoes were used for transportation in the southern part of the area. Edwards Creek and Roop Creek at the east end of Edwards Creek are navigable, Roop Creek as far as Wilson's Cabin. Other water routes used in the past are from Ladue Lake along the Keno Ladue River to the eastern border of the area, and up the South McQuesten River to McQuesten Lake, through a chain of lakes and across a short portage to Scougale Creek and thence to Beaver River. Most of the creeks and rivers in the larger valleys are meandering and slow flowing; the only fast water along these routes is on Beaver River upstream from the mouth of Scougale Creek. Other water routes are not suitable for use in geological mapping because they are set in deep valleys and in many places separated from outcrops by marshy ground.

Pack-horses were used for transportation in other parts of the area. There are few good trails but horses can travel in most places. Feed is poor in sloughs and burned-over areas in larger valleys, but there are extensive meadows above timberline.

Field Work and Acknowledgments

The first geological investigations in the district were by J. Keele, Geological Survey of Canada, in 1904 and 1905. In 1904 (Keele, 1906a) he studied the placer deposits of the Duncan Creek Mining District, and in 1905 (Keele, 1906b) he made

[1]Unless otherwise stated the name Keno Hill refers to the geographic feature.

a topographical and geological reconnaissance map of most of the area covered in this report. In 1921, Cockfield (1922) mapped and described the deposits of the Davidson Range. In the period 1938 to 1941, Bostock (1947) mapped the Mayo map-area (63°00′ to 64°00′N, 134°00′ to 136°00′W) on a scale of 4 miles to 1 inch. The Mayo Lake map-area is included in this area.

In addition to the mapping within the area, detailed geological maps have been made of the Keno Hill and Galena Hill areas which lie to the south and west of the area covered in the present report (Cockfield, 1920, 1921a, 1924a; Stockwell, 1926; Bostock, 1947, 1948a; McTaggart, 1960; Smitheringale, 1950; Kindle, 1962; and Boyle, 1957a,b, 1965). Cockfield (1924a, 1925) reported on the upper Beaver River area which lies immediately to the north of the area mapped.

Systematic mapping of the areal geology was carried on by the writer in 1952, 1953, 1954, 1955, and 1957. Operation Ogilvie, a helicopter-supported mapping project in 1961, included the McQuesten Lake and Scougale Creek map-areas within a much larger project area and some mapping was done in them at this time (Green and Roddick, 1962). The writer did some additional mapping in the McQuesten Lake map-area in 1965.

The writer wishes to acknowledge assistance and courtesies extended in the field by E. P. Callison of Callison's Flying Service, the late S. Arbutina, the late E. Verrau, officials of United Keno Hill Mines, Limited, and the townspeople of Mayo.

Able assistance in the field work was given by E. W. Grove in 1952; P. Dorozynski, K. W. Lyle, and D. L. Bowman in 1953; B. J. Burley, T. R. Pearson, and E. T. Kimura in 1954; J. F. S. Allan and R. D. Orr in 1955; V. G. Beckie and J. E. Thomlinson in 1957. Special thanks are also due to Mr. and Mrs. T. O. Southwick who were with the party in 1954, and E. Dopp who was with the party in 1955 and 1957.

Climate

The area has a continental climate characterized by low precipitation and a wide temperature range. Winters are cold and long but the short summers are generally pleasant with almost continuous daylight during June and July. Climatological tables for Elsa and Mayo are given in Tables I and II. Table I for Elsa is probably more representative of the project area as Mayo Landing (Table II) has a local climate controlled by its setting in a deep valley bottom. In contrast to the higher elevations typical of most of the area, Mayo Landing may have lower precipitation, and air temperatures showing higher summer maxima and lower winter minima.

Summer weather is extremely variable within the project area, and may change suddenly from warm and sunny to cool and overcast. Precipitation may occur either as sudden thundershowers or as scattered light showers during a period of prolonged overcast. Showers are frequently confined to the immediate vicinity of the higher peaks. Rainstorms, with snow at higher elevations, are common in late August and early

September, and field work is frequently hindered for as long as a week. Frost may occur at any time during the summer.

Ice on Mayo Lake commonly breaks up during the first week of June. Long warm days in late May and early June may result in a very rapid run-off; the highest water levels in the rivers commonly occur early in June. Plateau surfaces are free of snow by mid-June, and sufficient grass for pack-horses is available at higher elevations by the end of June.

TABLE I *Climatological table for Elsa*

Lat. 63°55′N, Long. 135°29′W

Elevation 3,000 feet above mean sea level

As compiled in Weather Office, Whitehorse based on data 1950-1963

	Air Temperature			Precipitation		
Month	Daily Mean (°F)	Mean of Daily Max. (°F)	Mean of Daily Min. (°F)	Mean Total of all forms (in.)	Mean Snowfall (in.)	Number of days of 0.01 in. or more of all forms
January	–9.0	–4.5	–14.4	0.86	8.6	8
February	–0.4	5.9	–6.9	0.76	7.6	9
March	7.9	17.7	–2.0	0.55	5.5	6
April	24.8	35.0	14.6	0.59	5.7	6
May	41.3	50.3	32.1	0.92	1.4	7
June	53.6	63.8	43.4	1.27	0.0	10
July	57.1	67.1	46.9	2.53	0.0	11
August	50.5	60.4	41.6	2.50	0.0	14
September	39.9	31.0	48.7	1.52	1.5	10
October	22.1	28.9	15.2	1.31	10.5	10
November	6.0	11.5	0.4	1.50	13.4	12
December	–1.8	4.4	–7.9	1.38	13.6	11
Mean	24.3	31.0	17.6			
Total				15.69	67.8	114
Number of years of observation	14 years of observations were used. Although observations are missing for some months of some years, means are representative of the Elsa area.					

Highest temperature recorded 83

Lowest temperature recorded –51

TABLE II — *Climatological table for Mayo Landing*

Lat. 63°35′N, Long. 135°51′W

Elevation 1,625 feet above mean sea level

(Kendrew and Kerr, 1955, p. 216)

Month	Air Temperature			Precipitation		Number of days						Percentage of time	
	Daily Mean (°F)	Mean of Daily Max. (°F)	Mean of Daily Min. (°F)	Mean Total of all forms (in.)	Mean Snow-fall (in.)	Rain 0.01 in.	Snow 0.1 in.	Frost (in screen)	Fog vis. 1 Km	Thunder	Clear sky 2/10 cover	Over-cast sky 8/10 cover
January	−11	−1	−20	0.8	7	0	8	31	5	0	27	60
February	−5	6	−16	0.4	4	0	5	28	4	0	33	53
March	13	26	−1	0.4	4	0	4	31	1	0	32	52
April	30	42	18	0.3	2	2	3	27	<1	<1	26	52
May	46	58	34	0.8	<1	7	1	13	<1	<1	17	53
June	56	69	42	1.4	0	9	0	2	<1	1	12	54
July	58	72	45	1.6	0	12	0	<1	1	1	13	58
August	53	66	40	1.8	0	13	0	6	1	<1	20	56
September	43	54	32	1.2	1	10	<1	14	1	<1	17	62
October	29	37	22	0.9	6	3	5	26	2	0	19	64
November	4	12	−4	0.8	8	1	7	30	4	0	27	58
December	−10	0	−19	0.8	8	0	8	31	6	0	28	59
Mean	26	37	14								24	57
Total				11.2	41	57	41	239	25	2		
Number of years of observations	26	26	26	26	26	17	17	11	9	9	9	9

Highest temperature recorded 96
Lowest temperature recorded −73

Flora and Fauna

The abundant trees are black spruce, white spruce, alpine fir, and willows. Less common are aspen poplar, balsam poplar, white birch, and alder. Several isolated lodgepole pines were observed in the southern part of Mayo Lake area: the nearest known stand of these trees is to the south along the Stewart River (H. S. Bostock, *pers. comm.*). Timberline is at about 4,000 feet.

Southfacing slopes and gravel terraces in the larger valleys are characterized by white spruce, aspen, and balsam poplar. Much of the area has been burnt, but a few mature stands contain spruce up to 24 inches in diameter. Most northfacing slopes and areas in the larger valleys underlain by permafrost are heavily moss-covered and timbered by small stunted black spruce. Locally in the larger valleys, trees have tilted due to the thawing of the underlying ground, and patches of 'drunken forest' were observed. Near timberline, alpine fir is mixed with spruce and becomes dominant at higher elevations. Many small valleys contain dense willow thickets, and the higher uplands are characterized by moss and lichen with scattered areas of dwarf birch.

The area supports a varied fauna but many of the species are scarce. Stone caribou are common in the northern parts of Scougale Creek and McQuesten Lake areas and in late summer groups of as many as fifteen bull caribou are common in the open uplands. Grizzly bears were observed throughout the area but appear to be most numerous in the mountains north of the Clark Lakes. Other large mammals known in the area are black bear, moose, timber wolf, and wolverine.

Fur-bearing animals trapped in the area in the past include red squirrel, marten, muskrat, beaver, mink, fox, lynx, and weasel. Except for a heavy beaver population along Beaver River, fur-bearing animals are not abundant.

Other small mammals include hoary marmot, ground squirrel, vole, pika, and varying hare. Less common but known in the district are porcupine, least chipmunk, otter, coyote, and water shrew.

Common game birds of the district are spruce grouse (spruce hen), and ptarmigan, the less common include blue grouse, ruffed grouse (willow grouse), and sharp-tailed grouse. Ducks and geese are relatively common in the Roop, Clark, and Scougale Lakes.

Fish known in the district include grayling, jackfish, lake trout, and whitefish.

The only amphibian observed in the area was the small tree frog (hyla ?), observed in swampy ground near Wilson's Cabin.

Mosquitoes are a nuisance in the area from late May until early August. Black flies, moose flies, and deer flies are not troublesome to man but are a serious nuisance to horses, the black flies in particular during late July and August.

Physiography and Glaciation

The area lies within Stewart Plateau, a subdivision of the Yukon Plateau (Bostock, 1948b, pp. 63-64). The plateau surface is undulating, varying between 4,000 and 5,500 feet in elevation, and characterized by broad smooth uplands. The higher mountains rise smoothly from the plateau surface, and most of the steeper faces were produced by glaciation which postdated development of the plateau surface. The main drainage is in wide, flat-bottomed, valleys that divide the plateau surfaces into isolated blocks. The main valleys have a typical U-shaped cross-section and have been modified by glaciation.

For information on glaciation in this part of central Yukon the reader is referred to Vernon and Hughes (1966) and Bostock (1966). Vernon and Hughes (op. cit.) described the surficial geology of the Operation Ogilvie area, which includes the McQuesten Lake and Scougale Creek map-areas within a much larger project area, and Bostock's notes (op. cit.) included the Mayo Lake map-area.

Vernon and Hughes (1966, p. 6) described three glaciations, an *old*, an *intermediate*, and a *last*, with intervening periods when ice was absent or nearly absent. In general, the *old* was more extensive and marked by erratics above the limit of the later glaciations, whereas the *intermediate* and much less extensive *last* glaciations are marked by moraines and changes in topography. The *old* glaciation is believed to correspond to the *Klaza* and *Nansen* glaciations of Bostock (1966), the *intermediate* to the *Reid*, and the *last* to the *McConnell*.

The present project area was not a centre of ice accumulation probably because precipitation during the Pleistocene was relatively low, as at present, and there was insufficient snow to form extensive ice sheets. Most glacial features were produced by ice that flowed into the area from the east and southeast. The bulk of the ice was confined to the main through-going valleys, but locally, for example, east of Rambler Hill in McQuesten Lake map-area, the ice covered parts of the plateau surface. Much of the plateau surface and the higher peaks lie above the elevation of well-developed glacial features, but the presence of scattered erratics indicates that these too have been covered in an earlier glaciation, presumably the old glaciation of Vernon and Hughes (1966) and the *Klaza* or *Nansen* of Bostock (1966). Botanical material collected by the writer and examined by J. A. Calder *(pers. comm.)* of the Plant Research Institute, Canada Department of Agriculture, contains some material indicative of unglaciated terrain.

Several of what are now the main valleys of the area were widened and deepened by valley glaciers flowing through them. One of the main routes followed by the ice was along the Beaver River from the east and through the large valley now occupied by Scougale, Clark, and McQuesten Lakes. Another route was along what is now the Keno Ladue River valley, and south through the low divide to the Roop Lakes; there it was joined by ice flowing west in what is now the valley of Roop Creek, and the two together flowed south to Mayo Lake where they were joined by ice flowing in what is now the valley of Edwards Creek, the whole mass then turned west and followed the valley now occupied by Mayo Lake. A large tongue of ice, presumably derived from ice flowing west in Roop Creek valley and ice flowing south from the Keno Ladue valley, pushed up Granite Creek to the western edge of the Mayo Lake map-area where the limit reached by this ice is marked by well-developed, terminal moraine. Some ice that pushed up the valley of Granite Creek appears to have flowed across the plateau surface and spilled into the valley now occupied by Mayo Lake.

Alpine glaciers were present in the Davidson and Patterson Ranges but ice from these glaciers does not appear to have joined ice flowing in the major valleys during the

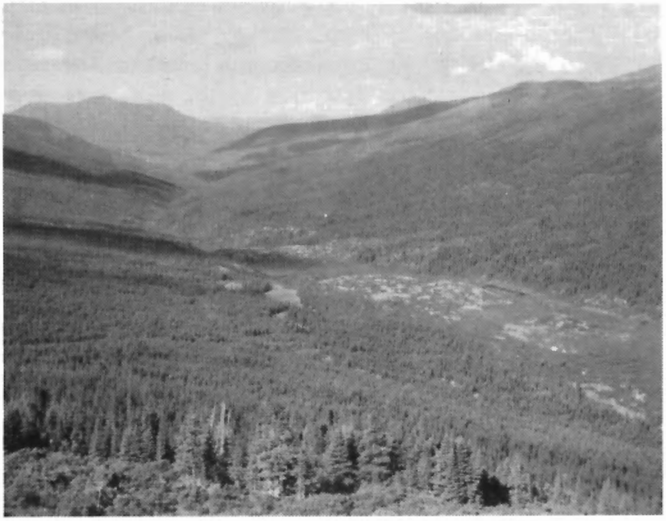


FIGURE 2. Moraines in the valley of Contrast Creek, Mayo Lake map-area. Ice originating in cirques to the left of and behind the camera, scoured and widened the creek valley as far as the moraines but beyond this the creek flows in a narrow 'V'-shaped valley. The lower part of the valley is believed to have been filled, at one stage, by slowly flowing, nearly stagnant ice, fed by the valley glacier in what is now the valley of Keno Ladue River (background).

last or *McConnell* glaciation. This is shown on Contrast Creek (Fig. 2) where well-developed moraines separate the wide valley at the head of the creek from the narrow 'V'-shaped valley downstream. The lower part of the valley is believed to have been filled at one stage by slowly flowing, nearly stagnant ice fed by the valley, or transection, glacier in what is now the valley of the Keno Ladue River.

As the ice in the main valleys melted, large ice-marginal streams developed along the sides of the valleys. In some places these streams have cut benches into the bedrock but elsewhere their courses are marked by well-developed gravel terraces. In many places more than one terrace developed; the lower terraces are believed to have formed in successive stages as the level of the ice dropped. In some cases where the ice-marginal stream had cut a small gorge, water from higher on the slopes continued to flow in the gorge after a lower ice-marginal stream had been established. Commonly, the water in an upper channel broke through and cut a canyon directly down the slope to the lower channel.

FIGURE 3. An abandoned meltwater channel that crosses the ridge northeast of Mount Cameron at just below 5,000 feet. The bank in the centre of the photograph is about 12-feet high.

A number of incised channels cross the plateau surface. These channels appear to have been formed by relatively large meltwater streams that cut through the ice and into the plateau surface. The best developed are at an elevation of over 4,000 feet on a ridge south of Clark Lakes and west of the bend of Rankin Creek in Scougale Creek map-area (Fig. 3), and at an elevation of over 4,300 feet in a saddle in the upland surface southwest of the mouth of McKim Creek in Mayo Lake map-area.

An extensive complex of pitted outwash and moraine across the present valley of the South McQuesten River in the vicinity of Hanson Lakes may mark a still-stand during the retreat of the *last* glaciation. At a later stage, a lake filled much of the valley now occupied by McQuesten and Clark Lakes, and much of the bottom is floored by silt modified by thermokarst topography.

At one stage a large lake developed along the Keno Ladue River valley, extending from Ladue Lake in McQuesten Lake map-area to the eastern margin of Mayo Lake map-area. Extensive silt deposits as much as several hundred feet thick were laid in the lake at the latter point. At various stages this lake may have drained into what is now Mayo Lake through the low pass between Keno Ladue River and Roop Creek, and into the valley of South McQuesten River west of Ladue Lake where a large abandoned river channel is visible.

Much of the area is underlain by permanently frozen ground or permafrost, and features associated with this phenomenon have had a marked effect on the physiographic development of the area. In the larger valleys, the surficial deposits are overlain by black muck and moss, and extensive areas of muskeg are common in the valley bottom. Where the thick moss cover has been removed, the permafrost does not appear to be stable and thawing occurs during the summer. A forest fire removed the moss cover from extensive deposits of frozen glacial silts along the Keno Ladue River during the summer of 1953. When the region was visited the following year it was found to be thawing, and numerous small streams, all heavily charged with silt, had developed from the water released.

Effects produced by frost action are prominent at higher elevations, particularly on the plateau surfaces. Rocks tend to be reduced to rubble, the size of the fragments being in part determined by foliation and jointing. Greenstones are commonly reduced to coarse polygonal blocks up to 10 feet across, quartzites to smaller blocks, and schists to thin plates not more than a few inches in diameter. Greenstones are commonly mapped on the basis of the coarse areas of greenstone rubble or felsenmeer. Fragments of phyllitic material tend to move down slope through solifluction (Fig. 4). Contacts are frequently displaced through this action and there are very few outcrops where foliation or bedding can be determined with certainty. Stone rings are common on upland surfaces underlain by phyllitic rocks.

FIGURE 4. Solifluction around a greenstone body intruded into rocks of the Lower Schist division, Davidson Range, McQuesten Lake map-area. Platy fragments of phyllite are moving past the greenstone, and the depression at the uphill end of the greenstone is about 6-feet deep. The greenstone itself has been reduced to coarse rubble by frost action along joints. Remnants of the upland surface are visible in the background.

GENERAL GEOLOGY

Much of the three map-areas (Mayo Lake, McQuesten Lake, and Scougale Creek) is underlain by metamorphosed sedimentary rocks (Fig. 5) formerly assigned to the Yukon Group and considered of probable Precambrian age. This general terminology was used in most earlier reports dealing with the general area (e.g., Bostock, 1947; Green, 1957, 1958; and Kindle, 1962), but the mapping by Operation Ogilvie (Green and Roddick, 1962) demonstrated that several of these rock units were of much younger age. The age relationships are best demonstrated in the Tombstone map-area in Dawson map-area, about 100 miles west of the present area, but one key fossil collection was made at 64°15′N, 135°10′W, a few yards north of the margin of the McQuesten Lake map-area. Later work in the Tombstone area by Tempelman-Kluit (1966) resulted in further modification of the ages of the various rock units but confirmed the overall succession suggested by Operation Ogilvie.

This report, originally prepared prior to Operation Ogilvie, has been recast to fit the revised stratigraphy. Many uncertainties with regard to the structure and stratigraphy of the present area still remain, but these are minor compared to those involved in retaining the previous stratigraphic succession in the face of the new evidence.

The introduction of new formal names has been avoided and informal names, in common local usage, have been retained. Throughout the area, the distinctive Keno Hill Quartzite (unit 8) forms the only usable marker horizon, and the terms Lower Schists (unit 7) and Upper Schists (unit 1) are used to describe the apparent position of rocks of these two units with respect to those of the Keno Hill Quartzite, despite the fact that rocks of the Upper Schist division are now considered much older than those of the other two units (units 7 and 8). With so many problems remaining in the area it seems certain that these purely descriptive terms will continue to be meaningful.

The Upper Schist division (unit 1) of probable Precambrian age underlies the eastern part of Mayo Lake map-area and is believed to have been thrust on younger rocks of the Keno Hill Quartzite (unit 8). In the extreme southeast corner of the map-area it is overlain by metamorphic rocks (unit 2) of slightly different lithology.

The Grit division (units 3 and 4), consisting of gritty quartzite, varicoloured phyllite and argillite, graphitic phyllite, and limestone (unit 4), of probable Precambrian age, underlies much of the northern parts of the Scougale Creek and McQuesten Lake map-areas. It was not observed in contact with older rocks.

Poorly exposed phyllite, slate, chert, and quartzite (unit 5) of probable Ordovician to Silurian age overlie rocks of the Grit division with probable unconformity in the northeast part of Scougale Creek map-area.

Massive dolomite (unit 6) of Ordovician to Silurian age overlies rocks of unit 5 unconformably in the northeast corner of Scougale Creek map-area.

The Lower Schist division (unit 7), consisting of graphitic phyllite, phyllitic quartzite, and phyllite, of probable Jurassic age, overlies rocks of the Grit division (units 3 and 4) in a contact extending south from the north-central part of McQuesten Lake map-area and east to the east-central part of Scougale Creek map-area. These rocks are also present on the west side of McQuesten Lake map-area and in the northern part of Mayo Lake map-area.

The Keno Hill Quartzite (unit 8), consisting of distinctive blue-grey quartzite,

TABLE OF FORMATIONS

Era	Period or epoch	Name or map-unit	Lithology
Cenozoic	Recent		Stream deposits, talus, rock fragments transported by solifluction
	Pleistocene		Till, gravel, sand, and silt
	Unconformity		
	Tertiary (?)	11	Quartz porphyry, granite porphyry
Not in contact			
Mesozoic	Cretaceous	10	Granodiorite, quartz monzonite
	Intrusive contact		
	Cretaceous	9	Diorite, gabbro and altered equivalents
	Intrusive contact		
	Lower Cretaceous (?)	8; Keno Hill Quartzite	Massive quartzite, minor phyllite and graphitic phyllite
	Conformable contact		
	Jurassic	7; Lower Schists	Graphitic phyllite, phyllitic quartzite, phyllite
Unconformity			
Paleozoic	Ordovician to Silurian	6	Massive dolomite
		Unconformity	
		5	Phyllite, slate, chert, and quartzite
Probable unconformity			
Precambrian and later (?)		3 and 4; Grit	3; gritty quartzite, varicoloured phyllite and argillite, graphitic phyllite 4; limestone
		Not in contact, relationship unknown	
		2	Thin-bedded, phyllitic quartzite, phyllite
		Conformable contact (?)	
		1; Upper Schists	Phyllitic and thin-bedded quartzites, phyllite, graphitic phyllite

minor phyllite and graphitic phyllite, of probable Lower Cretaceous age, overlies rocks of the Lower Schist division (unit 7) conformably.

Sills and lens-like bodies of diorite and gabbro (unit 9), now extensively altered to 'greenstone' composed of secondary minerals, have intruded rocks of most of the older succession but principally the Lower Schists (unit 7) and the Keno Hill Quartzite (unit 8).

Granitic rocks (unit 10) were probably emplaced in Cretaceous time.

Small, infrequent, sill-like bodies of quartz porphyry and granite porphyry (unit 11) of probable Tertiary age have intruded the Lower Schists (unit 7).

Deposits of Pleistocene age are present in most of the valley bottoms and include morainal material, material washed from stagnating ice, and silt laid down in glacial lakes.

