R L CHRISTIE

CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
MEMOIR 274

GEOLOGY AND MINERAL DEPOSITS OF AIKEN LAKE MAP-AREA, BRITISH COLUMBIA

BY

E. F. Roots

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1954.

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No. 2514

Aiken Lake. View westward from the moraine dam at the outlet of the lake, showing the deep, heavily glaciated valley of Kliyul Creek in the middle distance. The flat valley floor, below which the lake basin and the present Mesilinka River bed have been cut, forms a conspicuous terrace at the right. The nearer mountains are underlain by mainly Takla group rocks; the distant peaks are within the Hogem batholith. (Pages 7, 13, 15, 18, 22.)

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PREFACE

Aiken Lake map-area extends westward from the Rocky Mountain Trench to include the crest of Swannell Ranges and the mountains underlain by the Hogem batholith, and embraces a characteristic part of the Omineca Mountains of the northern interior of British Columbia. It is underlain by a great variety of metamorphic, sedimentary, and volcanic rocks, ranging in age from Proterozoic to Cenozoic and invaded by plutonic rocks of several distinct types. Deposits of base and precious metals have been found at many places in the map-area, and although none has yet been commercially exploited, several are of definite promise. Prospecting has been done intermittently since the late 19th century, but the search for lode deposits has been confined to a very few individuals, who discovered new evidences of metallic mineralization almost every season between 1925 and 1940, and to the activities of about eight prospectors in the immediate post-war years, culminating in a minor staking 'rush' in 1947. The area cannot be considered to have been thoroughly prospected.

This report is based on field work in the map-area from 1945 to 1948, inclusive, compiled in the light of recent investigations of areas to the south and west. Because of the fortunate coincidence of the occurrence of most of the geological formations found in the surrounding region, and a degree of rock exposure considerably better than that commonly found in the Canadian Cordillera, the map-area has provided evidence on the mutual relations and subdivision of rock units that would not be as readily obtainable elsewhere. Descriptions of the rocks and their structures, and interpretations of their correlations and history are, therefore, presented in greater detail than might ordinarily be required for a report of this type, in the hope that the information will be of value in interpreting the geology and guiding the search for mineral deposits in this and surrounding areas, and particularly in the relatively unexplored region to the north.

The report is illustrated by several figures and plates, and by a geological coloured map of the area on a scale of 1 inch to 4 miles.

W. A. BELL,
Director, Geological Survey of Canada

OTTAWA, May 20, 1953

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Geology and Mineral Deposits of Aiken Lake Map-Area, British Columbia

CHAPTER I

INTRODUCTION

LOCATION AND ACCESSIBILITY

Aiken Lake map-area occupies about 2,640 square miles of north-central British Columbia, between latitudes 56 and 57 degrees and longitudes 125 and 126 degrees. The area is included within Cassiar land district and Omineca mining division.

Aiken Lake, in the west-central part of the area, may be reached by a winter tractor road, 95 miles long, from Germansen Landing on Omineca River. A fair motor road extends about 185 miles south from Germansen Landing, via Fort St. James, to Vanderhoof on the Prince Rupert branch of the Canadian National Railways. The northeastern part of the area is accessible by boat from Summit Lake, 40 miles by road from Prince George, by means of Crooked, McLeod, Parsnip, and Finlay Rivers. The area may be conveniently serviced, through several suitable lakes, by charter aircraft based at Fort St. James. In the years 1945 to 1948, the carrying charge on freight flown in to Aiken Lake in lots of 1,200 pounds, with no outgoing load, was 20 cents a pound.

TRAVEL WITHIN THE MAP-AREA

The main line of travel in the area is the winter tractor road entering from the south and extending past Uslika Lake to Aiken Lake. This road has been used by a tractor train as far as the crossing of Tenakihi Creek (mile 50), and at one time, during a period of extreme low water, a truck was driven to Uslika Lake. For the rest of its length it has been maintained as an excellent trail for pack-horse, pack-dog, and foot travel. No bridges span the main streams, but Osilinka River, Thane Creek, and Mesilinka River crossings are provided with manually operated cable-cars, capable of carrying four persons, which are maintained by the British Columbia Department of Public Works.

The pack-horse is the most practical means of transportation during the summer season, and in almost all of the larger valleys sufficient feed can be found to maintain a string of twenty horses. The Indians, and many of the local prospectors and trappers, transport their goods by pack-dogs in the summer and by toboggan in the winter.

The area is well supplied with trails. The Royal Canadian Mounted Police pack-trail from Fort St. John to Telegraph Creek crosses the area from east to west by way of Mesilinka River, Tutizika River, and

Hornway Creek Valleys, and pack-trails in various stages of disrepair are to be found in most of the other major valleys. Once constructed, and except where damaged by forest fire, landslide, or avalanche, trails in this district may be abandoned for many years and yet made passable with little effort. A wagon road was built about 1927 from the Ferguson mineral claims to Finlay River; it is still in fair condition except for stream crossings.

Except during extreme low water, Ingenika River is navigable for small river boats below the mouth of Wrede Creek, and Osilinka River below Tenakihi Creek.

Almost all parts of the map-area may be reached on foot. In parts of the most rugged alpine terrain in the southwest, mountaineering techniques and precautions must be used, and in places travel is most efficient and safest in roped parties of at least two.

GEOLOGICAL WORK

The first geological work in the area was done in 1893 by McConnell (1896)[1], who mapped the northeastern part adjacent to Finlay River Valley as well as a strip of country bordering Omineca River, just south of the map-area. In 1927, Dolmage (1928) examined the geology of Finlay River Valley, the lower part of Ingenika River Valley, including the Ferguson lead-zinc property, and traversed the Royal Canadian Mounted Police trail. An examination of several mineral prospects in the vicinity of Uslika and Aiken Lakes was conducted in 1939 by Douglas Lay (1940) of the British Columbia Department of Mines. Systematic mapping of the areal geology was commenced in 1945 by J. E. Armstrong (1946a), and continued by the writer in 1946, 1947, and 1948.

ACKNOWLEDGMENTS

In the course of these investigations the writer has received assistance from many persons, both in the field and in subsequent laboratory work; their co-operation and many services are gratefully acknowledged. For courtesies extended in the field he is indebted to representatives of various mining companies, particularly E. Bronlund of The Consolidated Mining and Smelting Company of Canada, Limited, and J. W. Burton and other officials of Springer, Sturgeon Gold Mines, Limited; to R. Baker and P. Carey of Central British Columbia Airways; and to many prospectors and residents in the region. Special thanks are due E. Kohse, Sr., E. Kohse, Jr., N. Henry, and L. R. Dickinson of Fort St. James; F. Brumblay and A. Sharp of Germansen Landing; C. Reinertson of Vanderhoof; and A. B. Gooderidge and E. and G. Davies.

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[1] Dates in parentheses are those of references in Bibliography at end of this chapter.

Laboratory work, in addition to that done in the offices of the Geological Survey, was carried out at the University of British Columbia and at Princeton University. The writer appreciates the advice and criticisms received from the faculty of these institutions, particularly Professors H. C. Gunning and K. DeP. Watson of the University of British Columbia and Professors A. F. Buddington, H. H. Hess, and B. F. Howell of Princeton University. For examination of fossil collections in addition to that done by the officers of the Palæontological Division of the Geological Survey of Canada, the writer is especially indebted to Professor V. J. Okulitch of the University of British Columbia and Professor B. F. Howell of Princeton University; Professor E. C. Stumm of the University of Michigan, Professor M. A. Fritz of the University of Toronto, and Dr. T. H. Withers of the British Museum also kindly examined material. The writer's field assistants J. O. Wheeler and W. H. Dow also assisted with mineralographic investigations.

Lastly, the writer would like to express his indebtedness to Dr. J. E. Armstrong of the Geological Survey, under whose direction he worked in 1945, and upon whose knowledge of the geology of the surrounding areas he has drawn freely.

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CHAPTER II

GENERAL CHARACTER OF THE AREA

TOPOGRAPHY

Aiken Lake map-area lies almost entirely within the Omineca Mountains of the Central Plateau and Mountain area of the Interior system of the Canadian Cordillera (Bostock, 1948, pp. 42-44). The extreme northeast corner of the map-area extends into the Rocky Mountain Trench of the Eastern system of the Cordillera.

The Omineca Mountains of the map-area are characterized by irregular, dissected mountain units, ranging in size from single peaks to composite masses of 10 by 20 miles, with little general tendency to form well-defined ranges. The mountain massifs are arranged in a more or less rectangular pattern, with a northwest-trending axis, and are separated by straight or broadly curving, relatively wide-floored, steep-sided valleys, the larger of which measure as much as 10 miles between mountain summits on either side (*See* Plate I). Most of the mountains of the eastern and northern parts of the area have smooth profiles and rounded summits, although the local relief is just as great and the over-all slopes as steep as elsewhere, and the Russel Range contains several rugged peaks. The general character of the landscape becomes increasingly precipitous toward the southwest, culminating in rugged, alpine topography around the headwaters of Osilinka, Tutizika, and Mesilinka Rivers.

River, and have an altitude of about 8,060 feet. The lowest point is in the Rocky Mountain Trench at 2,150 feet above sea-level. Local relief
The highest peaks in the map-area lie near the headwaters of Osilinka
between mountain summits and adjacent valley floors is relatively uniform for the entire area, and varies between 3,500 and 4,000 feet.

DRAINAGE

Aiken Lake map-area lies entirely within the Arctic Ocean watershed, and is drained by Finlay River and its tributaries. The main rivers flow east and southeast. Owing, however, to the characteristic asymmetrical profile produced by more intense glacial erosion on the northeast slopes of the mountains, the drainage within each mountain group is predominantly to the northeast.

The large valleys have relatively gentle gradients for a mountainous terrain, and the heavily loaded larger rivers have all developed a complex system of meanders and shifting bars (Plate II A), in sharp contrast with the steep, turbulent, actively down-cutting character of the tributary streams and headwaters of the main streams. A common feature of the larger tributaries, most of which flow in valleys left by glacial erosion in a hanging relation to the trunk valleys, is the presence of long canyons and gorges near their mouths. Such a gorge is best exemplified on Lay Creek, where it has a length of 7½ miles and a maximum depth in excess of 450 feet; other good examples are found on Polaris, Pelly, and Haha Creeks and on the south branch of Wasi Creek. Some tributary streams, as for example Cutbank, Abraham, and Matetlo Creeks, have developed only small canyons, but have extended their channels as much as 2 miles out into the main valleys on large alluvial fans.

The larger lakes are confined to the lower valleys, and are dammed chiefly by glacial deposits or alluvial fans of tributary streams. Innumerable rock-basin and moraine-dammed lakes and tarns occur in cirques and hanging valleys at and above timber-line.

The map-area at present contains glaciers only in the west and southwest, and even within these parts perennial ice covers only about 8 per cent of the area. Drainage by ice is thus restricted to numerous, scattered, small cirques and basins, and to a few sheltered valleys in which glaciers reach down to timber-line.

CLIMATE

No weather records have been kept within the map-area. In general the climate appears to be similar to that of much of the northern interior of British Columbia, with probably a heavier precipitation than in the Nechako Plateau to the south, the Spatsizi Plateau to the north, or the Rocky Mountains to the east. The summers are moderate, and frosts are rare in the main valleys between June and the latter part of August. The winters are relatively cold, usually bright and clear, and occasionally subject to periods of intensely cold, clear weather. The extremes of temperature in the valleys are probably similar to those recorded by Stanwell-Fletcher (1943) in Driftwood River Valley to the west, namely, a maximum of about 95° F. and a minimum of about —60°F.

The precipitation appears to be fairly well distributed throughout the year, with a slight maximum in autumn and early winter, and a minimum in late winter. Although prolonged storms are not unknown, the area is somewhat unique in that in both summer and winter the precipitation is mainly from small scattered showers and flurries of short duration. On almost every day in summer the view from a high summit will disclose several, sometimes as many as a score, small individual rain-storms sweeping across the country from west to east. Most of the showers appear to originate in persistent cloud banks over the Sustut Peak and Bear Lake districts of McConnell Creek map-area to the west (Lord, 1948, p. 5); from them, individual cloud masses are detached and drift over Aiken Lake map-area at elevations of 8,000 to 12,000 feet. Most of the showers end before completely crossing the area; few reach the Rocky Mountain Trench. During the summer of 1947, for example, rain fell in 38 out of 42 days in Ingenika River Valley, but no storm was of more than 2 hours duration, and most lasted less than ½ hour; the days were almost without exception warm and sunny. In this area almost all of the showers passed over in the late afternoon. In contrast, all-day rains are not uncommon at Croydon Creek.

The net result of these daily showers that dissipate as they move eastward is a much heavier precipitation in the western than the eastern part of the map-area; the effect of this can be seen in the greater abundance of glaciers in the west. From the character and profusion of the vegetation, the amount and distribution of perennial ice and snow, and the texture of drainage and average size of streams, it is estimated that precipitation in the eastern and northeastern parts of the map-area may be of the order of 20 inches a year or less, whereas in the western and southwestern parts it is probably more than 50 inches. The average depth of snow in the Pelly Lake and lower Ingenika River districts is reported[1] to be between 2 and 4 feet; farther east and north it is even less, and horses are wintered regularly on open range in the Rocky Mountain Trench 100 miles north of the map-area, where the floor of Kechika River Valley is free of snow at intervals throughout much of the winter. In contrast, in the south-central and western parts of the area, 12 feet of snow have remained on the ground in April at the Vega mineral claims, elevation 4,200 feet[2]; and on July 17, 1947, 8 feet of snow still covered some of the veins on the Shell mineral claims in the Croydon Creek district. Three weeks later this snow had disappeared. The yearly increment of the névé fields at the head of Abraham Creek and around Ferriston Creek, as seen from the annual stratification exposed in the highest crevasses of the glaciers proper, is between 5 and 8 feet. Taking 0·82 as the average density at which the transition from snow to ice takes place, this would correspond to a precipitation, in excess of that lost by summer wastage, equivalent to 50 to 90 inches of water during the snow accumulation season.

The ice on the rivers and large lakes usually breaks up about the third week in April. The high-water period in the main rivers is usually quite long, and commonly occurs in late June and early July. In 1948, an abnormal year, an extreme flood stage was reached in late May. Snow banks remain in the lee of ridges throughout the summer in all parts of the area, but as a rule the highest ridges are bare enough for effective prospecting by the first week in June. About this time also, the meadows at lower elevations contain sufficient grass to support pack animals. The prospecting season usually lasts until about the first week of October, although at higher elevations severe snow-storms may be encountered any time in September. The larger rivers and lakes are usually frozen sufficiently to enable ski-equipped aircraft to be used in early December.

SOIL

All vegetation in the area, except the lichen and moss on rock outcrops, is growing on recently transported material. This material, consisting of colluvium from the valley slopes, glacial drift, and alluvial deposits, is still undergoing transportation, or periodic erosion and deposition, over almost the entire land surface. Consequently, areas in which a zonal soil profile has begun to be established are very limited. The most prolific plant growth is found on the flood-plain floors of the larger river valleys, and on lake deposits. The material deposited on the flood plains

[1] William Isaac, Indian trapper on Ingenika River, personal communication, 1947.
[2] Note on cabin door, Vega mineral claims.

is composed mainly of fresh, unweathered particles of silt or fine sand, in part supplied by the present glaciers, which have become mixed with enough organic matter to form a fertile silt loam or sandy loam.

The beginnings of development of an equilibrium profile can be seen on low, drift-covered ridges, some large river terraces of glacio-fluvial origin, and on the deposits of several presumably ice-dammed lakes. In these places, under the influence of the prevailing coniferous forest cover, grey, lime-poor, iron- and aluminium-rich, podsol soils are being developed, and the entire region is included in the area of grey wooded soils of the podsol zone that covers most of the northern parts of the western Canadian provinces (Kelley and Farstad, 1946).

FLORA

Timber-line is at about 5,500 feet. The forest cover below this level is predominantly coniferous, with the proportion of deciduous trees increasing markedly toward the eastern, drier regions. The main forest trees are:

—	Average diameter (at breast height) in mature stands, inches	Maximum diameter at breast height, inches
Lodgepole pine (*Pinus contorta* var. *murrayana*)	5	20
Balsam fir (*Abies lasiocarpa*)	8	50
White spruce (*Picea canadensis*)	15	40
Black spruce (*Picea mariana*)	small—confined to muskegs	
Engelmann's spruce (*Picea engelmanni*)	10	30
Aspen poplar (*Populus tremuloides*)	5	15
Balsam poplar (*Populus balsamifera*)	20	60

Less abundant forest trees include paper birch (*Betula papyracea*), alder (*Alnus incana*), and several varieties of willow. The underbrush in the forests is comparatively light, and consists mainly of soopolallie, buffaloberry (*Shepherdia canadensis*), dwarf birch (*Betula glandulosa*), mountain rhododendron (*Rhododendron albiflorum*), bearberry (*Arctostaphylos Uva-ursi*), and Labrador tea (*Ledum groenlandicum*). Except in burned-over areas or in a few over-mature balsam forests, travel on foot is pleasant and easy. The amount of muskeg, dominated by black spruce and Labrador tea, is not large. At timber-line, stunted balsam fir, dwarf birch, slide alder (*Alnus sinuata*), juniper (*Juniperus communis* var. *montana*), and willow cover fairly extensive areas with a thick matted tangle through which progress is extremely laborious. These areas are interspersed with sub-alpine meadows and parklands supporting a profusion of flowering plants. Grassy alps, and slopes covered with false heather (*Phyllodoce glanduliflorus* and *P. empetriformis*) and heath (*Cassiope mertensiana*) extend up to elevations of about 7,200 feet.

Edible wild fruits include at least three species of blueberry, of which the most common, locally called the northern huckleberry, appears to be a variety of the dwarf bilberry (*Vaccinium caespitosum*), raspberry, dwarf red blackberry, strawberry, smooth gooseberry, black and red currant, cranberry, and saskatoon.

A general list of the flora of a nearby district is given by Stanwell-Fletcher (1943).

FAUNA

Game animals are well represented in the district. The most abundant of the large mammals is the mountain goat (*Oreamnos americanus*), which was seen, in small family groups and in herds of as many as forty-three, on nearly every mountain massif and in each of the larger stream canyons. In the valleys, moose (*Alces americana*) are still relatively abundant, despite indiscriminate hunting. Mule deer (*Odocoileus hemionus hemionus*) appear restricted to the lower Ingenika River Valley and to the Rocky Mountain Trench. Caribou (*Rangifer arcticus osborni*) may be encountered, in summer, on the upper slopes of the central and northern parts of the area; and a herd of more than seventy is reported to have spent the winter of 1947-48 in the Rocky Mountain Trench and lower Ingenika Valley. The stone sheep (*Ovis dalli stonei*) has been encountered, in groups numbering up to eight, in the central and northwestern parts of the area.

The common black bear (*Euarctos americanus*) is relatively abundant in the valleys, and brown and cinnamon varieties were observed near Uslika Lake and in Omineca River Valley. The grizzly (probably *Ursus tahltanicus*), ranging in colour from golden-tan to nearly black, was quite frequently met at or far above timber-line. The timber wolf (*Canis lupis columbianus*) ranges throughout the area and is said to be increasing in numbers. Less abundant predators include coyote, lynx, and wolverine.

Fisher, marten, weasel, and mink are the mainstay of most of the trappers in the region; foxes are plentiful on some trap lines, and a few otter and skunks are taken. Beaver were once plentiful in many parts of the district, but have been nearly exterminated, except on those trap lines whose owners are re-establishing colonies. The muskrat, although still fairly plentiful, has also been seriously depleted by trapping.

Other small mammals present in important numbers include: porcupine, varying hare, hoary marmot (*Marmota caligata*), red squirrel, flying squirrel, little brown bat, and varieties of chipmunk, lemming, wood rat, jumping mouse, meadow mouse, and shrew.

Bird life is remarkably abundant and varied; although no systematic survey of the bird population was attempted, fifty-two species were observed during the course of the field work. Game birds include Franklin's grouse (spruce hen), grey ruffed grouse (willow grouse), sooty grouse (blue grouse), and ptarmigan. The chief waterfowl are Barrow's golden-eye, other ducks including mallards and mergansers, teal (probably green-winged teal), grebe (Holboell's), Canada goose, herring gull, common tern, common loon, and American bittern. The most popular resting places for migratory waterfowl, especially Canada geese, are Aiken Lake and Mesilinka River immediately upstream from it, and Hornway Creek, where hundreds of birds were observed in September.

Fish taken include grayling, rainbow trout, Dolly Varden, char, lake trout, whitefish, suckers, and bull trout.

The most common amphibian is the northwestern toad, which was encountered in all parts of the area, including dry pine terraces and hot talus slopes; one individual was found near the summit of one of the higher peaks, 2,500 feet above the nearest alp meadow. Frogs appear confined to muskegs and small streams and lakes below an elevation of about 4,000 feet.