Upper Schist division (unit 1)

The Upper Schists (unit 1) comprise a thick assemblage of graphitic phyllite, phyllite, quartz-mica schists, phyllitic quartzites, and thin-bedded quartzite overlying the Keno Hill Quartzite (unit 8) in Mayo Lake map-area. The top of the division is drawn to include the uppermost layers of graphitic phyllite, and thin-bedded dark grey quartzites. The unit was originally described by Bostock (1947) for Mayo map-area, which includes Mayo Lake map-area. Elsewhere in Mayo map-area, the map-unit described by Bostock is much more graphitic. Bostock (1947) gives the following description:

> "The succeeding member is composed mainly of schists, of which graphitic types are prominent. Quartzite beds similar to those of the underlying member, and quartz-mica, mica, and chlorite schists are also important constituents. Bodies of crystalline limestone follow an horizon about 500 feet above the base of the member."

Lithology

In Mayo Lake map-area it has been possible to separate three lithologically distinct members within the map-unit: la, mainly phyllitic and thin-bedded quartzites, phyllite, and mica schists; lb, mainly thinly bedded dark grey quartzite and graphitic phyllite; lc, massive grey quartzite similar to map-unit 8.

What appears to be a complete section of the map-unit is exposed along Roop Creek where the apparent thickness is in the order of 10,000 feet. However, the rocks have undergone a great deal of deformation, and it is possible that this apparent thickness may include beds repeated by faulting or folding.

Non-graphitic rocks of unit la overlie the Keno Hill Quartzite (unit 8) in Mayo Lake map-area, in contrast to the graphitic beds with minor limestone (unit lb) that overlie it to the west of the area covered in this report. The unit is composed of buff to greenish grey quartzite with beds as much as 1 foot thick, but commonly only a few inches thick, buff to light grey phyllitic quartzite with a parting every few millimetres, quartz-muscovite-chlorite schist and phyllite and minor limestone and grey graphitic phyllite. Beds of quartzite are commonly separated from adjacent layers by thin beds of schist or phyllite a fraction of an inch thick. Individual beds of quartzite are uniform and do not show internal structure. A few beds contain coarse grains of quartz and minor plagioclase feldspar up to 2 millimetres in diameter, and most of the quartzites are flecked with grains of an iron-bearing carbonate of about the same size. Schists and phyllites are commonly light buff, grey, or green, and are composed of varying amounts of quartz, muscovite, and chlorite. In addition, many have undergone some metamorphism which produced biotite and less commonly garnet. Light grey quartzose limestone occurs in beds up to a few feet thick.

Unit lb is composed mainly of thin-bedded dark grey quartzite and graphitic phyllite. Beds of quartzite are rarely more than a few inches thick, and are separated from adjacent layers by thin partings of graphitic phyllite. The relative proportion of quartzite to phyllite varies widely from outcrop to outcrop; some are almost entirely quartzite, others phyllite. The phyllite is commonly a soft, dark grey to black, foliated rock with a well-developed wrinkle lineation. Many of the graphitic rocks contain enough graphite to mark paper.

Unit lc consists of beds of massive grey to blue grey quartzite with numerous beds over 1 foot thick. Individual beds are commonly separated by thin partings of graphitic phyllite. These quartzites are identical to those of the Keno Hill Quartzite and may be fault slices of that unit.

Structural Relations

All rocks assigned to map-unit 1 show evidence of having undergone some degree of deformation. The least altered show a pronounced platy foliation parallel with the bedding. The foliation surface is invariably lineated by faint crenulations with a wavelength of several millimetres, and an amplitude of about 1 millimetre. Elsewhere, the beds have been folded into irregular crumples with a wavelength and amplitude of a few inches. The easternmost band of graphitic rocks (unit lb) has undergone a great deal of deformation of this type and outcrops of this band are all strongly crumpled. Locally, individual beds have been thrown into isoclinal folds with the axial planes parallel with the bedding. Folds of this type appear to be common within a few miles of the contact with granitic rocks. More extreme deformation includes the development of gleitbrett folds[1], in some cases to the extent that the bedding is almost totally destroyed and the rocks are essentially phyllonites.

Metamorphism

Rocks of the map-unit have undergone considerable metamorphism. Adjacent to the granitic rocks (unit 10), phyllite and quartzite are commonly altered to quartz-biotite-garnet schist and gneiss, and impure limestone to garnet and diopside skarn. Between Edwards and Roop Creeks the rocks of map-unit la commonly contain fine secondary biotite and, less commonly, tourmaline, garnet, chloritoid, and staurolite. Andalusite occurs in several places in the graphitic phyllites of map-unit lb.

Age and Correlation

Rocks of the Upper Schist division (unit 1) are tentatively considered of Precambrian age but conclusive evidence is lacking. The suggested age is based on correlations with somewhat similar rocks in other areas; rocks of unit 1 are not known to be overlain by fossiliferous strata.

[1]Described under Foliation in STRUCTURAL GEOLOGY.

Interbedded schist and quartzite, separated into a number of map-units, underlie much of the area between Mayo Lake and Tintina Trench about 50 miles to the southwest (Bostock, 1947 and 1964). The only dating in this region is the suggestion by Bostock (1947) that older rocks (unit 6, op. cit.) lie beneath distinctive red and green slates (unit 9, op. cit.; and presumably part of unit 3 of this report). This distinctive rock forms part of the Grit division (units 3 and 4) that has been mapped from northern British Columbia to the International Boundary, north of Dawson, Yukon Territory (Gabrielse, 1967, p. 275), and has been dated as Cambrian and earlier in the Flat River area (Gabrielse, *et al.*, 1965), about 270 miles to the southeast.

Some of the rocks included in the Upper Schist division may represent fault slices of rocks of either the Lower Schists (unit 7) or the Keno Hill Quartzite (unit 8). Rocks of unit 1 show no lithological similarity to rocks believed to overlie and be younger than the Keno Hill Quartzite in the Tombstone district, about 100 miles to the west.

No age determinations have been made from rocks of the Upper Schist division (unit 1) but one from overlying rocks (unit 2 of this report, unit 5 of Bostock, 1947) gave an age of 101 $\pm$ 6 million years (Wanless, *et al.*, 1967, pp. 45-46). This age is close to that obtained from intrusive rocks nearby.

Map-unit 2

Map-unit 2 is exposed in the southeast corner of Mayo Lake map-area where it appears to overlie graphitic phyllites (unit lb) of the Upper Schists. There are only a few small outcrops of map-unit 2 within the area covered in this report, and the unit is best exposed to the south and west from where Bostock (1947) gave the following description:

> "The overlying member is composed predominantly of interbedded, brownish, quartz-mica schist and schistose quartzite. These are characteristically dotted or closely packed with lenticular pebbles of quartz and altered feldspar, usually ⅛ to ½ inch long giving the rock the appearance of crushed and altered porphyries. In a number of places the pebbles are as much as 1½ to 2½ inches in size, and are composed of white, cherty quartz, chalky feldspathic material, and light brown carbonate. The matrix is of smaller particles of the same materials, and these and the larger pebbles are wrapped in a mass of brown mica giving the planes of schistosity a lumpy appearance. The limestone masses in this member are commonly crystalline, except that the larger bodies are finer in grain and show some evidence of bedding."

Lithology

In Mayo Lake map-area, unit 2 is characterized by phyllitic quartzite, quartz-muscovite-chlorite schist, and white chloritic quartzite. Green chloritic schist and white quartzite with minor coarse chlorite outcrop near the contact with the Upper Schists (unit 1) on the ridge north of Roop Creek on the eastern boundary of Mayo Lake map-area. Farther along the ridge to the east of the map-area, the principal rock type is a grey to light buff phyllitic quartzite that contains scattered grains of quartz and, less commonly, plagioclase feldspar up to 2 millimetres in diameter. Iron-bearing carbonate is a common accessory in the phyllitic quartzite. South of Roop Creek there are scattered outcrops of grey to greenish thin-bedded quartzite, chloritic schist, and minor grey banded limestone. The two bands of limestone observed were both less than 50 feet thick. In this area, map-unit 2 has undergone considerable metamorphism with the development of biotite, garnet, tourmaline, and feldspar.

Structural Relations

Many of the phyllitic rocks are crumpled into chevron folds with a wavelength and amplitude of about 1 inch. The phyllitic quartzites are commonly foliated and all the rocks of the map-unit show a wrinkle lineation.

Age and Correlation

Rocks of map-unit 2 are tentatively considered to be of Precambrian age but conclusive evidence is lacking. The suggested age is based on correlations to somewhat similar rocks in other areas, and on the fact that rocks of unit 2 are not known to be overlain by fossiliferous strata. Possible relationships are similar to those described for the Upper Schist division (unit 1).

One age determination (101 $\pm$ 6 m.y.) has been made by the Geological Survey of rocks west of the present area but included in the same unit by Bostock (unit 4, 1947) in regional mapping (GSC 66-48 *in* Wanless, *et al.*, 1967). The age is close to that obtained from intrusive rocks in the district and described under map-unit 10. Since the Mesozoic Lower Schists appear to have undergone the same deformation and metamorphism as Precambrian rocks of unit 2, either a single Mesozoic episode is involved or a more pervasive alteration in Mesozoic time has masked an earlier, and presumably less severe, episode. The radioactive age may reflect either the Mesozoic episode or the intrusion of granitic rocks that followed it.

Grit division (units 3 and 4)

The Grit[1] division (units 3 and 4) is composed of light buff to grey-green, recrystallized gritty quartzite, phyllitic quartzite, green, grey, black, and maroon argillite and phyllite, and thin bands of limestone (unit 4). Rocks assigned to this division outcrop in the northern half of Scougale Creek map-area, and in the northeast corner and along the west side of McQuesten Lake map-area.

The division has been intensely deformed and the bedding destroyed in most outcrops. For this reason, it was not possible to measure a stratigraphic section and the overall thickness of the two map-units is unknown.

Gritty quartzites are prominent south of Clark Lakes and in a broad band south of the limestone lenses (unit 4) that extends from Beaver River to the northern margin of the map-area. Sheared gritty quartzites with minor green and brown phyllite and limestone outcrop west of McQuesten Lake. Limestone (unit 4), with associated green, grey, and black phyllites and gritty quartzites, outcrops in a wide band trending northwest across the map-area.

[1]In this description the 'grit' is used to refer to quartzites containing grains of conspicuously unequal size. The original larger grains, commonly up to 2 millimetres in diameter, but occasionally much larger, have been deformed as a result of metamorphism but are believed to have been rounded rather than angular.

Lithology

The gritty quartzites occur in bands ranging from a few feet to several hundred feet thick, commonly separated by chloritic phyllite. The quartzites are massive and do not show any trace of original structure. The colour of the fresh surfaces ranges from green to grey to a very light buff, and the weathered surfaces from brown to almost white. Many fracture surfaces show dark manganese stain. The gritty quartzites are composed of coarse quartz grains and, less commonly, plagioclase feldspar in a matrix of fine-grained quartz and sericite. The coarse grains are commonly 2 millimetres or less in diameter and may form from 10 to 80 per cent of the rock. Within an individual bed of gritty quartzite, the coarse grains are commonly about the same diameter but the size and the amount present may vary widely between beds. Some of the rocks are quartz-pebble conglomerates, with pebbles up to 10 millimetres in diameter forming much of the rock. The coarse grains are generally grey but some beds are characterized by distinctive pale blue and, less commonly, black grains. The gritty quartzites commonly contain a small amount of iron-bearing carbonate which is frequently altered to limonite. In addition to the gritty quartzites, map-unit 3 contains fine-grained, light coloured cherty quartzites and considerable phyllitic quartzite. The latter is commonly gritty.

Viewed in thin section, the gritty quartzites consist of coarse grains of quartz and minor feldspar, both potash feldspar and plagioclase, in a matrix of fine-grained quartz and sericite. The rocks have recrystallized to the extent that the quartz grains now have sutured boundaries but in some the outlines of well-rounded grains are still visible. Generally, the coarse quartz grains or pebbles are elongated and may be in the form of augen with the major axis as much as four times the minor axis. The gritty quartzites contain minor amounts of detrital heavy minerals.

Phyllites and argillites, commonly chloritic and less commonly graphitic, occur throughout map-unit 3. Most are various shades of green but other colours include black, grey, yellow, brown, and maroon. Much of the rock is poorly foliated with the original bedding still visible, and the rocks show extremely complex structures including ptygmatic folding and 'Gleitbretter'. Rocks with well-developed slaty cleavage occur locally throughout the map-unit. Many of the latter are dark grey to dark green but some are mottled green and black or green and maroon. Generally the mottling is irregular and does not appear to represent original bedding. Viewed in thin section, the slaty rocks are composed of fine sericite, chlorite, and quartz with minor amounts of opaque minerals including graphite, magnetite, hematite, ilmenite, and limonite. Chloritoid is a common metamorphic mineral and may form as much as 10 per cent of the rock. Some thin sections show neither bedding nor foliation; others show poor to good foliation, and still others show bedding almost totally destroyed by the development of 'Gleitbretter' or false cleavage.

Limestones (unit 4) are in the form of lenses up to several hundred feet thick. Many limestone lenses cannot be traced from ridge to ridge and commonly pinch out along strike to be replaced by similar lenses in the overlying or underlying strata. It is not known whether the lenses are due to original sedimentation or to later deformation.

Most of the limestone weathers light grey, and the colour of fresh surfaces includes white, grey, blue-grey, and black. Banding produced by layers of contrasting colour a few millimetres thick is widespread. The banding of many of the limestones shows ptygmatic folding and the development of numerous veinlets of white calcite. Some of the limestones show a well-developed foliation parallel with the long axis of the lens. The foliation may be at any angle to the colour banding.

Structural Relations

The gross structure of the Grit division (units 3 and 4) is unknown. No major repetitions of lithological units, as for example, the zone containing numerous limestone lenses (unit 4), were recognized in mapping. Excluding rocks west of the McQuesten Lake assigned to this division, the overall distribution of the division is along a northwest trending band and most of the attitudes obtained are in agreement with this. However, bedding is believed to have been destroyed in most outcrops and most of the attitudes probably represent foliation. In many cases where bedding could be determined, very complex minor structures were common and included open chevron, isoclinal, and ptygmatic folds and 'Gleitbretter'. Quartz veins are common throughout the division and occur both along joints in the gritty quartzites and following folds in the phyllitic rocks.

Foliation is very strongly developed in the rocks assigned to the Grit division (units 3 and 4) west of McQuesten Lake where the gritty quartzites tend to break in irregular plates a few millimetres thick, and some of the rocks appear to be deformed to the point where they approach mylonites. The foliation surfaces in both the quartzite and phyllite show well-developed wrinkle lineation.

Metamorphism

Most exposures of the Grit division (units 3 and 4) contain abundant sericite and chlorite, and minor chloritoid, and are in the muscovite-chlorite subfacies. However, biotite is common in the quartzites and phyllites south of Clark Lakes and along Rankin Creek. The fine flakes of biotite are generally oriented at random in the quartzites but perpendicular to the foliation in the phyllites. Other metamorphic minerals observed in this area include garnet, staurolite, feldspar, and coarse magnetite.

Age and Correlation

Rocks of the Grit division are believed to be of Precambrian age. Rocks lithologically similar to and believed correlative with those of the Grit division have been traced from northern British Columbia to the Yukon Territory border west of the present map-area (Gabrielse, 1967, p. 275) and westward into Alaska. In the Flat River area, about 270 miles to the southeast, these rocks underlie strata of Middle and (?) Upper Cambrian age and have been dated as Cambrian or earlier (Gabrielse, *et al.*, 1965).

One age determination has been made by the Geological Survey on a specimen from unit 3 and gave an age of 93 ± 12 m.y. (GSC 65-47 *in* Wanless, *et al.*, 1967). This age is close to that obtained from intrusive rocks in the district described under map-unit 10. Since Mesozoic rocks of the Lower Schist division appear to have undergone the same deformation and metamorphism as Precambrian rocks of the Grit division, either a single Mesozoic episode is involved or a more pervasive alteration in Mesozoic time has masked an earlier, and presumably less severe, episode. The radioactive age may reflect either the Mesozoic episode or the intrusion of granitic rocks that followed it.

Map-unit 5

Map-unit 5 comprises the graphitic rocks on both sides of Beaver River in the northeast corner of Scougale Creek map-area.

Lithology

West of Beaver River the common rock types are grey weathering, dark grey to black phyllite, dark chert, and quartzite. The rocks are well foliated and in many cases the foliation cuts the bedding. Quartzites and phyllites are interbedded and individual beds are rarely more than a few inches thick. East of Beaver River, outcrops on the lower slopes consist of poorly foliated chloritic rocks with numerous metacrysts of calcite and iron-bearing carbonate. The origin of these rocks is unknown and they may represent carbonatized sediments or greenstones. Farther east, outcrops consist of thin-bedded micaceous quartzite and chloritic quartzite with interbedded grey and black weathering black phyllites and green chloritic phyllites. Beyond this and extending to the contact with the overlying dolomite (unit 6), the outcrops are thinly banded, dense black chert and black shale. Scattered thin bands of dark grey quartzite are also present. Beds of chert, shale, and quartzite are rarely over a few inches thick. In this area the rocks show little evidence of metamorphism; secondary minerals are lacking and the shales are not foliated.

Age and Correlation

No fossils were found in the rocks of unit 5 but on the basis of similar lithology it is correlated with the Road River Formation and considered of Ordovician to Silurian age. Extensive areas underlain by this formation have been mapped to the north and west of the present map-area (Green, in preparation; Norris, *et al.*, 1963).

Map-unit 6

White to whitish grey weathering dolomite (unit 6) outcrops in the northeast corner of the Scougale Creek map-area. To the east of the map-area this unit underlies most of the triangular wedge of mountains bounded by Beaver River on the west and southwest, Rackla River on the southeast, and the low valley extending from Kathleen Lakes to Beaver River on the north.

The thickness of map-unit 6 in this area is not known with certainty but must be in excess of several thousand feet. About 45 miles to the north-northeast, correlative rocks (unit 8 of Green and Roddick, 1962; Green, in preparation) are about 4,600 feet thick in a well-exposed section.

Lithology

Map-unit 6 consists of a thin lower zone composed of limestone conglomerate, fine-grained buff-weathering limestone and dolomite, and intraformational conglomerate, overlain by a great thickness of light grey dolomite with minor limestone.

The lower conglomerate contains rounded pebbles and cobbles in a matrix of fine-grained grey limestone. The fragments in the conglomerate are up to 1 foot in diameter but most are less than 1 inch. They consist predominantly of limestone although a few pebbles of phyllite were observed. No fragments of the gritty quartzite of map-unit 3 were recognized. The intraformational conglomerate is separated from the lower conglomerate by buff-weathering, light grey, fine-grained limestone and dolomite. The former consists of slab-like pieces of cream coloured dolomitic limestone up to 1 foot long and 1 inch thick in a matrix of similar material.

The remainder of map-unit 6 consists mainly of grey to white weathering light buff, cream, and grey dolomite. Most outcrops are massive and the rocks shows little evidence of bedding. The grain size of the dolomite ranges from about 0.1 to 1.0 millimetre. Much of the dolomite contains some quartz, and a few bands are as much as 70 per cent quartz. Most of the quartz occurs as angular grains up to 0.1 millimetre across which may have formed by the recrystallization of chert. The quartz grains commonly form subrounded blebs up to 3 millimetres in diameter and in a few cases, where the quartz content of the rock is high, the dolomite occurs in similar blebs. One band showing well-developed oolitic structure was observed. Interbedded with the lighter dolomite are small amounts of dark grey and black dolomite. Slightly north of the map-area, a 30-foot bed of fossiliferous grey limestone was discovered.

Map-unit 6 overlies map-unit 5 with an unconformity marked by a basal conglomerate. No overlying rocks are present in the map-area.

Age and Correlation

Rocks of map-unit 6 form part of an unnamed unit (unit 8 of Green and Roddick, 1962; Green, in preparation) of carbonate rocks of Ordovician to Silurian age that underlies much of the area to the north of the map-area. The rocks in the present area lie near the south end of a northwest-trending belt and another wider band of similar rocks lies about 15 miles farther north. One fossil collection was made from rocks of the unit on the boundary of Scougale Creek map-area:

GSC loc. 47068 (64°15'N, 134°33½'W)
echinoderm columnals
rugose and favositid corals
Age: probably Silurian or Devonian

The collection was examined by B. S. Norford of the Geological Survey of Canada. To the north, correlative rocks are well-dated paleontologically (Green, in preparation).

Lower Schist division (unit 7)

The name 'Lower Schist division' has been applied to graphitic phyllite and thinly bedded, fine-grained, phyllitic quartzite that appear to underlie the quartzite of Galena and Keno Hills and Patterson Range. Rocks assigned to this unit (unit 7) outcrop in a broad band extending from the northwest corner of McQuesten Lake map-area across most of Davidson and Patterson Ranges. Lithologically similar rocks that appear to overlie the quartzite (unit 8) of Davidson Range have also been included in the Lower Schists.

The true thickness of the Lower Schist division is unknown but its distribution indicates a minimum thickness of several thousand feet. Apparent thicknesses are very great, as for example, in the vicinity of Cobalt Hill in Mayo Lake map-area, where an apparent thickness of 18,000 feet is exposed from the base of map-unit 8, north to the foot of Cobalt Hill. However, rocks of map-unit 7 have undergone considerable internal deformation and much of the apparent thickness may be due to repetition. Distinctive horizons are lacking and no such repetitions were recognized in the field.

Lithology

The Lower Schist division is composed of interbedded black graphitic phyllite and dark grey to grey thin-bedded phyllitic quartzites or siltstones. The relative amount of phyllite to quartzite varies widely; some outcrops are almost entirely phyllite but others are thin quartzite beds separated by fine phyllite partings. Individual beds of phyllite rarely exceed a few inches in thickness, and few beds of quartzite exceed a foot in thickness – most are less than six inches thick. In outcrops, the rock tends to break along the phyllitic partings and a rubble of platy material is characteristic below frost-heaved outcrops of map-unit 7. Crossbedding was observed here and there in the quartzites but this feature is not common enough to permit widespread determination of tops. In Mayo Lake map-area, between Cobalt Hill and the contact with the overlying Keno Hill Quartzite (unit 8) to the south, two lithologically distinct members could be traced across the Keno Ladue River valley but not into Patterson Range. On Cobalt Hill, the rocks consist of interbedded phyllitic quartzite, phyllite, and schist with individual beds rarely more than a few inches thick. The phyllitic partings are commonly grey rather than black and the rocks in this area appear to contain less graphite than elsewhere. To the south, from the contact with unit 8 to about 2 miles to the north, the rocks consist of thinner bedded black and grey graphitic phyllite interbedded with thinly banded grey to black quartzite. The banding in the quartzite is commonly a few millimetres thick. Contacts between the bands are abrupt and there is no evidence of graded bedding. Both the black bands in the quartzite and the graphitic phyllite commonly contain a small amount of pyrrhotite and most outcrops are rusty, in marked contrast to those near Cobalt Hill.

In McQuesten Lake map-area, rocks assigned to unit 7 west of Hanson Lakes are similar to the thinly banded rocks south of Cobalt Hill. North of McQuesten Lake, rocks assigned to it are mainly platy, grey to black graphitic phyllites with minor amounts of thin-bedded quartzite, green and brown phyllite, and impure limestone. The limestone occurs as buff-weathering bands a few inches thick which may form as much as 50 per cent of some exposures. In Davidson Range and Patterson Range, rocks assigned to the Lower Schists commonly fit the general description, although in Patterson Range, green chloritic phyllites are common in map-unit 7 immediately below the overlying quartzites (unit 8).

Viewed in thin section, the quartzites are impure rocks composed of fine-grained quartz and muscovite or sericite with lesser amounts of black opaque material believed to be graphite. In addition, minor amounts of ilmenite, iron oxides, chlorite, and tremolite-actinolite may be present. Ilmenite is commonly altered to leucoxene. The quartz grains are generally subangular and less than 0.05 millimetre in diameter, although a few grains are up to 0.1 millimetre. According to Pettijohn (1956, p. 377) these rocks should be described as siltstones on the basis of the grain size of the quartz. Muscovite and chlorite are commonly very fine grained.

All gradations are present between the quartzites and a phyllitic rock composed essentially of a very fine mass of quartz and sericitic mica. The colour of the more phyllitic rocks may vary from brown to grey to black depending on the amount of graphite present. The more graphitic rocks commonly contain up to 5 per cent of 0.5

millimetre blades of ilmenite which are partly or entirely altered to leucoxene. Metamorphic minerals observed in the Lower Schist division (unit 7) listed in the approximate order of abundance include: biotite, staurolite, chloritoid, garnet, tourmaline, andalusite, and kyanite.

Structural Relations

There is a wide variation in the structures observed in outcrops of map-unit 7. A few outcrops show only a foliation parallel with the bedding whereas at the opposite extreme some outcrops show the development of a secondary foliation that has completely destroyed the original bedding. The origin and possible significance of the secondary structures is discussed under Structural Geology. Foliation parallel with the bedding is present in almost all outcrops of map-unit 7, and is generally well developed in the more phyllitic layers. In addition, phyllitic layers commonly show the development of one or more wrinkle lineations lying in the plane of the bedding foliation. Wrinkle lineations take the form of irregular wave-like crenulations with a wave length of several millimetres and an amplitude of less than one millimetre. Slaty cleavage at an angle to the bedding was observed in some outcrops. Folding is present in many outcrops, the folds ranging from open crumples to tight isoclinal folds. 'Gleitbretter' and false cleavage are also common. The spacing of the foliation planes on which the 'Gleitbretter' are developed varies from a fraction of a millimetre to five or more centimetres.

Metamorphism

A broad belt of metamorphism follows the valleys of Keno Ladue River and Rankin Creek in Mayo Lake and Scougale Creek map-areas. Biotite is the most common metamorphic mineral. It commonly occurs as ragged plates up to one millimetre in diameter oriented perpendicular to the bedding. Staurolite is also common, particularly on the north slope of Cobalt Hill where crystals up to several inches in length were observed. Both the size and abundance of crystals of biotite and staurolite appear to be dependent upon the original composition of the rock, and wide variations in both occur between bands of different composition in an individual outcrop. Garnet, andalusite, kyanite, and feldspar were observed in metamorphosed rocks of this belt in scattered outcrops but did not have the widespread distribution of biotite and staurolite.

Age and Correlation

Rocks of the Lower Schist division (unit 7) are considered to be of Jurassic age on the basis of fossil collections made in the Tombstone area (Tempelman-Kluit, 1966; Green, in preparation). An additional collection supporting the concept of a young age was made just to the north of McQuesten Lake map-area.

The Lower Schist division has been traced westward about 100 miles to the Tombstone area where it is truncated against Tintina Trench (Green and Roddick, 1962; Green, in preparation). In the Tombstone area, rocks of unit 7 are underlain by about 200 feet of siltstone, shale, and limestone of Triassic age (Tempelman-Kluit, 1966, p. 26; Green, in preparation). About 20 miles east of this locality, several fossil collections of Jurassic age have been made from a band of rocks correlated with the Lower Schist division (Tempelman-Kluit, 1966, p. 26; Green, in preparation). The fossiliferous rocks are exposed in a band about 15 miles long lying between two thrust faults.

Just north of the McQuesten Lake map-area, a fossil collection of probable Permian age was made (Green, in preparation) from a thin band of fetid limestone, about 100 feet thick, lying between rocks of the Grit division (units 3 and 4) and the Lower Schist division (unit 7). The rocks are believed to be in normal stratigraphic succession and if this is correct the Lower Schist is post-Permian, corroborating the relationships observed to the west. The collections were examined by E. W. Bamber of the Geological Survey of Canada who comments as follows:

GSC loc. 47212 (64°15′N, 135°10′W) 7 miles north of McQuesten Lake
?*Muirwoodia* sp.
Cancrinella sp.
?*Chonetina* sp.
Other unidentifiable brachiopods, including a large spiriferid which may be the same as *Pterospirifer* (GSC loc. 47207).

GSC loc. 47211 (same location as loc. 47212)
?*Pterospirifer* sp.—possibly the same as that in GSC loc. 47207
rhynchonellid brachiopod
Cancrinella sp.
?*Waagenoconcha* sp.
?*Muirwoodia* sp.
Age: Pennsylvanian or Permian, probably Permian.
Fossils in both collections are poorly preserved and the identifications are uncertain.

Extensive areas of shale and sandstone of Jurassic age have been mapped in northern Yukon Territory (Norris, *et al.*, 1963), and northwest in Alaska, Brabb and Churkin (1964) mapped a band of black carbonaceous shale and argillite that extends, with one interruption, from the International Boundary near 66°35′N, westward to Woodchopper, a distance of about 75 miles. Distribution of these rocks, regional lithological correlations, and paleogeography were discussed by Frebold, *et al.*, (1967).

Keno Hill Quartzite (unit 8)

Strata consisting predominantly of massive quartzite have been assigned to the Keno Hill Quartzite (unit 8). The name in common local use is derived from Keno Hill, south of the present area, where rocks of this division are well exposed. The quartzite is associated with graphitic phyllite, phyllitic quartzite, and phyllite. In places where the phyllitic rocks constitute a mappable unit they have been shown separately (unit 8a). Gritty quartzites (unit 8b) occurring within the Keno Hill Quartzite division (unit 8) have also been mapped separately. It is not known whether all the massive quartzite represents one horizon that has been repeated structurally or whether several horizons are present.

In Mayo Lake map-area, quartzites continuous with those crossing Galena and Keno Hills have been traced to the southern boundary of the map-area. In the northeastern part of this map-area, similar quartzites, which may represent a continuation of the quartzites to the south, have been traced from Roop Creek across Keno Ladue River valley and thence northeast into the southeast corner of the Scougale Creek map-area. The quartzites extending north from Roop Creek contain interbedded phyllitic beds (unit 8a) and gritty phyllitic quartzites (unit 8b). In McQuesten Lake map-area, a band of quartzite (unit 8) sweeps in from the west, bends sharply to the southwest and crosses the western margin of the map-area. In the Davidson Range, a belt of quartzite (unit 8), apparently interbedded with rocks of the Lower Schist division (unit 7), is involved in a major recumbent fold. The stratigraphic position of the latter quartzite with regard to the main bands of quartzite is not known with certainty but it may be equivalent to the No. 9 quartzite mapped by Boyle (1965) on Keno Hill, a few miles to the south.

No accurately measured sections of the Keno Hill Quartzite (unit 8) were obtained within the project area. Very few good sections are exposed and the rocks have undergone so much internal deformation, in addition to possible repetitions of portions of the section through faulting or complex folding, that, in the author's opinion, representative sections could not be obtained. In the Tombstone area about 100 miles to the west where the structural pattern is one of concentric folding and thrusting, Tempelman-Kluit (1966, pp. 160-162) measured a thickness of 1,771 feet of rocks assigned to the Keno Hill Quartzite. The true thickness in the area studied is probably close to this figure.

Two sections in which the true thickness and structure are unknown but indicating typical lithology were measured by the author about 5 miles northwest of McQuesten Lake. The first is of a lower band of rocks of the Keno Hill Quartzite (unit 8), and the second of an upper band separated from the lower by a septum of rocks of unit 3.

A section of lower part of Keno Hill Quartzite at about 64°13′N, 135°20′W is given below.

Lithology	Thickness (feet) *Unit*	*Total from base*
Talus of phyllite, grey, graphitic	140	2,780
Talus of quartzite, massive, in large blocks	95	2,640
Greenstone (unit 9) thickens to the east of section	95	2,545
Talus, mixed grey quartzite, grey phyllite and greenstone	130	2,450
Quartzite, massive, grey	10	2,320
Phyllite, grey-green, buff weathering, pencilled, may have formed from altered greenstone	130	2,310
Greenstone (unit 9) saussuritized, thickens to east	100	2,180
Talus, mixed, massive grey quartzite, thin-bedded brown quartzite, and grey phyllite	140	2,080
Quartzite, massive, medium grey; quartzite, buff; and phyllite, grey; all in about equal amounts	150	1,940
Interbedded quartzite and phyllite; quartzite, thin bedded buff weathering, slightly limy; phyllite, grey	140	1,790
Phyllite, graphitic; minor rusty weathering limy quartzite	50	1,650
Quartzite massive, mainly dark grey but minor or light grey and brown, limy, weathers pale brown but generally has black lichen cover, beds often 3 feet thick or more; minor grey phyllite at base, and 85 feet above base, graphitic phyllite with some limy quartzites, 225 feet above base	240	1,600
Quartzite, massive, brown, talus with black lichen cover, beds up to 6 feet thick, a few thin phyllite beds	180	1,360
Talus of brown quartzite, beds probably several feet thick; minor limy quartzite	200	1,180
Phyllite, graphitic	40	980

Lithology	Thickness (feet) Unit	Total from base
Quartzite, massive, buff, weathers buff to brown but often with black lichen cover, beds commonly from 2 to 3 feet thick but some up to 6 feet thick	240	940
Talus of graphitic phyllite in thin plates	95	700
Quartzite, massive, brown to buff, beds originally up to 6 feet thick but much sheared and slickensided	50	605
Talus of graphitic phyllite	180	555
Quartzite, medium grey, beds up to 1 foot thick	10	375
Talus of green chloritic phyllite; minor grey phyllite	230	365
Quartzite, brown and phyllitic near base but grading upward to massive grey with beds up to 10 feet thick	135	135
Conformable contact		
Underlying beds of Lower Schist division (unit 7)		
Talus of mixed quartzite and phyllite	270	1,110
Greenstone (unit 9), saussuritized but with outline of original grains up to 3 mm in diameter visible	70	840
Talus of platy grey phyllite	600	770
Quartzite, massive, dark grey, banded, some beds up to 1 foot thick	40	170
Talus of phyllite	130	130

Section of upper part of Keno Hill Quartzite (unit 8) about 60° 11½'N, 135° 20½'W.

Lithology	Thickness (feet) Unit	Total from base
Overlying crumpled phyllite of unit 3		
Thrust fault?		
Quartzite, dark grey, beds up to about 3 inches thick	35	1,145
Quartzite, dark grey to blue-grey, beds up to several feet thick; minor interbedded graphitic phyllite; rock shows evidence of movement between beds	180	1,110
Quartzite, brown, beds up to several feet thick but often with partings a few inches apart; minor, thin, lime-bearing beds	30	930
Phyllite, platy grey to greenish grey, beds a few inches thick	40	900
Quartzite, grey, beds up to several feet thick; minor grey phyllite partings and thin lime-bearing beds	90	860
Quartzite, blue-grey, massive, beds up to 6 feet thick; minor interbedded graphitic phyllite near base but very little towards top	370	770
Covered	85	400
Quartzite, massive medium blue-grey, beds up to 2 feet thick	10	315
Greenstone, dark grey, foliated	10	305
Talus of grey phyllite	10	295
Altered grey-green, carbonate bearing rock	5	285
Talus of phyllite containing some coarser quartz grains	105	280
Quartzite, massive, dark grey, much contorted	145	175
Covered	30	30
Possible fault or unconformable contact?		
Underlying sheared and contorted grit of unit 3.		

Boyle (1965, p. 22) gave a section of unit 8 (his Central Quartzite formation) on Galena Hill (63°55'N, 135°24'W) about 6 miles south of McQuesten Lake map-area and the following has been generalized from this:

Member	Description	Thickness (feet) Unit	Total from base
	UPPER SCHIST DIVISION		
	Keno Hill Quartzite division (unit 8)		
Silver King member	Grey, thick-bedded quartzites, beds up to 15 feet thick at Silver King mine; bed of white cherty quartzite near top. In places two greenstone sills, at other places two zones containing greenstone lenses	350	2,350
	Thin-bedded quartzites, interbedded with graphitic schists and phyllites. A few beds of quartzite 3 feet thick or more	550	2,000
Hector-Calumet member	Massive pale grey to grey, thick-bedded quartzite interbedded with minor thin-bedded quartzite, phyllite, and graphitic schist; beds of quartzite from 5 to 25 feet thick; centre of sequence marked by two or more beds of white to pale grey, thick-bedded, cherty quartzite interbedded with two highly sheared greenstone sills or lenses	800	1,450
	Grey to black, thin-bedded quartzite interbedded with graphitic schist and phyllite; most beds 1 foot to 2 feet thick; some up to 5 feet thick	350	650
Galkeno member	Massive, pale grey to black, thick-bedded quartzite; most beds 5 to 10 feet thick, some 25 feet thick or more; a few layers interbedded graphitic schist and thin-bedded quartzite	300	300
	LOWER SCHIST FORMATION		

Other estimated total thicknesses of the Keno Hill Quartzite are as follows:

1. Location: Davidson Range, McQuesten Lake map-area.
   Thickness: 1,200 feet, plus or minus ? feet.
   Notes: The thickness is measured on the limbs of the fold in the projected section (Fig. 17) and appears fairly constant, except that the quartzite is much thicker on the folds and in one place the projected thickness of the limb is only 750 feet.
2. Location: North side of Mayo Lake near the western edge of Mayo Lake map-area.
   Thickness: 6,000 feet, plus or minus 2,000 feet.
   Notes: This estimate is calculated from the amount of quartzite exposed on the west flank of the Mayo Lake Anticline.
3. Location: Patterson Range, Mayo Lake and Scougale Creek map-areas.
   Thickness: 14,000 feet (maximum thickness).
   Notes: This thickness is calculated across the entire Keno Hill Quartzite using the general dip. Attitudes in this area are not consistent and numerous minor folds are known. In addition, it is possible that the bands of massive quartzite may, in fact, be one band repeated.

Lithology

Typical outcrops of unit 8 consist of thick, grey to blue-grey quartzite with beds from a few inches to 6 feet thick and separated by thin partings of graphitic phyllite, phyllitic quartzite, and phyllite. Pink, white, and buff quartzite also occurs. In mapping, an outcrop was generally considered to be massive quartzite if most of the beds were more than 1 foot thick. The quartzites commonly display a faint grey banding parallel with the surfaces of the bed; crossbedding is rare. The quartzites weather medium to dark grey, although surfaces partly protected beneath an overhang, particularly in Davidson Range, are commonly rusty.

The phyllitic rocks separating the quartzite beds are generally less than 1 inch thick and form a very small percentage of the outcrop. In the Davidson Range, quartzite (unit 8) is generally thinner bedded than elsewhere. Many individual beds of quartz display a crude foliation such that the rock can be cleaved into plates an inch or so thick. This foliation is produced by a very thin micaceous parting within the bed; the bulk composition of the bed is probably almost identical with that of the more massive beds of quartzite found elsewhere. A typical outcrop of the massive quartzites of the Davidson Range is shown in Figure 6 where most of the beds are from 6 inches to 1 foot thick. Elsewhere in the Davidson Range, particularly along the contact of the quartzite extending northwest from near Mount Cameron, rocks believed to be crush breccias are common. These rocks are porous and have a distinctive 'pepper and salt' appearance produced by light and dark grey fragments about 2 millimetres in size. They are believed to be crushed, thin-bedded, somewhat impure, graphitic quartzites.

As well as the thin bands of phyllitic material separating the quartzite beds, entire outcrops or parts of outcrops in areas mapped as massive quartzite may be composed

FIGURE 6
Typical outcrop of massive quartzite of the Keno Hill Quartzite, Davidson Range, McQuesten Lake map-area. Note the tight fold in centre foreground, with the axial plane parallel with foliation and probable bedding. The folded bed is about 1-foot thick.

of phyllitic material. In general, these more phyllitic areas are less competent than the more massive quartzites and there is probably more phyllitic material than the appearance of the outcrop indicates.

Both the quartzites and the associated phyllitic rocks contain numerous veinlets of white quartz. The veinlets are commonly a fraction of an inch or less thick and may be as much as several feet in length. They occur as crosscutting veinlets or lenses parallel with the bedding: the latter commonly follows the outlines of small folds within the rock (*see* Fig. 15).

R. W. Boyle (1965, pp. 251-253, and *pers. comm.*) gave the following analyses of quartzites and phyllitic rocks from the Keno and Galena Hills area to the south of present map-areas.

TABLE III — *Analyses of composite samples of quartzite, Keno Hill-Galena Hill area*

Constituent	A-694 %	A-622 %	A-698 %	A-620 %	A-697 %	A-619 %
SiO_2	97.4	88.2	88.9	66.9	63.6	65.7
Al_2O_3	0.6	2.1	1.5	8.4	15.5	12.2
Fe_2O_3	0.0	0.3	0.2	0.8	1.7	1.4
FeO	0.34	1.10	1.05	1.72	2.44	1.93
CaO	0.9	1.5	3.2	2.4	2.3	7.7
MgO	0.0	1.1	0.0	0.8	1.5	1.1
Na_2O	0.1	0.4	0.2	1.1	0.7	1.1
K_2O	0.1	0.3	0.2	1.6	2.7	2.3
H_2O (total)	0.15	0.56	0.71	0.90	2.82	3.49
TiO_2	0.1	0.2	0.2	0.5	0.8	0.7
P_2O_5	0.0	0.1	0.1	0.2	0.4	0.4
MnO	0.0	0.1	0.1	0.1	0.0	0.2
CO_2	0.00	2.49	2.94	7.97	2.05	4.66
S	0.02	0.17	0.10	0.52	1.18	0.56
C		0.09		0.29	1.34	1.00
Total	99.7	98.7	99.4	99.5	99.1	99.0
Less O≡S		0.1	0.0	0.2	0.5	0.2
Net total		98.6	99.4	99.3	98.6	98.8
Specific gravity		2.70		2.74		2.77

Analyst: K. G. Hoops, Geological Survey of Canada.

Nature of samples, location, and correlation to map-units of present map-areas:

A-694 Composite sample of white cherty quartzite, Galena Hill (Keno Hill Quartzite).

A-622 Composite sample of medium- and thick-bedded grey quartzites, Keno and Galena Hills (Keno Hill Quartzite).

A-698 Composite sample of all thick- and thin-bedded quartzite, Keno and Galena Hills (Keno Hill Quartzite).

A-620 Composite sample of thin-bedded quartzite and quartz phyllite, Keno and Galena Hills (includes material from Keno Hill Quartzite division and Lower Schist division).

A-697 Composite sample of graphitic schist, argillite, phyllite, and slate, Galena Hill (includes phyllitic partings from Keno Hill Quartzite division and rocks from Lower Schist division).

A-619 Composite sample of graphitic schist, phyllite, argillite, and slate, Keno Hill (includes phyllitic partings from Keno Hill Quartzite division and rocks from Lower Schist division).

Specimens of quartzite from the vicinity of Mayo Lake and Patterson Range in thin section differ slightly from those of Davidson Range and northwest of McQuesten Lake, and it is proposed to consider them separately.

Those in the Keno Hill to Mayo Lake area and in the Patterson Range commonly consist of quartz grains varying in diameter from 0.05 to 0.25 millimetre, although a few thin sections contain grains up to 0.5 millimetre. Many specimens are banded and there may be a considerable variation in grain size between the bands. Within the bands there is commonly a uniform distribution of grain between the smallest and the largest sizes. The grains are commonly elongated parallel with the foliation of the rock and boundaries with adjacent grains vary from sutured to almost straight lines following a crude polygonal outline. No trace of the boundaries of original detrital grains or of the cementing matrix remains. Common accessory minerals include tourmaline, zircon, ilmenite, and magnetite. In addition to quartz and accessory minerals, the quartzites commonly contain black carbonaceous material, believed to be graphite, which occurs as thin streaks and produces a pronounced banding in the rocks. Muscovite and chlorite generally form as fine grains oriented parallel with the banding of the quartzites. Several outcrops that crumbled readily and appeared similar to a poorly consolidated sandstone were observed along Mayo Lake, and it is believed that fine muscovite grains oriented parallel with the foliation are responsible for this tendency to crumble.

The purer quartzites are interbedded with thinner bedded phyllitic quartzites and graphitic phyllites, and all gradations between these rocks and massive quartzites occur. The less siliceous rocks are similar to those of the Lower Schist division (unit 7) discussed previously.

The quartzites of Davidson Range are commonly more phyllitic than those of Mayo Lake and Patterson Range. In addition, many appear to have been altered to crush breccias. Most of the quartzites contain 20 to 40 per cent of grains about 0.25 millimetre in diameter and approximately the same amount of very fine grains, generally less than 0.05 millimetre in diameter. The remainder of the quartz grains lie between these two distinct size groups. The quartz grains commonly show very complex sutured boundaries. In some thin sections, the larger quartz grains consist of a well-rounded detrital grain with an overgrowth of secondary quartz that has sutured contacts with the adjoining grains. The accessory minerals consist of tourmaline and zircon with some ilmenite; the grain size of these minerals is mostly about 0.1 millimetre in diameter. In addition to quartz and accessory minerals, the rocks commonly contain graphite, sericite, and chlorite. A thin section of a phyllitic quartzite contains about 5 per cent of graphite drawn out in thin lenses that are commonly bent around quartz grains. Muscovite and chlorite mostly occur as fine grains oriented parallel with the foliation of the rock.

In hand specimens, the 'crush breccias' appear as massive, medium to dark grey rocks with a distinctive 'pepper and salt texture', produced by fragments about 2 millimetres in size. In thin section, the crush breccias are composed of single grains of quartz with a maximum size of almost 0.5 millimetre, and fragments up to 2 millimetres across, composed of finer grained quartz with or without graphitic material, sericite, and chlorite. Most large single grains of quartz consist of an original rounded detrital grain with an overgrowth of secondary quartz that has sutured contacts with the surrounding material. The graphitic phyllite of these rocks is commonly squeezed between fragments of more competent rocks. The crush breccias are believed to have originated from thin-bedded, impure, graphitic quartzites that contained bands of fine-grained quartz with considerable muscovite, and sericite separated by thin graphitic partings from bands containing coarser grained quartz. On crushing, fragments of fine-grained material were mixed with the coarser material and the graphitic material separating the two drawn out along the boundaries of the fragments.

Map-unit 8a is composed of mappable bodies of thin-bedded and phyllitic quartzite, chloritic and graphitic phyllites with minor limestone and massive quartzite. They are apparently interbedded with the massive quartzites of the Keno Hill Quartzite (unit 8). Map-unit 8a is present in Patterson Range in both Mayo Lake and Scougale Creek map-areas.

In the two bands of unit 8a north of Keno Ladue River, the principal rock types are green chloritic phyllites and phyllitic quartzites, and graphitic phyllites with thin partings of dark grey quartzite. There are a few beds of limy quartzite and limestone, rarely more than 10-feet thick. A few gritty rocks containing scattered grains of quartz in a fine-grained matrix were observed.

South of Keno Ladue River, in Mayo Lake map-area, the most common rock types are black graphitic phyllites and thin-bedded dark grey quartzites with lesser amounts of chloritic rocks and massive grey quartzite. In this area, the rocks (unit 8a) have undergone considerable deformation; many outcrops are complexly folded and 'Gleitbretter' is common (Fig. 19). Most of the outcrops are heavily iron-stained. Metamorphic minerals include andalusite and biotite. The rocks south of Keno Ladue River mapped as unit 8a are similar lithologically to those of the Lower Schist division, to which, indeed, they may belong. There is a distinct topographic break between the rocks assigned to map-unit 8a and the massive quartzites (unit 8a) to the east. This contact may be along a fault but such evidence as could be obtained suggested that the change in topography reflected the relative competency of the two rock types.