Mosquitoes are most numerous from late May to the middle of August and black flies from late June until September. 'Bulldogs' and several types of deer flies are a serious nuisance to horses in the early part of the summer.

INHABITANTS

The area has no permanent inhabitants. One Indian family from the Bear Lake settlement to the west frequently winters at Aiken Lake. Five different trappers have parts of their trap lines within the area, so that many of the main valleys contain cabins spaced about 1 day's travel apart. Camps at several of the prospects have been occupied at different times for periods of as much as 5 years.

CHAPTER III

PHYSIOGRAPHIC DEVELOPMENT

GENERAL STATEMENT

The landscape presented by Aiken Lake map-area is mainly one of land forms produced or modified by glacial and glacio-fluvial processes (Plate I). The detail of the present topography dates from the occupation of the entire area by an ice-cover related to the Pleistocene continental glaciers. The land surface left by the regional ice-cover has been modified by subsequent alpine glaciation, frost action, and stream action to produce the present land forms. All of these modifying processes are still active within the map-area.

There are no extensive high-level erosion surfaces within the map-area. The landscape is completely mature, in that all the upland area has been reduced to slope, and essentially the entire area is being actively modified by present geomorphic processes. The only evidence of a land surface distinct from that being at present developed are a few remnants, totalling less than ½ square mile, of the highly undulating surface vacated by the regional ice-sheet. The surface exhibited by these small remnants may be little different from the pre-Glacial erosion surface.

In common with many mountainous areas undergoing rapid degradation, the Omineca Mountains present a general accordance of summit altitude, which in Aiken Lake map-area is between 6,500 and 7,200 feet above sea-level (Plate II B). This broadly accordant summit level seems to be due entirely to the relation between the effectiveness of erosional agencies and the height of the peaks (Daly, 1912, pp. 631-641; von Engeln, 1942, p. 99) rather than to any relation to a former erosion surface.

CHARACTER OF THE PRE-GLACIAL LAND SURFACE

Little direct evidence can be obtained from Aiken Lake map-area on the character of the land surface in pre-Glacial times. Remnants of an erosion surface older than the one being formed at present are too fragmentary to provide any indication of the nature of the pre-Glacial surface.

To the northwest, and to a lesser extent to the south, of the map-area, however, the land surface vacated by the last regional ice-cover has been much less dissected, and large areas of rolling upland, which grade into the extensive plateaux of central and northern British Columbia, remain. The physiographic history, as reconstructed in these areas (Dawson, 1891, pp. 3-74; Lay, 1941, p. 68; Holland, 1940, p. 19; Hedley and Holland, 1941, p. 25; Watson and Mathews, 1944, p. 34; Lord, 1948, p. 4) suggests that by late Tertiary time stream dissection had produced a mature topography of moderate relief with a well-organized drainage system. Holland (1940) and Lay (1941) have presented evidence for a late Tertiary rejuvenation of stream action, and a period of canyon cutting immediately preceding the advance of Pleistocene ice.

GLACIATION

General Statement

The glacial cycle in a mountainous region involves a development of small mountain glaciers, an expansion of the ice-cover to an ice-sheet of regional dimensions, in which the movement and extent of the ice are controlled mainly by climatic factors and are largely independent of the underlying topography, and a subsequent decrease of ice-cover to valley glaciers and finally to small mountain glaciers (Kerr, 1934b; 1936; Davis and Mathews, 1944). The regional ice-sheet phase of this cycle produces erosional and depositional land forms distinctly different from those produced by the valley and mountain glaciers that precede and follow it. In Aiken Lake map-area, land forms produced mainly by valley and mountain glaciers dominate the topography; the effects of a regional ice-sheet are less conspicuous.

The Cordilleran Ice-sheet

All parts of Aiken Lake map-area were, apparently, covered by an ice-sheet that moved across the mountains and over valleys to some extent independent of the local topography. This ice-sheet was part of the complex of glaciers and ice-sheets that covered most of British Columbia during periods of Pleistocene glaciation, and which is generally referred to as the Cordilleran Ice-sheet (Flint, 1947, p. 216). In Aiken Lake map-area this ice-sheet deposited erratics at elevations up to 7,600 feet (summit of peak between Lay Creek and Croydon Creek).

Investigations in various parts of northern British Columbia have been accumulating evidence that there were at least two major advances of the Cordilleran Ice-sheet, separated by an interglacial stage long enough to enable extensive deposits of silt and gravel to be laid down in the lowland areas, and to allow streams to erode channels in bedrock below the glaciated level (Dawson, 1891; Malloch, 1910, p. 128; Johnston, 1926, p. 147; Holland, 1940, p. 20; Lay, 1941, p. 16; Armstrong and Tipper, 1948, p. 306; Armstrong, 1949, p. 14). Whether the ice completely disappeared from the mountainous areas during this interval is not known.

There is ample evidence that the last major movement of the Cordilleran Ice-sheet over the map-area was toward the northeast. Glacial striæ and large groovings on peaks and crests of ridges, well above and at an angle contrary to the obvious direction of motion of the valley glaciers, trend north 30 to 60 degrees east. The most abundant erratics at high elevations are of granodioritic rocks, whose only possible source is the Hogem batholith or other intrusive bodies to the west or southwest. The Uslika formation of Conglomerate Mountain has been the source of boulders of characteristic conglomerate, which are widespread on the mountains and ridges to the northeast to and beyond the eastern limits of the map-area. A 5-foot erratic of this conglomerate rests on a spur of the mountain east of Wasi Creek at an elevation of 6,200 feet, higher than any present outcrop of the Uslika formation itself. Nor were boulders of this conglomerate found in any other direction from Conglomerate Mountain.

Armstrong and Tipper (1948) have summarized the evidence that the regional ice movement followed a large arc trending southeast, east, and northeast through north-central British Columbia.

The amount of erosion accomplished by the Cordilleran Ice-sheet in northern British Columbia is believed to be slight (Holland, 1940, p. 20; Watson and Mathews, 1944, p. 37; Armstrong and Tipper, 1948, p. 306). Davis and Mathews (1944) have pointed out that the activity of the ice-cover in the Cordillera was probably at all times influenced to some extent by the underlying topography and that conditions in the mountains probably never developed from a mountain ice-sheet phase into a true continental ice-sheet phase. During the mountain ice-sheet phase, erosion was limited, and was restricted to smoothing and rounding of peaks and ridges, without effectively reducing the relief. The land surface so produced has been almost completely destroyed by later valley and mountain glaciation in the western part of Aiken Lake map-area, and is preserved in only a few places, rarely more than 50 acres in extent, on the crests of ridges (Plates II B, III A). Elsewhere in the map-area, bold, rounded summits and smooth ridges have, apparently, been but little modified since the disappearance of the ice-sheet.

Valley and Mountain Glaciation

The characteristic land forms in Aiken Lake map-area are erosional forms produced by valley and mountain glaciers. The most striking of these forms are the heavily glaciated trunk valleys of the major streams, and through valleys (Davis and Mathews, 1944, p. 408). The east and southeast trending parts of all the large stream valleys are broad, relatively straight or smoothly curving, with low gradients and with a wide floor and concave slopes giving a U-shaped cross-profile (Plate I). These valleys are connected by broad, low passes and straight, through valleys, also with typical concave cross-profile, that divide the terrain into more or less rectangular units. One of the best-developed through valleys extends from the valley of Discovery Creek, south of the map-area, northward across the valleys of Osilinka River and Thane Creek, is followed for a short distance by Vega Creek, and continues across Tenakihi Creek Valley to the major trough of Tutizika and Mesilinka River Valleys. Almost in a direct line with this valley, a through valley extends north from Blackpine Lake to Swannell River Valley, down the north-trending part of Swannell Valley, and across to Ingenika River Valley in line with Pelly Creek Valley. A score of other through valleys may be recognized in the area and although all must have been initiated on older weathered or stream-worn gaps, their development is essentially the work of ice erosion, and the resulting reticulate valley pattern is never developed to an equal extent by stream erosion alone. The through valleys and glaciated trunk valleys would appear to indicate that the area was subjected for a relatively long time to an ice-cover that completely filled the valleys, but whose motion was controlled by the valley walls. This stage of ice occupation was passed through at least twice, and four times if the area was freed of ice during an interglacial period. There is some evidence that a large part of the erosion was done by valley glaciers that preceded the last advance of the ice-sheet.

One of the characteristic depositional features of the trunk valleys and through valleys is the presence of kame terraces, and terrace-like deposits of ice-dammed lakes along the valley walls (Plate III B). These terraces occur at all elevations from near the valley floor to the summits of ridges more than 6,500 feet above sea-level. Some of the higher terraces are found on peaks that must have been merely small nunataks at the time the terraces were deposited.

An unusual feature of many of these terraces is their persistence from the walls of trunk valleys up to the heads of small tributary valleys. It is evident that at the time the terraces were formed many of the smaller valleys did not support alpine glaciers tributary to the main glaciers. Instead, they were apparently filled by a 'backwater' of ice from the trunk valley. The mouths of other tributaries were blocked by the ice in the main valley, and the tributary valleys contained, at times, pro-glacial lakes. Upon the disappearance of ice from the main valley, there was no retreat of ice up these tributary valleys in the form of independent glaciers, to end as small cirque glaciers at the heads of the valleys. Instead, the 'backwater' ice merely stagnated, to leave kame terraces and silt deposits essentially undisturbed. Most of these tributary valleys containing kame terraces or silt deposits, however, show signs of an earlier valley glaciation. The west fork of Orion Creek, for example, is a normal glaciated valley heading in a cirque. Its floor at its lower end contains many kettle-holes and chaotic morainal deposits apparently indicative of stagnation of the last ice fill in that part of the valley. Its upper part contains at least ten levels of well-developed terraces, some of which are continuous around the head of the cirque, at elevations slightly above the cirque floor. It is evident that these terraces were formed after the last glacier in the cirque; in other words, the last ice occupying the valley retreated down, rather than up, the valley.

The kame terraces in the tributary valleys would appear to indicate that some of the tributary valleys had been heavily glaciated and sculptured to more or less their present form before the trunk valleys were nearly or completely filled with ice for the last time. The preservation of the terraces in the valley heads suggests that the last period of extensive ice occupation ceased comparatively abruptly, and that the ice-cover wasted rapidly from large valley glaciers to small cirque glaciers present in only the higher mountains.

Erosion by small cirque glaciers has been active in all of the mountain ranges of the area, although most pronounced in the higher, southwestern part. The degree of cirque development would appear to indicate that the extent of glacier cover has been, for a considerable length of time, only slightly greater than at present. Many of the mountain massifs contain compound cirques, with two, or in some instances three, distinct levels of cirque incision (Plate IV A). The floors of the abandoned cirques are at about 5,600 to 6,000 and 6,300 to 6,800 feet above sea-level respectively, whereas most of the present glaciers head in cirques whose floor level suggests a regional snow-line at about 7,200 feet above sea-level. Many of the glaciers have well-developed, unbreached terminal moraines a short distance down the valley from their snouts, indicating a stage of comparative stability at a time in the relatively recent past when the glaciers were not much larger than at present. From the position of these abandoned moraines and the size and form of the cirques, it is estimated that the amount of ice was about twice as great when the moraines were formed as at present. The rate of retreat of existing glaciers is believed to be relatively slow; those above the regional snow-line are fairly 'healthy', filling their cirques and vigorously eroding their basins, but those below about 7,200 feet are much less active, and are existing mainly on their remaining ice mass (Plate IV B). Part of the glacier at the head of the main branch of Abraham Creek has advanced slightly in recent years and ploughed into its own moraine.

A conspicuous feature of the erosion by mountain glaciers in all parts of the map-area is its asymmetrical character. The difference in the rate of ice and snow wastage on north facing as compared with south facing slopes is sufficient to concentrate the largest and most active glaciers on the north and northeast facing slopes. As a result, ice erosion by mountain glaciers has been almost entirely from the north and northeast. Ridge divides have migrated southward, and the heads of many of the smaller, east or west trending valleys turn southward (e.g., Jim May Creek). The Lay Range is an outstanding example of a range whose divide has migrated to its southwest edge, and whose main mass is deeply dissected by a series of parallel, northeast draining, cirque-headed valleys (*See* Map 1030A). Most of the valleys in the map-area have smooth, regular north or east walls and deeply dissected south or west walls, breached by hanging cirque basins and small hanging valleys. The general landscape has an asymetrical wave-like appearance, with relatively gentle south slopes and precipitous north slopes.

Deposition by Ice

The material carried by the Cordilleran Ice-sheet was probably mainly deposited beyond the map-area. Except for erratic boulders on a few high shoulders and balanced precariously on some of the ridges, it is probable that all deposits of the ice-sheet have been covered, or reworked by, and incorporated into, the deposits of the later valley glaciers.

Morainal deposits are abundant in all parts of the map-area. Those in the valleys are largely intermingled with outwash. Each of the main valleys contains bands of chaotic knob and kettle topography and of recessional moraine. Well-formed recessional moraines, almost continuous across the valley, are found in Osilinka River-Chudelatsa Lake Valley at the south boundary of the map-area; in the west branch of Osilinka River Valley upstream from the river forks; and in Mesilinka River Valley near mile 76, Aiken Lake winter road. The depth of the drift in the valleys varies considerably. In most places the ground moraine from the last ice advance in the larger valleys is between 5 and 10 feet thick. Kettles in non-stratified drift in Osilinka Valley above the forks, however, are 70 feet deep, and the recessional moraine at mile 34, Aiken Lake winter road, reaches to 450 feet above the nearby, slightly entrenched, Osilinka River. At the point where it leaves a through valley and cuts across the mountains northwest of Uslika Lake, Vega Creek has been incised into more than 100 feet of drift.

A large lateral moraine of the trunk glacier in Finlay River Valley completely blocks the through valley of Zygadine Creek and Pelly Lake and, in a single, steep-sided, very narrow ridge 150 feet high, forms the 'barrier' of Barrier Pass.

The medial moraine formed at the junction of the Lay Creek Valley and Mesilinka River Valley ice streams can be traced down Mesilinka Valley for about 5 miles. This moraine, backed by the rock bastion of the hanging floor of Lay Creek Valley projecting into Mesilinka Valley, together with morainal deposits in Mesilinka Valley itself, has dammed Mesilinka River to form Aiken Lake (Plate I).

STREAM ACTION

General Statement

Although the form and detail of most of the landscape features in Aiken Lake map-area are characteristically the result of glacial processes, the basic pattern of valleys and mountain masses, which was available to modification by glaciation, was developed by stream action. The major valley systems in the area, namely: the Ingenika, with tributaries such as Wrede Creek and Cutbank Creek; the Mesilinka, with Lay, Kliyul, and Abraham Creeks and Tutizika River; and the upper Osilinka-Chudelatsa Lake Valley, each shows a normal, balanced, dendritic pattern that cuts indiscriminately across major lithologic and structural contacts. It is evident that these master valley systems are relatively old features, and their pattern has possibly been superimposed from valley systems developed in a rock cover, now removed by erosion, of different geological characteristics from the present cover. Except for the Rocky Mountain Trench, the main valleys do not lie along the transverse or longitudinal faults that traverse the area, nor are they noticeably offset where crossed by these faults. These relations suggest two possibilities, both of which may apply in certain places: (1) the faults along which there has been considerable movement may be mainly older than the cover on which the present drainage pattern originally developed, and the position of the valleys had become established by the time the streams cut down to rocks that had been affected by the faulting; (2) some faults of relatively small displacement may post-date the drainage pattern; if so, they did not appreciably affect the main stream valleys, but may have helped localize tributary streams, and in particular may have been partly instrumental in bringing about late pre-Glacial (and inter-Glacial ?) stream piracy.

Whatever the relation to faulting or to bedrock formations that have since been completely removed by erosion, it appears that by late Tertiary time a normal, dendritic drainage pattern had been established on the present, relatively complex bedrock. In very late Tertiary, immediate pre-Glacial time this pattern seems to have been disrupted to some extent by rejuvenation of some streams, causing significant drainage changes, with the result that the main rivers are not now always to be found in the large valleys. Examples of these changes will be described.

Since the onset of glaciation, stream action has played only a minor part in shaping the land surface, and has been mainly confined to the deposition of glacio-fluvial material. In inter-Glacial time, the process of rejuvenation and piracy, begun prior to glaciation, was resumed in some areas. In other places, disruption of the pre-Glacial drainage pattern by glacial erosion and deposition was followed by deposition of considerable alluvial or lacustrine material. During the periods of ice occupation, channels were cut in drift and in bedrock along the sides of valley glaciers; many of these, floored with boulders derived from rock formations exposed farther upstream, are now preserved high and dry on the mountainside, associated with boulder paths and various kame and pro-glacial lake deposits. The natural outlets of several valleys became blocked with ice, and in some cases with drift, forcing the streams to cut new channels through the valley wall or across mountain spurs.

Subsequent to the retreat of the last large valley glaciers, a cycle of canyon cutting commenced. This cycle is still in its early stages, and has resulted in long gorges at the mouths of several low-lying tributary valleys. The amount of notching of the lips of higher hanging valleys and cirque basins has been negligible.

Drainage Changes

The drainage pattern of a large part of the map-area has been profoundly altered since pre-Glacial times. The suggested histories of two river courses that have undergone relatively large-scale rearrangement are presented here as illustrations of the type of drainage changes that produced the present stream pattern. The interpretations are tentative, and may require modification as more evidence becomes available.

SWANNELL RIVER

The present Swannell River has four distinct parts, separated by three, roughly right-angle bends. The upper reaches lie in a broad, relatively high-level valley that separates Ingenika and Lay Ranges and, now occupied by the headwaters of Wrede Creek, continues west of the map-area. This valley probably drained originally to Mesilinka Valley near the present Blackpine Lake. Some time before the area was occupied by glaciers, this relatively high-level valley was beheaded by a tributary of what is now Wrede Creek; robbed of much of its water supply, the remainder was lowered by stream erosion more slowly than the surrounding valleys, and its drainage was ultimately captured east of Mount Lay by a tributary of Ingenika River, eroding southward along the line of a fault zone in what is now a large through valley. Thus the first right-angle bend was established.

Prolonged and perhaps repeated glaciation enlarged and deepened the through valley east of Mount Lay, and similarly deepened Mesilinka Valley to the south, leaving the Swannell-Mesilinka pass in about its present position. A trunk glacier occupied Ingenika Valley; streams flowing along its side cut a channel across the end of Chase Mountain. Retreat of the glacier in Swannell Valley apparently began while Ingenika Valley was still largely filled with ice. This ice blocked the outlet of Swannell Valley, and diverted meltwater from the Swannell Valley glacier, through the channel across Chase Mountain, to Tomias Lake Valley[1]. The channel was lowered as the ice retreated, and by the time the ice-dam in the old outlet of Swannell Valley had disappeared, the river had, apparently, been established in its present anomalous course, turning abruptly from the relatively broad through valley to the narrow rocky channel north of Chase Mountain, and again at right angles down the Tomias Lake through valley.

At some time an ice-dammed lake occupied the through valley section of Swannell Valley, leaving terraces and delta deposits perched on the mountain slopes as much as 300 feet above the valley floor.

A subsidiary effect of the retreat of the last large valley glaciers was the diversion of the streams on the massif northeast of Blackpine Lake. The glaciers in the northwest trending valleys of these streams, which previously had drained to Swannell River, apparently retreated to small cirque glaciers while stagnant ice still covered the broad Swannell-Mesilinka pass and blocked the lower ends of the valleys. The small streams in these blocked valleys overrode the southwest walls of their respective valleys, and cut channels that have now developed into deep, narrow canyons, by which the streams turn at an acute angle and flow directly to Mesilinka River (*See* Map 1030A).

OSILINKA RIVER

The upper branches of Osilinka River occupy broad valleys that unite to form a large southeast-trending trough near the south border of the map-area. The trough continues beyond the map-area, as the valley of what is now Discovery Creek, to Omineca River Valley. A mile below the mouth of Steele Creek, however, Osilinka River abruptly leaves this trough and flows northward through Uslika Lake and a narrow, tortuous, V-shaped valley north of it, to the mouth of Tenakihi Creek. There the river enters another broad, southeast-trending trough, which it follows beyond the limits of the map-area. The two large southeast-trending troughs are further connected by the broad, glaciated valley of Wasi Lake.

A fragmentary terrace, about 100 feet above present river level, is present on both sides of Osilinka River Valley between the crossing of the Aiken Lake winter road and Uslika Lake. The terrace is in part followed by the winter road, and near the 37 mile-post it is seen to be a mixture of silts and gravels, capped by about 3 feet of till. On the west flank of Conglomerate Mountain, stream gullies cutting through the terrace show it to be mainly crossbedded silt and sand, overlain by a thin layer of till. The terrace appears to be the remnants of the shoreline, marked largely by deltas of small tributary streams, of a lake that filled Uslika Lake Valley to a level about 100 feet higher than the present lake.