Map-unit 8b occurs only in Patterson Range in Mayo Lake map-area, where it appears to be interbedded with other rocks of the Keno Hill Quartzite. It is a distinctive rock containing relatively coarse, rounded grains of quartz, and less commonly plagioclase feldspar, in a matrix of fine-grained quartz, chlorite, sericite, and secondary biotite. The quartz and feldspar grains are up to 2 millimetres in diameter; the quartz grains commonly contain fine needles, probably rutileted, and are pale blue in colour, although clear, pink, and black grains were observed. Unit 8b also contains fine-grained rocks similar in composition to the matrix of the gritty rocks. Rocks of map-unit 8b differ from gritty rocks in map-units 1, 2 and 3 in the relatively high feldspar content and the finer grained argillaceous nature of the matrix. Viewed in thin section, some of the feldspar grains are probably detrital whereas others are irregular grains, elongated parallel with the foliation, and crowded with inclusions. The latter grains may have formed by the recrystallization of either a sheared coarse grain of feldspar or the fine-grained matrix. Rocks identical to those of map-unit 8b have not been recognized elsewhere in the map-area although they are somewhat similar to portions of the Grit division (unit 3) and rocks to the south of the map-area described by Bostock (1947, units 5 and 6). Rocks of unit 8b may have been laid down at a time when conditions of deposition were different from those for the bulk of the Keno Hill Quartzite or, more likely, they may be an infold or fault slice of older rocks.

Age and Correlation

Rocks of the Keno Hill Quartzite (unit 8) are considered to be of Cretaceous age on the basis of relationships observed in the Tombstone area and correlations with rocks in Alaska (Tempelman-Kluit, 1966; Green, in preparation). They have been traced westward about 100 miles from the present map-area to the Tombstone district where they are truncated against Tintina Trench (Green and Roddick, 1962; Green, in preparation). In this area, they overlie rocks of the Lower Schist division (unit 7) believed to be of Jurassic age, and are overlain by about 1,500 feet of shale, siltstone and limy siltstone of unknown age. Plant remains and gastropods, both indeterminate other than being indicative of a post-Precambrian age were collected from rocks of unit 8 in this area (Green, in preparation). Farther northwest, Tempelman-Kluit (1966, pp. 38-39) considered that rocks of the 'Keno Hill Quartzite' type, mapped by him in the Tombstone district, are lithologically similar to, and the probable time equivalent of Member A of the Kandik Formation of early Lower Cretaceous age, as mapped by Brabb and Churkin (1964).

The distribution of Lower Cretaceous rocks in northern Yukon Territory is shown in Norris, *et al.* (1963) and Frebold, *et al.* (1967).

'Greenstone' (unit 9)

The term 'greenstone' is used locally to refer to sills and lens-shaped bodies of diorite, gabbro, and peridotite and their altered equivalents. The term is a convenient one and will be used throughout this report.

The original composition of most of the greenstone is believed to have ranged between diorite and gabbro. Peridotite and serpentinized equivalents (unit 9a) are rare and occur only in Mayo Lake map-area between Keno Ladue River and Roop Creek, and in Scougale Creek map-area approximately 2 miles southeast of Mount Patterson. In both places more acidic greenstones, typical of those elsewhere in the area, occur close to the basic greenstones. The greenstones range from rocks showing an original igneous mineral composition and texture to those in which both the original minerals and the texture have been destroyed by later alteration. Some of the greenstones are foliated parallel with the foliation of the enclosing sedimentary rocks.

FIGURE 7
Greenstone sills in the Patterson Range, Scougale Creek map-area. Sill-like bodies of greenstone are more competent and stand above the enclosing rocks, mainly phyllites of the Lower Schist division. Foliation strikes into the picture and dips right.

FIGURE 8
Greenstone sills in the large recumbent fold in the Davidson Range, McQuesten Lake map-area (see Fig. 17). Three competent sills, each about 100-feet thick and bordered by darker, rusty weathering phyllite, are involved in the structure. The nearer beds, which are overturned, strike parallel with the ridge and dip left whereas those near the peak are steeply dipping to vertical.

Sills and lenses of greenstone (Figs. 4, 7 - 12) occur in all rocks assigned to map-units 1, 3, 7, and 8. They are most numerous in the Lower Schist division (unit 7) but are also common in the Keno Hill Quartzite (unit 8). The greenstone bodies range in size from lenses a few feet thick and less than 100 feet in length to the Mount Cameron greenstone body which is about 600 feet thick and is exposed for 5½ miles. Some of the bodies, particularly those in the Lower Schist division immediately below the Keno Hill Quartzite are continuous for a considerable distance and are best described as sills (Fig. 8) but most are believed to be lens-shaped. The terminations of many greenstone bodies are well exposed on the steep headwalls of cirques. One body commonly thins and terminates and another of about equal thickness appears in an overlying or underlying bed. In a few cases, the terminations are associated with fold-like structures, some of which are described in detail later.

The greenstones are more competent than the enclosing sedimentary rocks and commonly outcrop as pronounced ridges, standing above the upland surface (Fig. 4). Most have not undergone much chemical weathering but mechanical weathering, particularly frost action along the joint faces, has been extremely active. Many greenstone ridges on the plateau surface do not contain any rock in place and are composed of a rubble of angular blocks several feet across.

Lithology

Very few greenstones still retain their original minerals and texture. Observed alterations include: the replacement of both mafic minerals and feldspar by secondary amphiboles, saussuritization, or the replacement of plagioclase by albite and epidote group minerals, carbonitization, serpentinization, sericitization, chloritization, and steatization, or the replacement of pryoxene minerals by talc. In many altered specimens the original texture is still visible although the minerals may have been almost completely replaced.

Unaltered greenstones, ranging in composition from diorite to gabbro, are commonly composed of about equal amounts of feldspar and a mafic mineral, commonly hornblende, and up to 5 per cent of both ilmenite and quartz. Generally the feldspar occurs in tubular crystals 1 to 2 millimetres long and the hornblende in crystals as much as 5 millimetres long. Some greenstones show a diabasic texture. Ilmenite and quartz commonly fill the interstices between grains of both feldspar and hornblende. Other accessory minerals are rare but pyrite, magnetite, and apatite were observed.

The feldspars commonly show well-developed albite twinning, and in several specimens a faint zoning was observed. The composition of the plagioclase ranges from andesine to labradorite. In ten thin sections where the composition of the plagioclase feldspar could be determined, eight were found to be andesine and two labradorite. Hornblende is the most common mafic mineral, but one exceptionally fresh specimen contained coarse grains of a clinopyroxene with properties close to those of augite.

The development of secondary amphiboles is the most common alteration. Two types occur, a distinctive pleochroic, bluish green hornblende, and a fibrous, faintly pleochroic amphibole, probably actinolite. The blue-green hornblende commonly forms thin rims on the original brown hornblende crystals and the crystal itself may be replaced by a fine aggregate of this hornblende. In addition, the hornblende commonly replaces part or all of the plagioclase feldspar. In a few cases the replacement has been so complete that the specimen consists of fine hornblende with minor amounts of quartz, ilmenite, and its alteration product leucoxene. The secondary hornblende is pleochroic from bluish green to green and the original hornblende from brownish green or yellowish green to olive green to green. The fibrous amphibole, believed to be actinolite, replaces grains of both the brown and the blue-green hornblende with fine fibrous grains having nearly the same orientation as the replaced grain. In some thin sections, the secondary blue-green hornblende is lacking, and the brown hornblende almost completely replaced by fibrous amphibole and chlorite.

Saussuritization, or the alteration of plagioclase to a mixture of fine albite and epidote group minerals, is also common. In most thin sections, the alteration is recognized by the high birefringence of the very fine grains of epidote group minerals. In a few thin sections these grains were coarse enough to study optically; in some, the mineral is believed to be epidote and in others, clinozoisite.

Carbonatization of the greenstones is common, especially near the contacts with the enclosing sedimentary rocks. Irregular rhombs of carbonate as large as 1 millimetre in size may form up to 50 per cent of the altered greenstone. The rhombs are commonly crowded with inclusions of saussurite, sericite, and fine hornblende. Fresh grains of carbonate are light brown but weathered grains are heavily stained with iron oxides, suggesting that the carbonate is iron bearing.

Chloritization and sericitization had occurred in many of the thin sections studied. However, these types of alterations were generally less common than those previously described.

The more basic greenstones (unit 9a) are believed to have been peridotites containing somewhat larger amounts of olivine than pyroxene. Remnants of the original minerals in some specimens suggest that the original grain size was about 5 millimetres. Only one specimen contained fresh pyroxene and this was identified as enstatite. The more basic greenstones are extensively altered, the olivine being replaced by serpentine, and the pyroxene by talc and to a lesser extent serpentine and secondary amphiboles.

Boyle (1965, p. 255) gave two analyses of composite samples of greenstone from Keno and Galena Hills, to the south of the present map-areas. These are reproduced in Table IV.

TABLE IV *Analyses of composite samples of greenstone, Keno Hill-Galena Hill area*

Constituent	A-621 Keno Hill %	A-691 Galena Hill %	Average Diorite[1] %	Average Gabbro[1] %
SiO_2	49.7	46.3	51.86	48.36
Al_2O_3	15.3	13.8	16.40	16.84
Fe_2O_3	2.6	0.8	2.73	2.55
FeO	8.07	10.12	6.97	7.92
CaO	9.3	12.9	8.40	11.07
MgO	6.3	4.5	6.12	8.06
Na_2O	2.2	1.7	3.36	2.26
K_2O	0.2	0.2	1.33	0.56
H_2O (total)	2.90	4.05	0.80 (H_2O+)	0.64 (H_2O+)
TiO_2	1.7	1.7	1.50	1.32
P_2O_5	0.2	0.2	0.35	0.24
MnO	0.0	0.1	0.18	0.18
CO_2	0.31	2.56		
S	0.30	0.14		
Total	98.8	99.1		
Less O≡S	0.0	0.1		
Net total	98.8	99.0		
Specific gravity	3.04			

Analyst: K. G. Hoops, Geological Survey of Canada.
A-621 is a composite sample of suites of specimens collected from 8 greenstones.
A-691 is a composite sample of suites of specimens collected from 6 greenstones.
[1]Average diorite and gabbro as given by Nockolds (1954).

The metamorphic rank of the greenstone is often above that of the enclosing sedimentary rocks, and varies depending on whether the secondary amphibole is blue-green hornblende or actinolite. Those with blue-green hornblende have this mineral plus epidote and albite as their essential components, and their metamorphic rank according to Turner and Verhoogen (1960) is the quartz-albite-epidote-almandine subfacies of the greenschist facies. Those with actinolite have this mineral plus epidote, albite, and chlorite as their essential components, and their metamorphic rank (op. cit.) is the quartz-albite-muscovite-chlorite subfacies or, less commonly, the quartz-albite-epidote-biotite subfacies of the greenschist facies. The enclosing sedimentary rocks generally belong to the quartz-albite-muscovite-chlorite subfacies or, less commonly, to the quartz-albite-epidote-biotite subfacies of the greenschist facies. Some alterations of the greenstones, principally the formation of the blue-green hornblende and the saussuritization of feldspar, may be deuteric in origin, occurring late in the cooling history.

The alterations are generally present throughout a greenstone sill, rather than concentrated in zones or structures as might be expected if the alteration were produced by hydrothermal means, or as a response to the deformation of the greenstone and the enclosing sedimentary rocks. Other alterations, such as the development of fibrous amphibole (actinolite?), carbonates, chlorite, and sericite, indicate equilibrium between the greenstone and the enclosing sedimentary rock. Some alterations, particularly the formation of carbonates, are best developed in foliated greenstone near the contacts and appear closely related to the development of foliation in the enclosing sedimentary rocks.

Many greenstones are foliated, either along the contacts or throughout, and two distinct mineral assemblages, the first of blue-green hornblende and saussurite, and the second of sericite, chlorite, and carbonate may be associated with the foliation. The first assemblage, commonly developed throughout the greenstone and identical with many greenstones in which the original texture is still visible, consists of secondary blue-green hornblende replacing original hornblende and saussurite replacing the feldspars. In these foliated rocks the ilmenite and saussurite are drawn out in elongate blebs and the coarse grains of original hornblende rotated and broken. The secondary hornblende commonly replaces the original hornblende and forms fine needles projecting into the saussurite. These needles, commonly oriented in the plane of the foliation, show no indication of rolling or breaking. The second assemblage, commonly developed only along the margins of the greenstone bodies, consists of sericite, chlorite, and carbonate. In this alteration, the original texture is completely destroyed and the rock consists of a fine-grained ground mass of micaceous minerals, quartz, and ilmenite in which coarse grains of iron-bearing carbonate have developed.

The first assemblage (hornblende-epidote-albite) in the foliated greenstones does not appear to be in equilibrium with the enclosing sedimentary rocks, and the presence of this assemblage in foliated rock suggests that the foliation may have developed while the greenstone was still undergoing deuteric alteration. The second assemblage (sericite-chlorite-carbonate) is in equilibrium with the sedimentary rocks, suggesting that the greenstone had solidified previously and that the foliation developed concurrently in both rock types.

Structural Relations

Most greenstones are conformable with the bedding of the enclosing sedimentary rocks and may be described as either sills or lens-shaped bodies. Greenstones differing from this general pattern include a crosscutting dyke and several bodies associated with fold-like structures.

The crosscutting dyke was observed in McQuesten Lake area. It is about 5 feet thick and cuts directly across the foliation of the enclosing sedimentary rocks to within 10 feet of a greenstone sill. It probably was a feeder pipe. The outcrop is on a steep slope, and the relationship between the slope and the plunge of the dyke may be such that the contact with the greenstone is not exposed.

A number of greenstones associated with fold-like structures were encountered. These structures are extremely puzzling and, as it was felt that they might supply some information as to origin of the greenstone bodies, several of them were mapped in detail. In these, the greenstone appears to occupy the nose of a fold-like structure, and to have altered the adjacent sedimentary rocks and protected them when foliation was developed in the sedimentary rocks farther from the contact. Possible origins are considered in a later section of this report.

Greenstone north-northwest of Mount Patterson (64° 06′N, 134° 41′W)

The largest greenstone associated with fold-like structures occurs in Scougale Creek map-area approximately 2¼ miles north-northwest of Mount Patterson (*see* Fig. 9). Figure 13A shows the points where the attitudes of the bedding around the nose of this

FIGURE 9. Fold-like structure in greenstone, 2¼ miles north-northwest of Mount Patterson, Scougale Creek map-area (see Fig. 13A). The competent greenstone in the centre is almost completely surrounded by a rusty-weathering altered zone.

structure were obtained; the poles to these attitudes have been plotted on a meridian (Wulff) stereonet. By inspection, most of the poles lie close to a great circle, and following Dahlstrom (1954) it is suggested that the structure is a cylindroidal fold with the axis plunging 30° at S 20°E. The bulk of the greenstone retains its original igneous texture, although feldspar has been completely replaced by saussurite, and hornblende partly replaced by a nonpleochroic amphibole, probably actinolite. Near the margins there has been some shearing and, where this has been most intense, all trace of the original texture has been destroyed and the mineral assemblage consists mainly of fine chlorite and carbonate. A distinctive rusty weathering quartzite occurs at the contact and, except for a small section on the upper limb, it has been traced completely around the fold. This rock is composed of fine grains of quartz with up to 30 per cent of fine flakes of sericite and chlorite and up to 10 per cent fine pyrite. It does not show the foliation developed in the graphitic phyllite and phyllitic quartzite a few feet farther from the contact.

Greenstone southwest of Mount Patterson (64° 02'N, 134° 43'W)

Another fold-like structure of this type occurs 3.1 miles southwest of Mount Patterson in Scougale Creek map-area where it is exposed in the head of cirque above the horseshoe-shaped lake. The greenstone (Fig. 13B) intrudes phyllitic quartzite and phyllite of the Lower Schist division. In this body two limbs join to form a thick mass of greenstone that continues for some distance and then terminates in a fold-like structure. The poles of the bedding measured around this structure were plotted on a stereonet (Fig. 13B) and a great circle drawn suggesting a fold with an axis plunging 30° at S 8°W. This structure is partly obscured by talus, and faulting may occur near the nose. A few attitudes were obtained in the sedimentary rocks between the two limbs of the greenstone and, as near as could be determined, these attitudes project directly into the greenstone and the sedimentary rocks do not appear to be folded between the two greenstone limbs.

Greenstone near Mount Cameron (64° 04½'N, 135° 02½'W)

The most puzzling of these structures occurs near Mount Cameron in McQuesten Lake map-area. Similar appearing greenstones occur both on Mount Cameron and on the smaller ridge about 0.6 mile to the west. As these greenstones are traced to the south on the west side of Mount Cameron (Fig. 10), and on both sides of the smaller ridge, they appear to end abruptly. Greenstones generally form prominent ridges, and it appears impossible for a greenstone body comparable in thickness to the Mount Cameron body to be completely covered in the cirque between the two ridges, although a very thin band of greenstone might be present. The termination of the Mount

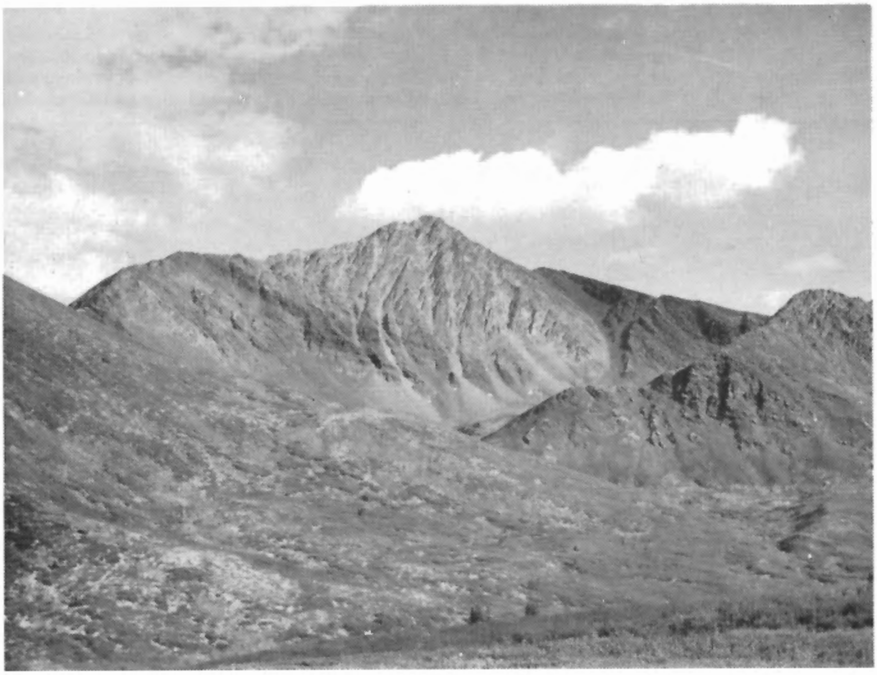


FIGURE 10. Mount Cameron viewed looking southeast. The Mount Cameron greenstone body forms the summit of the peak and terminates in the cirque to the south. The nature of the termination is obscured by talus. The higher parts of the smaller ridge to the right are greenstone, and the termination shown in Figures 11 and 13C lies to the right of the photograph. The greenstone shown in Figure 13D is visible at the base of the ridge leading to Mount Cameron.

FIGURE 11. Fold-like structure in greenstone on the ridge west of Mount Cameron, McQuesten Lake map-area (Fig. 13C). The greenstone sill (left) is overlain by phyllitic rocks of the Lower Schist division. Platy and massive grey-green quartzite, believed to represent an alteration zone, was traced along the upper part of the structure but the lower part is obscured by talus and may be faulted.

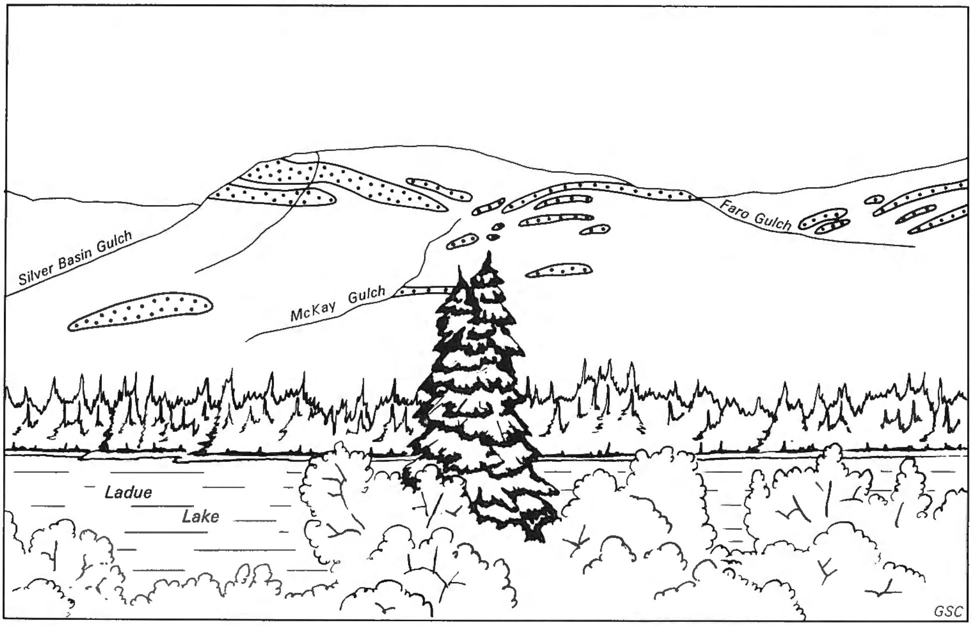


FIGURE 12. Greenstone bodies on north face of Keno Hill, viewed across Ladue Lake at head of Keno Ladue River. Large greenstone body between McKay and Faro Gulches is approximately 2,000 feet long.

Cameron greenstone on the west face of Mount Cameron is particularly difficult to understand as the greenstone is so continuous on the east face. On both Mount Cameron and the ridge to the west, there appears to be faulting in the sedimentary rocks near the termination of the greenstone, and the structures are partly obscured by talus. However, sedimentary rocks were traced almost completely around the structure (Figs. 11, 13C) exposed on the west face of the ridge west of Mount Cameron. The poles of the bedding were plotted (Fig. 13C) and a great circle drawn suggesting a fold with an axis plunging 32° at S 17°E.

The suggested axis for the fold-like structure is at an angle of about 65° to the axes of both major (Fig. 17) and small-scale (Fig. 16) folds in the Davidson Range, both of which plunge about 20° at S 55°W. In the author's opinion it is doubtful if a single fold-like structure is responsible for the termination of the greenstone on both Mount Cameron and the ridge to the west. If correctly interpreted the plunge on the ridge to the west is such that a major fault with a minimum horizontal displacement of about ½ mile would be required to join them as a single structure. Greenstone of comparable thickness to the Mount Cameron body is lacking west of the area described.

A distinctive alteration zone occurs on the contacts of both the Mount Cameron greenstone and the greenstone on the ridge to the west. In the latter, the alteration has been traced part way around the structure. Most of the greenstone is believed to have been a relatively coarse grained hornblende diorite with hornblende grains up to 5 millimetres long and somewhat finer feldspar grains. The original hornblende has been altered to a secondary blue-green hornblende and an aggregate of fine-grained nonpleochroic amphibole, probably actinolite; the feldspars have been completely saussuritized. The nearer the contact with the sedimentary rocks the finer the grain size becomes, until at the contact the greenstone is virtually indistinguishable from the enclosing greenish quartzites. There is no evidence of shearing along the contact and the quartzites are not foliated. They have a total thickness of about 40 feet and grade from beds several feet in thickness near the contact to much thinner beds near the gradational contact with thin-bedded dark grey quartzite and graphitic phyllite typical of the Lower Schist division (unit 7). A specimen of quartzite taken about 1 foot from the greenstone contact consisted of 90 per cent quartz grains up to 0.3 millimetre across and 10 per cent pleochroic blue-green hornblende grains of about the same size. The hornblende grains appear to have formed through the metamorphism of an impure quartzite by the greenstone. Similar quartzites overlie and underlie the greenstone on Mount Cameron.

A similar structure on a smaller scale is present on the west face of the ridge north of Mount Cameron about half a mile from the summit (Fig. 13D), where a small greenstone body appears to thin and terminate. The bedding of the enclosing sedimentary rocks could not be traced completely around the end, but it was possible to trace it around the end of a finger-like projection on the upper surface of the body. The poles of the attitudes obtained were plotted on a stereonet (Fig. 13D) and a great circle drawn suggesting a fold with an axis plunging 34° at S 22°E, very close to that suggested for the larger structure nearby (32° at 17°E). Like the latter, the suggested axis for this fold-like structure is at an angle of about 65° to the axes of both major and small-scale folds in the Davidson Range.

Greenstone southeast of Mount Patterson (64° 03'N, 134° 33'W)

The termination of two greenstone bodies are exposed on a steep north-facing slope 3.4 miles southeast of Mount Patterson. The poles of attitudes obtained around the end of the lower greenstone were plotted on a stereonet (Fig. 13F) and a great circle drawn suggesting a fold with an axis plunging 40° at S 75°E. The axes of two minor crumples observed near the structure are close to that suggested for the main structure.

Origin of Greenstone Bodies

The origin of greenstone bodies is a two-fold problem in that it is necessary to consider both the mode of emplacement and the extent that original shape has been modified by later structural disturbances. Many explanations have been suggested, mostly based on field work in the Keno and Galena Hills area, and there have been almost as many suggestions as there are greenstones in this important area.

Previous suggestions

The following is a brief summary of some of the explanations suggested by other workers in the general area. Keele (1906b) considered the greenstones to be basic eruptive rocks, principally diorites and diabases, intruded along the bedding planes of the sedimentary rocks and subsequently sheared and altered. Cockfield (1921a) mapped the greenstones as continuous sills, ranging from diorite to diabase, displaced by occasional faults. He concluded that they were emplaced prior to the deformation of the enclosing sedimentary rocks. Stockwell (1926) described the greenstones as andesite and related rock types. He considered that the shape of the greenstone was controlled to some extent by the type of rock intruded; those intruded into the Lower Schist division (unit 7) occurring as irregular discontinuous massess elongated in a direction approximately parallel with the schistosity, and those intruded into the Keno Hill Quartzite (unit 8) as much more uniform sill-like bodies controlled by the bedding planes. Bostock (1947) described the greenstones as hornblende-rich diorites having the form of flattened cylinders and extending down the dip of the enclosing strata. Blackadar (1951) suggested two probable origins for the greenstones. In the first, the greenstones represent pipe-like bodies originating at a central source, the pipes subsequently being broken by recumbent folding and shearing so that they are no longer connected with the source. In the second, the greenstones were originally part of much more continuous sills that were broken into boudins during the subsequent deformation. Blackadar favoured the first hypothesis but considered that the question of origin was still uncertain. Boyle (1965, pp. 16-18) considered the greenstones were originally much more continuous sill-like bodies that were fractured parallel with and perpendicular to the strike and then sheared into sausage-like bodies or boudins. These boudins have been further cut and displaced by bedding plane faults, low-angle thrust faults, shear zones, vein faults, and cross faults. He thought that boudins would form more readily in the schists, which are incompetent compared to the greenstones, than in the quartzites, which are of about equal competency, and he used this to explain the large number of lens-like bodies in rock of the Lower Schist division. McTaggart (1960, pp. 12-17) considered that relict igneous texture and composition left little doubt that the greenstones are of igneous origin and that field evidence indicated that many of the greenstones are lenticular in strike section and that some at least, and perhaps many, are lenticular in all directions. Mechanisms that work in combinations to produce the lenticular greenstone bodies include: intense folding and later preservation from erosion of the axial parts of folds, local strong compression and plastic flow with the development of boudins, and slicing by thrust faults lying close to the axial planes of earlier folds (op. cit.).

Igneous origin

Some of the greenstones are fresh, relatively coarse grained diorites and gabbros and many of the altered ones can be shown to have had a similar composition and texture. Structures normally associated with extrusive rocks are absent and there seems little doubt that the greenstones are intrusive sills and lenses rather than flows extruded at the time of sedimentation. Chilled margins are rare although the Mount Cameron greenstone in McQuesten Lake area is markedly finer grained within a few feet of the contact.

Time relationship between intrusion and development of foliation

The time relationship between the intrusion of the greenstone and the development of the foliation is uncertain. Certainly, some of the greenstones were emplaced early enough to be foliated together with the enclosing sediments and have a mineral assemblage (muscovite, chlorite, and carbonate) of the same metamorphic rank. Other foliated greenstones with a mineral assemblage of blue-green hornblende and saussurite are of higher metamorphic rank than the enclosing sedimentary rocks, and this foliation may have developed while the greenstone was undergoing deuteric alteration. If this relationship is correct, these greenstones would be intruded very nearly at the same time as foliation was developed. Similar time relationships are also suggested by some of the fold-like structures associated with greenstone, the origin of which is discussed in the following paragraphs. Poldervaart (1953) pointed out that in some cases it has been possible to prove that schistosity, foliation, or lineation in basaltic rocks is not a result of deformation. However, in the present case, the apparent rotation of the grains of original brown hornblende, and the smearing out of ilmenite and saussurite are strongly suggestive of deformation.

Formation of boudins

Although the shape of the greenstone bodies resembles in many ways that of boudins as described elsewhere (Cloos, 1946, 1947; Ramberg, 1955; Jones, 1959), the shape of the greenstone bodies is believed to be controlled by the competency of the intruded rocks rather than later deformation and the production of boudins. Greenstone bodies are well exposed in the headwalls of many cirques, and individual boudins may be seen to thin and terminate at one level but others appear in the nearby overlying or underlying strata. No examples were observed in which it could be established with certainty that a single greenstone sill had been broken into boundins. If the greenstone bodies are indeed boudins, there must have been much movement subsequent to their formation in order to produce the present distribution. Minor shearing has been observed at the contacts of some of the greenstone bodies, but Boyle's (1965, p. 16) statement that they are highly sheared at their contact with both quartzite and schist does not apply to the present area. As an alternative to boudins, it is suggested that the contrast between lens-like and sill-like bodies results from the relative competency of the rock intruded. Thus, lens-like bodies might be expected in less competent rocks, such as those of the Lower Schist division where the intrusion could only force the beds apart for short distances, and sill-like bodies in more competent rocks, such as the Keno Hill Quartzite where the intrusion could force the beds a much greater distance apart.

Comparison of greenstone bodies to lenses of limestone in the Grit division

In considering the shape of the greenstone bodies, it should be noted that they are similar in outline to the limestone lenses (unit 4) present in the Grit division (unit 3). A few greenstone bodies, identical in shape with the nearby limestone lenses, actually occur in the Grit division. In many of the limestone lenses the original banding has been partly destroyed, and many appear to have formed through flowage of the limestone. The limestone appears to have been less competent than the enclosing sedimentary rocks. This relationship, if correctly interpreted, is the reverse to that in boudinage structures where the boudinaged layer is relatively more competent than the surrounding rocks (Jones, 1959, p. 105).

Conclusions

In the author's opinion, the greenstones are intrusive and were emplaced before and possibly during the development of foliation in the enclosing sedimentary rocks. This time relationship is suggested because some foliated greenstones are composed of metamorphic minerals in equilibrium with the enclosing sedimentary rocks, whereas others contain minerals of higher rank, especially blue-green hornblende, suggesting that foliation may have developed under higher pressure-temperature conditions, possibly as a deuteric alteration. The discontinuous nature of the greenstones in the more schistose rocks, particularly the Lower Schist division (unit 7), is believed to be due to the original shape of the intrusions rather than later deformation and the production of boudins. However, the shape of many greenstones may have been modified considerably by later deformation.

Origin of fold-like structures in greenstone

Definite evidence as to the origin of the fold-like structures was not obtained in the mapping, and it is possible that they may have originated in more than one manner. Several possible origins, none of which appear adequate to explain all the field evidence are discussed.

1. *Simple faulting or folding or a combination of both.* In the author's opinion, neither a few, relatively uncomplicated, faults or folds, either singly or in combination, could produce the fold-like structures. The fold-like terminations could not be produced by a simple fault. The greenstones, with one exception, lack a core of sedimentary rocks that might be expected with a simple fold and in no case was it possible to trace folded foliation in a greenstone. If the structures were formed by faulting or folding of a more continuous sill it should be possible to trace this sill beyond the deformed area, but this is not the case.

2. *Boudins formed from a once continuous body.* Although the bedding appears to be continuous around the noses of the structures, it was nowhere possible to trace an individual bed completely around any of them and it is possible that the structures may be scar-folds[1] at the neck of a boudin. In this case, it seems unlikely that the scar-folds would appear as a cylindrical fold or that alterations, such as the iron-stained zone in the large structure in the Patterson Range or the metamorphosed quartzites in the structure on

[1]Jones (1959, pp. 106-107) defines a scar-fold as one formed in the host layers resulting from the host flowing into the scar void left by separation of boudins. As illustrated, scar-folds formed from the host layers above and below the boudin are crudely symmetrical about a neck-line and a concentric fold similar to those observed in the present structures is lacking.

Mount Cameron, could be continuous around the nose of the structure. Also, additional boudins of similar thickness might well be expected in the immediate vicinity.

3. *Diapiric structures formed around a mobile mass of greenstones.* All the structures occur in greenstone bodies in relatively incompetent foliated rocks of the Lower Schist division (unit 7). If a mobile mass of greenstone were forced into these rocks, it might be expected to pry apart the foliation rather than force the sedimentary rocks into large isoclinal folds. Diapiric folds commonly occur when a mass of lower specific gravity, commonly salt, has broken through more brittle overlying rocks. If the present structures are diapiric folds, conditions are reversed in that the specific gravity of the greenstone (about 3.0) is higher than that of the enclosing sediments (about 2.7).

4. *Greenstones fill dilatant zones in the noses of folds.* Greenstones may have intruded the cores of early formed folds producing the metamorphic haloes that have been observed. In the following deformation that produced the intense foliation in the area, the unfoliated haloes were either protected by the greenstone or their compact hornfelsic texture was not destroyed. Most greenstones show no evidence of foliation, either in a single plane or folded, and retain an igneous texture although original minerals are largely replaced by blue-grass hornblende and saussurite. The greenstones involved are relatively thick and have been traced for some distance, and it is difficult to understand how dilatant zones of the size required could exist at a time of compressional tectonics. In addition, rocks of the Lower Schist division (unit 7) are rather incompetent and might be expected to deform by small-scale folding, faulting, and shearing rather than by large-scale folds required by this origin.

5. *Complex structure.* The structures may have been produced by large-scale transposition structures such that the greenstones are tectonic 'fish' in highly deformed phyllitic rocks. Examples of this type of deformation are given by Whitten (1966, pp. 199-215). Structures of this type result from intense folding in which the folds become isoclinal and appressed such that the limbs lie in the plane of foliation. With continuing differential slip, the folds may be torn apart and eventually the only relicts of the folds are the 'rootless' attenuated closures of the folds. Some of the folds observed in rocks of the Keno Hill Quartzite are 'rootless' in this manner, and the fold-like structures in greenstones may be examples of this on a grand scale. However, both foliation within the greenstone and evidence of intense slip along the margins might be expected if the structures originated in this manner. Both are lacking.

Conclusions. There are serious objections to all the origins proposed but it must be noted that, with the exception of 1, all involve complex structures on a relatively large scale. Whatever the origin, the structures, including the structure in the Davidson Range (Fig. 17), are simply large-scale examples of the complex deformation indicated by the ubiquitous development of foliation and other small-scale structures common to the area.

The author was impressed by the fold-like nature of the terminations, the massive igneous texture of the greenstone, and the metamorphic halo surrounding them, and favours the view that some of the structures, particularly north-northwest of Mount Patterson (*see* Fig. 9) may indeed have been formed by the intrusion of the nose of an early formed fold.

Comparison of greenstones of study area to greenstones of other areas

Intrusive sills and laccoliths showing some similarities to the greenstones of this part of Yukon Territory have been described in Scotland, the Swiss Alps, and Utah.

Scotland

The 1-inch to 1-mile geological maps of Scotland published by the Geological Survey of Scotland show many areas where epidiorite sills have intruded sedimentary rocks that are now phyllites, schists, and other metamorphic rocks. The epidiorites are believed to have had an original composition similar to dolerite or basalt, with augite and plagioclase as the principal minerals. The most common alteration is the replacement of augite by a fibrous amphibole. Subsequent to intrusion, the epidiorites were folded and subjected to regional metamorphism. Wiseman (1934) has described the metamorphism of those in the Dalradian series in detail. The epidiorites, as mapped, are very similar in outline to those of the Mayo district, and in many cases occur in metamorphic rocks of approximately the same rank. The main difference between the two areas would appear to be the suggestion that those of the Mayo district may, in part, have been intruded during the deformation of the enclosing sedimentary rocks.

Wilkinson (1907) has described epidiorites on the Isle of Islay which appear to be very similar to those of the Mayo district. On Islay, numerous epidiorites have intruded the Port Ellen Phyllites, a unit that varies from lustrous slates to soft grey and dark sericitic mica-schists that are in part calcareous. The sills vary from schistose to massive, the texture of the massive sills varying from porphyritic, to granitic, to ophitic. The sills have shared in the folding and there is believed to be considerable repetition of sills as a result of isoclinal folding. Some of the sills have been mapped around the noses of folds.

Swiss Alps

In the Swiss Alps, Cadisch (1953) has described 'Ophiolithe' as occurring for the most part as concordant intrusions into Mesozoic sediments. Under the term 'Ophiolithe' he included ultrabasic rocks, gabbro, diabase, and metamorphic rocks such as amphibolite, with primary igneous structures. A number of his illustrations show features similar to those of the greenstones in the present map-area. He remarked that 'Ophiolithe' are almost always concordant with the enclosing schist, that they only locally cut the bedding, and that they probably represent sills or laccoliths. He also remarked that in some areas it had been assumed that the intrusions accompanied the first tectonic movements, and that they migrated along planes that had been opened tectonically. Collett (1927, p. 196) referred to a sill of gabbro that is intruded along the thrust plane of a nappe showing that some of the intrusions, at least, occurred late in the tectonic history.

Henry Mountains, Utah

The laccoliths of the Henry Mountains, Utah, are similar in some respects to the greenstone bodies of the Mayo district. Gilbert (1877) introduced the term 'laccolite', later changed to 'laccolith', to describe certain of the intrusions of the former area. The laccoliths are dome-shaped with both floor and roof concordant with the bedding planes of the enclosing formations, the roof being arched upwards as a result of the intrusion. The area has been described more recently by Hunt (1953).

Each of the Henry Mountains has a core consisting of a stock composed predominantly of diorite porphyry that has forcefully intruded slightly deformed Mesozoic sedimentary rocks. Clustered around these stocks are laccoliths and other intrusive bodies. Many of the laccoliths appear to have been fed from the central stock whereas others are believed to have had dyke-like feeders. The laccoliths have spread along the bedding planes of the enclosing formations and have arched their roofs. Hunt (1953) stated that most of the laccoliths have diameters measurable in thousands of feet, and an average volume of about one-quarter cubic mile. However, he listed a number with volumes less than one-tenth cubic mile. The volumes of the Mayo greenstone bodies cannot be calculated as the dimensions are not accurately known; nonetheless, with a few notable exceptions, most of them probably have volumes less than one-thousandth cubic mile. The laccoliths are composed of diorite porphyry consisting of phenocrysts of oligoclase, hornblende, and magnetite in an exceedingly fine-grained groundmass. The only contact metamorphism associated with the laccoliths is a slight induration of the sedimentary rocks which may extend a few yards from the contacts. The Jurassic and Cretaceous rocks of the area consist of shales and sandstones, and most of the laccoliths occur in incompetent shale in very thick units separated by thin competent sandstone layers rather than in the underlying, more competent, sandstones. In arching the overlying formations, some of the laccoliths have produced folds with relatively steep dips at their terminations.

The laccoliths of the Henry Mountains differ from the greenstone bodies of the Mayo district in that they are porphyries; they are associated with intrusive stocks; they contain numerous inclusions, generally of hornblende; and they were intruded into virtually undeformed sedimentary rocks. They are similar in that some of them are almost identical in shape to the greenstone bodies, in general they appear to be concentrated in relatively incompetent rocks, they are conformable to the bedding (or in the Mayo district, foliation) of the enclosing rocks, and there is relatively little evidence of alteration of the enclosing rocks at the contacts.

Age and Correlation

Field relationships suggest a Cretaceous age for the greenstone sills. They intrude rocks of Jurassic (unit 7) and probable Lower Cretaceous (unit 8) age, and are in turn altered by granitic rocks (unit 10) of Cretaceous (?) age.

Similar greenstone sills have been mapped (Green and Roddick, 1962; Green, in preparation) for about 90 miles between the present area and Tintina Trench near the International Boundary. The sills have intruded rocks of varying ages from Precambrian to Lower Cretaceous (Keno Hill Quartzite). The form of the intrusive is to some extent controlled by the nature of the enclosing rock but the sills show remarkably little variation in composition. There is some field evidence to suggest that greenstones intruding older rocks, principally of Precambrian age, may, in part at least, be older than those intruding Mesozoic rocks (units 7 and 8 of this report).

Granitic rocks (unit 10)

Granitic rocks occur north and east of Mayo Lake in Mayo Lake map-area and west of Hanson Lakes in McQuesten Lake map-area. In both areas they are similar in composition and grain size and are believed to belong to one period of intrusion.

Lithology

These rocks are commonly grey, medium grained, and range in composition from quartz diorite to granite. Most are composed of varying proportions of potash feldspar—either orthoclase or microcline, plagioclase feldspar—commonly andesine, quartz, biotite, and hornblende. Accessory minerals include magnetite, pyrite, sphene, and zircon. Much of the potash feldspar occurs as coarse phenocrysts and in many cases the percentage of these phenocrysts is the principal difference between granodiorite, quartz monzonite, and granite. The plagioclase feldspars are commonly zoned. Most of the granitic rocks are fresh and the feldspars show little alteration, although most of the hornblende is partly or entirely altered to biotite and some biotite has in turn been altered to chlorite.

The granitic rocks have been relatively resistant to weathering and they outcrop freely, except where they are deeply covered by glacial debris as on Granite Creek in Mayo Lake map-area. Mechanical weathering, particularly frost action, has been much more active than chemical weathering. Frost has acted principally along grain boundaries, joints, and fractures. The surface of many outcrops is crumbled and shows a crude gridiron structure controlled by joints and fractures.

A number of analyses of composite samples of the granitic rocks are presented by Boyle (1965, p. 257) from material collected by the author. For the convenience of the reader these analyses are repeated in Table V.

TABLE V *Analyses of composite samples of granitic rocks, Keno Hill-Galena Hill area*

Constituent	A-699 %	A-701 %	A-700 %	A-702 %	Average Hornblende Biotite Adamellite[1] %	Average Hornblende Biotite Granodiorite[1] %
SiO_2	61.3	68.8	64.9	70.1	65.88	65.50
Al_2O_3	16.6	16.5	16.5	15.5	15.07	15.65
Fe_2O_3	0.3	0.5	0.8	0.3	1.74	1.63
FeO	3.59	1.50	2.82	2.36	2.73	2.79
CaO	7.0	2.9	3.6	2.6	3.36	4.10
MgO	2.5	1.2	1.2	1.2	1.38	1.86
Na_2O	2.6	2.9	3.0	2.5	3.53	3.84
K_2O	3.4	4.5	4.1	3.3	4.64	3.01
H_2O (total)	0.56	0.50	0.57	0.80	0.52(H_2O+)	0.69(H_2O+)
TiO_2	0.5	0.3	0.7	0.4	0.81	0.61
P_2O_5	0.2	0.1	0.4	0.1	0.26	0.23
MnO	0.0	0.0	0.1	0.0	0.08	0.09
CO_2	0.10	0.00	0.00	0.00		
S	0.02	0.02	0.01	0.00		
Total	98.7	99.7	98.7	99.2		

Analyst: K. G. Hoops, Geological Survey of Canada.
Location of samples:
A-699 5 samples, margins of Mayo Lake batholith, includes quartz diorite, monzonite, aplite.
A-701 3 samples, non-porphyritic phase (unit 10) of Mayo Lake batholith, includes granodiorite, quartz monzonite.
A-700 3 samples, porphyritic core (unit 10a) of Mayo Lake batholith, includes quartz monzonite and granite.
A-702 2 samples, stock west of Hanson Lakes, quartz monzonite.

[1]Analyses from Nockolds (1954).

Mayo Lake batholith

The Mayo Lake batholith lies north of the east end of Mayo Lake. It occurs in an area heavily mantled by drift but the outcrop pattern suggests that the granitic rocks underlie a surface area of about 45 square miles. The batholith intrudes rocks of the Keno Hill Quartzite (unit 8) and the Upper Schist division (unit 1). The granitic rocks are composed of varying amounts of coarse potash feldspar—either microcline or orthoclase, plagioclase feldspar—commonly intermediate between an oligoclase and andesine in composition, quartz, biotite, and hornblende. Rock types include granite, quartz monzonite, monzonite, quartz diorite, and quartz gabbro. The rocks are commonly medium grained with most grains between 2 and 3 millimetres across, although phenocrysts of potash feldspar may be as much as 20 millimetres in size and coarse hornblende crystals as much as 15 millimetres. Most of the rocks are fresh although the plagioclase feldspar of one specimen of quartz diorite was found to be completely altered to scapolite.

Two areas of porphyritic rocks (unit 10a) have been mapped within the batholith. Rocks in these areas contain up to 40 per cent coarse potash feldspar phenocrysts. Identical porphyritic rocks were observed elsewhere within the batholith and in the other areas of intrusive rocks in the district, but were not widespread enough to permit mapping as a separate unit.

The remainder of the batholith is composed predominantly of granodiorite with lesser amounts of quartz monzonite, quartz diorite, and quartz gabbro. The more basic quartz diorite and quartz gabbro commonly occur near the margins of the batholith. The latter commonly contains abundant green hornblende.

The contact of the intrusive rocks (unit 10) with the enclosing sedimentary rocks is best shown on the slope east of Wilsons Cabin. There the granitic rocks are in contact with thin-bedded quartzites, phyllites, and minor thin limestones of the Upper Schist division (unit 1a). The contact zone is several hundreds of feet in width and consists of sedimentary rock cut by numerous sills and dykes of granodiorite, aplite, and pegmatitic material. Near the contact, quartzites are recrystallized and secondary biotite and minor garnet developed, impure limestones are altered to garnet-diopside rocks, and saussuritized greenstones are recrystallized to pyroxene-hornblende-feldspar rocks, probably very close to their composition prior to alteration. Garnet and biotite are common elsewhere in the sedimentary rocks near the contact, and sillimanite was observed in the Keno Hill Quartzite where it is in contact with the batholith on the west side of Keno Ladue River.

Stock east of Mayo Lake

A stock about 1 square mile in surface area intrudes rocks of map-unit 2 east of Mayo Lake. What is probably a continuation of this stock, or a small outlier from it, intrudes the Upper Schists (unit 1) and map-unit 2 immediately to the west. The granitic rocks are medium grained, commonly 1 to 2 millimetres in grain size, and composed of potash feldspar, commonly microcline, andesine, quartz, biotite, and minor green hornblende. Both porphyritic and nonporphyritic rocks were observed and the composition is believed to vary between granodiorite, quartz monzonite, and granite depending on the amount of potash feldspar present as phenocrysts. One specimen of granite examined in thin section contained 70 per cent microcline phenocrysts up to 10 millimetres long.