It would appear that in pre-Glacial times the upper section of Osilinka River drained directly to Omineca River through the valley of what is now Discovery Creek. This valley seems to have had a tributary in what is

[1] The valley occupied by Tomias Lake, and the part of the present Swannell River that is an extension of Ravenal Creek Valley, appears to have been originally occupied by Mesilinka River. It is probable that Mesilinka River was originally a major tributary of Ingenika River, and that in pre-Glacial times it was captured, at a point about 3 miles east of the map-area, by a tributary of Omineca River eroding northwest along the west side of Butler Range. At the elbow of capture, Mesilinka River changes its course by 120 degrees. Tomias Lake and Carina Lake (east of the map-area), joined by a small 'misfit' stream, lie in the abandoned valley.

now a conspicuous through valley, not well shown on the topographic map, that lies about 2 miles west of Uslika Lake and includes parts of the valleys of Vega Creek and the south branches of Tenakihi Creek, and that joins the upper Osilinka-Discovery Creek trough near Chudelatsa Lake. To the north, the next major pre-Glacial valley was the smooth trough now occupied by the lower section of Osilinka River and the main part of Tenakihi Creek, with tributaries that probably included the large stream, now flowing to Tutizika River, west of Tenakihi Creek. At some earlier date this drainage system may also have included the present Tutizzi Lake Valley, but the available evidence suggests that Tutizika River had established its connection with Mesilinka River considerably prior to the beginning of glaciation.

The mouth of Tenakihi Creek is 315 feet below the level of Osilinka River at the Aiken Lake winter road crossing, which is the lowest point in the section of the upper Osilinka-Discovery Creek trough here under consideration. The amount of glacial overdeepening, or the depth of fill, in this trough and in the Tenakihi Creek-lower Osilinka trough is not known, but it seems probable that the latter was already the lower valley in pre-Glacial time. If this were so, conditions would be favourable for north-flowing tributaries of the Tenakihi Creek-lower Osilinka Valley system to advance headward and capture parts of the upper Osilinka-Discovery Creek system. A stream in what is now Wasi Lake Valley made the greatest headway, and it appears that, whether or not actual capture of the river had been effected, a connection had been established, through this valley, between the valleys of the upper and lower parts of Osilinka River before occupation of the area by ice. A smaller tributary stream eroding southward from what is now the mouth of Tenakihi Creek apparently had not at this time cut through to the part of the valley now occupied by Uslika Lake.

During a period of glaciation prior to the last advance of ice in this area, the trunk glacier in the upper Osilinka-Discovery Creek trough sent a distributary to the lower Osilinka Valley through Wasi Lake Valley, which was smoothed and widened.

During retreat of the ice from this first advance, an extensive recessional moraine was deposited in the upper Osilinka-Discovery Creek trough, from the south end of Conglomerate Mountain to about 5 miles south of the map-area. This moraine dammed Discovery Creek Valley, and to a lesser extent Wasi Lake Valley, forming a lake that, apparently, drained over the moraine dam into Wasi Lake Valley. The shore of this lake is marked by the terraces on Conglomerate Mountain and southwest of Uslika Lake. Vigorous stream erosion was resumed in the postulated inter-Glacial period (or periods), and eventually a stream eroding southward from the present mouth of Tenakihi Creek tapped the moraine-dammed lake in what was then the upper Osilinka-Wasi Lake Valley drainage system. Rapid down-cutting by the north-flowing pirate stream lowered the lake to about its present level (Uslika Lake), and enabled small east-flowing tributaries of the pirate stream, together with independent pirate streams from what is now Tenakihi Creek, to capture segments of the relatively large south-flowing stream in the valley 2 miles west of Uslika

Lake. These small streams became Thane Creek, Vega Creek, and the south branches of Tenakihi Creek. By the onset of the last period of glaciation the drainage pattern was apparently not greatly different from that at present.

The last advance of the Cordilleran Ice-sheet had little large-scale effect on the drainage pattern. The trunk glaciers followed the large troughs, as before, although a proportionately larger amount of the ice drainage from the upper Osilinka Valley appears to have been distributed through Wasi Lake Valley. The south-trending through valley west of Uslika Lake, which had been segmented by Thane, Vega, and Tenakihi Creeks, was again filled by a south-flowing glacier, which deposited till in the gorges of the pirate streams. The newly completed valley northeast of Uslika Lake appears to have been too tortuous, and in too sheltered a position, to carry a vigorously flowing glacier, and here, unique among the larger valleys in the map-area, evidence of glaciation is limited to a slight rounding of the interlocking spurs, and a series of connected and *en échelon* channels cut in the valley walls by streams flowing along the margin of the glacier. Till was spread on the remnant shorelines of the inter-Glacial Uslika Lake. The recessional moraine in the upper Osilinka-Discovery Creek trough was preserved and perhaps added to; near Chudelatsa Lake it now stands 450 feet above the slightly entrenched Osilinka River. But wherever the deposits of the last ice advance have been identified they are thin; and all the evidence is in accord with the conclusion, reached elsewhere (Armstrong, 1949, p. 14), that the last ice-sheet in north-central British Columbia, and the valley glaciers of its dying stages, carried a comparatively light load of debris.

Post-Glacial stream erosion has as yet caused little change in the drainage pattern: a pirate stream from Tutizika River has captured what was formerly the head of the Tenakihi Creek system; down-cutting in the narrow valley north of Uslika Lake has entrenched Osilinka River in a rocky gorge; the level of the outlet of Uslika Lake is being maintained by an alluvial fan at the mouth of Thane Creek; and Wasi Creek appears to be resuming its status as a pirate stream, and is cutting a new channel, in bedrock and moraine, into the upper Osilinka-Discovery Creek trough.

Glacio-fluvial Deposits

Glacio-fluvial material is mixed with moraine in almost all the valleys of the map-area, and presents no special features. Most is an interlayered, highly variable assemblage of silts, sands, and gravels. In the larger valleys this outwash has accumulated to an unknown depth, forming a flat floor that has been cut into by the present streams. The original level of glacio-fluvial fill is preserved in a line of extensive terraces on each side of the more open parts of Ingenika, Mesilinka, and Osilinka River Valleys, below which the present river meanders over a flat floor as much as 150 feet lower (Plates I, II A). The abundance of smaller terraces on the mountain-sides, made at the edge of valley glaciers, has been noted above (Plate III B). In a few places no terraces are recognizable, but a cover of boulder clay and sand blankets the valleys slopes to a depth of as much as 50 feet up to 1,500 feet above the river level (Plate V A). At other places, boulder paths, as much as 100 feet wide and ¼ mile long, lie in incongruous positions on the slopes and valley floors, and attest to the presence of englacial and perhaps superglacial streams.

Laminated silts and clays are widespread; many of them were probably deposited in small, ephemeral, ice-dammed lakes. Most of the silt is interlayered with some gravel. The thickest observed section of apparently lacustrine material consists of about 45 feet of laminated silt, clay, and fine sand, deposited in a basin that covers the junction of the present Tomias Lake, Ravenal Creek, and Swannell River Valleys.

The various minor topographic forms characteristic of glacio-fluvial deposits made in contact with the glaciers themselves, such as eskers, kames, crevasse fillings, etc., may be observed in many places; Tutizika River Valley is outstanding in this respect. Weathering of the thicker drift deposits has developed characteristic hoodoos and furrowed slopes (Plate V A).

FROST ACTION

Felsenmeer and Talus

The most active single weathering agent at present effective in the map-area is undoubtedly frost action. More than one-quarter of the map-area is above timber-line and lacking in tundra vegetation, and is thus exposed to direct mechanical disintegration; and on most of such areas the slopes are sufficiently steep that disintegrated rock material is relatively rapidly removed by gravity. Disintegration of the rock by frost action appears to be the major process in the erosion of peaks and ridges, and is thought to be the main factor in the development of a general accordance of summit levels (Daly, 1912, p. 631).

The efficacy of frost action above timber-line is shown by the highly shattered condition of most of the exposed bedrock, and by the immense amount of angular rock waste, which occurs mainly as felsenmeer and talus. Except in those cirques still occupied by active glaciers, the removal of frost-riven fragments is accomplished by four main processes: (1) wind action is remarkably effective in some places, and has commonly removed all loose surface material less than an inch in diameter. The large snow cornices that line the lee crests of ridges in late spring contain occasional stones weighing up to a pound or more, which must have been blown over the crest of the ridge onto the cornice by strong winter winds. There is evidence that large marker cairns on high ridges, probably loosened and heaved into unstable positions by frost action, have been literally blown down within 3 years after their construction. (2) The more gentle ridge crests and rounded shoulders are covered with a uniform mantle of frost-riven fragments, or felsenmeer, which creeps slowly, more or less en masse, directly down the slopes (Plates II B, V B). The rate of creep is not known, but in many places it is so slow that lichens cover the blocks, and rock contacts can be followed across the felsenmeer in places, displaced downslope but, apparently, relatively little distorted. (3) Where slopes are steeper, or are interrupted by cliffs, the rock fragments descend rapidly and chaotically as rock-fall, rock-slide, or avalanche, to collect on less precipitous lower slopes as talus, nivation ridges, avalanche debris, etc.

Despite the activity on its surface, most of the talus is probably quite stable, except for a small amount of compaction, unless its base is undercut by stream action or glacial erosion. The lower adit on the Granite Basin mineral claims, for example (*See* page 217), has been driven 104 feet through talus blanketing the wall of the cirque. The outer slope of the talus lies at the angle of repose of large fragments, which here as elsewhere (Behre, 1933) attain a uniform maximum angle of about 36 degrees. Rock-fall on this talus was sufficiently abundant that exploration of the mineral deposits was hazardous in places, and open-cuts at the edge of the talus and trails on the talus itself were soon obliterated. The adit had been abandoned for 12 years when visited by the writer, but showed no sign of displacement or distortion by movement of the talus, and its relatively light timbers had not been destroyed. In a few places, especially at the foot of couloirs carrying considerable water, wedging and heaving by interstitial ice may be a factor, along with the accumulation of avalanche debris at the foot of the slope, in producing an irregular, concave profile of the talus. (4) In places, frost-riven fragments have formed 'streams' that are flowing, in a manner that resembles the behaviour of a viscous mass; these 'streams' are the puzzling rock glaciers, some of whose features, and the problems they present, are discussed below.

Of the total amount of disintegrated rock removed from the higher mountains, the proportion removed by wind is not known, but may be considerable, especially with rocks such as gneissic quartzites and schists, which tend to disintegrate to small flaky fragments. The remainder of the material mainly becomes felsenmeer, and creeps slowly down the slopes. About half of the sheets of felsenmeer terminate at cliffs or on oversteepened valley slopes, where the fragments break free and plunge headlong to the lower slopes, there to become talus. A smaller proportion of material travels directly, via rock-fall or avalanche, from the outcrop to talus. The amount of material transported by rock glaciers, over the map-area as a whole, is small; it is probably of about the same order of magnitude as that carried by the normal ice glaciers under present climatic conditions.

Rock Glaciers

Rock glaciers have been observed in all the higher mountain units in Aiken Lake map-area, but are best developed in the region of rugged, alpine topography in the west and southwest parts. They occur at elevations down to 4,900 feet above sea-level. The largest observed rock glacier measured 2,700 feet from its snout to the distinct junction with the talus slope at its head. Most of these bodies head on steep slopes at the angle of repose of talus (36 degrees maximum), but the main body of the rock glacier may flow on much flatter slopes, and tongues have pushed down valleys with an average gradient of as little as 12 degrees. Some rock glaciers, still active, have become detached from the steep slope at their head. All are discrete bodies, with unstable, oversteepened sides and snout, and an upper surface raised a few tens to as much as 200 feet above the surrounding talus. The upper surface commonly has a billowy, rolled appearance (Plate VI A). At least four of the rock glaciers examined are advancing, and are overriding ground that has not received talus or moraine in the recent past.

Many explanations have been put forward to account for the formation and behaviour of rock glaciers (Capps, 1910; Sharpe, 1937; Kesseli, 1941). The variety of hypotheses may in itself be an indication that rock glaciers are the result of a combination of several processes, and that different rock glaciers may have had considerably different origins. In general, rock glaciers appear to have been regarded as either: (1) a phase of normal glaciers in which the rock fragments greatly predominate over interstitial ice, developed during the wasting stages of a glacier's history; these rock glaciers could be considered an end member of a series of rock-and-ice mixtures whose other extreme is represented by glaciers of pure ice; or (2) 'runaway' talus, felsenmeer, or moraine deposits that have accumulated to sufficient size, or have acquired sufficient interstitial lubricant, to render them unstable and capable of flowing more or less as a unit.

Most of the rock glaciers in Aiken Lake map-area do not seem to be merely moraine-choked dying glaciers. The area contains many dying glaciers, in the form of thin sheets of ice, heavily coated with moraine, on cirque floors; as small ice patches hanging in sheltered recesses in the cirque headwall; and as "fan" glaciers at the feet of couloirs, nourished chiefly by avalanche snow and containing many rock fragments. No single instance was noted of a transition between one of these dying glaciers and a rock glacier, and no rock glacier was observed in such a position as to suggest that it developed directly from such a glacier. Rock glaciers appear invariably to head on steep slopes, whose gradient is controlled by the angle of repose of coarse dry talus, whereas most dying ice glaciers containing abundant moraine are found far back in the cirque basins, where the gradient is so low that the thin sheet of ice becomes stagnant long before its embedded rock load becomes concentrated to the proportions found in active rock glaciers. The few ice patches found on steep slopes rarely contain an appreciable rock load. Ice glaciers and rock glaciers are found side by side. A compound cirque at the head of Tenakihi Creek contains two dying glaciers, one of which is nearly buried in talus. A well-developed rock glacier, conspicuously distinct from the surrounding talus, descends beside one of these glaciers and flows along the valley floor below one of the terminal moraines of the existing glacier. There appears to be no tendency for the moraine of the remnant glacier, developed on nearly the same slope and composed of the same type of rock as the rock glacier, to flow.

Most rock glaciers in the map-area are in cirques, because most of the area above timber-line is composed of cirques. The best-developed rock glaciers are not confined to the heads of cirques; and, indeed, are rarely found there. More commonly, the rock glaciers head high on one wall of a cirque or hanging valley, flow down to the valley floor, and turn along it (Plate VI A). Streams in the valley floor pass under the tongues of these rock glaciers. Other rock glaciers are not found in cirques but are flowing down open valley slopes, with south, as well as north and east, exposures. Some active, low-level rock glaciers are found near the bottom of valleys that have been long vacated by ice. In general, the rock glaciers do not head in natural drainage basins or channels, but begin on relatively smooth, steep slopes directly from a ridge crest or beneath a cliff.

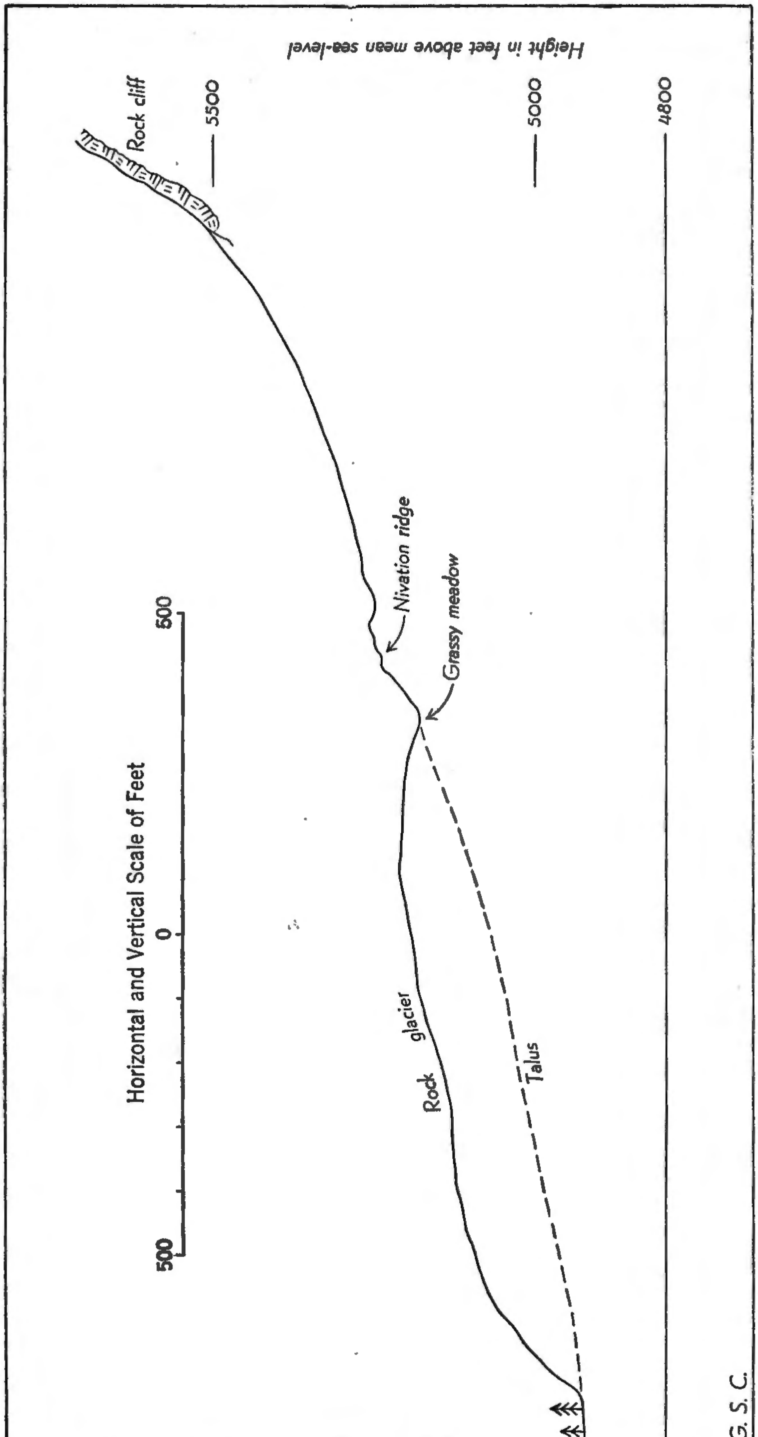

Figure 1. Profile of surface of rock glacier and adjacent talus slopes in Lay Range.

There appears to be no doubt that at least some of the rock glaciers are advancing. Four of the rock glaciers studied are pushing their way into forest or across meadowland. All have the same characteristics: a smooth, lobate ground plan; a very steep, unstable snout; and, perhaps most significant, an almost total lack of 'runaway' boulders ahead of the snout. Trees and bushes have been pushed down and overridden in such a way as to indicate that the rock glacier is advancing along the present ground surface. Some of the rock glaciers are flowing down relatively gentle gradients, and have become detached from the talus behind them. The upper end of one such 'detached' rock glacier is marked by a grassy floored depression 40 feet deep (*See* Figure 1). These features would seem to indicate that the rock glaciers studied cannot have reached their present positions by landslides, piecemeal rock-fall, or by avalanching, but must have flowed slowly, as a more or less plastic mass. The fragments of rock glaciers carry somewhat less lichen than those of the felsenmeer; the lichen coating is commonly best developed on the upstream faces of the blocks, and may be an indication that the surface blocks of a rock glacier rotate backward during its flow. Further evidence of the activity of rock glaciers may lie in the observation that marmots have made their home in talus and felsenmeer in all parts of the map-area, but none was found living in rock glaciers.

Just as there seems to be no evidence of a gradation between debris-loaded ice glaciers and most of the rock glaciers in Aiken Lake map-area, there is in most places an apparent lack of gradation between normal talus or felsenmeer and rock glaciers. One of the most remarkable features of the rock glaciers observed in the area is their conspicuous appearance; a given pile of rock fragments appears to be a rock glacier, or it does not; the distinction between talus, felsenmeer, and moraine is often difficult and in part arbitrary, but the rock glaciers are mostly unique and easily recognized.

The only consistent difference observed between the rock glaciers and the adjacent talus is a coarser size and a much better sorting of fragments on the surface of the rock glacier than in the talus (*See* Figure 2). Careful examination of the bedrock above both talus and rock glaciers in three different parts of the map-area, however, has shown no recognizable difference in the joint pattern or intensity of shattering of the rock that has supplied both deposits. It may be that rock glaciers are sorted during their flow, with coarse fragments jostled to their upper surfaces, rather than that they have developed from more coarsely jointed bedrock.