Sills on ridge north of headwaters of McKim Creek

Three small sill-like bodies, all less than 100 feet thick, outcrop on the ridge north of the headwaters of McKim Creek in the Mayo Lake map-area. These rocks are composed of zoned feldspars ranging from labradorite to andesine, quartz, biotite, and green or black hornblende. Most of the grains are from 0.5 to 1 millimetre in size but some of the hornblende crystals are as much as 5 millimetres long. The rocks range from granodiorite to quartz gabbro. They are associated with hornblende diorites of map-unit 9 and appear to have gradational contacts with them. The sills are similar to some of the granitic rocks near the margins of the Mayo Lake batholith and for this reason have been included in map-unit 10.

Stock west of Hanson Lakes

A stock about 6 square miles in surface area intrudes rocks of the Lower Schist division (unit 7) west of Hanson Lakes, McQuesten Lake map-area. It consists of a medium-grained, grey, quartz monzonite, composed of microcline, andesine, quartz, biotite, and minor green and black hornblende. Much of the microcline occurs as coarse irregular grains up to 5 millimetres in size, which are crowded with fine-grained biotite and plagioclase feldspar. Neither markedly porphyritic material nor basic marginal phases were noted in several traverses across the stock. The rocks commonly show a poor foliation.

Age and Correlation

The granitic rocks are considered to be of Cretaceous age, an age suggested both by field relationships and by a number of isotopic age determinations. The youngest rocks intruded by the granitic rocks are those of the Keno Hill Quartzite division (unit 8), of probable Early Cretaceous age. About 100 miles to the west, granitic debris is present in Tertiary conglomerates (unit 23 of Green, in preparation) deposited in Tintina Trench. Several isotopic age determinations have been made by the Geological Survey of Canada (*see* Leech, *et al.*, 1963, Nos. 62-78, 80, 81; and Wanless, *et al.*, 1967, No. 65-50).

The ages (81, 85±7, 102, 106 m.y.) are mainly Late Cretaceous (65 to 100 m.y.) following the Geological Society of London (1964) time scale as given in Wanless, *et al.* (1967). These ages are in general accord with others (Gabrielse, 1967, p. 286) obtained from an arc of relatively small granitic intrusions strung out for about 400 miles along the northeast side of Tintina Trench, almost from British Columbia to the Alaskan border.

Porphyritic rocks (unit 11)

Thin sill-like bodies of white to cream coloured, buff-weathering quartz porphyry and granite porphyry occur in all three map-areas. They are commonly less than 10 feet thick and none was traced farther than a few hundred feet. In most cases, they appear parallel with the foliation of the enclosing sediments but one particularly well exposed body was observed alternately to parallel and crosscut the foliation.

Lithology

The porphyries commonly contain phenocrysts of quartz, feldspar, and, less commonly, biotite and muscovite in a fine-grained sugary matrix. The phenocrysts are generally up to 2 millimetres in size and may comprise as much as 15 per cent of the rock. In thin section the sugary matrix was seen to be fine quartz grains, lesser amounts of feldspar, and a felted mass of fine muscovite. Part or all of the muscovite may have formed through the alteration of feldspar. Another alteration product consists of a carbonate which is commonly ferruginous, and may comprise as much as 50 per cent of the groundmass. The carbonate grains are irregular and crowded with inclusions of muscovite and quartz. The rock may contain as much as 5 per cent pyrite and the oxidation of the pyrite as well as the ferruginous carbonate is believed to be responsible for the buff colour of the weathered surfaces. The feldspar phenocrysts observed include orthoclase, an acidic plagioclase, probably oligoclase, and some microcline.

The intrusive rocks that outcrop on the ridge northwest of Barney Creek in McQuesten Lake map-area have been included with map-unit 11. In hand specimen these rocks resemble muscovite granite but in thin sections were seen to consist of phenocrysts of quartz and muscovite in a fine-grained matrix of the same minerals. The finer muscovite may have formed by a secondary alteration. Quartz phenocrysts up to 5 millimetres in size, but more commonly about 2 millimetres, form up to 40 per cent of the rock, and muscovite phenocrysts up to 2 millimetres across form up to 10 per cent.

Cockfield (1924a) reported that the quartz and granite porphyries of the Keno Hill area contain pyrite, galena, and occasionally tetrahedrite. These minerals are more common along joint planes but also occur in the body of the rock. In the present mapping, the only mineralization observed, other than ubiquitous pyrite, was a small siderite veinlet containing a few small grains of galena and sphalerite.

Boyle (1965, p. 257) gave an analysis (Table VI) for a composite of three specimens of quartz porphyry from the Galena Hill-Mount Haldane area.

TABLE VI *Analysis of composite sample of quartz feldspar porphyry, Galena Hill-Mount Haldane area*

Constituent	A-696 %
SiO_2	67.0
Al_2O_3	16.7
Fe_2O_3	0.6
FeO	2.31
CaO	1.9
MgO	0.7
Na_2O	3.6
K_2O	2.9
H_2O (total)	1.50
TiO_2	0.3
P_2O_5	0.0
MnO	0.0
CO_2	1.07
S	0.01
Total	98.6

Analyst: K. G. Hoops, Geological Survey of Canada.

Age and Correlation

Within the map-area, rocks of unit 11 were not observed cutting rocks younger than early Mesozoic, hence they may be of either late Mesozoic or Tertiary age. Elsewhere similar rocks are reported to cut Tertiary volcanic rocks. Two such areas, both on the opposite side of Tintina Trench from the project area, are the Carmacks area (Bostock, 1936, p. 44) about 130 miles to the south-southwest and the Sixtymile area (Cockfield, 1921b, p. 34) about 150 miles to the west. However, as noted by Wheeler (1961, p. 102) the possibility exists that some of these rocks may be closely related to and the same age as nearby granitic rocks. One age determination of 81±5 m.y. from the Mayo district supports this possibility (*see* Wanless, *et al.*, 1967, No. 65-49).

STRUCTURAL GEOLOGY

In 1961, the discovery (Green and Roddick, 1962) of fossiliferous rocks immediately below the Lower Schist division (unit 7) destroyed the earlier concept that rocks of the district formed a simple stratigraphic succession of Precambrian age. Many problems still remain in the application of these discoveries to the present area, but these are of a minor nature compared to those arising from an attempt to retain the earlier interpretation.

The earlier interpretation was based on field work in the vicinity of Keno and Galena Hills (Fig. 5) where Cockfield (1921a) on Keno Hill, and Stockwell (1926) on Galena Hill both regarded the major structure as a homocline with a simple stratigraphic succession, although Stockwell recognized the complexity of the minor folds. Bostock (1948a) considered the Mayo Lake Anticline to be the main structure of the district with two westerly plunging minor anticlines on its west side. McTaggart (1950) was the first to suggest that the structure might be much more complex with the terminations of bands of quartzite on the north face of Keno Hill resulting from large-scale recumbent folds. This interpretation was later extended to portions of the present map-area in a joint paper by Green and McTaggart (1960). The major problem that remains is the age of the Upper Schist division (unit 1) and the overlying map-unit 2. These rocks are believed to be Precambrian on the basis of lithology, and if this is correct a thrust must lie between rocks of unit 1 and the apparently underlying Keno Hill Quartzite. This contact was crossed many times during the mapping but no such thrust was observed, although it could conceivably be masked by pervasive foliation present in all the sedimentary rocks of the area.

Two periods of deformation are believed to be present, an older period characterized by development of pervasive foliation and complex folding, and a younger characterized by open folding that produced structures such as the Mayo Lake Anticline.

Structures Related to Older Deformation

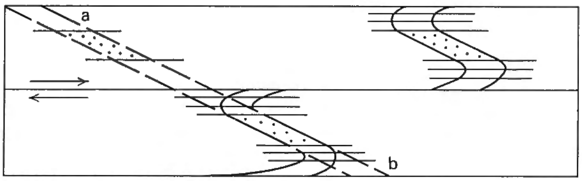
Structures believed related to the older deformation include the development of pervasive foliation, both small- and large-scale complex folding, fold-like structures associated with greenstone, and possible thrusting of rocks of the Upper Schist division (unit 1) onto those of the Keno Hill Quartzite (unit 8).

Foliation

Strongly developed foliation is the most conspicuous structural feature of the area, and is visible in virtually every outcrop of pre-granitic rocks. In the thinly bedded, mica-rich rocks such as those of the Upper and Lower Schist divisions (units 1 and 7) the foliation is developed on silky micaceous surfaces, often a few millimetres (Fig. 18) apart. Viewed in thin section, rocks of this type alternate between quartz and mica-rich bands with fine-grained mica flakes, both muscovite and chlorite, usually lying in the plane of the foliation. In most places, the foliation is parallel with compositional banding, possibly bedding, as shown by the interlayering of quartz and micaceous material, but in some outcrops foliation cuts the banding and, in a few, foliation parallel with the banding is cut by an equally conspicuous foliation at a large angle to it. In thicker bedded quartzite of the Keno Hill Quartzite (unit 8) the foliation is shown by glistening micaceous partings that parallel the banding of the rock and which are from a few millimetres to several feet apart. Complex minor folds in the rock between the partings bear witness to extensive deformation and where the quartzites are well exposed, as in the main adit at the Hector Mine, many of the 'beds' are found to disappear within a few feet, either through complex folding or pinching out. Many greenstone sills (unit 9) show well-developed foliation of secondary minerals, principally blue-green hornblende and saussurite.

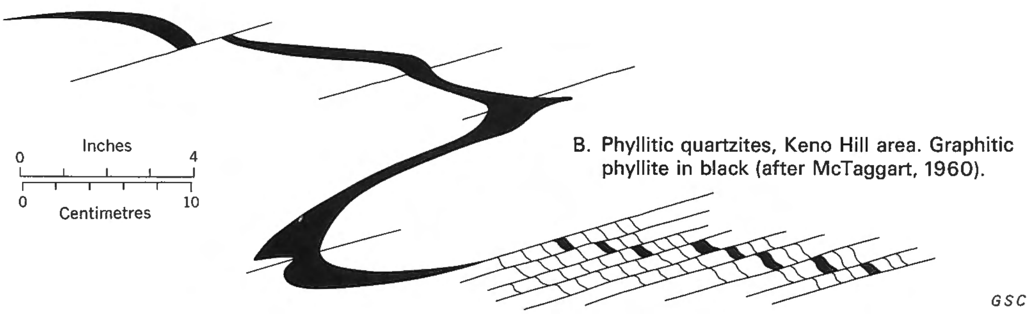
In many places where the foliation is at an angle to the original bedding, small 'S-shaped' folds have been produced by movement along foliation planes. Structures of this type have been described elsewhere as 'Gleitbrett' folds (Knopf and Ingerson, 1938, pp. 157-158; Fairbairn, 1949, pp. 173-174). Figure 14A, modified from Knopf and Ingerson, shows the development of these structures. Figure 14B shows a typical example from the Mayo district. In discussing 'Gleitbrett' folds, Knopf and Ingerson (1938, pp. 157-158) wrote as follows:

> "Schmidt has emphasized the importance in rock deformation of what he calls "Gleitbrett", or sliding board folds. The principle of "Gleitbrett" folding is that the displacement is distributed through certain layers in the moving mass that are



An original band a - b has been displaced along a slip plane. The stippled parts of the band have moved forward as a whole with no permanent deformation. The intervening sections have been displaced with variable rates of displacement reaching a maxima along the slip plane. Similar slip planes occur at the top and bottom of the figure.

A. Origin of Gleitbrett folds (after Knopf and Ingerson, 1938, Fig. 44A, p. 158).



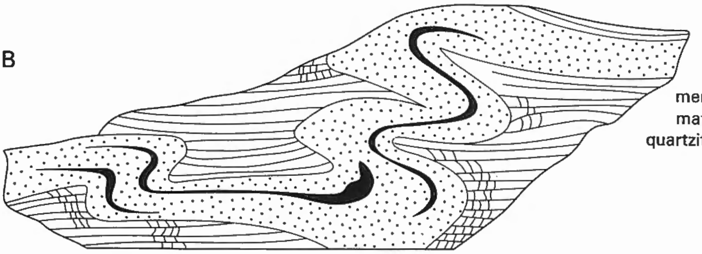
B. Phyllitic quartzites, Keno Hill area. Graphitic phyllite in black (after McTaggart, 1960).

FIGURE 14. 'Gleitbrett' folds.

A

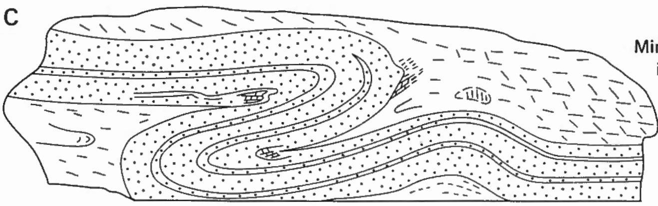
Typical 'rootless' fold; Patterson Range, SE Scougale Creek map-area. Scale indicated by hammer.

B



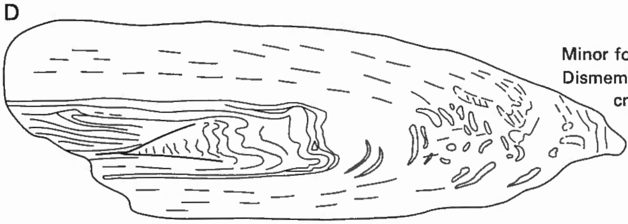
Complex fold in quartzite (stippled) with quartz veinlets (black). 'Gleitbrett folds' containing segments of bedding visible in phyllitic material near the noses of folds in quartzite; NE Mayo Lake map-area.

C



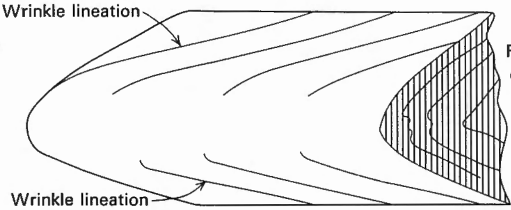
Minor fold in quartzite (stippled) enclosed in sheared phyllitic material; Patterson Range, SE Scougale Creek map-area.

D



Minor fold in banded light and dark grey quartzite. Dismembered sections of light grey quartzite are crowded in the nose of fold; near Mount Albert, Keno Hill map-area.

E



Fold with parallel wrinkle lineation on both limbs indicating that the lineation postdates the fold; Elsa mine, Keno Hill map-area (after McTaggart, 1960, p. 20).

GSC

FIGURE 15. Minor folds in Keno Hill Quartzite.

particularly susceptible to differential displacement, in contrast to other layers that are relatively inert. The relatively inert "boards" shown by the stippled sections in figure 44 move forward as a *whole* upon the sliding planes of the more mobile layers. The fact that the direction of slip makes an acute angle with the "inert" section of the curved structure shows which way the undisplaced layer lay with reference to the displacement and indicates that the relative displacement of material is greater in the higher layers than in the lower. Schmidt found evidence for this mechanism in the long drawn-out recumbent folds and extended transport of the East Alpine decken tectonics."

Such structures are readily visible only when deformed bedding lies at an angle to the foliation, such as on the noses of folds (Fig. 15B). In the present area, they are most common in thinly laminated phyllitic quartzite and phyllite. Their rarity in quartzite is attributed to the less conspicuous lamination in this rock and the tendency of the quartzite to yield by folding rather than by displacement along closely spaced planes (Fig. 15B).

The well-developed foliation considered in conjunction with the apparent thickening of rock units such as the Keno Hill Quartzite, and with 'Gleitbrett' and complex minor folds (discussed in the following section) suggests that the rocks involved have undergone much internal deformation. In some exposures it can be demonstrated that some 'beds' or laminae are inverted with respect to other nearby laminae (Fig. 15A) and this condition may be widespread, despite the fact that many outcrops appear to show a simple stratigraphic succession. It is significant that when many such 'simple' outcrops are examined in detail, small portions of the outcrop, often 10 per cent or less, show evidence of 'Gleitbrett' folds.

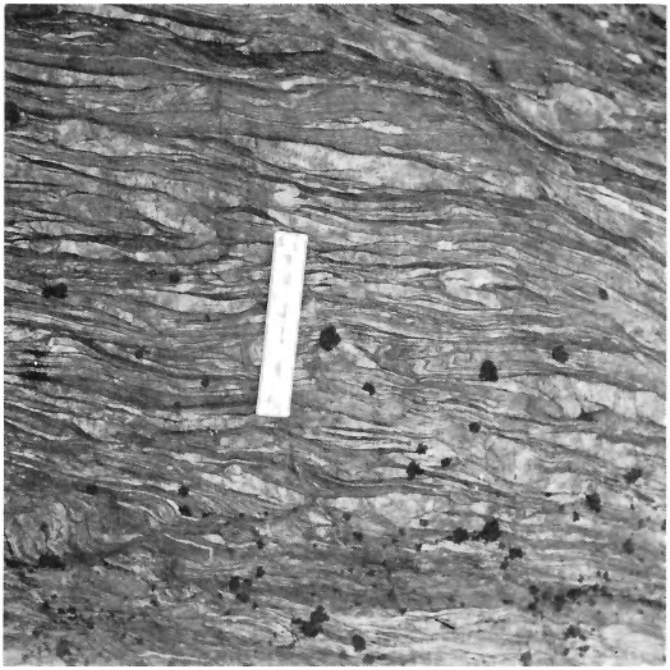


FIGURE 18
Intensely deformed rocks near the bend of the Keno Ladue River, Mayo Lake map-area, showing the development of foliation and 'Gleitbrett' structures. Lenses of secondary quartz follow the foliation and occasionally outline small folds. The shape of the quartz lenses is similar to that of greenstone lenses, but of a much reduced size. The scale shown in the photograph is just over 6 inches long.

Folds

Minor folds

Minor folds, rarely measuring more than a few feet between the limbs, are especially conspicuous in the Keno Hill Quartzite (unit 8). Many are isoclinal, and most have axial planes parallel with the bedding and foliation of the enclosing rocks. Examples of typical folds are shown in Figure 15. They range from simple folds to complex groups of folds in which the synclinal parts are missing and the anticlinal parts are stacked on one another between gently dipping faults. The orientation of the axes of minor folds throughout the district is shown in Figure 16. The stereoplots show rough maxima for the orientation of fold axes. Those from Keno Hill and Davidson Range are not well concentrated and the axes lie along girdles. These girdles may be the result of changing of the orientation of fold axes through continuing deformation. They are not consistent with redeformation by the Mayo Lake Anticline of the *younger* deformation. All through the district, many of the complex minor folds may be interpreted as resulting from northwesterly, northerly, or northeasterly movement of the overlying beds relative to the underlying beds. An alternative explanation involving possible rotation of the axes of southeast-plunging minor folds is given in a later section.

Folds in Davidson Range

A much larger fold structure, originally recognized by McTaggart and mapped in detail by the author, forms the core of Davidson Range. Parts of the structure were recognized in the field but their interrelation and the complexity of the fold were not appreciated until a projected section was drawn (Fig. 17, section C-D). The procedure used to prepare the section was as follows. First the poles of bedding and foliation were plotted on an equal-area stereonet and contoured. The maximum concentration of points lies along a broad zone through which a number of great circles with slight variation in strike and dip may be drawn. Following Dahlstrom (1954, p. 235) the fold axis of a cylindroidal fold is assumed to be perpendicular to the great circle through the poles of the bedding. An axis, plunging 20° at S 55°E and close to the axes of minor folds in the area (Fig. 16C), was selected and the projected section drawn using the method described by Stockwell (1950). Cross-folds with axes at an angle to the major fold axes and faults cannot be projected accurately in a section of this type. Such a fold-like structure in greenstone with an axis at an angle of about 65° to that used for the projected section produced the abrupt termination of the thick Mount Cameron greenstone shown in the lower part of the projected section (Fig. 17, section C-D). In the southern part of the Davidson Range, the massive quartzite could not be traced into Keno Ladue River valley. Outcrops are poor in this area and the quartzite may be covered by drift or cut out by a fault.

Probable folding on Keno Hill

In detailed mapping on Keno and Galena Hills, McTaggart (1950, 1960) showed four bands of quartzite terminating on Keno Hill. Somewhat similar relationships are shown by Boyle (1965, p. 21) who has suggested that the terminations may be due to the interfingering of the quartzites with thin-bedded quartzites, schists, and phyllites or to faulting. McTaggart (1950) has suggested that large-scale recumbent folds may be responsible for the terminations. A projected section across the quartzite bands (Fig. 17, section A-B) suggests isoclinal folding and shows many similarities to the section (Fig. 17, section C-D) in Davidson Range.

On Keno Hill, the quartzite bands appear to thicken near the terminations. If the quartzite terminate through a gradual facies change as suggested by Boyle (op. cit.) it is difficult to understand why there should be a marked thickening just before they interfinger with the more micaceous rocks and disappear. On the other hand, if these terminations are fold structures, the thickening might be produced by flowage of material from the limbs to the nose of the fold or conversely the limbs of the fold may have thinned while the nose retained its original thickness. Many of the minor folds (Fig. 15) show similar apparent thickening on the nose.

Fold-like structures associated with greenstones

These structures were described in the section on General Geology, and a number of possible origins suggested. The axes of three such structures described in the Patterson Range are at a relatively small angle to the axes of the minor folds in the same area. In contrast, the axes of the two structures near Mount Cameron in the Davidson Range are at a large angle (about 65°) to the axes of minor folds in the area. The axes of all these structures are crudely parallel to that of the Mayo Lake Anticline but the type of structure is not compatible with the latter. It is not proposed to consider these fold-like structures further except to note that all appear to involve relatively complex structures with either isoclinal folding or intense movement parallel to the foliation of the enclosing rocks.

Slaty Cleavage

Slaty cleavage was observed in interbedded graphitic phyllite, phyllite, and thin-bedded quartzite of the Lower Schist division (unit 7) south of Cobalt Hill in Mayo Lake map-area, and in black slate interbedded with thin quartzite (unit 7) south of Mount Cameron in McQuesten Lake map-area. A number of cleavage and bedding determinations taken over a distance of two-thirds of a mile along the ridge south of Mount Cameron are shown below. The attitude of the cleavage shows a wide variation, but with two exceptions the azimuth and plunge of the intersection of cleavage and bedding are nearly identical and are parallel to the axis of the major folds as determined by plotting the bedding attitudes for the Davidson Mountains. It is believed that the slaty cleavage may have formed early in the deformation and have undergone some rotation as the deformation continued.

	Bedding		Slaty Cleavage		Intersection of Bedding and Cleavage	
	Strike	Dip	Strike	Dip	Bearing	Plunge
1.	050	59°SE	143	64°SW	180	51°S
2.	079	59°SE	062	35°SE	090	18°E
3.	177	46°W	102	29°S	208	28°SW
4.	030	46°NW	070	43°SE	229	19°SW
5.	005	35°W	078	37°SE	222	23°SW
6.	157	31°SW	085	28°S	205	23°SW
7.	154	40°SW	110	34°SW	208	34°SW

(Axis of main folds 235 20°SW)

Possible thrusting of Upper Schists onto Keno Hill Quartzite

On the basis of the proposed stratigraphy, a major thrust fault or a complex combination of folds and thrusts must separate rocks of the Keno Hill Quartzite (unit 8) and the apparently overlying Upper Schists (unit 1). This thrust was not observed but some field evidence is not in accord with a simple stratigraphic succession across this important contact.

Traverses across the contact

What appears to have been a single band of Keno Hill Quartzite, now broken by later faulting, has been traced through the Keno and Galena Hills district (Fig. 5). The band of similar quartzite underlying much of the Davidson Range is not included in this discussion as its exact relationship to the main quartzite band is uncertain. The author has crossed the upper contact of the Keno Hill Quartzite in the northwest corner of McQuesten Lake map-area; on the east side of Mayo Lake map-area; in the Mount Haldane-Seattle Creek area (southwest of the project area); and in the Mount Albert area, just west of the Mayo Lake map-area. The lithology of the overlying rocks varies considerably from place to place but nowhere was a distinct structural break or a marked change in metamorphic rank observed across the contact. Without exception, rocks above and below show the same development of foliation and the contacts appear gradational. More phyllitic bands in the quartzite (unit 8) frequently appear identical in lithology to those in the overlying rocks (units 1 or 3) and, here and there, thin bands of the distinctive grey quartzite occur in the overlying rocks.