It seems obvious that the rock glaciers in Aiken Lake map-area are in part normal talus and felsenmeer that has been rendered mobile. The suggestion that the mobility is controlled mainly by interstitial ice is reasonable; the difficulty in explaining rock glaciers lies in accounting for the localization of that control. Rock glaciers, talus, and felsenmeer must all contain interstitial ice, at least in their surface layers, during winter and spring, and a considerable amount probably remains from year to year. The Granite Basin adit showed ice in the talus, 5 to 15 feet from the surface, in July. If it is postulated that rock glaciers contain more interstitial ice than do talus, or felsenmeer, rock glaciers should be best developed in local drainage channels, or should head in snow-catchment basins; there should be examples of all gradations between normal talus or felsenmeer and rock glaciers; and there should be some sign of a meltwater stream issuing from those well-established rock glaciers that are advancing over ground carrying nearby surface streams. These features are not found in the typical rock glaciers examined. It seems more probable that if ice is the main

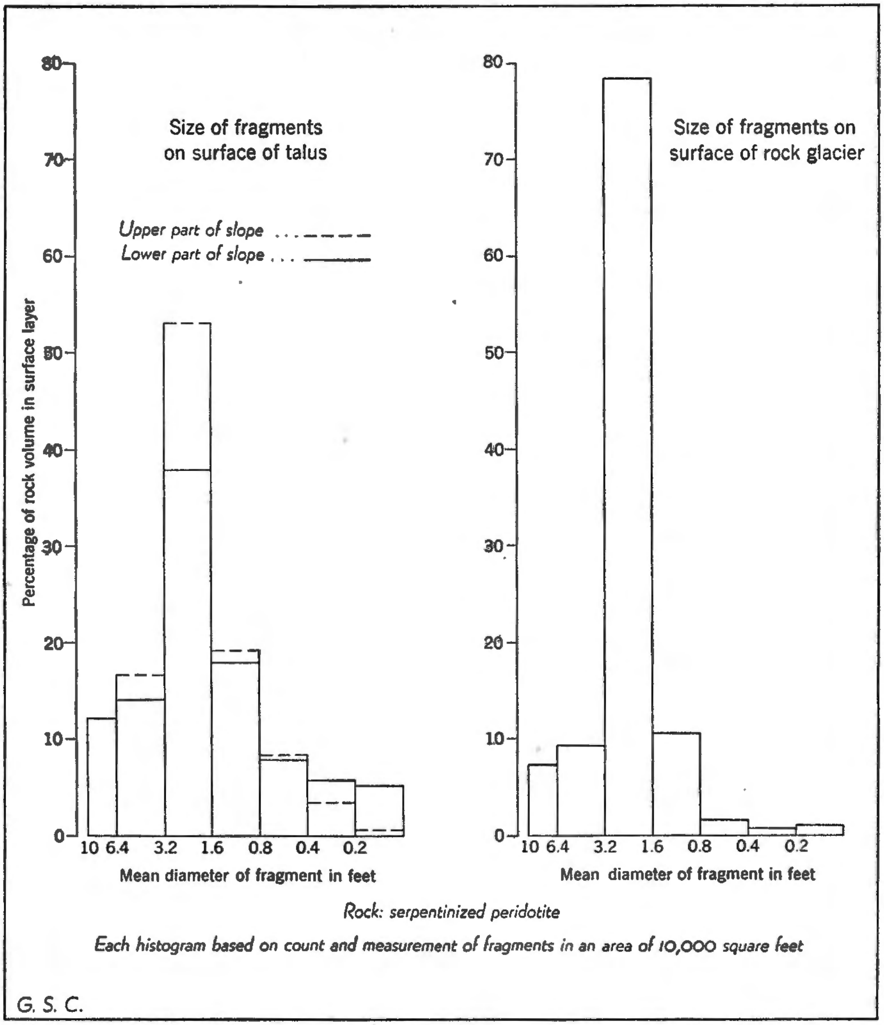

Figure 2. Illustrating size of fragments distributed on the surface of talus and rock glacier in Lay Range.

lubricating medium, there is an optimum condition in which interstitial ice is sufficiently abundant to decrease the internal friction of the mass, but not enough to provide an anchoring matrix. The surrounding talus may perhaps contain either more or less interstitial ice. Certainly some of the dying glaciers, choked with ablation moraine, contain more ice; this ice may act as a binding, rather than a lubricating, medium. It might be that by the time that the ice has dissipated to the extent that the mass is potentially mobile, most of the remnant glaciers and their moraines are marooned on a cirque floor so flat that a rock glacier cannot develop.

No fully satisfactory explanation of the origin or maintenance of the rock glaciers in the Aiken Lake map-area is known to the writer. They are definitely not merely an end phase of present glaciation, although some may develop from dying glaciers. Once started, they appear to be more or less self-perpetuating under present climatic conditions, and develop into unique, flowing bodies, distinct from the surrounding talus and felsenmeer. Some of them are actively advancing at levels far below the present snow-line, and they continue to flow across relatively gentle gradients even when detached from their steep parent slopes. They maintain their identity and peculiar behaviour, which must be due in part to freeze-and-thaw processes in their interstitial ice, over a wide range of temperature, moisture supply, and drainage conditions; for a single rock glacier may have a vertical range of more than 1,000 feet, and may head on a dry ridge, with its lower part occupying the floor of a valley carrying a stream of considerable volume, which is forced to percolate through the rock glacier. Most inexplicable of all, adjacent deposits of talus, composed of the same type of material, apparently shattered to the same extent, and exposed to the same conditions, may not develop rock glaciers; and gradational phases appear to be rare.

Solifluction

The mountains and valleys above timber-line in the less rugged parts of the map-area support tundra vegetation, which ranges from sparse lichens and mosses to a thick mat of grasses and flowering plants growing on many feet of peaty material. Much of the ground is frozen at depth throughout the year, but alternate freezing and thawing of the surface layer has facilitated a slow downslope flow, or solifluction, analogous to the felsenmeer creep of more alpine areas. Where typically developed in the northern and central parts of the map-area, solifluction has resulted in low, bulbous terraces, turf-covered ridges, parallel strips of muskeg ground, and alplands where the surface material has been sorted into polygonal areas or long lanes of coarse boulders, separated by fine material.

CHAPTER IV

GENERAL GEOLOGY

SUMMARY STATEMENT

Consolidated formations within the map-area range in age from Proterozoic to Tertiary, and comprise a great variety of sedimentary, volcanic, metamorphic, and intrusive types.

A thick, folded succession of regionally metamorphosed, Late Proterozoic sedimentary rocks strikes northwest across the central part of the area. This succession, the Tenakihi group[1], is overlain by the Ingenika group, which includes Lower Cambrian beds, and underlies almost all of the northern third of the map-area. Near the eastern border, these rocks have been intruded by granodiorite stocks and further altered by processes of granitization and metamorphism to a sedimentary-igneous complex known as the Wolverine complex.

An assemblage of volcanic and sedimentary rocks of late Palæozoic age occupies a belt 10 to 15 miles wide extending from the southeast corner of the map-area northwest to the head of Lay Creek. Similar rocks outcrop in the extreme southwest corner of the map-area. Parts of this general assemblage accumulated in late Mississippian time; parts are lithologically similar to rocks of the late Palæozoic Asitka group of the adjoining McConnell Creek map-area to the west; other parts may be correlated with rocks that have been classified as belonging to the Cache Creek group of central British Columbia. Some rocks mapped with this assemblage may be Triassic in age, and form part of the Takla group.

The Takla group includes a thick, folded succession of Upper Triassic and Jurassic volcanic and minor sedimentary rocks.

Post-Carboniferous intrusive bodies range in composition from dunite and peridotite to granite and syenite. The most abundant are ultramafic stocks and sills, emplaced probably in Upper Triassic or earlier time, and provisionally correlated with the Trembleur intrusions of areas to the south, and the Omineca intrusions of mainly intermediate and acidic rocks, of late Jurassic or early Cretaceous age.

The Uslika formation is a conglomerate body, probably late Lower Cretaceous in age, which is, apparently, faulted into position in late Palæozoic rocks east and north of Uslika Lake.

Conglomerate of the Upper Cretaceous or Paleocene Sifton formation is found in Finlay River Valley in the northeastern part of the map-area. A body of conglomerate, sandstone, shale, and coal of late Cretaceous to Tertiary, possibly post-Paleocene, age outcrops west of Uslika Lake. Both these rocks and those of the Sifton formation may be parts of the Upper Cretaceous and early Tertiary Sustut group.

Unconsolidated Pleistocene and Recent deposits mantle the lower slopes and valley floors in all parts of the map-area.

[1] *See* footnote, page 33.

TABLE OF FORMATIONS

Era	Period or Epoch	Formation and thickness (feet)	Lithology
Cenozoic	Recent		Stream and glacier deposits, felsenmeer, talus, soil
	Pleistocene		Glacial and glaciofluvial deposits
Mesozoic or Cenozoic	Post-Lower Cretaceous; possibly post-Paleocene	Sustut group	Conglomerate, sandstone, shale, coal
	Relations not known		
	Upper Cretaceous or Paleocene	Sustut group (Sifton formation)	Conglomerate
	Relations not known		
Mesozoic	Lower Cretaceous (Aptian)	Uslika formation 4,200	Conglomerate, minor argillite
	Erosion interval		
	Upper Jurassic or Lower Cretaceous	Omineca intrusions	Granodiorite; adamellite-granite; minor syenite, syenodiorite, pegmatite, aplite, lamprophyre, feldspar porphyry
			Quartz diorite, diorite; minor syenodiorite, meladiorite, amphibolite, andesite
			Hornblendite, appinite, meladiorite, hornblende diorite; biotite pyroxenite; minor feldspathic pyroxenite, uralite amphibolite
	Intrusive contact		
	Upper Triassic and Jurassic	Takla group ±12,000	Andesitic flows and breccias; minor basaltic flows; tuff, agglomerate, shale, conglomerate, limestone

Era	Period or Epoch	Formation and thickness (feet)	Lithology
	Erosion interval		
Palæozoic (?) and Mesozoic	Pre-Lower Jurassic		Feldspar porphyry
	Relations of ultramafic intrusions to Takla group and to pre-Lower Jurassic feldspar porphyry not known		
	Post-Middle Permian, pre-Upper Triassic (?)	Trembleur intrusions ?	Peridotite, dunite, pyroxenite, serpentinite; minor hornblendite and related rocks
Intrusive contact			
Palæozoic	Pennsylvanian (?) and Permian	Cache Creek group +10,000	Limestone; minor argillite, chert, andesite
			Argillite, slate, ribbon chert, greenstone; minor tuff, limestone
			Andesitic and basaltic flows, tuffs, breccias, agglomerate; minor argillite, slate, chert, limestone
	Fault contact; Cache Creek group and post-Lower Cambrian rocks may be in part of same age		
	Post-Lower Cambrian; includes beds of late Mississippian age	+17,000	Tuff, andesitic and basaltic flows; agglomerate, greywacke; sandstone, grit, conglomerate, limestone, chert, slate, argillite
	Unconformity and erosion interval		
p.107	Post-Lower Cambrian, probably pre-Mississippian	Part of Wolverine complex	Granodiorite, leucogranite, alaskite, pegmatite, aplite

Era	Period or Epoch	Formation and thickness (feet)	Lithology
		Intrusive contact	
Palæozoic and possibly Proterozoic	Includes Lower Cambrian beds	Ingenika group +18,000	Quartz-chlorite schist, crystalline limestone, sericite schist quartzite, quartzitic conglomerate, slate, phyllite, chloritoid schist, tourmaline-zoisite schist. Part, included in Wolverine complex, altered to feldspathic quartzite, quartz-mica-feldspar gneiss, migmatite, leucogranite, silicated marble, skarn, and amphibolite
		Possible erosion interval	
Proterozoic	Probably late Proterozoic	Tenakihi group +13,000	Quartz-mica schist, quartzite, quartz-mica-feldspar schist, garnetiferous schist, cyanite, and staurolite schist. Part, included in the Wolverine complex, altered to feldspathic quartzite and quartz-mica-feldspar gneiss
	Post-Lower Cambrian; may be Tertiary		Feldspar porphyry, granophyre, dacite
	Post-Lower Cambrian		Diorite(?) porphyry, altered to chlorite-sericite-carbonate rock; andesite(?)

TENAKIHI GROUP[1]

Name and Distribution

The oldest recognized rocks within Aiken Lake map-area consist of interbedded quartz-mica schists, micaceous quartzites, and quartzites exposed in an irregular belt 4 to 8 miles wide extending diagonally across

[1] This group was first named the Ruby group in the preliminary account of Aiken Lake map-area by Armstrong and Roots (1948), but it has seemed best, in the interests of conventional formational nomenclature, to rename it after the range of mountains in which it is typically exposed.

the map-area from Osilinka River on the east to Wrede Creek on the west. Similar rocks outcrop southeast of Ingenika Cone. Rocks of this map-unit are characteristically exposed in the Tenakihi Range around the Ruby group of mineral claims on Jim May Creek, and the unit has, accordingly, been named the Tenakihi group.

The Tenakihi group is exposed over an area of about 360 square miles in Aiken Lake map-area, mainly on the crests of major northwest trending anticlinoria. In the Tenakihi Range, a curving, northwest plunging asymmetrical anticlinal structure, with steeper dips on the southwest limb, exposes Tenakihi group rocks in a band 4 to 5 miles wide that strikes nearly west at the east border of the map-area, and swings to north 30 degrees west southeast of the mouth of Tutizika River. In this area the overlying Ingenika group rocks rest with apparent structural conformity on the north limb of the anticlinorium of Tenakihi group rocks. On the south side of the anticlinorium the Ingenika group is in faulted contact with the Tenakihi group.

Between Mesilinka and Ingenika Rivers, a major asymmetrical anticlinorium, with steeper dips on the southwest limb, exposes Tenakihi group rocks in a belt 3 to 8 miles wide extending north 35 degrees west from near the east border of the map-area to Swannell River. At Swannell River Valley the crest of the anticlinorium is apparently offset about 8 miles to the south, from which point it continues along the north side of the valley to Wrede Creek on an average strike of north 55 degrees west.

Southeast of Ingenika Cone, rocks assigned to the Tenakihi group are exposed in the crest of a large anticline that has been overturned to the southwest. These exposures occupy about 12 square miles in Aiken Lake map-area, and are only the northwestern part of an extensive area of similar rocks in the Butler Range to the east of the map-area.

Lithology

General Statement

The most abundant rock of the Tenakihi group is a golden brown to grey, relatively coarse-grained quartz-mica schist, consisting chiefly of quartz and biotite with more or less plentiful muscovite and minor feldspar. Other members of the group represent all gradations from quartz-mica schist through micaceous quartzite to relatively pure quartzite. Garnetiferous and strongly feldspathic schists form distinctive but relatively minor parts of the assemblage.

The Tenakihi group rocks have a distinctly layered appearance. In many places adjacent layers exhibit marked differences in mineralogical content and texture, but individual layers can be traced many thousands of feet with no appreciable variation in composition or texture. All the rocks have been metamorphosed, but there seems little reason to doubt that the differences between individual layers represent differences in mineral or chemical composition of the original rocks, and that these rocks represent metamorphosed sedimentary strata, whose original bedding corresponds to the layering of the present schist and quartzite.

The Tenakihi group rocks are characterized throughout Aiken Lake map-area by a relatively uniform chemical composition, which, together with the even degree of metamorphism to which the rocks have been subjected, has resulted in a simple mineralogical composition of the rocks, and a limited range of rock textures and micro-structures. Metamorphism has progressed so far that the original differences between successive beds and groups of beds are preserved only by the different proportions of the principal minerals, namely, quartz, the micas, feldspar, and in places garnet and kyanite; the few accessory minerals occur in almost all beds of suitable metamorphic grade.

Quartz is the predominant mineral in at least 80 per cent of the Tenakihi rocks. Except for a few of the larger grains, which may be detrital, it is entirely recrystallized, or crystalloblastic, with a certain degree of shape orientation parallel with the schistosity of the rock. In the lower beds of the group the quartz is mainly clear and unstrained, whereas in the higher beds it commonly shows wavy extinction due to strain. Many of the purer quartzites have a well-developed mortar structure, with large, strained grains rimmed by a profusion of smaller grains, suggesting that there has been deformation and slight recrystallization of an already recrystallized quartzite. The feldspar, which composes up to 35 per cent of individual specimens, is nearly all authigenic, commonly occurring in irregular, skeletal grains interstitial to, and including, oriented grains of quartz and the micas. Most of the feldspar grains whose optical properties could be accurately determined are oligoclase or andesine, but some albite and orthoclase have been recognized. Biotite is the predominant mica, and is the mineral mainly responsible for the fissile character and banded appearance of the Tenakihi group rocks. Viewed in transmitted light, the biotite is of both brown and green varieties, with the latter type restricted to the stratigraphically higher beds of the group. The brown biotite occurs in two distinct forms, commonly present in the same specimen. One form consists of thin, lath-like flakes, commonly straight, or, if bent, splintered; these grains show the most perfect parallel orientation of any mineral in the rock. The other type of biotite is typically crystalloblastic, poikilitic, or skeletal, surrounding grains of almost all the other minerals in the rock, including the lath-like form of biotite. Muscovite, as distinct flakes, is an important mineral only in the lower half of the Tenakihi group stratigraphic sequence. In the very uppermost beds it reappears as sericite. Chlorite occurs only in the highest beds, associated with green biotite and garnet.

Garnets are the most abundant and conspicuous porphyroblasts in the Tenakihi group. They occur throughout the entire upper 6,000 feet of the section, and in a few beds as much as 3,000 feet stratigraphically lower. The garnets range in abundance from a few minute crystals in relatively pure quartzites to nearly half the rock volume in strongly porphyroblastic garnet-mica schists. Individual crystals range in size up to 2½ centimetres in diameter, though most are 1 to 3 mm., and in form from attenuated networks and irregular patches to symmetrical, dodecahedral crystals. Most crystals are crowded with inclusions of quartz, chlorite, biotite, muscovite, tourmaline, and magnetite; in many the inclusions are arranged in a spiral or S-shaped pattern, probably indicating a rotation of grains during growth. The composition of the garnets appears relatively independent of the position in the stratigraphic section or of the lithology of the bed in which the grains occur; those grains tested are almandine, with about 85 per cent of the almandite molecule. Kyanite forms porphyroblasts in a fairly definite stratigraphic range, extending from about 7,000 to 10,000 feet stratigraphically above the lowest beds of the section of Tenakihi group rocks in the Tenakihi Range, although a few crystals occur as low as 3,000 feet above the lowest beds. The kyanite is typically developed in medium- to coarse-grained, feldspathic quartz-muscovite-biotite schists, where it forms porphyroblasts as much as 5 centimetres long and constitutes up to 10 per cent of the rock volume. Staurolite was recognized only in the Tenakihi Range, where it forms euhedral porphyroblasts up to 2 centimetres long, in favourable beds, over a stratigraphic range of about 1,000 feet near the lowest levels at which kyanite is abundant. Among the minor minerals, sillimanite is confined to the stratigraphically lowest beds, where it forms small needle-like crystals that traverse biotite and quartz grain boundaries and afford evidence that these beds have suffered high-grade metamorphic recrystallization. Other accessory minerals include tourmaline, apatite, zircon, magnetite, sphene, rutile, and calcite.

Rocks in the Tenakihi Range

The anticlinorium in the Tenakihi Range, trending west and northwest on both sides of Jim May Creek Valley, exposes about 13,000 feet of conformable quartzites, gneisses, and schists. The stratigraphically lowest beds in this section are medium-grained, light grey to buff-coloured, slightly rusty quartzite, typically in beds 1 foot to 3 feet thick, separated by bands of quartz-mica schist that range in thickness from a fraction of an inch to a foot or more. In places the schist bands are grouped together and are locally more abundant than the quartzite. All of the quartzite examined in these beds is micaceous and slightly schistose; typical specimens contain 10 to 25 per cent mica, although all gradations to quartz-mica schists containing more than 50 per cent mica can be found. In most of these quartzites, biotite is about three times as abundant as muscovite; the two minerals are intimately mixed, usually uniformly distributed, and are well oriented, imparting a marked schistosity to the quartzite. In the lowest 6,500 feet of the exposed section, minerals other than quartz, biotite, and muscovite, large enough to be observed in hand specimen, are rare, and are mainly feldspar and a few crystalloblasts of cyanite and tourmaline. A little chlorite, apparently formed by alteration of the biotite, may be observed in some specimens, and nearly all contain rusty specks produced by the decomposition of iron-bearing minerals.

In places the micaceous quartzite has a gneissose aspect, with lens-like patches of quartz-rich or mica-rich material, usually not more than 6 inches long and ½ inch thick, scattered through otherwise uniform rock. Most of the schist has an augen-like appearance produced by lenticular aggregates of quartz grains, usually about ⅛ inch in diameter by ½ inch long, scattered 2 to 3 inches apart. Some change of texture and rearrangement of material was observed along the strike of individual beds in this area, and at one place near the col at the head of Jim May Creek a mica schist with numerous lenticular aggregates of quartz grains has been followed along the bedding through a banded quartz-mica schist, with thin continuous partings of quartzite, into schistose quartzite within a distance of 2,000 feet. For the most part, however, the beds appear to be quite uniform in texture and mineralogical composition for distances of a mile or more.

About 6,500 feet stratigraphically above the lowest exposed beds, both the schists and the quartzites become markedly porphyroblastic, and this character is maintained throughout almost the entire upper part of the Tenakihi group section. Garnet is by far the most common porphyroblast developed in these rocks, and occurs mainly as rough, equidimensional, rusty brown to reddish grains $\frac{1}{16}$ to $\frac{1}{2}$ inch in diameter, being smallest in the fine-grained schistose quartzites and largest in coarse, crumpled mica schist. In several places the garnets show good euhedral crystal form, but all those observed had rough exteriors and contained flakes of sericite or chlorite. In favourable beds, up to 10 feet thick, garnets were observed to comprise as much as one-half of the rock volume.

About 600 feet stratigraphically above the lowest level at which garnets were observed, porphyroblasts of kyanite become abundant. These have a stratigraphic range of about 3,100 feet, within which they were found to occur in all beds carefully examined. Porphyroblasts of kyanite were found to be more plentiful than those of garnet in only a few groups of beds, rarely more than 50 feet thick. In these beds the kyanite occurs as dark brown-grey to blue-grey, euhedral prismatic crystals, with very rough exteriors, up to 3 inches in length. The larger crystals are in many cases curved, and, although lying in the plane of schistosity, are in general not oriented in any obvious relation to the regional lineation.

Near the lower part of the stratigraphic interval in which kyanite porphyroblasts are conspicuous, brownish prismatic crystals of staurolite are found in the schistose porphyroblastic biotite-muscovite quartzite. The staurolite porphyroblasts were not recognized in the field as a mineral distinct from kyanite, and their relative abundance and stratigraphic distribution is not exactly known. From their occurrence in the samples collected it would appear that the staurolite porphyroblasts are mainly less than $\frac{1}{4}$ inch in length, and are much less abundant than the garnet or kyanite porphyroblasts in the same rocks. Kyanite apparently persists to much higher stratigraphic levels than does staurolite.

At about the highest stratigraphic level at which kyanite porphyroblasts were identified (about 10,000 feet stratigraphically above the base of the exposed section in the Tenakihi Range), a slightly feldspathic, garnetiferous, schistose quartzite contains clusters of epidote up to $\frac{1}{8}$ inch in diameter.

The uppermost 3,000 feet of the Tenakihi group section exposed in the Tenakihi Range show a general lessening of grain size compared with stratigraphically lower beds, and a predominant greenish colour due to the presence of green biotite and, in places, chlorite.

Rocks in the Chase Mountain Area

In that part of the map-area between Mesilinka River and the middle and lower reaches of Swannell River, west of Tomias Lake, a stratigraphic thickness of about 8,000 feet of Tenakihi group rocks is exposed in a large anticline that extends through the summit of Chase Mountain. The strata of the southern part of this region have been relatively complexly deformed, and have suffered more intense metamorphism than most of the Tenakihi group rocks. Stratigraphic and lithological correlation with the 'normal' Tenakihi group is difficult in detail, although an over-all correspondence of beds and structures is obvious, and in favourable locations it is possible to trace a group of beds from the typical Tenakihi group exposures southeast of Chase Mountain southward into more highly metamorphosed rocks. These latter rocks are considered to be a typical part of the "Wolverine complex" and are subsequently described under that heading in this report. The 'normal' Tenakihi group rocks exposed in the major anticline passing through Chase Mountain are very similar to those in Tenakihi Range, and consist of a succession of interbedded quartzite, micaceous quartzite, and quartz-muscovite-biotite schist, in part feldspathic and in places porphyroblastic. The lowest beds are in general coarser in grain, and in places have developed a crude 'augen' gneissic structure, with lenticular clots of quartz and quartz and feldspar. In general, it appears that the Tenakihi group rocks in this area contain less feldspar than those in Tenakihi Range.

At two places on the Chase Mountain massif, beds that appear to have been originally coarse conglomerates were observed. One of these is on the west side of Ravenal Creek Valley, almost due east of the summit of Chase Mountain, where rounded, pale grey to salmon-coloured, coarse-grained boulders up to 8 inches in diameter, composed of quartz, plagioclase, and potash feldspar, amphibole now largely altered to chlorite, and biotite, are embedded in an impure, foliated, micaceous quartzite. The boulders themselves are all more or less foliated; but the planes of foliation of individual boulders bear no relation to one another, or to the general plane of foliation of the matrix. They have the general appearance of water-worn fragments of a gneissic igneous rock of acidic to intermediate composition. The contacts of the boulders against the groundmass are for the most part sharp, in places outlined by a layer of biotite flakes surrounded by a layer containing no biotite, and the foliation of the groundmass passes around the boulders. This bed of apparent conglomerate is 25 feet thick, and lies very near the crest of the anticlinal structure passing through Chase Mountain. An estimated 8,000 feet of Tenakihi group rocks overlie the bed. No rocks in the Chase Mountain area were determined to be stratigraphically lower than this horizon.

In a col about 6 miles due south of the summit of Chase Mountain, a 20-foot bed of grey, sugary, micaceous quartzite contains rounded to subangular masses up to 1½ inches long of light grey and buff-coloured quartz and feldspar. Most of the fragments consist of recrystallized, intimately intergrown grains of colourless quartz and light grey to buff feldspar, with scattered feldspar crystals up to ¼ inch long. The matrix is medium grained, markedly granular, slightly foliated, and consists almost entirely of colourless quartz and black, fresh-looking biotite. The fragments themselves are not foliated, but show a general alinement parallel with the foliation of the matrix. They comprise about 40 per cent of the rock volume of the lowest exposure of this conglomerate, and are progressively less abundant upwards; in a stratigraphic interval of about 20 feet the rock grades into normal gneissic micaceous quartzite. The immediately underlying rocks are not exposed, but beds about 100 feet lower are normal garnetiferous quartz-biotite and quartz-biotite-muscovite schists, with the same general structural orientation. The stratigraphic position of this conglomerate bed within the Tenakihi group is difficult to place. On the basis of the present structural interpretation, it lies an estimated 6,500 feet above the lowest exposed beds in the crest of the main anticline, and about 4,000 feet below the contact with the overlying Ingenika group, but many minor folds render stratigraphic correlation and estimates of thickness of doubtful value.

Near the top of the Tenakihi group section exposed in the Chase Mountain area, beds of light grey to nearly white quartzite, 1 foot to 5 feet thick, are conspicuous. They are compact, fine-grained, very slightly schistose, and remarkably pure—only a few flakes of muscovite or biotite, and minute grains of garnet, can be observed in hand specimens.

Rocks in the Ingenika Range

The arch of Tenakihi group strata trending northwest from Mount Lay to Wrede Creek shows a sequence about 7,000 feet thick, in all general respects similar to that exposed at the northwestern end of the Chase Mountain massif. Mount Lay itself is part of a fault block about 3 by 3 miles, whose structural relation to the rest of the Tenakihi group is not exactly known, but which is believed to have been raised a stratigraphic distance of about 2,000 feet relative to the rocks to the northwest. The stratigraphically lowest beds of this block, which lie possibly 9,000 feet below the contact with the overlying Ingenika group, consist of dark grey, schistose, micaceous quartzite, and silver-brown quartz-muscovite-biotite schist. The rock is well bedded, with the schistose foliation parallel with the bedding planes, and breaks into thin, strong plates that are very resistant to mechanical weathering, so that typical outcrops at higher elevations in the Mount Lay area consist of narrow ridges and vertical cliffs with thin, overhanging ledges supporting large accumulations of talus.

About 800 feet stratigraphically above the lowest exposed beds of the Mount Lay block, relatively pure quartzite, in beds 1 foot to 10 feet thick, form a dominant part of the assemblage, and in the succeeding 2,500 feet, beds of pale buff to grey, very slightly micaceous quartzite comprise about 60 per cent of the rock volume. The overlying 1,000 feet of beds consist of about equal parts of crumpled muscovite-biotite schist, platy quartz-biotite schist, and compact to sugary, slightly micaceous quartzite. What is believed to be this same sequence of beds is exposed in Swannell River Valley 2½ miles due west of the summit of Mount Lay; and from this exposure the Tenakihi group section can be traced stratigraphically upward for more than 4,000 feet on almost continuous outcrop to the highest beds of the group. The entire section shows little over-all compositional or textural variation, and is composed of different proportions of quartzite, quartz-mica schist, and mica schist, all of which are in part garnetiferous. Two beds of cream-coloured, coarsely crystalline, siliceous limestone, each less than 20 feet thick, outcropping on the crest of a ridge 3 miles northeast of the summit of Mount Lay, constitute the only known exceptions in the general sequence of quartzite and schist. From the stratigraphically lowest beds observed west of the Mount Lay fault block, the general sequence in successively higher beds is as noted in the detailed section, page 46.

Rocks in the Butler Range

The Tenakihi group rocks exposed in the north end of the Butler Range, south of Ingenika Cone at the extreme east edge of Aiken Lake map-area, consist of at least 3,000 feet of interbedded golden brown to silver quartz-muscovite schist, grey to rusty quartz-muscovite-biotite schist and schistose quartzite, in part garnetiferous, micaceous to nearly pure granular quartzite, and quartz-biotite-feldspar gneiss. These rocks represent only the northern part of a large area of similar rocks exposed in the Butler Range to the east of the map-area. In large part they have a distinctive character due to a more intense metamorphism and alteration than has affected most of the rocks of the Tenakihi group, and thus they are a part of the "Wolverine complex" as defined in this report.

Structural Relations

The characteristic occurrence of Tenakihi group rocks in the cores of large anticlinal structures has been noted. Within these major structures, are structures of lesser size varying to minute crenulations and lineations.

LINEATION

As a whole, the Tenakihi group consists of competent strata, and the interbedded, strong, micaceous quartzites and tough, but relatively flexible, quartz-mica schists have facilitated the development of smooth, regular, asymmetric folds, without noticeable internal fractures, and very few dragfolds. Local deformation, within individual beds or groups of beds, is, with a few exceptions, mild in these rocks; and it would seem that even the smallest structural features show a regional pattern. The most remarkably uniform of these features is the linear structure developed to a greater or lesser extent in almost all the Tenakihi group rocks in the map-area. This lineation is shown by a parallel orientation of lath-like or splintery grains of mica; by elongated grains or clusters of grains of quartz; by 'tails' of earthy limonitic material strung out behind garnet porphyroblasts, or in places by strings of the porphyroblasts themselves; but it is most strikingly manifested in the crumpling, crenulation, and wrinkling to which the micaceous schists and mica-rich partings in the quartzites have been subjected. These crenulations vary in size from minute wrinkles, only clearly visible with the aid of a hand lens, characteristic of the fine-grained schists and phyllites, to small drag-folds 2 to 4 inches from crest to crest, typically found in coarse, flaky, muscovite schist.

Every carefully studied outcrop of Tenakihi group rocks in the map-area was found to possess lineation to some degree; in a few places in the Tenakihi Range two distinct directions of lineation could be discerned. The predominant linear direction is singularly uniform over the entire exposed area of Tenakihi rocks; a strike of north 20 to 50 degrees west is maintained with extraordinary fidelity without regard to the present folded attitudes of the rocks. The plunge of the lineation varies somewhat in consequence of the deformed schistosity and bedding planes, so that in most places the lineation lies within the foliation planes of the rock. The range of plunge of the lineation, however, is not as great as the change in attitude of the bedding and schistosity surfaces; upon encountering a sharp fold the elongated mineral grains elsewhere lying in the plane of foliation may be seen to penetrate that plane and so maintain approximately the same absolute orientation. The minor crenulations may be observed at such a point to change from long, parallel, wave-like folds in the schistosity surface to an anastomosing pattern, then to short elliptical cups and domes, and, in extreme cases, to small crescentic corrugations, elongated more or less perpendicular to the general direction of lineation. Such relationships may be seen south of Jim May Creek and east of the head of Cutbank Creek.

Several outcrops in the Tenakihi Range show a second, much less distinct lineation. Where best observed the second lineation is approximately parallel with the fold axes of the bedding (and schistosity), independent of the direction of the more widespread lineation exhibited by corrugations lying in the foliation plane at an oblique angle to the fold axes.

SCHISTOSITY

All of the Tenakihi group rocks, except the purest quartzites, have a schistose or gneissic structure determined by the parallel orientation of mica and chlorite grains. The planes of schistosity or gneissosity are deformed into the small 'lineation' crumples previously described, but in any area larger than a few square inches, they are nearly always found to lie in large gentle folds almost exactly coinciding with bedding structures. Over many large areas, schistosity and bedding appear to be rigorously parallel; and in other areas the maximum angular difference between them is less than 5 degrees. In areas of relatively highly deformed rocks it has been observed that the schistosity is commonly less sharply contorted than the bedding. The general relations are such that the schistosity planes are parallel or very nearly parallel with the major bedding structures, but cut across the bedding of the smaller folds, although exceptions to this generalization have been noted. The plane of schistosity thus reflects the large-scale structure of the anticlinoria in which the Tenakihi group rocks characteristically occur, but in many places bears no relation to minor contortions of bedding.

GENERAL FOLD STRUCTURES

The structures of individual beds in the Tenakihi group are dominated by the major northwest trending anticlinoria already mentioned, and minor folds can be recognized as local variations from this general pattern. The axis of each anticlinorium is curved and undulating, ranging from flat-lying to a northwest plunge of as much as 15 degrees; and the axial plane dips 55 to 70 degrees northeast. The individual folds forming the anticlinoria are for the most part open and gentle, and range from 500 feet to a mile or more from crest to crest. The anticlinorium on Chase Mountain and the area of Tenakihi group rocks in the north end of the Butler Range are believed to be connected by the overturned synclinorium in Tomias Lake Valley. The synclinorium appears to be essentially isoclinal between limbs about 7 miles apart. If this interpretation is correct, all the Tenakihi group rocks of the Butler Range in the map-area are overturned.

ABNORMAL FOLD STRUCTURES

In addition to the relatively regular, wave-like undulations forming the major, compound anticlines or anticlinoria of the Tenakihi group, there are some fold structures in which the attitude of the bedding deviates by as much as 30 degrees from the general trend. These take the form of elongate noses or elliptical dome- and basin-shaped structures 50 to 2,000 feet in greatest dimension. They are most common southeast of Chase Mountain, in the area of Tenakihi group rocks included in the Wolverine complex, where in places they obscure the general pattern of the anticlinorium. Elsewhere these flexures are not so abundant, and their relation

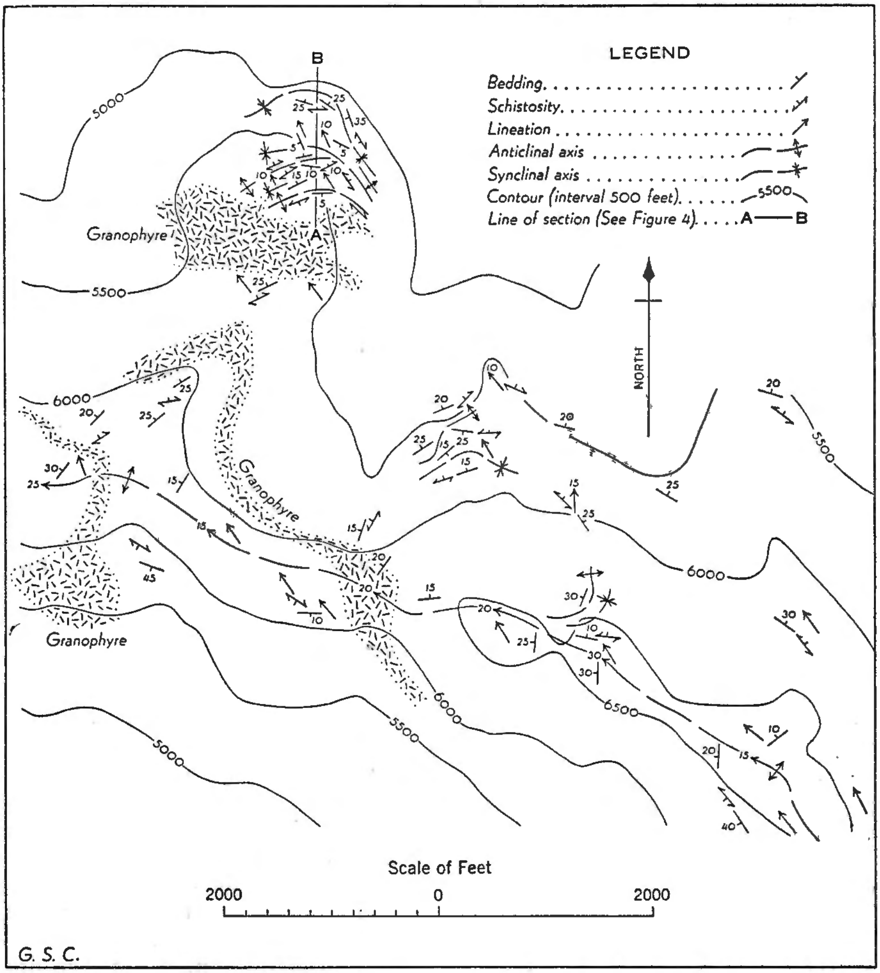

Figure 3. Illustrating structures of Tenakihi group rocks on ridge south of Jim May Creek.

to the anticlinorial structure is more obvious. There appears to be a definite tendency for these minor structures to be alined in northwest-trending groups. The long axis of each individual minor structure does not necessarily parallel the trend of the group in which it lies. One of the best examples of such a 'train' of minor structures lies in the Tenakihi

Range, where a series of small domes and noses, superimposed on the general anticlinorium, can be traced north 35 degrees west for about 4½ miles from a point southeast of the main anticlinal axis, across that axis, which there strikes north 65 degrees west, and across the valley of Jim May Creek to the Ruby mineral deposit. Figures 3 and 4 show a part of this 'train' of flexures, and also illustrate the general relation between lineation, schistosity, and bedding in a relatively highly deformed area of Tenakihi group rocks. Another well-developed 'train' of minor flexures is exposed east of Orion Creek; it is at least 3 miles long, strikes north 20 degrees west, and also crosses the crest of the anticlinorium, which at this point strikes north 50 degrees west. The general structures of the Tenakihi group rocks are reflected in the topography, and these 'trains' are in places conspicuous as lines of minor peaks, and systems of buttresses and couloirs oblique to the general pattern of the terrain.

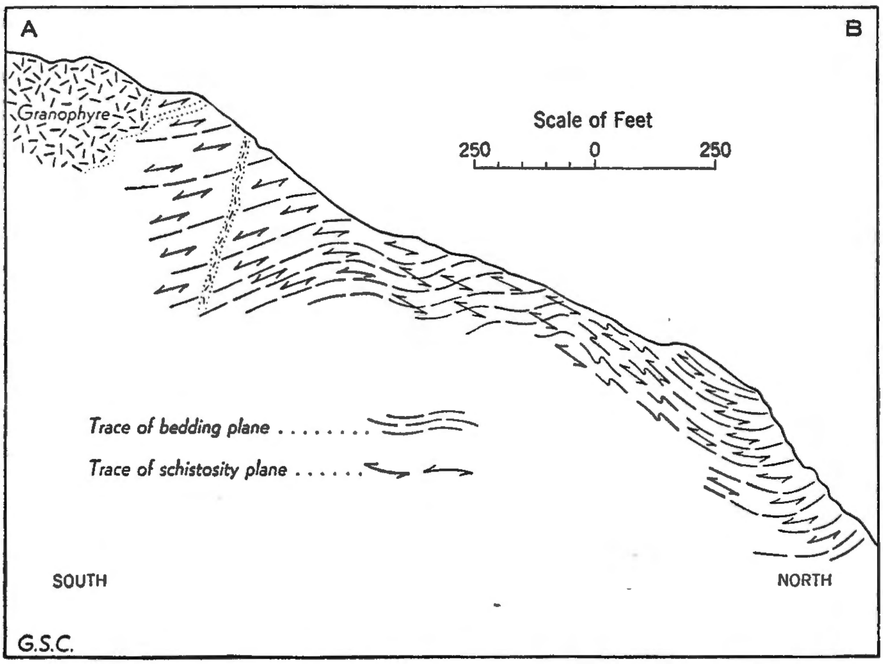

Figure 4. Structure-section along line A-B, Figure 3, in Tenakihi group rocks.