Variations in the overlying rocks

The lithology of the Keno Hill Quartzite (unit 8) is reasonably consistent but there is considerable variation in the lithology of the overlying rocks. In the northwest corner of McQuesten Lake map-area overlying rocks are assigned to the Grit division (units 3 and 4). Most of the rocks immediately above the contact are phyllites that might well belong to a number of map-units but gritty quartzite and limestone, both typical of rocks in the Grit division (units 3 and 4), occur a few hundred feet above the contact. In the Mount Haldane-Seattle Creek area, the overlying rocks consist mainly of thin-bedded, schistose, chloritic quartzites, often with scattered coarser quartz grains 1 or 2 millimetres in diameter, and chloritic phyllite. In the Sourdough Hill-Mount Albert area, dark grey graphitic phyllites with a few thin bands of limestone are prominent above the contact. Along the east side of Mayo Lake map-area, overlying rocks of the Upper Schist division (unit 1a) consist of thin-bedded buff to green quartzite, often with scattered coarser quartz grains, lesser amounts of phyllite quartzite, green chloritic phyllite and minor limestone. Thin bands of quartzite (unit 1c), lithologically similar to the Keno Hill quartzite, occur to the east of the contact as does dark graphitic phyllite (unit 1b) similar to that against the contact in the Mount Albert area.

Conclusion

Despite the lack of clear-cut physical evidence for a thrust fault at the upper contact of the Keno Hill Quartzite in the present area the writer prefers this interpretation. Certainly this thrust fault can be demonstrated as the Keno Hill Quartzite is traced west to the Tombstone area (Green and Roddick, 1962; Green, in preparation). Possibly thrusting took place early in a period of overfolding and thrusting, herein referred to as the *older* deformation, such that all evidence for this important thrust, or series of thrusts, was obliterated in the continuing development of pervasive foliation in the area. Confirmation of this interpretation hinges on establishing an older age, presumably Precambrian, for rocks of the Upper Schist division (unit 1).

Structures Related to Younger Deformation

Structures believed to be related to a *younger* deformation include the Mayo Lake Anticline and other open folds, wrinkle lineation, and the possible rotation of the axes of folds formed in an older deformation.

Mayo Lake Anticline

The Mayo Lake Anticline (Figs. 5 and 16) is a broad, irregular, open structure outlined by massive quartzites of the Quartzite division. Dips associated with the structure rarely exceed 45°. The western limb of the anticline extends from Keno Hill to south of Mayo Lake and the eastern limb extends from Mayo Lake to Patterson Range, although the latter is cut by the Mayo Lake batholith.

Other open folds in the district (Fig. 5) include an irregular anticlinal structure along South McQuesten River valley, a partly developed fold along Lynx Creek, and possibly a fold to produce the abrupt change in strike of rocks of the Keno Hill Quartzite in the northwest corner of McQuesten Lake map-area.

Wrinkle Lineation

Minute wrinkle lineations are common in schist and phyllite. Many specimens show more than one and as many as three distinct lineations have been observed in a single specimen. Most of the wrinkles have an amplitude of about 0.02 to 0.1 millimetre and a wavelength of 0.15 to 1.0 millimetre. Some small chevron folds were observed and their axes appear to be parallel with those of the wrinkles. The wrinkle lineation commonly plunges to the southeast at about 30°, parallel with the axis of the Mayo Lake Anticline. The orientation of the wrinkle lineation is remarkably constant throughout the district, and thus contrasts markedly with the orientation of the fold axes which show a wide variation (Fig. 16).

In the Keno and Galena Hills area, McTaggart (1960, p. 27) suggested that the main wrinkle lineation postdated the overturned folds as in a few places he found parallel lineations on both limbs of isoclinal folds and at an angle of about 60 degrees to the fold axis, showing that the lineation had not been folded.

Possible Rotation of the Axes of the Minor Folds

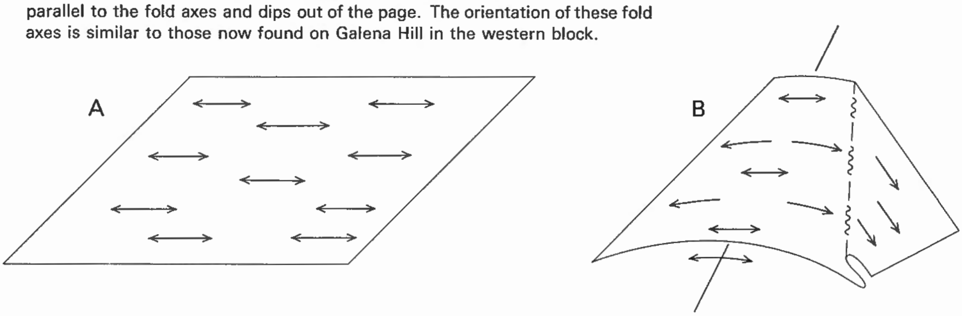
The orientation of the axes of minor complex folds of the district is shown in Figure 16. The number of observations recorded is somewhat meagre but on the basis of these the area may be divided into two blocks, a western in which the axes of the minor folds are horizontal or plunge to the southwest, and an eastern in which the axes plunge to the southeast. Regional considerations (Fig. 5) suggest that easterly trending folds prevail and it is suggested that the eastern block may have been displaced with respect to the western.

The western block includes Galena Hill, Keno Hill, and the Davidson Range, and the eastern, the Patterson Range. The difference between the two blocks is marked and with the possible exception of the area around Mayo Lake, axes with orientations intermediate between those of the two blocks are scarce. On the slopes north of Mayo Lake, minor open folds believed to be related to the Mayo Lake Anticline are common and a few minor complex folds were observed, the axes of the latter ranging in orientation from east-west and horizontal to southeast and moderately plunging.

The area is believed to have undergone two distinct types of deformation, an *older* characterized by the development of isoclinal and recumbent folds, commonly with axial planes parallel with the bedding and, in part, with axes having some variation in orientation, and a *younger* characterized by the open anticlinal structure indicated by the outcrop pattern of the Keno Hill Quartzite (Figs. 5 and 16). If the axes of complex minor folds of the *older* deformation were originally more or less parallel throughout the entire area, considerable displacement of the axes must have taken place in the *younger* deformation.

Using the stereographic method described by Phillips (1954, pp. 40-42) and generalized attitudes of bedding from Galena Hill and Patterson Range, and assuming (a) that the Mayo Lake Anticline is the main structure producing the rotation of the complex fold axes and (b) that the orientation of the fold axes throughout the district was parallel to that of the fold axes of Galena Hill prior to this folding, it may be shown that an east-west trending horizontal fold axes originally parallel with those on Galena Hill would be rotated to plunge 20° at N 80°E in Patterson Range. The angle between this calculated orientation and the observed orientation of the fold axes in the Patterson Range is approximately 56° and displacement by open folding of this type seems improbable.

A. East-west-trending horizontal fold axes are developed in a plane that strikes parallel to the fold axes and dips out of the page. The orientation of these fold axes is similar to those now found on Galena Hill in the western block.



B. The right-hand side of the plane (eastern block) has been twisted with respect to the left-hand side (western block) so that the fold axes on the right-hand side (eastern block) now plunge steeply. A portion of this twisting movement may have occurred along a fault with a scissor-like movement suggested in the area of greatest crumpling. An open anticline corresponding to the Mayo Lake anticline has formed on the left-hand side of the plane. The orientation of the fold axes on this side (western block) is virtually unchanged.

GSC

FIGURE 19. A suggested explanation for the difference in orientation of the fold axes of the western and eastern blocks. (The western block is comprised of Keno and Galena Hills and the Davidson Range, the eastern block, the Patterson Range.)

An alternative explanation, preferred by the author, is shown in Figure 19 where the eastern block has been rotated with respect to the western block and the Mayo Lake Anticline is a subsidiary feature related to this rotation. The sharp break between the two blocks would extend down the creek separating Davidson and Patterson Ranges (Rankin Creek), along the Keno Ladue River valley, and thence south to the fault at the east end of Mayo Lake. There is some evidence for a zone of faulting along this line. Along the Keno Ladue valley south of the mouth of Rankin Creek, rocks exposed at river level on the east side of the river strike east-west and dip south, but rocks a few hundred feet to the east and higher up the slope strike northeast and dip southeast. South of Mayo Lake there appears to be an abrupt change in attitude between the quartzites and the more phyllitic rocks, although outcrops are few in this area and the relationship cannot be established with certainty. The phyllitic rocks along this zone show a higher metamorphism than the rocks on each side. Along lower Rankin Creek and the Keno Ladue valley heavily contorted biotite, staurolite, and garnet schists are common, in marked contrast to quartz-muscovite and quartz-muscovite-chlorite schists and phyllites exposed higher on the valley walls. The granitic rocks also occur along the contact between the two blocks and they may have been emplaced and metamorphism concentrated along a pre-existing break.

Faults

Late faults, generally steeply dipping to vertical, are common throughout the map-area. Most were observed only where they crossed the ridges, their trace on the lower slopes being largely obscured by talus. The faults are better known on Keno and Galena Hills where they have been traced underground as well as on the surface. McTaggart (1960, pp. 28-31) described three types:

1. Bedding faults
2. Vein faults
3. Northwest faults

The bedding faults are believed to be related to an older deformation. Most of the vein faults strike north to east and dip from nearly vertical to about 45°S. The vein faults are cut by younger, moderately to steeply dipping, northwest-striking faults. The formation of the vein faults and the northwest-trending faults is believed to postdate the *younger* deformation as both types of faults contain fragments of lineated phyllite. The lineation on each fragment shows random orientation with respect to other fragments and to the country rock adjacent to the faults.

Faults in the present area are seldom well exposed and no definite evidence of their time relationship, either to the *younger* deformation or the intrusion of granitic rocks was observed in the field. However, the general impression is that many of the faults are late and probably postdate both the other events.

Suggested Structural History

A number of structural features, many of which are not in agreement with the previously accepted concept of relatively simple structure, have been described. The following structural history is proposed:

1. An *older* deformation with pervasive development of foliation and associated complex folds and thrust faults.

2. A *younger* deformation with open folds, wrinkle lineation, and possible rotation of the axes of complex minor folds formed in the earlier deformation.

3. Intrusion of granitic rocks.

4. Late faulting, possibly in part a final phase of 2.

The early stages of the *older* deformation may have involved the overthrusting of Precambrian rocks (units 1 and 2) onto distinctive Mesozoic quartzite (unit 8). This may have been followed by intense overthrusting with the more competent beds yielding by complex folding, both large and small scale, and the less competent beds by movement essentially parallel to the bedding. By the close of this deformation the rocks involved were altered to foliates retaining few of their original characteristics. The stratigraphic succession had been destroyed so that many adjacent 'beds' may, in fact, be inverted with respect to one another. The intrusion of some greenstone sills preceded the *older* deformation as many of the smaller sills show well-developed foliation. However, there is evidence suggesting that some of the larger sills may have been intruded during deformation. If most of the greenstone lenses are boudins formed from sills that were originally more continuous, deformation, particularly in the Lower Schist division (unit 1) must have been extreme. The direction of movement, as indicated by the orientation of fold axes in the Keno Hill Quartzite (unit 8) appears to have been toward the north, with the possible exception of the Patterson Range. There the fold axes plunge southeast but it is suggested that they may have been rotated by later deformation.

Structures assigned to the *younger* deformation, believed to be superimposed on the *older* deformation, include the Mayo Lake Anticline, other open folds, and the wrinkle lineation. It is suggested that rocks of the Patterson Range may also have been displaced with respect to those of the remainder of the area in such a manner that fold axes in the Range, produced in the *older* deformation, now plunge to the southeast.

Granitic rocks of the area are of probable Cretaceous age and clearly postdate the *younger* deformation. Late faults, including vein faults, probably postdate the granitic rocks.

A possible alternative to the proposed *older* and *younger* deformation would combine the two. Thus, if a northerly moving thrust sheet was restrained on the eastern margin it might buckle in such a manner that the Mayo Lake Anticline and production of wrinkle lineation resulted. Further, this restraint might be responsible for the difference in orientation of the axes of complex folds in the eastern and western blocks. A somewhat similar mechanism has been proposed by Cloos (1946, p. 27) in a hypothetical example in which compression of a thrust sheet produces minor folds parallel with the direction of movement of the sheet. The principal objections to this hypothesis in the project area are (a) the lack of fold axes intermediate in orientation between those of the two blocks, and (b) the occurrence of wrinkle lineation at a sharp angle to the axis of some of the minor complex folds and with the same orientation on both limbs of the fold. The latter relationship of wrinkle lineations and minor folds indicates that the lineation must have formed after the fold.

ECONOMIC GEOLOGY

Placer Deposits

No important gold placer deposits are known in the area although there is considerable evidence of test-pitting and other forms of prospecting on some of the creeks. Keele (1906a) referred to work on Edmonton Creek in one report, but there is no reference to this in his report for the following year (Keele, 1906b) and it is assumed that the workings were abandoned.

During the Pleistocene many of the larger valleys were enlarged and deepened by ice flowing along them and subsequently were partly filled with thick deposits of glaciofluvial material. In the author's opinion, any pre-existing placers along such valleys were destroyed.

In general, the only creeks that escaped scouring by the glaciers or burial by later glaciofluvial deposits were those at right angles to the main valleys followed by the ice.

Edmonton Creek heads in a number of cirques south of Mayo Lake map-area, and although the part of the creek valley within the map-area does not appear to have been scoured by ice flowing down it, it is partly filled with glaciofluvial deposits. These are believed to have originated both from the alpine glaciers at the head of the creek and from the ice sheet that filled the valley now occupied by Mayo Lake. The floor of Edmonton Creek lies far below the kame terraces formed on the margin of the latter ice sheet. Two relatively small creek valleys that are believed to be, at least in part, unglaciated are Contrast Creek and the creek that flows southwest to join Roop Creek west of the lake near the margin of Mayo Lake map-area. There appears to be little possibility of important gold placer deposits being discovered within the area.

Lode Deposits

Silver, Lead, and Zinc

Deposits of silver, lead, and zinc are known in both Mayo Lake and McQuesten Lake map-areas and there has been a limited production from the Cobalt Hill deposit in Mayo Lake map-area.

The deposits all occur as fracture fillings in steeply dipping fault zones. The common mineral assemblage includes galena, sphalerite, chalcopyrite, and pyrite in a gangue of quartz and siderite. The deposits occur in rocks of the Lower Schist division (unit 7); near the contact of the Lower Schist division with the Keno Hill Quartzite (unit 8); and the rocks of the Grit division (units 3 and 4). All the deposits discovered to date have a much lower silver to lead ratio than those of Keno and Galena Hills and, because of this and their relatively small size, little work has been done on them in recent years. The silver to lead ratio is commonly expressed as the number of ounces of silver present per one per cent of lead in the assay, and this figure for assays from the present map-areas rarely exceeds 1.5 ounces of silver per 1 per cent lead; ores of Keno and Galena Hills, on the other hand, commonly carry 4 ounces of silver per 1 per cent lead or more.

(1)[1] *Cobalt Hill Property (63° 59½'N, 134° 57'W; Mayo Lake map-area)*

This showing lies south of Keno Ladue River, near the northwest corner of Mayo Lake map-area. A winter tractor trail to the showing follows the Keno Ladue valley from Elsa, a distance of about 18 miles. A better summer route follows a trail from Keno Hill up Lightning Creek and down Faith Creek to the tractor trail crossing on Allen Creek.

A fracture zone, trending approximately N 32°W, has been traced some 400 feet southeast from the north face of Cobalt Hill in a number of trenches and test pits; these expose much fractured, iron-stained, slightly mineralized rock. An adit about 40 feet long has been driven at the southern end of the zone. The fractured zone cuts thinly bedded, medium to dark grey phyllitic quartzites separated by lesser amounts of grey, crumpled phyllite. The foliation of the rocks strikes northeast to east and dips steeply to the south. Three greenstone bodies have also been cut and on the northeast side of the zone, the lowest is believed to have been displaced 40 feet to the northwest. From the base of the section, the greenstone bodies have estimated thicknesses of 20, 200, and 10 feet respectively.

The fracture system appears to be a group of branching and joining, subparallel breaks filled with a gouge of crumpled phyllite and massive galena, with lesser amounts of siderite. None of the galena veinlets observed was over 2-inches thick, although massive pieces up to 3-inches wide were found on the dump. Much of the vein material has been heavily oxidized, the galena being partly altered to anglesite and the siderite to limonite and hydrous manganese oxides. The fault zone appears to split and to terminate on the north face of Cobalt Hill; it has not been exposed southeast of the adit.

Two picked samples composed mainly of galena, the first from the adit and the second from the upper dump, assayed as follows:

Gold oz/ton	Silver oz/ton	Lead %	Zinc %	Copper %	Antimony %	Cadmium %
Trace	31.34	73.1	n.d.	0.02	0.42	0.01[1]
Trace	44.93	71.8	0.10	0.05	0.39	0.02[1]

[1]Spectographic determinations.
(Assay by Mines Branch, Department of Energy, Mines and Resources.)

Fred Taylor of Mayo and a crew of two men did some work on the property in the winter of 1947-48. Some 5 tons of hand-cobbed ore was moved by cat train to the United Keno Hill Mines Limited mill at Elsa. The silver and lead assays of the shipment were essentially similar to those above.

The deposits uncovered to date are small and the fractures too narrow for veins of significant width to have formed. The fractures may have been wider where they intersect the larger greenstone body. Both the greenstone body and the fault zone are believed to be steeply dipping and the intersection should plunge steeply to the east.

[1]Number that is used to indicate the property on the accompanying geological maps.

(2) *Stand-to Property (Foley Silver Mines Limited) (64° 02′N, 135° 10′W; McQuesten Lake map-area)*

References: Cockfield (1922, pp. 1-6)[1]; Findlay (1967, pp. 25-26).

The main showing is at an elevation of 4,750 feet on the north face of Stand-to Hill in McQuesten Lake map-area. Early work on the showing was described by Cockfield. Since then the showing has been staked many times but little more than representation work was done until the most recent work, commenced in 1966 (Findlay, op. cit.). For this work an 8-mile tote-road was built to the property from the McQuesten-Hanson Lakes road.

The original showing was visited by the author in 1957 at which time the property was inactive. The showing is in rocks of the Lower Schist division (unit 7) near the contact with Keno Hill Quartzite (unit 8). A fault, trending N 25°E and dipping steeply to the northwest brings greenstone (unit 9) in contact with dark grey graphitic phyllite and thinly bedded quartzite. An adit driven approximately 6 feet below the top of the greenstone body exposed a sheared zone about 4 feet wide. The adit, which appeared to be about 30 feet in length, had caved some 15 feet from the portal and was ice-filled beyond. Specimens from the dump show limonite, which has formed as an alteration of siderite, containing nodules of galena up to 3 inches in diameter and a little chalcopyrite. No sphalerite was observed.

A picked specimen consisting mainly of galena assayed:

Gold oz/ton	Silver oz/ton	Lead %	Zinc %	Copper %	Antimony %	Cadmium %
0.005	71.78	83.4	0.10	0.32	0.39	0.04[1]

[1]Spectographic determination.
(Assay by Mines Branch, Department of Energy, Mines and Resources.)

The silver-lead ratios are similar to those obtained by Cockfield (1922, p. 4A) in assays of samples taken across the face and back of the adit.

In 1966, bulldozer trenching resulted in a new discovery just above Homestead Creek, about 300 feet east and 200 feet north of the old adit. Findlay (op. cit.) wrote:

> "...The new discovery was visited in late August, 1966, and at that time consisted of a partly-stripped vein break cutting massive greenstone intercalated with fine-bedded quartzite and quartz-mica schist . . . . The break is up to 12 feet wide and is bounded by two strong, sub-parallel shears trending about N 15°W and dipping vertically or steeply east. Between the shear zones in highly fractured, locally gougy, reddish-brown limonite-stained material carrying sub-parallel lenses and veins of quartz-siderite with disseminated to massive galena, sphalerite, and minor chalcopyrite. Because of the great deal of disturbed rubble left by the bulldozer, the actual extent of mineralization was difficult to assess, but individual veins appeared to contain pods of massive ore up to 2 to 2½ feet in width. A chip sample across 12 feet near the up-slope (south) end of the zone assayed: 0.005 ounces per ton gold, 3.52 ounces per ton silver, 5.2 per cent lead, 1.0 per cent zinc, and 0.07 per cent copper. A grab sample from a massive lens assayed: 0.005 ounces per ton gold, 61.5 ounces per ton silver, 77.3 per cent lead, trace zinc, and 0.06 per cent copper."

[1]Earlier reports on the Yukon Territory that are reprinted in Geological Survey of Canada Memoir 284 (Bostock, 1957) are indicated in the text with an asterisk.

The company reports (The Northern Miner, 26 October 1967, p. 6) that during 1967 two adits were driven on the showing and two new veins exposed by bulldozer stripping.

(3) *Rambler Hill Property (64° 04½'N, 135° 16'W); (McQuesten Lake map-area)*

Reference: Cockfield (1919, pp. 1-15[1]; 1922, pp. 1-6[1]).

This property lies southwest of the summit of Rambler Hill in McQuesten Lake map-area, at an elevation of 4,850 feet. A good trail leads from the end of the road at Hanson Lakes to upper Cache Creek. From the ruined cabin on Cache Creek a poor trail follows the hillside to the property. The showing has been staked a number of times in recent years and a limited amount of bulldozer stripping was done in 1961.

The showing lies on a north-trending lineament which can be traced for approximately 3 miles on air photographs. The country rock in the vicinity of the showing consists of grey phyllites, probably of the Lower Schist division (unit 7) and associated greenstone (unit 9).

When visited by the writer in 1957, very little work appeared to have been done since Cockfield's (1922, pp. 4A-5A) description which follows:

> "At the time of the writer's visit (July, 1921) the shaft was full of water and the upper workings could not be examined. The data obtained from a previous examination are given here for purposes of reference. The vein-filling consists of limonite, galena, pyrite, quartz, cerussite, anglesite (?), malachite, and chalcopyrite. Limonite makes up by far the greater mass of the deposit. Included in it are small nodules of galena, coated with oxidation products. Near the surface and extending downward for 37 feet are large masses of galena. Farther down, these disappear, leaving only the small nodules.
>
> "Galena appears in three open-cuts along the vein between the shaft and the adit. In the adit the vein is 3 to 4 feet wide. The strike and dip are both variable. The vein-filling consists of iron oxide and carbonate, manganite, and galena with lead carbonate and a little chalcopyrite. The galena occurs in small bands in the vein, and the chalcopyrite as small specks in the galena."

An assay was made of a picked specimen from the dump containing galena. This assay and assays of similar material given by Cockfield are as follows:

	Gold oz/ton	Silver oz/ton	Lead %	Zinc %	Copper %
Specimen GC7-62[1]	0.01	49.53	80.0	0.10	0.40
Cockfield (1922)					
No. 1	Nil	36.80	54.91		
No. 2	Nil	36.00	52.60		

[1]Assay by Mines Branch, Department of Energy, Mines and Resources.

(4) *Paul Group (Mount Cameron) Property (64° 05'N, 135° 00½'W)*

Reference: Cockfield (1920, p. 5; 1922[1], pp. 1-6).