RELATION BETWEEN LINEATION, SCHISTOSITY, AND BEDDING

An instructive example of the relations between lineation, schistosity, and bedding in the Tenakihi group rocks was found in the Tenakihi Range on the crest of the ridge immediately south of the headwaters of Jim May Creek. At this place (*See* Figure 3) the crest of the ridge almost coincides with the crest of the anticlinorium, here marked by a regular, northwest-plunging anticline, locally free from minor contortions. At a point just north of the crest of the anticline, approximately 5,000 feet stratigraphically above the lowest exposed beds in this part of the map-area, a fragment of quartzite about 6 by 2 inches was found embedded in medium-grained, foliated, moderately crumpled quartz-biotite-muscovite schist. The bedding, as shown by layers of quartzite and schist, here strikes north 70 degrees west and dips 15 degrees northeast; the schistosity is, as closely as could be measured, parallel with the bedding. A well-developed lineation in the form of parallel, wave-like corrugations $\frac{1}{4}$ to 1 inch from crest to crest and up to $\frac{1}{8}$ inch deep lies in the plane of foliation and plunges northwest at an angle of 35 to 40 degrees as measured in the plane of foliation; the true orientation of the lineation can, thus, be calculated to be: strike, north 35 degrees west; plunge, 8 degrees northwest. In addition, the schist shows a less distinct lineation, which can be recognized only on the surface of the plane of foliation, caused by a subparallel arrangement of individual flakes and groups of flakes of biotite. Assuming it to lie in the plane of the foliation, this second lineation is nearly horizontal and strikes north 60 degrees west, or parallel with the axis of the anticline as exposed nearby on the crest of the ridge. The quartzite inclusion has been so impressed in the plane of foliation that it accurately follows the corrugations of the major direction of lineation in the schist. In addition, it has been sharply deformed into a series of small drag-folds about $\frac{1}{4}$ inch wide parallel with the second, less distinct direction of lineation. These drag-folds are asymmetrical, with their axial planes dipping nearly vertically, that is, obliquely into the plane of foliation and more or less parallel with the axial plane of the anticline. The small drag-folds are apparently unchanged in form in passing from crest to crest of the corrugations of the major lineation in the schist; it does not seem probable that the quartzite could have been a closely drag-folded rock at the time of its inclusion in the sediment from which the schist was formed, for in that case the drag-folds would be expected to have been at least in part destroyed or modified by the later crumpling of the schist. It seems logical, therefore, to assume that the small folds were developed after the quartzite inclusion had reached its present position. In that case, they must have been formed by forces acting in approximately the same direction as those that produced the anticline and thus are presumably related to the formation of the anticline. If this is so, it seems to follow that the obscure lineation of biotite flakes, also parallel with the small folds in the quartzite and with the axis of the anticline, is also related to the formation of the anticline. This type of lineation, parallel with the fold axis, is commonly ascribed to a rotation of elongate grains produced by slippage of rock surfaces during folding (Cloos, 1946, p. 6). The best-developed lineation in the schists, that evidenced by the predominant corrugations, is apparently not directly connected with the second direction of lineation, nor with the present folded structure of the planes of schistosity and bedding. It has already been noted that this lineation is uniform over the entire region, and that to a large extent it is independent of the deformed bedding and schistosity surfaces.

Stratigraphy and Thickness

A stratigraphic section of the type area of Tenakihi group rocks, extending from the crest of the anticline at the head of Jim May Creek northward toward Mesilinka River Valley, is given below, and is followed by a section showing the sequence of beds west of Mount Lay.

Very little crumpling, or swelling and pinching of beds, is found in the Tenakihi group rocks, probably because of their strong, competent nature and the regular, large-scale folding to which most parts of the group have been subjected. There is probably some thickening, particularly of the schist beds, at the crest of the anticlinorium, although the change in thickness in beds between crest and limbs of the large folds is imperceptible in the field; consequently, the thickness of the lowermost beds of the measured sections may be slightly too great.

DETAILED SECTIONS

Generalized Section in the Tenakihi Range

The Tenakihi group rocks in Tenakihi Range may be conveniently divided into conformable units, of distinctive lithology or repetitions of lithological sequence, whose thickness, measured in the field, ranges from 60 to more than 1,500 feet. The boundaries between the units are in part arbitrary, and there may be, in some instances, as much variation within a unit as there is from unit to unit. Microscopic study of representative specimens from each unit shows a relatively regular change in the kind and abundance of porphyroblasts, and in the composition of the groundmass, with successively higher stratigraphic units.

Overlain by Ingenika group (*See* stratigraphic section page 75)

Top of Section	Thickness Feet
Quartz-biotite-muscovite-chlorite schist, silver-green, crumpled, sparingly garnetiferous; interbedded with and grading to quartzite, sugary, micaaceous; beds ½ foot to 3 feet thick; includes a total of 300 feet not exposed	1,320
Quartz-biotite-muscovite-chlorite schist, smooth, platy to finely crenulated, with irregular porphyroblasts up to 8 mm. in diameter forming in clusters of chlorite grains, and a few large grains of magnetite	380
Quartz-muscovite-biotite schist, sliver-grey-green to rusty grey, moderately coarse-grained, crumpled, strongly porphyroblastic, with dark brown to black subhedral garnet porphyroblasts up to 2 cm. in diameter	190
Phyllite, silver-grey, finely crumpled, sparingly garnetiferous..................	220
Quartz-biotite schist, garnetiferous, silver-green; interbedded phyllite, lustrous silver-green, crumpled, containing minute euhedral garnet porphyroblasts in a quartz-biotite groundmass	140
Quartzite, feldspathic, pale silver-green, banded, containing minor chlorite(?) and amphibole; interbedded quartz-biotite schist, garnetiferous, grey-green	410
Quartz-mica schist, garnetiferous; interbedded quartzite, slightly garnetiferous, light grey, schistose, partly gneissic, with clusters of epidote grains accompanying garnet porphyroblasts	1,580
Quartz-mica schist, garnetiferous, kyanite-bearing; about 25 per cent interbedded quartzite, feldspathic, slightly garnetiferous, schistose	1,390
Kyanite-garnet schist, silver-coloured, porphyroblastic, with kyanite, garnet, and lesser staurolite porphyroblasts in a biotite-muscovite-chlorite-quartz groundmass	150
Quartz-mica schist, garnetiferous, grey-brown to silver-grey; about equal amount of interbedded quartzite, slightly garnetiferous, micaceous	200
Garnet-mica schist, crumpled, with corroded garnets up to 3 mm. in diameter composing as much as 20 per cent of the rock; minor quartzite, thin-bedded	420
Quartz-mica schist, orange-brown and grey-brown; about 30 per cent quartzite, grey, in beds 1 foot to 3 feet thick	580

	Thickness Feet
Quartz-mica schist, orange-brown, grain size varies from 0·5 to 5 mm., with biotite in most places constituting about half the rock, and the remainder composed of various proportions of muscovite and quartz, with minor chlorite, feldspar, and garnet; minor quartzite, medium-grained, micaceous, in uniform beds 1 inch to 1 foot thick	1,220
Quartzite, golden to toffee-coloured; interbedded quartz-biotite schist, orange-brown, coarse-grained (2 to 5 mm.), crumpled	270
Quartz-muscovite-biotite schist, with thin partings of quartzite and lenses of quartz-albite-muscovite pegmatite; grades, along bedding, to quartz-mica schist with thin continuous bands of quartzite; grades further into gneissic quartzite, by increase of quartz content; a few persistent beds of quartzite, golden brown, relatively pure, up to 20 feet thick; tourmaline crystals up to 2·5 mm. comprise up to 5 per cent of some beds	1,160
Biotite quartzite, gneissic, in part feldspathic, grain size about 1 mm.; minor interbedded quartz-chlorite-biotite schist, crumpled, in lenticular beds 1 inch to 2 inches thick, in places grouped into schistose bands 3 to 4 feet thick; upper part of this series contains up to 20 per cent biotite-quartz-feldspar schist, silver-grey, speckled	600
Quartzite, light grey, massive to slightly schistose	240
Quartzite, light grey, moderately fine-grained; interbedded quartz-mica schist, in beds 1 foot to 10 feet thick	320
Quartzite, light grey, white weathering, massive to schistose, slightly feldspathic, coarsely bedded; thin partings of quartz-mica schist	1,320
Breccia, composed of fragments of white quartzite in a fine-grained, 'pasty', micaceous matrix	60
Muscovite-biotite schist, flaky, medium- to coarse-grained; interbedded quartz-muscovite-biotite schist and micaceous quartzite; typically in large smooth slabs	580
Quartzite, light grey to buff, slightly rusty, in part gneissic and schistose, medium to coarsely bedded	840
Approximate total thickness	13,500

Generalized Section in the Ingenika Range

In the following generalized stratigraphic section of the Tenakihi group exposed in the Ingenika Range between Mount Lay and Orion Creek, the thicknesses given are only approximate; they have been scaled from plotted structures on maps, not measured in the field:

Overlain by Ingenika group (*See* section page 77)

Top of Section	Thickness Feet
Quartzite, dull grey to rusty brown, medium-grained, schistose, micaceous and chloritic, containing scattered garnet porphyroblasts; interbedded schist, grey to pale silver-green, in part coarse-grained and flaky, in part very fine-grained, minutely wrinkled	500
Muscovite-quartz schist, porphyroblastic, with garnet and biotite porphyroblasts; minor quartzite, slightly micaceous, in beds up to 20 feet thick	200
Quartzite, buff-coloured, medium-grained, slightly micaceous; this entire unit seems to be a single bed	200
Quartz-mica schist, foliated, similar to that in the underlying beds, but with an increase in the proportion of quartzite in successively higher horizons until it constitutes about one-quarter of the rock volme	1,200
Quartz-mica schist, silver-grey to buff-coloured, composed of fine flaky muscovite and scattered grains of biotite in parallel layers $\frac{1}{16}$ to $\frac{1}{4}$ inch thick, separated by colourless or rusty quartz-rich bands of about the same thickness; about 20 per cent of the total is quartzite, light grey, brown, or rose-coloured, in beds 2 to 15 feet thick	800

	Thickness Feet
Mica schist, silver-grey-green and golden brown, soft, in part porphyroblastic, with garnets up to 1 inch in diameter; about 25 per cent of the total is quartzite, micaceous, showing all gradations to quartz-mica schist; about 10 per cent is quartzite, grey, relatively pure	700
Quartz-muscovite schist, silver-grey to silver-brown, garnetiferous, containing scattered flakes of biotite, in part coarse-grained with muscovite flakes up to 2 cm. across; interbedded quartzite, buff to rose-coloured, nearly pure, thin bedded	500
Quartz-mica schist, golden or silvery, moderately coarse-grained; about 20 per cent quartzite, in part grey, sugary, schistose, biotite-rich, in part buff, speckled, with scattered muscovite and biotite flakes and small garnet porphyroblasts	2,000
Quartzite, grey to buff-coloured; about 40 per cent muscovite schist, red-brown to golden, soft, coarse-grained; minor quartz-muscovite schist, grey	500
Quartzite, light creamy grey; about 20 per cent quartz-mica schist, golden brown, typically in beds 1 foot to 10 feet thick; sections as much as 200 feet thick of quartzite contain no interbedded schist	500
Muscovite-biotite schist, crumpled; quartz-biotite schist, platy; quartzite, slightly micaceous; all three rock types intimately interbedded in about equal proportions	500
Total	7,850

Metamorphism

SEQUENCE OF METAMORPHIC CHANGES

The Tenakihi group sedimentary strata, together with those of the overlying Ingenika group, have been altered by regional metamorphism that has produced remarkably uniform effects in all parts of the map-area where these rocks are exposed. There is a gradation from slightly altered sediments of the highest Ingenika group beds to relatively high-grade metamorphic rocks of the lowermost beds of the Tenakihi group. Throughout this sequence, the boundaries between metamorphic zones approximately coincide with stratigraphic horizons.

It would appear that the Tenakihi group rocks were originally argillaceous and arenaceous sediments, all relatively rich in silica. The remarkably uniform regional metamorphism to which they have been subjected has recrystallized and reconstituted their component minerals under conditions in which temperature, hydrostatic pressure, and stress have reached a given equilibrium at, so far as can be determined, very nearly the same stratigraphic horizon over the whole area studied.

The schists, probably derived from shaly and silty sediments, are the most sensitive to changes in metamorphic conditions. They demonstrate, from highest to lowest stratigraphic levels in the Tenakihi group, changes almost exactly corresponding to those regarded as typical of argillaceous sediments under increasing temperature and hydrostatic pressure, subject to the maximum possible shearing stress for each stage. The Tenakihi group rocks range, under this scheme, from the 'biotite zone' of Barrow (1912) and others, as shown by the stratigraphically highest beds, just into the 'sillimanite zone' in the lowest horizons.

In the stratigraphically highest beds, the quartz has been almost completely recrystallized (even the quartzites are crystalloblastic and show a certain degree of schistosity) and the chlorite, which is a predominant mineral in the overlying Ingenika group, has been largely replaced by biotite. Rocks from these beds show, upon microscopic examination, strings and patches of biotite developing from the chlorite. Material for the formation of biotite is probably also drawn from the sericite, magnetite, and quartz present, but the first biotite formed appears to be pseudomorphous after chlorite. Along with this change is an increasing development of a banded, instead of a merely schistose, structure; the biotite shows not only a more perfect parallel orientation of each grain, but a greater tendency for the grains to be grouped into strings or layers. These rocks would correspond to Barrow's 'biotite zone'. Below about 3,000 feet stratigraphically beneath the uppermost beds of the Tenakihi group, chlorite is an insignificant mineral, and is chiefly confined to the purer quartzites, where it persists in diminishing amounts to the zone of highest grade metamorphism.

The presence of two types of biotite—one commonly occurring as splintery laths, the other as irregular skeletal or 'poikilitic' grains—in some of the Tenakihi group rocks has been noted. Although plates of chlorite are intergrown with, and may be found between, fractured fragments of the same grain of splintery biotite, this type of biotite appears to be older than and distinct from chlorite. It is the poikilitic type of biotite that can be observed in thin section in various stages of formation from chlorite. The textural relations, the distribution of minute inclusions of zircon, rutile, tourmaline, etc., and the uniformity of grain size suggest that some, at least, of the splintery biotite is original detrital material, whereas the poikilitic biotite is of metamorphic origin produced from chlorite during a single period of increasingly intense metamorphic conditions.

Sericite, which is fairly abundant in the less-metamorphosed overlying Ingenika group rocks, seems to be lacking or relatively inconspicuous below the upper beds of the Tenakihi group. As successively higher grades of metamorphism within the 'biotite zone' are reached, however, white mica is reconstituted as coherent flakes of muscovite, which increase in size and abundance as lower stratigraphic levels (and, therefore, presumably higher temperatures and pressures during metamorphism) are reached.

Only the uppermost beds of the Tenakihi group can be considered to fall strictly within the 'biotite zone'. Within 500 feet of the contact with the Ingenika group in the Tenakihi Range and near Cutbank Creek, and more or less coincident with the contact on Swannell River north of Chase Mountain, rudimentary garnets can be observed in thin sections of the schist; these, becoming more coherent and conspicuous at slightly lower stratigraphic levels, mark the advance of the rock into the 'garnet zone'. Under the microscope it can be seen that small irregular grains of garnet form in patches of chlorite at a metamorphic stage very little higher than that at which biotite becomes conspicuous. Indeed, in a few places garnets occur in the overlying Ingenika group rocks. No difference in optical properties was observed between garnets from the lowest and from the highest grade metamorphic zones in which they are conspicuous in the Tenakihi group.

Garnet is a conspicuous mineral over a stratigraphic range of about 6,000 feet in the type section of Tenakihi group rocks in the Tenakihi

Range; east of Mount Lay, the stratigraphic range is at least 5,500 feet. It seems to form mainly from the decomposition of the remaining chlorite in the rock, though it probably also draws material from magnetite, and possibly from biotite. The garnets from the lowest grade metamorphic zone are irregular in outline and are pseudomorphous after patches or groups of grains of chlorite. Most of them enclose grains of quartz, biotite, and feldspar, commonly to such an extent that as much as 90 per cent of a large skeletal crystal may consist of inclusions. All stages of growth toward euhedral, dodecahedral crystals relatively free from inclusions can be observed in specimens of successively higher metamorphic grade. That this growth of crystals was taking place at a time of crustal movement is shown by spiral lines of inclusions in garnet porphyroblasts from about the middle of the Tenakihi group section, indicating a rotation of the grain during growth, and that at least some deformation had already occurred at the time of crystal growth is shown by helecitic lines of inclusions that preserve and early, wavy, crumpled 'schistosity' in garnets in a rock now almost completely recrystallized to coarse, regular layers.

The clinozoisite-epidote-bearing rocks are apparently restricted to beds of distinctive chemical composition. It has been established (Turner, 1948) that clinozoisite may occur in rocks with or without plagioclase, if the amount of available lime exceeds the maximum that can enter into plagioclase under the existing temperature and shearing stress. In almost all the other rocks in the Tenakihi group plagioclase appears to be the only essential mineral containing lime.

Kyanite forms conspicuous porphyroblasts in beds about 2,500 feet below the top of the Tenakihi group section; it is plentiful over a stratigraphic range of at least 3,000 feet, and persists as a few sparsely distributed crystals almost to the zone of highest grade metamorphism. Thus, a large part of the group falls within the 'kyanite zone'. Coincident with the most plentiful kyanite, porphyroblasts of staurolite are abundant; their statigraphic range appears to be limited to about 1,500 feet, and within this range staurolite is confined to certain beds, presumably those rich in ferrous iron. Thus no true 'staurolite zone' appears to exist; but staurolite occurs locally within the kyanite zone.

The main change at successively lower horizons within the kyanite zone is one of slightly increasing grain size and a tendency toward gneissic foliation. Within 5,000 feet of the lowest beds of the exposed section, in the Tenakihi Range, and in almost the stratigraphically lowest beds in the Chase Mountain and Mount Lay areas, small, needle-like crystals appear in the grains of biotite, muscovite, and quartz. These crystals have been tentatively identified as sillimanite; although they constitute less than 1 per cent of the rock in all thin sections examined, the temperature and pressure conditions appropriate for their formation appear to have been reached, and the lowermost exposed horizons in all main areas of the Tenakihi group rocks may be tentatively considered to have entered the 'sillimanite zone' . In the stratigraphically lowest rocks of each of these areas, the crystalloblastic texture is considerably more regular than in higher beds; the mutually poikilitic texture, in which large irregular grains of biotite contain inclusions of quartz and feldspar, and large irregular grains of quartz contain inclusions of biotite and feldspar, has given way to rounded elongate grains relatively free from inclusions; and the principal minerals have segregated into bands with a gneissic, rather than schistose, pattern. In some beds at this stage, particularly in parts of beds near the crests of folds, the quartz and feldspar have segregated into lens-shaped augen 3 cm. or more in length, and the rock becomes a typical augen-gneiss. Megascopically, many specimens of these rocks have a granitic appearance, but the bedding, as outlined by alternate layers of gneissic quartzite and quartz-mica-feldspar gneiss, is well preserved (*See* Plate VI B). The gneissic folation is in most cases parallel or nearly parallel with the bedding.

QUARTZ VEINS

Coincident with the increasing grade of metamorphism of the Tenakihi rocks, there must have been an expulsion of excess silica, for large quartz veins are characteristic of all exposures of the group. In some places, in an area of as much as half a square mile, it was estimated that at least 1 per cent of the area of rock exposed is vein quartz. Most of the quartz veins are from 3 to 15 feet thick, and from 100 to 300 feet long, although a few veins have been traced for more than 1,000 feet. The largest body of vein quartz found in the map-area is in the low hills of Tenakihi Range about 4 miles east of mile 55 on the Aiken Lake winter road. Here, over an area 600 feet by 180 feet, the only material outcropping is white vein quartz; and the 'depth' or thickness of the body, as shown by gullies, is at least 25 feet. The structural relations of this body of quartz to the surrounding rocks are not known.

Small stringers and veinlets of quartz are scarce. The quartz of the large veins is opaque, milky white, and almost completely free of rusty discoloration. The only other minerals observed within the veins—muscovite, biotite, and tourmaline—occur in minute amounts. In some places small fragments of the surrounding schist or quartzite lie within the vein a few inches from its walls, and one vein in Jim May Creek Valley contains a horse of rock about 100 feet long.

Most of the quartz veins parallel the bedding, although a step-like pattern, in which the veins alternately follow bedding planes and crosscut the beds to reach and follow a different bedding plane, is not uncommon. In some of the schist the veins form lenticular masses around which the planes of schistosity are deformed. Where the beds are transected by the veins they are sharply terminated, and there is very little small-scale penetration of quartz along the foliation planes of the host rock.

The remarkable purity of these veins, with an almost total absence of hydrothermal minerals other than quartz, their lenticular form, lack of interconnecting 'feeders' or branches, and distribution over the entire exposed area of Tenakihi group rocks, has led to the conclusion that they are probably composed in large part of quartz expelled from the surrounding rocks during metamorphism, without appreciable addition of material from sources at greater depth.

The quartz veins are, in any one area, usually found within, or along, a contact of a series of quartzite beds. This position is favourable probably because of the greater amount of excess silica in the quartzite, and because the quartzite is a mechanically stronger rock than the associated schists and is thus more capable of forming and sustaining fractures into which the siliceous solutions could migrate.

These milky white, thick, barren quartz veins are clearly of different origin from the colourless to smoky, commonly mineralized, usually narrow, networks of quartz veins that cut them and that are attributed to a later, epigenetic (probably magmatic) origin.

RELATION OF METAMORPHISM TO STRATIGRAPHY AND STRUCTURE

Any explanation of the development of metamorphic changes in the Tenakihi group rocks must account for both the general correspondence of metamorphic grade with stratigraphic position over large areas, and the marked parallelism or near-parallelism of the schistosity and bedding planes. That the metamorphic changes took place during a time of differential rock movement is suggested by the observation that the common minerals found in these rocks are all minerals that can form under conditions of shearing stress—minerals such as andalusite, nepheline, and scapolite, which are unstable under applied stress appear to be missing—and from the textural evidence that the rocks were being deformed during recrystallization.

One mechanism that is effective in producing a uniform increase of temperature and pressure conditions at successively lower stratigraphic positions over a large area is simple deep burial of relatively undeformed sediments. In this connection it is of interest to note that the structurally conformable Ingenika and Tenakihi group beds have a measured total exposed thickness in Tenakihi Range of approximately 26,400 feet; and the maximum apparent total thickness of the two groups in the map-area is of the order of 35,000 feet. The observed sedimentary record thus indicates that the lowermost Tenakihi beds now exposed were buried at least 6 miles at the time the uppermost Ingenika sediments were deposited. The stresses contributing to the metamorphism must, therefore, likewise have been active at depth and, consequently, regional in character.

The general relations between bedding planes, and cleavage and schistosity foliation, set forth by Leith (1905) have been accepted by most workers as explaining the development of schistosity in orogenically deformed rocks. Under the influence of orogenic compressive forces the flow cleavage is oriented in the direction of maximum elongation of the deformed rocks (the direction of the easiest relief of stress), which cannot be parallel with the bedding of folded rocks except along the limbs of isoclinal folds. According to these principles, the schistosity and the present folds of the Tenakihi group rocks cannot have been developed simultaneously by a tangential compressive force, for the schistosity is parallel with the bedding in both the limbs and the crests of the major folds.

In view of the fidelity with which metamorphic grade follows stratigraphic horizons through all parts of the Tenakihi group anticlinoria, including the overturned limb in the Butler Range, it seems very improbable that the main schistose foliation could have developed during the folding that produced the present large-scale structures. If the schistosity is postulated to have developed perpendicular to the direction of greatest stress, it is very difficult to conceive of a mechanism that would produce the required change of direction of stress concurrently with the development of the present folded structures, for the normal to the plane of schistosity changes direction as much as 90 degrees in 3 miles across the exposed anticlinoria, and 180 degrees in 6 miles across the synclinorium through Tomias Lake Valley. On the other hand, it does not seem unreasonable to suppose that fissile, previously metamorphosed strata could be folded to their present position without suffering extensive cataclasis or recrystallization. The folds are for the most part quite regular, and of large radius of curvature. The alternate layers of competent quartzites and fissile flexible schists could accommodate the differential motion between beds required by the folding. That some movement has followed the main period of crystallization of the rock is indicated by a weak lineation, due mainly to bent and fractured biotite grains, parallel with the axes of the present folds; by drag-folds in fragments embedded in the rocks; and by the strained and fractured condition of some of the grains of quartz and feldspar. It would appear, therefore, that the Tenakihi group rocks were probably metamorphosed prior to their deformation into the present large-scale folds.

There is strong evidence of deformation earlier than, and independent of, that producing the main folding in the Tenakihi group rocks. The predominant linear crumpling of the schists, its persistence and uniform direction over the entire exposed area of the Tenakihi group, and its disregard for the present folded structures, has been described (pages 40, 43). The crumpling is so oriented that it suggests that there has been a general crustal shortening in a direction about normal to north 30 degrees west, that is, a roughly northeast-southwest shortening distinct from the north-northeast-south-southwest shortening involved in the development of the present anticlinoria. In addition, the 'trains' of anomalous fold structures, superimposed on the larger, simpler folds now dominant, and trending about north 30 degrees west, seem to indicate that there are strips, striking in this direction, of an 'excess' of volume of sedimentary rock incorporated in the major folds (page 42; Figure 3). Such structures would be expected if a folded terrain whose fold axes had a strike of approximately north 30 degrees west was later deformed into folds striking north 60 to 70 degrees west, so that the original folds were overwhelmed and preserved as an anomalous deformation trending obliquely through the later structures. The small size of the anomalous structures suggests that, if this interpretation of their origin is correct, the earlier folding was relatively gentle. The main regional metamorphism of the rocks, which appears to have preceded the development of the anticlinoria, and yet to have taken place during differential rock movement, may well have been connected with this earlier deformation. The smaller folds in the more highly deformed parts of the major anticlines, not conspicuously anomalous in form but notable because the schistosity does not parallel the bedding but cuts across conformably with the major structures, may likewise be explained as the product of an earlier, oblique folding, with fortuitous positions on the present large folds.

The general parallelism of schistosity and bedding planes in the Tenakihi group rocks appears, therefore, to be a condition attained while the rocks were only slightly deformed; and, consequently, the schistosity cannot reasonably be due to the influence of tangential compressive forces. The mechanism of developing schistosity essentially parallel with bedding in comparatively undisturbed strata has received considerable discussion

(Turner, 1948, p. 295), centred mainly around the process of 'mimetic' or imitative recrystallization, and the possible effects of unbalanced vertical stress or tangential shearing stress. Mimetic recrystallization refers to the tendency of those newly formed metamorphic minerals that happen to be so oriented that their directions of most rapid growth are parallel with the bedding of the original rock, and thus, in most strata, parallel with the plain of greatest mechanical weakness and easiest movement of recrystallizing solutions, to develop at a greater rate than less favourably oriented grains, and so to become the dominant minerals in the rock. The recrystallized rock thus develops a schistosity that is not controlled by a directed stress, but is merely a reflection of the original laminated structure. Such a process is undoubtedly a factor in the recrystallization of any rock whose schistosity parallels the bedding, but it cannot be primarily responsible for this phenomenon in the Tenakihi group strata. It could not account for the planes of schistosity that parallel the major folds but cut across the bedding of the minor, apparently older, folds; nor for the condition, obtained over larger areas, wherein the schistosity is not rigorously parallel with the bedding, but differs from it by about 5 degrees. The strongest evidence against the dominance of mimetic recrystallization in producing the schistosity, however, is provided by the many megascopic and microscopic features that attest to the rock having recrystallized under conditions of differential rock movement. That the metamorphic minerals crystallized during the development of the linear crumpling attributed to deformation earlier than that which produced the present major folds is shown by the curved, unstrained grains outlining the crumpled texture, the migration of quartz into crests and troughs of small linear folds not clearly related to the major folds, spiral lines of inclusions in garnet indicating rotation during growth, and similar features that seem to point conclusively to a recrystallization in which the schistosity developed under conditions of differential stress—a stress that cannot have been a simple horizontal compression.

The required stress can only be applied to, and maintained in, relatively undeformed rocks on a regional scale as an approximately horizontal shear or couple. The many geologists who have dealt with this problem in many parts of the world have proposed two main mechanisms to provide this stress, either of which may apply, in part, to the Tenakihi group rocks. A slow rise of large igneous or 'migmatitic' bodies, though incapable of producing a vertical compression beyond that already due to the superincumbent load, may result in a gentle doming of the rocks, with the development of vertical stresses induced by the tensional strength and resistance to deformation of the overlying rocks, accompanied by a thinning of strata normal to the bedding and a complementary elongation parallel with the plane of bedding. In this way, lateral relief is afforded in a direction normal to the axis of greatest compression, and conditions are favourable for the development of schistosity essentially parallel with the gently domed bedding. An essentially horizontal, forceful invasion by magma, to form sheet-like igneous bodies at depth, would have the same result, and would help to explain some of the minor deformation as the effect of drag and shear on the overlying rocks by the advancing magma. Both of these mechanisms provide a theoretical source of heat to furnish the increased but comparatively uniform temperature gradient necessary for the gradation, through about 30,000 feet of strata, from the 'sillimanite zone' in the lowest Tenakihi group beds to the 'chlorite zone' in the upper Ingenika group.

Whether the mechanism involves a vertically rising magmatic body, a large-scale horizontal invasion of an igneous layer at depth, or the presence of a region of migmatization and anatexis underlying the area at a fairly uniform depth, is an open question. Whatever the process, for the Tenakihi group rocks as a whole it would appear probable that magmatic or grantizing processes were to some extent effective in controlling the temperature of metamorphism. The available evidence, and comparison with the interpretations advanced for other areas (Cairnes, 1940; Turner, 1948, p. 295), would seem to suggest that the Tenakihi group rocks were metamorphosed under conditions of moderately high hydrostatic pressure due to burial of the lower beds under probably more than 30,000 feet of sediments, of a temperature gradient due perhaps primarily to the depth of burial but also probably in part to underlying igneous or anatectic material, and of stress produced by relatively gentle orogenic deformation that resulted in differential rock movements between beds of different competency. The metamorphic rocks developed under these conditions show a systematic increase in grade of metamorphism with successively lower stratigraphic horizons, a uniformity of metamorphic grade at approximately the same stratigraphic position over large areas, and a schistosity parallel or nearly parallel with the bedding.

Origin

Evidence has been presented to show that the Tenakihi group was originally an assemblage of sandstones and shales, with very minor conglomerates. The regular alternation of arenaceous and argillaceous material, which is characteristically deposited in shallow water, indicates a fine balance between subsidence of the sedimentary basin and the rate of supply of sediments. This balance was maintained over an area of many thousand square miles in north-central British Columbia, through the deposition of, in the Aiken Lake map-area, at least 13,400 feet of strata. No evidence bearing on the direction from which the sediments were supplied was recognized in the map-area. The foliated granitic pebbles in the two known conglomerates, the relatively coarse grains of quartz and perthitic feldspar in some of the quartzites and schists, the grains of biotite that are interpreted as being part of the original sediments, and the general high silica, high alumina composition of the rocks, suggest a source area of granitic or possibly in part metamorphic character. The relatively fresh, apparently unrecrystallized, grains of perthite, and sound, rounded pebbles in the conglomerate, may mean that the source rocks were undergoing fairly rapid mechanical disintegration.

Age and Correlation

The earliest description of the formations in which the Tenakihi group is found was made by McConnell (1896, pp. 22-31), who found "medium-grained muscovite gneisses, micaceous and chloritic schists, and quartzites" in the Black Canyon of Omineca River, about 30 miles due east of the southeast corner of Aiken Lake map-area, and traced them northwest in the Butler Range along the west side of Finlay River Valley. McConnell considered the rocks to be Archæan, and correlated them with the "Shuswap series" of south-central British Columbia, also thought at that time to be of Archæan age. Dolmage (1928, p. 25), who observed Tenakihi group rocks in the Butler Range, found no evidence of their age, and followed McConnell's presumption that they were Precambrian. Douglas Lay (1940, p. 6) recorded the presence of "quartz-mica and quartz-sericite schists" along Jim May Creek in the Tenakihi Range, and correlated them with the schists described by McConnell on Omineca River.

In 1945, Armstrong (1946a), during the course of systematic mapping of the Tenakihi Range, distinguished the Tenakihi group rocks as a map-unit on structural and lithologic grounds, and suggested the name "Ruby group" as a field term. This and the overlying Ingenika groups were seen to be an extension of rocks of the Manson Creek area to the southeast (Armstrong and Thurber, 1945; Lang, 1942), where they form part of a meta-sedimentary and meta-igneous complex in the Wolverine Range. The age of the rocks of the Wolverine Range, collectively termed the 'Wolverine complex' was accepted, on the basis of McConnell's classification, as Precambrian, overlain by Cambrian beds, by Kerr (1934a), although he recognized that the differences between the various subdivisions of the rocks of the range might be due to "metamorphism and not differences in age". In accord with more recent investigations of the Shuswap rocks (Cairnes, 1940), which have shown them to be a metamorphic complex whose metamorphosed condition, induced by Mesozoic batholithic intrusions, is independent of the age of the formations involved, Lang (1942) and Armstrong and Thurber (1945) concluded that the rocks in the Wolverine complex may range up to Jurassic in age, although most were thought to be pre-Permian (Armstrong, 1949). They pointed out that the rocks of the Wolverine complex lie along a northwesterly projection of rocks of the Cariboo district, where Lower Cambrian rocks lie with apparent conformity on the Cariboo group, which is consequently assigned a Proterozoic age (Lang, 1938). Thus it was considered that the Wolverine Range might include Proterozoic rocks.

In Aiken Lake map-area, rocks equivalent to those found in Wolverine Range have been divided into two map-units, called the Ingenika group and the Tenakihi group, and the term 'Wolverine complex' has been retained only in those areas where intense, relatively local metamorphism has altered both units in such a way that the differences between them have been obliterated by the formation of a new, distinctive rock assemblage. In the upper group, the Ingenika group, fossils indicating a Lower Cambrian horizon have been found. The age of the Tenakihi group is, therefore, considered to be, for the most part, probably Proterozoic.

INGENIKA GROUP

Name and Distribution

An assemblage of interbedded quartz-chlorite schist and phyllite, sericite schist, crystalline limestone, quartzite, quartzitic conglomerate, slate, and argillite, not less than 18,000 feet thick, forms a belt as much as 5 miles wide on each side of the anticlinorium of Tenakihi group rocks in Tenakihi Range, and on the south side of the anticlinorial axis trending through Chase Mountain and Ingenika Range. North of this axis, the rocks of this assemblage spread northward to the limits of the map-area. The assemblage has been named the Ingenika group from its characteristic development in the mountains south and north of Ingenika River. It occupies about 880 square miles in Aiken Lake map-area.

Lithology

MEGASCOPIC DESCRIPTION

Fine-grained, thinly bedded, schistose and phyllitic rocks consisting principally of quartz and chlorite compose more than 60 per cent of the Ingenika group south of Ingenika River. North of the river, limestone and quartzite are more abundant, but relatively complex fold and fault structures there render any estimate of rock thicknesses or proportions of lithological types of little value. The limestone occurs in large, lenticular bodies, which attain a maximum thickness, including minor beds of clastic material, of more than 4,000 feet. The typical limestone is blue-grey to creamy, completely crystalline, poorly bedded, and in many places contains persistent zones of sugary, ivory-coloured rock composed of recrystallized calcite and abundant sericite. A distinctive rock consisting of thin beds of sugary, ivory-coloured, micaceous limestone separated by partings of chloritic slate is characteristic of many exposures. Beds of conglomerate up to 200 feet thick containing rounded quartz pebbles about $\frac{1}{8}$ to $\frac{1}{3}$ inch in diameter in a siliceous matrix are abundant, particularly in the lower and middle parts of the group. Remarkably pure, fine-grained, white quartzite outcrops on Ingenika Cone and as a distinct member about 500 feet thick in the mountains east of Pelly Creek.

North and east of Blackpine Lake, and from the mountains west of Tomias Lake northward to Ingenika Cone, assemblages of quartz-feldspar-mica gneisses, feldspathic quartzites, amphibolites, skarns, and silicated limestones are thought to represent severely metamorphosed Ingenika group strata. Because of their distinctive character, these rocks have been separated on the map from the typical Ingenika group rocks, and in this report are described under the general heading 'Wolverine complex'.

Rocks in the Southern Part of Tenakihi Range

On the north side of Osilinka River Valley, east of the mouth of Tenakihi Creek, an assemblage of slates, phyllites, chloritic schists, and limestones has been tentatively included in the Ingenika group. The lowest beds in this assemblage consist of well-layered, dark green to grey-brown, chloritic slate, interbedded with crumpled, medium-grained to sugary, grey-green quartz-sericite-chlorite schist containing cubes of pyrite up to $\frac{1}{2}$ inch across. Above these beds is a series of finely bedded grey-brown slate, greenish schist and fine-grained schistose chloritic quartzite, and blue-grey, calcareous, sericitic slate in about equal proportions. This series is overlain by at least 1,500 feet of crystalline limestone. The limestone is chiefly light grey to medium blue-grey, with scattered beds of impure brownish material and of buff-coloured and white recrystallized calcite. Almost all is sufficiently coarsely crystalline to enable the individual grains to be seen with a hand lens. Most of the limestone is more or less sheared, with the development of sericitic mica along shear planes; some specimens are estimated to contain as much as 2 per cent sericite. The shearing movement seems to have been evenly distributed through the massive rocks, producing a strong linear structure without any well-defined shear planes; in places such rocks crumble to pencil-like fragments. In thinly bedded limestone the shearing has been confined to planes nearly parallel with the bedding planes, and the rock possesses a conspicuous slaty fracture, with fracture planes commonly intersecting the bedding planes at very acute angles. In the brownish, impure, argillaceous and silty layers, the shearing has been much less uniform, and many of these beds show shear planes that are gently contorted and crumpled in contrast with the regular structures of the purer limestones. Overlying the large limestone member are at least 2,600 feet of interbedded sericite-chlorite phyllites, slates, and schists, relatively pure and micaceous quartzites, and blue-grey and ivory-buff crystalline limestone.

The quartzites in this section vary from those with a fine-grained, almost cherty texture, characteristic of several white to pale purple, apparently highly siliceous beds, to others with coarse, sugary or flaky texture, shown by the chloritic, micaceous quartzites. Different beds of limestone show every gradation between relatively pure, finely crystalline, blue-grey material and an ivory- or pale rose-coloured, sugary calcite-muscovite rock, some of which contains as much as 10 per cent mica. Many of the blue-grey limestones are fine grained and highly sericitic, with a wrinkled, lustrous appearance, and represent a gradation into calcareous phyllites.

Rocks Northeast of Tenakihi Creek

The small ridge on the northeast side of Tenakihi Creek Valley, between mile-posts 52 and 55 on the Aiken Lake winter road, exposes massive to well-bedded, blue-grey, crystalline limestone, and grey-green to silver-brown quartz-sericite and quartz-sericite-chlorite schist and phyllite, which have been included in the Ingenika group on the basis of their lithology and position on the southwest flank of the Tenakihi group anticlinorium in Tenakihi Range.

Rocks in the Northern Part of Tenakihi Range

On the northeast side of the Tenakihi Range anticlinorium, a conformable succession of strata at least 13,500 feet thick, resting without angular discordance on Tenakihi group beds, has been assigned to the Ingenika group. The lower 5,000 feet of this assemblage consists of interbedded chloritic and sericitic quartzite, quartzitic grit and conglomerate, chlorite and chlorite-sericite schist and phyllite, dark grey, phyllitic, calcareous and carbonaceous rocks, and minor graphitic schist. One of the most distinctive rock types in this section is a grit or fine conglomerate consisting of subangular to rounded or lenticular fragments of purplish, translucent quartz, and opaque, white to buff-brown feldspar up to $\frac{1}{4}$ inch (rarely up to $\frac{3}{4}$ inch) in diameter, closely packed in a silver-green to brown-grey, fine-grained, schistose quartz-sericite-chlorite matrix. Small flakes of biotite are conspicuous in some beds. In places the rock appears considerably recrystallized, and it is difficult to determine whether the large quartz grains represent original detrital fragments or later metamorphic porphyroblasts. The general origin as a coarse-grained sediment, however, is apparent in most instances. This type of rock, designated in this report 'quartzite conglomerate' or 'quartzitic grit', depending on its average pebble or granule size, comprises nearly half of the lowermost 4,000 feet of the Ingenika group on the northern flank of Tenakihi Range. Most of it is well bedded, with adjacent beds differing in texture and mineral proportion to yield all variations toward sericite-chlorite quartzite. Interbedded with the conglomerate, grit, and quartzite are beds up to 40 feet thick of soft, black or dark grey, lustrous phyllite, for the most part conspicuously crenulated, with parallel or subparallel corrugations less than $\frac{1}{20}$ inch apart. In a few places, thin beds of black, flaky, velvet-lustred, graphitic schist are interbedded with the phyllites.

The quartzitic conglomerate-phyllite assemblage is overlain by about 200 feet of interbedded, impure, dark grey to black, slaty limestone, brown calcareous slate, and calcareous chlorite-sericite schist; and this in turn is overlain by nearly 4,000 feet of slightly schistose quartzite, slaty argillaceous rock, sheared conglomerate, and schistose sericitic limestone, all of which are intimately interbedded, with a sequence of beds of one rock type rarely more than 15 feet thick. As in the lower beds of this series of exposures, the quartzites typically contain rounded grains or 'eyes' of quartz, which may represent either relatively coarse original sedimentary grains or porphyroblasts formed during recrystallization. The conglomerate occurs in uniform, coherent beds up to 12 feet thick, composed of colourless or light grey, rounded quartz pebbles up to 1 inch in diameter, and subrounded, light grey, in part rusty, feldspar grains up to $\frac{1}{4}$ inch in diameter, in a sheared, limonite-stained, sericitic matrix. The beds of conglomerate are in places separated by partings of dark brown argillaceous material, which, between the conglomerate beds, has been metamorphosed into a fairly strong slate, but which, where present as a contorted filling in cracks and funnel-shaped openings within the conglomerate beds, has been preserved as relatively incoherent argillite. The limestone in this finely interbedded section is confined to thin, impure, slaty, schistose, or sandy bands, which represent all gradations to calcareous slaty phyllites. Near the bottom of this section the sheared, slaty, calcareous material produces a conspicuous encrustation of soluble salts, mainly potassium nitrate and calcium sulphate.