The Paul Group, described as the Mount Cameron property by Cockfield (1922), is held by Falconbridge Nickel Mines Limited. The group is on the plateau north of

Mount Cameron in Nash Creek map-area. No work other than a claim survey appears to have been done on the property in recent years.

The mineralization occurs along a strong fault trending N 27°E that displaces the east side of a limestone band some 400 feet to the north. The limestone, which occurs in unit 3, has an apparent surface width of 800 feet. The fault has been traced 950 feet in a series of trenches and two adits, now caved, have been driven on it. An iron-cemented conglomerate similar to those observed elsewhere in the area occurs in a small creek, on trend with the line of trenches and some 250 feet beyond the last trench.

The vein material exposed on the dump and in the trenches consists of siderite, now altered to limonite, and hydrous manganese oxides, quartz crystals, galena, sphalerite, and chalcopyrite. Galena occurs in thin streaks following fractures and sphalerite and chalcopyrite commonly occur as small blebs up to one-half inch in size in the siderite. The heaviest mineralization, mainly by siderite replacing limestone, appears to be confined to some 400 feet along the fault where both walls are in limestone. Scattered ore minerals were noted along the entire length of the fault workings. The width of the mineralized body is not obvious from the present exposures but Cockfield (1922, p. 6A) reports it to be 50 feet.

Assays of a picked sample from the dump and of a similar specimen taken by Cockfield (1922, p. 6A) are as follows:

	Gold oz/ton	Silver oz/ton	Lead %	Zinc %	Copper %	Antimony %
GC7-78[1]	0.005	40.48	40.9	10.75	0.28	0.09
Cockfield (1922)	Nil	75.00	56.83			

[1]Assay by Mines Branch, Department of Energy, Mines and Resources.

Tungsten

In 1943, Bostock (*in* Little, 1959, p. 36) examined the margins of the stock near Wilsons Cabin in the hope of finding a possible source of scheelite. In his investigation, he found traces of scheelite in the soil and glacial material near the contact and was able to find scheelite in place on the hillside northeast of Wilsons Cabin. (Mayo Lake map-area, about 63° 51′N, 134° 38½′W.)

The sedimentary rocks adjacent to the contact belong to the Upper Schist division (unit 1) and consist of thin-bedded phyllitic quartzites and phyllites (unit 1a) with a few beds of impure carbonates, 1- or 2-feet thick. Contact metamorphism has altered quartzites and phyllites to quartz, biotite, and garnet rocks; the carbonate rocks are changed to a quartz-garnet-diopside skarn. Some specimens of skarn contain scheelite crystals as much as an inch long. However there is relatively little carbonate in the sedimentary rocks adjacent to the contact, and the possibility of developing a relatively large deposit appears poor.

Iron-bearing Springs and Limonite-cemented Conglomerate

Iron-bearing springs and limonite-cemented conglomerate occur in all three map-areas. They are of no direct economic significance except that the source of the iron may be in nearby sulphide deposits. Presumably, springs could form just as readily from scattered pyrite crystals in a phyllite as from a high-grade ore deposit.

The estimated flow of the iron-bearing springs is commonly less than 10 gallons per minute. The water is clear when it issues from the orifice but the precipitation of iron and, in the case of one spring, calcite, commences immediately. The springs commonly occur on hillsides or in valley bottoms a few feet from the base of the slope. The iron deposited in many places covers an area of several hundred square feet and vegetation is commonly killed. Heavy metal content of some of the spring waters and sediments is given by Gleason (1965, a to f).

Springs north of Keno Ladue River near the eastern edge of Mayo Lake area (63° 57'N, 134° 33'W) are depositing calcite as well as from oxides. The deposits consist of extensive areas of fine powdered red and brown iron oxides. Locally, fragments of iron oxides, plant material, and gastropod shells are cemented by crystals of calcite showing well-developed comb structure. Where the percentage of calcite is high, much of the material contains vugs lined with globular masses of fine calcite crystals. Three assays of the calcite-rich material did not show lead or zinc but contained silver amounting to 0.02, 0.01, and 0.045 ounce per ton. The silver values are believed to be significant as values as low as 0.005 ounce per ton are commonly determined and reported (R. A. Rogers, Chief Chemist, Mines Branch, *pers. comm.*). The source of the springs are unknown but strong lineaments that probably represent faults occur on the hillside some 500 feet vertically above them.

Iron-cemented conglomerates occur in many of the tributary creek valleys. Commonly, they lie away from the stream itself but in a few cases the present day stream channel is cut through conglomerate. The conglomerates contain boulders up to 1 foot in diameter, but commonly a few inches or less, cemented by a heavy coating of iron oxides. In deposits that occur in the creek the boulders are commonly well rounded but in those closer to the edge of the slope, many of the fragments are angular. The conglomerates frequently occupy areas up to several hundred feet in diameter, and on the creek immediately south of Mount Cameron, scattered outcrops of conglomerate, some of beds up to 15 feet thick, occur in the creek bed for almost a mile. The iron forming these conglomerates is believed to come from solutions similar to those forming the iron-bearing springs. The two types of deposit appear to grade into each other and in some cases iron-bearing springs occur near the upper end of conglomerate deposits.

Suggestions to Prospectors

Most of the ore deposits of Keno and Galena Hills (Boyle, 1965) are in or near rocks of the Keno Hill Quartzite division (unit 8). In the present area the Stand-to Hill showing is in this stratigraphic position, but those of Cobalt Hill and Rambler Hill occur in the Lower Schist division (unit 7) and that of the Paul Group in the Grit division (units 3 and 4). The Keno Hill Quartzite occurs in all three map-areas covered in the present report and in the author's opinion is worthy of careful prospecting. To date, the silver to lead ratios obtained in the district have been disappointing when compared with those of Keno and Galena Hills but higher ratios may be found. Prospecting is difficult where the quartzites are exposed on steep slopes, as they tend to break into coarse fragments that mantle the slopes, covering any evidence of mineralization. For this reason, there may be more chance of finding mineralized float on plateau-like surfaces underlain by these rocks. In this regard, it is interesting to note that the majority of the showings on Keno and Galena Hills lie either on an upland surface or on relatively gentle slopes where it was possible to observe and trace mineralized float.

Operation Keno, a helicopter-supported geochemical project carried out in 1964, resulted in the publication of a great deal of geochemical data for the district including the present map-areas (Gleeson, 1965, a to f; 1966, a to d; and 1967, a and b). Of these maps, that showing the lead content of stream and spring sediments (Gleeson, 1966a) is perhaps the most useful to the prospector in the search for additional silver-lead deposits. Once areas for detailed prospecting have been selected serious consideration should be given to the employment of detailed geochemical surveys, particularly for the determination of the lead content of surface materials.

SELECTED BIBLIOGRAPHY

Blackadar, R. G.

1951: The greenstone intrusions of the Mayo district, Yukon Territory; Univ. Toronto, unpub. thesis.

Bostock, H. S.

1936: Carmacks district, Yukon; *Geol. Surv. Can.*, Mem. 189.

1943: Upper McQuesten River, Yukon; *Geol. Surv. Can.*, Paper 43-9.

1947: Mayo, Yukon Territory; *Geol. Surv. Can.*, Map 890A with descriptive notes.

1948a: Mayo district, Yukon; *in* Structural geology of Canadian ore deposits, *Can. Inst. Mining Met.*, pp. 110-112.

1948b: Physiography of the Canadian Cordillera, with special reference to the area north of the fifty-fifth parallel; *Geol. Surv. Can.*, Mem. 247.

1948c: McQuesten, Yukon Territory; *Geol. Surv. Can.*, Paper 48-25.

1957: Yukon Territory (Selected field reports of the Geological Survey of Canada 1898 to 1933); *Geol. Surv. Can.*, Mem. 284.

1964: Geology, McQuesten, Yukon Territory; *Geol. Surv. Can.*, Map 1143A.

1966: Notes on glaciation in central Yukon Territory; *Geol. Surv. Can.*, Paper 65-36.

Boyle, R. W.

1956: Geology and geochemistry of silver-lead-zinc deposits of Keno Hill and Sourdough Hill, Yukon Territory; *Geol. Surv. Can.*, Paper 55-30.

1957a: The geology and geochemistry of the silver-lead-zinc deposits of Galena Hill, Yukon Territory; *Geol. Surv. Can.*, Paper 57-1.

1957b: Lead-zinc-silver lodes of the Keno Hill-Galena Hill area, Yukon; *in* Structural geology of Canadian ore deposits, *Can. Inst. Mining Met.*, pp. 51-65.

1965: Geology, geochemistry, and origin of the lead-zinc-silver deposits of the Keno Hill-Galena Hill area, Yukon Territory; *Geol. Surv. Can.*, Bull. 111.

Boyle, R. W., and Cragg, C. B.

1957: Soil analyses as a method of geochemical prospecting in Keno Hill-Galena Hill area, Yukon Territory; *Geol. Surv. Can.*, Bull. 39.

Boyle, R. W., Illsley, C. T., and Green, R. N.

1955: Geochemical investigation of the heavy metal content of stream and spring waters in the Keno Hill-Galena Hill area, Yukon Territory; *Geol. Surv. Can.*, Bull. 32.

Boyle, R. W., Pekar, E. L., and Patterson, P. R.

1956: Geochemical investigation of heavy metal content of streams and springs in the Galena Hill-Mount Haldane area, Yukon Territory; *Geol. Surv. Can.*, Bull. 36.

Brabb, E. E., and Churkin, J., Jr.

1964: Preliminary geologic map of the Charley River quadrangle, east central Alaska; *U.S. Geol. Surv.*, Open File Report.

Cadisch, J.

1953: Geologie der Schweizer Alpen; Basel, Wepf & Co.

Cairnes, D. D.

1914: The Yukon-Alaska International Boundary between Porcupine and Yukon Rivers; *Geol. Surv. Can.*, Mem. 67.

Cloos, E.

1946: Lineation, a critical review and annotated bibliography; *Geol. Soc. Amer.*, Mem. 18.

1947: Boudinage; *Am. Geophys. Union Trans.*, vol. 28, no. 4, pp. 626-632.

Cockfield, W. E.

1919: Mayo area, Yukon; *Geol. Surv. Can.*, Sum. Rept. 1918, pt. B, pp. 1B-15B, reprinted *in* Bostock, 1957, pp. 461-477.

Cockfield, W. E. (*Cont.*)
1920: Mayo area, Yukon; *Geol. Surv. Can.*, Sum. Rept. 1919, pt. B, pp. 3B-7B, reprinted *in* Bostock, 1957, pp. 483-487.
1921a: Silver-lead deposits of the Keno Hill area, Mayo, Yukon; *Geol. Surv. Can.*, Sum. Rept. 1920, pt. A, pp. 1A-6A, reprinted *in* Bostock, 1957, pp. 488-493.
1921b: Sixtymile and Ladue Rivers area, Yukon; *Geol. Surv. Can.*, Mem. 123.
1922: Silver-lead deposits of Davidson Mountains, Mayo district, Yukon; *Geol. Surv. Can.*, Sum. Rept. 1921, pt. A, pp. 1A-6A, reprinted *in* Bostock, 1957, pp. 494-500.
1924a: Geology and ore deposits of Keno Hill, Mayo district, Yukon; *Geol. Surv. Can.*, Sum. Rept. 1923, pt. A, pp. 1A-21A, reprinted *in* Bostock, 1957, pp. 508-527.
1924b: Silver-lead deposits of Beaver River area, Yukon; *Geol. Surv. Can.*, Sum. Rept. 1923, pt. A, pp. 22A-28A.
1925: Upper Beaver River area, Mayo district, Yukon; *Geol. Surv. Can.*, Sum. Rept. 1924, pt. A, pp. 1A-18A, reprinted *in* Bostock, 1957, pp. 528-543.

Collett, L. W.
1927: The structure of the Alps; London, Edward Arnold & Co.

Dahlstrom, C. D. A.
1954: Statistical analysis of cylindrical folds; *Bull. Can. Inst. Mining Met.*, vol. 47, pp. 234-239.

Fairbairn, H. W.
1949: Structural petrology of deformed rocks; Addison Wesley Press, Inc.

Findlay, D. C.
1967: The mineral industry of Yukon Territory and southwestern District of Mackenzie, 1966; *Geol. Surv. Can.*, Paper 67-40.

Frebold, H., Mountjoy, E. W., and Tempelman-Kluit, D. J.
1967: New occurrences of Jurassic rocks and fossils in central and northern Yukon Territory; *Geol. Surv. Can.*, Paper 67-2.

Gabrielse, H.
1967: Tectonic evolution of the northern Canadian Cordillera; *Can. J. Earth Sci.*, vol. 4, pp. 271-298.

Gabrielse, H., Roddick, J. A., and Blusson, S. L.
1965: Flat River, Glacier Lake, and Wrigley Lake, District of Mackenzie and Yukon Territory; *Geol. Surv. Can.*, Paper 64-52.

Gilbert, G. K.
1877: Report on the geology of the Henry Mountains; *U.S. Geog. and Geol. Surv.*, Rocky Mtn. region.

Gleeson, C. F.
1965a: Heavy metal content of stream and spring waters, Mayo Lake, Yukon Territory; *Geol. Surv. Can.*, Map 18-1964.
1965b: Heavy metal content of stream and spring sediments, Mayo Lake, Yukon Territory; *Geol. Surv. Can.*, Map 19-1964.
1965c: Heavy metal content of stream and spring waters, Scougale Creek, Yukon Territory; *Geol. Surv. Can.*, Map 26-1964.
1965d: Heavy metal content of stream and spring sediments, Scougale Creek, Yukon Territory; *Geol. Surv. Can.*, Map 27-1964.
1965e: Heavy metal content of stream and spring waters, McQuesten Lake, Yukon Territory; *Geol. Surv. Can.*, Map 28-1964.
1965f: Heavy metal content of stream and spring sediments, McQuesten Lake, Yukon Territory; *Geol. Surv. Can.*, Map 29-1964.
1966a: Lead content of stream and spring sediments, Keno Hill area, Yukon Territory; *Geol. Surv. Can.*, Map 45-1965.
1966b: Silver content of stream and spring sediments, Keno Hill area, Yukon Territory; *Geol. Surv. Can.*, Map 46-1965.
1966c: Zinc content of stream and spring sediments, Keno Hill area, Yukon Territory; *Geol. Surv. Can.*, Map 47-1965.
1966d: Arsenic content of stream and spring sediments, Keno Hill area, Yukon Territory; *Geol. Surv. Can.*, Map 48-1965.
1967a: Antimony content of stream and spring sediments, Keno Hill area, Yukon Territory; *Geol. Surv. Can.*, Map 49-1965.
1967b: Molybdenum content of stream and spring sediments, Keno Hill area, Yukon Territory; *Geol. Surv. Can.*, Map 51-1965.

Green, L. H.
1957: Mayo Lake, Yukon Territory; *Geol. Surv. Can.*, Map 5-1956.
1958: McQuesten Lake and Scougale Creek map-area, Yukon Territory; *Geol. Surv. Can.*, Paper 58-4.
in preparation: Geology of Nash Creek, Larsen Creek and Dawson map-areas, Yukon Territory—Operation Ogilvie; *Geol. Surv. Can.*, Mem. 364.

Green, L. H., and McTaggart, K. G.
1960: Structural studies in the Mayo district, Yukon Territory; *Proc. Geol. Assoc. Can.*, vol. 12, pp. 119-134.

Green, L. H., and Roddick, J. A.
1962: Dawson, Larsen Creek, and Nash Creek map-areas, Yukon Territory; *Geol. Surv. Can.*, Paper 62-7.

Hunt, C. B.
1953: Geology and geography of the Henry Mountains region Utah; *U.S. Geol. Surv.*, Prof. Paper 228.

Jenness, S. E. (compiler)
1965: Report of activities: field, 1964; *Geol. Surv. Can.*, Paper 65-1.

Jones, A. G.
1959: Vernon map-area, British Columbia; *Geol. Surv. Can.*, Mem. 296.

Keele, J.
1906a: The Duncan Creek mining district; *Geol. Surv. Can.*, Ann. Rept., vol. XVI, 1904, pt. A, pp. 18A-42A, reprinted *in* Bostock, 1957, pp. 127-143.
1906b: Report on the Upper Stewart River region, Yukon; *Geol. Surv. Can.*, Ann. Rept., vol. XVI, 1904, pt. C, pp. 5C-23C, reprinted *in* Bostock, 1957, pp. 160-173.

Kendrew, W. G., and Kerr D.
1955: The climate of British Columbia and the Yukon Territory; Ottawa, Queen's Printer.

Kindle, E. D.
1962: Geology, Keno Hill, Yukon Territory; *Geol. Surv. Can.*, Map 1105A.

Knopf, E. G., and Ingerson, E.
1938: Structural petrology; *Geol. Soc. Amer.*, Mem. 6.

Leech, G. B., Lowdon, J. A., Stockwell, C. H., and Wanless, R. K.
1963: Age determinations and geological studies (including isotopic ages-Report 4); *Geol. Surv. Can.*, Paper 63-17.

Little, H. W.
1959: Tungsten deposits of Canada; *Geol. Surv. Can.*, Econ. Geol. Ser. No. 17.

McConnell, R. G.
1905: Report on the Klondike Gold Fields; *Geol. Surv. Can.*, Ann. Rept., vol. XIV, 1901, pt. B, reprinted *in* Bostock, 1957, pp. 64-113.

McTaggart, K. C.
1950: Keno and Galena Hills, Yukon; *Geol. Surv. Can.*, Paper 50-20.
1960: The geology of Keno and Galena Hills, Yukon Territory; *Geol. Surv. Can.*, Bull. 58.

Mertie, J. B., Jr.
1930: Geology of the Eagle-Circle district, Alaska; *U.S. Geol. Surv.*, Bull. 816.

Nockolds, S. R.
1954: Average chemical compositions of some igneous rocks; *Geol. Surv. Amer.*, vol. 65, pp. 1007-1032.

Norris, D. K., Price, R. A., and Mountjoy, E. W.
1963: Geology, northern Yukon Territory and northwestern District of Mackenzie; *Geol. Surv. Can.*, Map 10-1963.

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

Phillips, F. C.
1954: The use of stereographic projection in structural geology; London, Edward Arnold (Publishers) Ltd.

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

Ramberg, H.
1955: Natural and experimental boudinage and pinch-and-swell structures; *J. Geol.*, vol. 63, no. 6, pp. 43-46.

Smitheringale, W. V.
1950: Geology of the Keno Hill area; *Western Miner*, vol. 23, no. 6, pp. 43-46.

Stockwell, C. H.
1926: Galena Hill, Mayo district, Yukon; *Geol. Surv. Can.*, Sum. Rept. 1925, pt. A, pp. 1A-14A, reprinted *in* Bostock, 1957, pp. 544-557.
1950: The use of plunge in the construction of cross-sections of folds; *Proc. Geol. Assoc. Can.*, vol. 3, pp. 1-25.
1957: Geology and economic minerals of Canada; *Geol. Surv. Can.*, Econ. Geol. Ser. No. 1 (4th ed.).

Templeman-Kluit, D. J.
1966: The stratigraphy and structure of the "Keno Hill quartzite" in Tombstone area, central Yukon; McGill Univ., unpub. Ph.D. thesis.
1970: The stratigraphy and structure of the Keno Hill Quartzite in Tombstone River-Upper Klondike River map-areas, Yukon Territory; *Geol. Surv. Can.*, Bull. 180.

Turner, F. J., and Verhoogen, J.
1960: Igneous and metamorphic petrology; 2nd ed., New York, McGraw-Hill.

United Keno Hill Mines Limited
1961: Current operations of United Keno Hill Mines; *Bull. Can. Inst. Mining Met.*, vol. 54, pp. 722-739.

Vernon, P., and Hughes, O. L.
1966: Surficial geology, Dawson, Larsen Creek, and Nash Creek map-areas, Yukon Territory; *Geol. Surv. Can.*, Bull. 136.

Wanless, R. K., Stevens, R. D., Lachance, G. R., and Edmonds, C. M.
1967: Age determinations and geological studies, K-Ar isotopic ages, Report 7; *Geol. Surv., Can.*, Paper 66-17.

Wheeler, J. O.
1961: Whitehorse map-area, Yukon Territory; *Geol. Surv. Can.*, Mem. 312.

Whitten, E. H. T.
1966: Structural geology of folded rocks; Chicago, Rand McNally and Company.

Wilkinson, S. B.
1907: The geology of Islay; Memoirs, *Geol. Surv. Scotland.*

Wiseman, J. D. H.
1934: The central and south-west highland epidiorites: A study in progressive metamorphism; *Quart. J. Geol. Soc. London*, vol. XC, pp. 354-417.

INDEX

MEMOIRS

Geological Survey of Canada

Comprehensive reports on the geology of specific areas, accompanied by one or more multicoloured geological maps. Some recent titles are listed below. (Information Canada Cat. No. in brackets):

340 Kluane Lake map-area, Yukon Territory, *by* J. E. Muller, $3.75 (M46-340)

341 Whitbourne map-area, Newfoundland, *by* W. D. McCartney, $3.50 (M46-341)

342 Geology and mineral deposits of the Chisel Lake area, Manitoba, *by* Harold Williams, $1.25 (M46-342)

343 Geology of Hopewell map-area, N.S., *by* D. G. Benson, $2.00 (M46-343)

344 Wakuach Lake map-area, Quebec-Labrador (23 O), *by* W. R. A. Baragar, $4.25 (M46-344)

345 Geology of Mingo Lake-Macdonald Island map-areas, Baffin Island, District of Franklin, *by* R. G. Blackadar, $2.00 (M46-345)

346 Westport map-area, Ontario, with special emphasis on the Precambrian rocks, *by* H. R. Wynne-Edwards, $3.25 (M46-346)

347 Bache Peninsula, Ellesmere Island, Artic Archipelago, *by* R. L. Christie, $2.00 (M46-347)

348 Willbob Lake and Thompson Lake map-areas, Quebec and Newfoundland, *by* M. J. Frarey, $2.25 (M46-348)

349 Reconnaissance geology of Shelburne map-area, N.S., *by* F. C. Taylor, $2.25 (M46-349)

350 Geology of the Southeastern Barren Grounds, N.W.T., *by* G. M. Wright, $3.00 (M46-350)

351 Baddeck and Whycocomagh map-areas, with emphasis on Mississippian stratigraphy of Cape Breton Island, Nova Scotia (11 K/2 and 11 F/14), *by* D. G. Kelley, $2.50 (M46-351)

352 Geology of Glenlyon map-area, Yukon Territory, *by* R. B. Campbell, $2.75 (M46-352)

353 Woodstock, Millville, and Coldstream map-areas, Carleton and York counties, New Brunswick, *by* F. D. Anderson, $4.50 (M46-353)

354 Shabogamo Lake map-area, Newfoundland-Labrador and Quebec, *by* W. F. Fahrig, $1.00 (46-354)

355 Palaeozoic geology of the Lake Simcoe area, *by* B. A. Liberty, $4.50 (M46-355)

356 A geological reconnaissance of Leaf River map-area, New Quebec and Northwest Territories, *by* I. M. Stevenson, $3.50 (M46-356)

357 Geology of Mayo Lake, Scougale Creek and McQuesten Lake map-areas, Yukon Territory, *by* L. H. Green, $3.00 (M46-357)

358 Geology of the Annapolis-St. Marys Bay map-area, Nova Scotia, *by* F. C. Taylor, $2.50 (M46-358)

360 Paleozoic geology of the Bruce Peninsula area, Ontario, *by* B. A. Liberty and T. E. Bolton, $4.50 (M46-360)

361 Geology of Benjamin Lake map-area, District of Mackenzie (75 M/2), *by* W. W. Heywood and A. Davidson, $1.50 (M46-361)

362 Geology and mineral deposits of Tulsequah map-area, British Columbia, *by* J. G. Souther, $3.00 (M46-362)