The finely interbedded sequence of quartzite, slaty argillite, conglomerate, and impure limestone is overlain by about 2,000 feet of well-bedded limestone, which is sheared and slaty, more or less micaceous in the lower beds, but predominantly blue-grey to creamy buff, crystalline, and relatively pure in the highest exposed beds.

Rocks in Mesilinka River Valley

Ingenika group rocks outcrop on both sides of Mesilinka River, near the eastern edge of the map-area, in canyons in the mouths of creeks tributary to the river. Each of the canyons examined is cut in a succession of quartzitic conglomerate, schistose augen quartzite and grit, and quartz-chlorite-sericite schist, slate, and phyllite. Similiar rocks outcrop on the ridges north of the Mesilinka for about 4 miles back from the river. Near the east border of the map-area, these rocks are in fault contact against highly metamorphosed and granitized rocks of the Wolverine complex, here thought to be altered Tenakihi group strata. About 8 miles west of the east boundary of the map-area, chloritic slates and phyllites are faulted against more highly metamorphosed Wolverine complex rocks, which in this place are considered to have been originally Ingenika group beds.

Rocks Between Blackpine Lake and Chase Mountain

In the through valley leading north from Blackpine Lake to Swannell River, Ingenika group rocks are represented by long ridges of massive to poorly bedded, blue-grey, crystalline limestone, with a few scattered exposures of quartzitic conglomerate and quartz-chlorite schist. On the east side of Swannell River Valley, southwest of Chase Mountain, limestone outcrops in large bluffs, ridges, and bare hills, and is the only rock type observed within an area 2 miles wide by 8 miles long, although some float of micaceous and chloritic rocks was found. Owing to the massive nature of most of the limestone, the structure is obscure, but it would appear that unless there is important repetition of beds by faulting, the total stratigraphic thickness in which limestone is the dominant rock is of the order of 6,500 feet. Uniform bodies of limestone at least 300 feet thick, with no intercalation of other rock types, are exposed on large broken bluffs. Most of the limestone in this area is light blue-grey, relatively non-crystalline, massive, or vaguely bedded. Some beds are strongly oolitic. Bands, which may be parallel with the bedding, and irregular areas, up to 500 feet across, of light grey or creamy buff weathering recrystallized limestone give the rock a variegated appearance on a large scale. In places the limestone is strongly brecciated; angular fragments of uniform, fine-grained limestone up to 4 inches in diameter are embedded in a creamy buff or reddish brown, coarsely crystalline carbonate matrix. In some exposures the whole rock is composed of semi-rounded fragments of blue-grey fine-grained limestone up to ½ inch in diameter, fairly well sized, and closely packed in a light brown crystalline carbonate groundmass; such rocks may be in part conglomerates, with the fragments transported a considerable distance from their source. In other places the brecciation has clearly involved only slight rock movement. In these places the brecciation is not confined to well-defined bands, and bears no obvious relation to the major tectonic structures of the rocks in the district. In some of the brecciated areas, the recognizable fragments of original rock do not compose more than about one-quarter of the rock volume; the remainder consists of brownish, reddish, and cream-coloured, crystalline carbonate material. The carbonate occurs in characteristic concentric bands of crystals oriented perpendicularly to the surface of the fragments they surround; variations in texture and colour of successive bands give a conspicuous 'cockade' appearance to the rock. Bands composed of radiating, prismatic crystals up to 3 inches long were noted. In all the breccias the fragments have sharp outlines.

Interbedded with the massive limestones and limestone breccias of the western part of this area are relatively minor amounts of grey, brown, massive to well-banded, slaty siltstone, containing considerable pyrite in some beds; and green, chlorite-sericite phyllite. One exposure of ivory-coloured sericitic limestone, with thin partings of chloritic slate, was noted.

Rocks East and South of Mount Lay

The mountain east of Mount Lay and the ridge 3 miles northeast of Mount Lay are composed of interbedded limestone and chlorite-sericite slaty rocks, with minor chloritic quartzites. East of Mount Lay, limestone is almost continually exposed for a stratigraphic thickness of 1,200 feet. Most of the limestone is blue-grey to light grey, massive, with irregular patches or beds of ivory-coloured recrystallized calcite. Ivory or pale rose-coloured, muscovite-rich, sugary limestone, in beds up to 4 inches thick, separated by bright green, soft, chloritic slates or crumpled chloritic phyllites, occur in many places throughout this assemblage. Beds of cream-coloured finely crystalline limestone an inch or two thick, separated by bright purple partings a fraction of an inch thick, make a conspicuously banded rock characteristic of much of the Ingenika group strata in this area (*See* Plate VII A). The chloritic schists, slates, and phyllites are all more or less calcareous.

In the mountains south of Swannell River Valley, south and southeast of Mount Lay, much the same general assemblage of limestone, chloritic phyllites, and slate is found. Relatively pure white quartzite, in beds up to 40 feet thick, forms the greater part of a small knoll about 4 miles south of Mount Lay. On the mountain southwest of Mount Lay, four bands of blue-grey, massive to bedded, non-slaty limestone, about 100 feet thick, are separated by 100 to 500 feet of black, dark grey, and brown, slaty limestone, and grey-green slaty calcareous schist, chlorite schist, quartzite, and grit. Some of the limestones have been recrystallized into a fine-grained variegated marble. Ivory-coloured, sugary, micaceous limestone, in thin beds separated by partings of bright green chloritic slate, is widely distributed throughout this assemblage, but comprises only a small part of the total rock.

Rocks in Upper Swannell River Valley

The same general sequence as that south of Mount Lay was observed in the valley of Swannell River west of Orion Creek, where the interbedded limestone-chloritic slate assemblage is underlain by about 3,000 feet of schist, slate, quartzite, quartzitic grit, and conglomerate. A distinctive, grey-green, schistose, quartzitic conglomerate or grit is abundant in this locality. About one-third of the typical grit consists of rounded, somewhat elongated grains of bluish grey quartz, $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter, and scattered grains of white feldspar up to $\frac{1}{32}$ inch in diameter, in a schistose or phyllitic matrix composed essentially of quartz, sericite, and chlorite. Some beds of this rock contain numerous streaks of limonitic material.

Ingenika group rocks are exposed continuously from Orion Creek northwest to the west border of the map-area. The proportion of calcareous material decreases toward the west. Some of the lowermost beds of this section contain scattered flakes of biotite, and a few porphyroblasts of garnet.

Rocks in the Northern Third of the Map-area

All of the rocks in Aiken Lake map-area north of the belt of Tenakihi group rocks exposed in the core of the anticlinorium that stretches from Mesilinka River at the east border of the map-area to Wrede Creek at the west border, except for a small area of the Sifton formation in the floor of the Rocky Mountain Trench, have been assigned to the Ingenika group. Within this large area, outcrops are largely confined to mountain massifs separated from one another by drift-covered areas that in places mark lines of structural dislocation. The individual members of any one part of the Ingenika group are in many places similar to members found at other stratigraphic levels of the same group, and few reliable horizon markers have yet been recognized. Consequently, it is difficult to trace smaller structures or to correlate beds across drift-covered areas, and the relative stratigraphic position of the beds exposed in any one massif, with respect to beds in the surrounding massifs, can rarely be ascertained. Nevertheless, based chiefly on lithological comparison and outcrop position with regard to regional structure, three main divisions of the Ingenika group rocks can be recognized.

The *first division* includes all the Ingenika group rocks north of the Tenakihi group strata exposed in the crest of the anticlinorium through Orion Creek, west of Swannell River and south of the Ingenika, as well as the rocks of Wrede and Tucha Ranges. The strata on both sides of Tomias Lake Valley probably also belong to this division, but they are of sufficiently unique mineralogical composition to warrant separate description as part of the Wolverine complex. This division is characterized by a thick succession of interbedded, impure, chloritic quartzites, quartz-chlorite schist, schistose chloritic grits and quartzitic conglomerates, and chlorite-sericite phyllites. Although present in many places in this area, limestones are much less abundant than in most areas where Ingenika group rocks are exposed. The lower 5,000 feet of strata exposed between Swannell River and Wrede Creek are characterized by coarse- to medium-grained, clastic, siliceous sedimentary strata. Every gradation was observed from fine conglomerates, composed of rounded pebbles of quartzite up to ¼ inch in diameter in a schistose, chloritic, medium-grained quartzite matrix, through schistose 'chlorite grit', to chloritic quartzite. A few thin beds of very pure white quartzite have been noted. Near the base of the section in this area, fine-grained schistose beds are in places flecked with biotite; some beds contain rough garnets. The middle and upper parts of the sequence exposed in this area (a thickness of nearly 18,000 feet of conformable strata has been measured near Cutbank Creek) are composed mainly of interbedded quartz-chlorite schist, quartz-chlorite-sericite schist, and fine-grained chloritic quartzite, with relatively few conglomeratic or gritty beds. A few beds of crystalline limestone, some blue-grey, others in part ivory-buff and highly micaceous, are exposed east of Cutbank Creek, and in the east end of Wrede Range.

The rocks of Tucha Range show a somewhat greater textural and compositional variation than those of this division south of Ingenika River. They consist of a succession of silver-coloured, crumpled, sericitic phyllites, quartz-chlorite schists, fine- and coarse-grained quartzites, quartzite- and feldspar-pebble grits and conglomerates, and numerous lenses of dark grey impure limestone. A 50-foot bed of grey, schistose, sericitic quartzite, containing numerous elliptical to cigar-shaped bodies up to 8 inches long of very fine-grained, hard, black rock, is exposed north of Mount Melvin for nearly a mile. This bed may be a sheared recrystallized conglomerate. A few beds northwest of Tutachi Lake show very little schistosity or evidence of recrystallization, and appear to be normal, well-indurated sediments.

The *second division* of Ingenika group rocks in the northern part of the map-area embraces a belt composed dominantly of limestone, which extends northwest from the westernmost ridges of the Butler Range east of Tomias Lake, through Lookout Hill and Ingenika Crag, and includes Forres Mountain, the valley of Pelly Creek, and probably the Espee Range. Blue-grey, massive to thick-bedded limestones predominate, although almost all large exposures show a few beds of brown to ivory-coloured, sugary material, which in places contains considerable muscovite. A few limestone beds, particularly the impure, carbonaceous or argillaceous varieties, are thin bedded. Oolitic beds have been found in each of the main areas of limestone outcrops within this belt. A few bed-like bands of limestone breccia outcrop east of Pelly Creek and on Forres Mountain. On the south slope of Forres Mountain, in Pelly Creek canyon, and east of Pelly Creek near the north border of the map-area, several beds of limestone are strongly pyritic; one bed about 10 feet thick, on Forres Mountain, appears to contain about 10 per cent pyrite for a distance of nearly half a mile. Other beds in this massif show a polygonal fracture pattern, confined to bedding surfaces, which may be mud-cracks. Where they occur in thicknesses greater than 100 or 200 feet, the limestones of this division are almost invariably highly contorted, and commonly isoclinally folded; consequently, no estimate of their true thickness can be made. The chloritic phyllites, schists, and quartzites interbedded with the limestones are in relatively minor proportion, and are in general similar to those typical of Ingenika group rocks elsewhere.

In the Espee Range, the main limestone member is overlain by at least 3,000 feet of finely interbedded, sedimentary rocks that exhibit a wide range of composition. Included in this assemblage are chloritic slate and schist, chloritic quartzite, quartz-pebble conglomerate, greywacke, siltstone, fine-grained light green shale or tuff, beds of green and purplish impure limestone, and relatively pure, grey, oolitic limestone.

The limestones of Mount Tsaydizkun and adjacent ridges in the northeast corner of the map-area are in most respects similar, and may be stratigraphically equivalent, to the rocks of the limestone division exposed on Ingenika Crag and east of Pelly Creek. The Mount Tsaydizkun rocks include a relatively high proportion of limestone breccia.

Sink holes were observed in the limestone at the north end of Butler Range and on Lookout Hill. The largest explored sink hole, whose mouth is near the summit of Lookout Hill, leads to a series of small caverns and tortuous passages. The passages follow both joint systems and bedding planes.

The *third division* of Ingenika group rocks is exposed in an irregular area extending northwest from Ingenika Cone and Flood Creek to the north border of the map-area, including Mount Isola, Barrier Peak, and most of the Russel Range. This division is characterized by a predominance of quartzite, interbedded with fine conglomerate, grit, chloritic slate, and schist. At least 60 per cent of the lower 7,000 feet of strata exposed in the Barrier Peak area and in the Russel Range is estimated to consist of quartzite, which in this area ranges from pale golden brown to pure white, and is compact and massive to sugary in texture, with grain size ranging up to $\frac{1}{10}$ inch. Most of the quartzites contain more than 90 per cent quartz; in many beds no other mineral, except very minor stains of limonitic material, can be observed. The chief impurities, where present, are muscovite (sericite) and chlorite. A distinctive series of beds of remarkably pure white quartzite, with a maximum total stratigraphic thickness of about 1,500 feet, is exposed on Ingenika Cone, in a belt leading north from Mount Isola to Barrier Peak, and on the ridge east of Pelly Creek. This series consists almost entirely of milky white, fine-grained, crystalline quartzite, in which the only impurities visible in hand specimens are scanty, minute grains of mica or metallic sulphides, and in which many beds show no impurities. The quartzite is fairly well bedded, with the bedding planes outlined chiefly by differences in texture; and in places partings of chloritic slate from a fraction of an inch to 2 inches thick occur at intervals of 50 to 200 feet. South of Ravenal Peak, a pale buff quartzite exhibits good crossbedding.

The stratigraphically higher beds in this area are also characterized by abundant quartzites, but include a greater proportion of conglomerate, quartzitic grit, chloritic schist, phyllite, slate, and limestone. A bed of conglomerate consisting of rounded, slightly elongated quartzite pebbles up to 3 inches in diameter in a mixed micaceous quartz-sericite phyllite matrix, is exposed near Flood Creek, south of Ingenika River at the eastern border of the map-area. Beds of fine conglomerate containing quartzite and quartz-feldspar pebbles less than ½ inch long in a sericite-chlorite phyllitic matrix, are widespread in the eastern part of Russel Range. North of Pelly Lake, a 60-foot bed of light grey, crystalline limestone contains many rounded to subangular fragments of detrital quartz.

PETROGRAPHIC DESCRIPTION AND CHEMICAL COMPOSITION

General Statement

The Ingenika group strata represent a varied assemblage of coarse- and fine-grained clastic material, and chemical precipitates. All the rocks have suffered some degree of regional metamorphism, but, with the exception of those included in the Wolverine complex, the grade of metamorphism has been low, and original differences in chemical and mechanical composition of the beds have been largely preserved. The minerals comprising these rocks include detrital minerals, stable under low-grade metamorphism, and metamorphic minerals produced by alteration of sedimentary rocks of normal composition. The original sedimentary textures are, in most places, recognizable; they have been obliterated by superimposed metamorphic textures to only a minor degree.

The following is a description of the principal rock types of the Ingenika group, as viewed mainly in thin section under the microscope.

Conglomerate

Coarse conglomerates are relatively scarce in the Ingenika group of Aiken Lake map-area, and are restricted to a few individual beds, such as those exposed south of Ingenika River near Flood Creek and in the Russel Range east of Ed Bird Creek, where rounded fragments of quartzite up to 3 inches in diameter occur in a schistose quartzitic matrix.

Fine conglomerates[1], containing an abundance of fragments from 2 to 10 mm. in mean diameter, are, however, abundant, and are a distinctive feature of all parts of the Ingenika group exposed in the map-area. As much as 60 per cent of the volume of the rock of these conglomerates may be composed of rounded fragments of granule or pebble size. The granules are almost exclusively of three types; single quartz grains, single grains or aggregates of grains of feldspar, and fine-grained quartzite composed of an aggregate of quartz grains with very minor muscovite and feldspar. The proportions of these constituents vary widely from bed to bed; but in general the granules of individual quartz grains are more abundant than those of feldspar and quartzite together. About half the feldspar in the granules is twinned oligoclase or andesine. Other feldspar grains include microcline, perthite, and an untwinned alkali plagioclase. Almost all the feldspar grains are relatively unaltered. Most of the quartzite pebbles are of uniform, crystalloblastic texture, with an average grain size about 0·2 millimetre. A few quartzite pebbles contain parallel-oriented muscovite flakes, and grains of cloudy feldspar partly altered to sericite.

Most of the pebbles are well rounded, and well sorted in any one bed. An excellent shape orientation persists, with elongated and lenticular pebbles lying parallel with the bedding. Recrystallization has been slight to moderate, and has developed fine, sutured, interlocking contacts between the pebbles and matrix. In a few instances it has undoubtedly been effective in promoting a lenticular, oriented shape of some of the quartz pebbles. However, the presence of broken pebbles with partly rounded, partly jagged outlines, and the general lack of crystalloblastic contacts of the feldspar granules, suggest that the amount of recrystallization has been slight, and that most of the grains have their original detrital form.

The matrix of the conglomerates ranges from relatively pure quartzite to quartz-sericite schist, in every respect similar to the non-conglomeratic quartzites and schists.

The elliptical and cigar-shaped, very fine-grained, black bodies embedded in schistose quartzite north of Mount Melvin are seen in thin section to be composed of minute grains and flakes of black opaque material, so abundant that the other minerals in the rock cannot be identified. Accompanying the black matter are a few rounded blebs up to 0·01 mm. in diameter of orange-brown material, apparently aggregates of minute, variously oriented crystals, for the blebs remain illuminated in all positions under crossed polarized light. Both the black flakes and the orange-brown material are thought to be carbonaceous matter, probably derived from organic material in the original sediment. The black 'pebbles' themselves, however, are very hard, and probably contain much siliceous material.

Quartzites

Probably more than half the Ingenika group rocks may be classed as quartzites, in that they are metamorphosed sedimentary beds whose chief detrital constituent is quartz of sand size. The quartzites range from granular rocks composed of coarser granules in a distinctly finer grained

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[1] In this report the classification of detrital sediments recommended by Pettijohn is followed. Conglomerate is defined as a clastic rock containing an appreciable (10 per cent or more of the rock volume) number of rounded fragments greater than 2 millimetres in diameter (Pettijohn, 1949, p. 195).

matrix, differing from the fine conglomerates only in the size of the larger grains, to fine, metamorphosed siltstones and sandy argillites; and from extremely pure orthoquartzites to rocks in which quartz makes up less than 50 per cent of the total volume. With the exception of the orthoquartzites, almost all of the quartzites of the Ingenika group appear to have originated as "subgreywacke" (Pettijohn, 1949, p. 255), that is, as sandstones containing less than 15 per cent feldspar with a cement that is equivalent in composition to a slate. A few beds contain enough feldspar to be classed as true greywacke. Rocks of this type grade, with apparently about the same mineral assemblage, from the conglomerates already described to fine argillites and slates by a simple decrease in the amount and coarseness of detrital quartz and feldspars. In the Espee Range some beds are so little metamorphosed that they may be called greywacke and subgreywacke (*See* section page 81).

The purest quartzites, such as the conspicuous group of white beds exposed on Ingenika Cone, Barrier Peak, and in the Russel Range, are composed of rounded single quartz grains, or fragments of vein quartz or quartzite, in a more or less crystalloblastic, very fine-grained, siliceous matrix (*See* Plate VII B). The size of the larger grains varies from 0·1 to 1·0 mm., but in any one bed the sorting and degree of rounding of the grains are excellent. The degree of recrystallization varies considerably; in the purest white quartzites the entire rock has been recrystallized, with a uniform crystalloblastic texture.

Schists, Phyllites, Slates, and Argillites

The fine-grained clastic sediments of the Ingenika group rocks differ from the impure quartzites only in a finer grain size and lesser relative proportion of detrital quartz and feldspar, and a corresponding increase of argillaceous material. All gradations are represented between quartzites and metamorphosed subgreywackes and slates whose texture is too fine grained to enable the mineral constituents to be determined microscopically. Most of the slaty rocks are of about silt grade; the extremely fine-grained rocks are found chiefly in thin beds intercalated with limestones. Most commonly, these rocks have been metamorphosed to slaty phyllites; in a few upper beds the recrystallization has been minor and the rocks are normal, highly indurated argillites; other beds have a well-developed slaty cleavage, and many of the lower beds are fine- to medium-grained quartz-chlorite-sericite schists.

On the crest of Espee Range, near the north border of the map-area, impure slaty limestones and phyllites have been deformed around lenses and pod-like bodies up to 50 feet by 30 feet of an unusual, green, finely granular material. The 'pods' are not confined to one stratigraphic horizon, but make up about one-tenth of the rock volume in a stratigraphic interval of about 100 feet, over an exposed length of ¼ mile. In thin section, this rock appears to have had an originally coarse inequigranular texture, but it is now composed of a confused aggregate of colourless and green grains containing abundant minute rod-like bodies. The colourless grains have a tabular to radiating habit, an average refractive index of about 1·565 to 1·570, a relatively low birefringence, parallel or nearly parallel extinction, and are optically length-slow. They are tentatively identified as antigorite, and occur more or less evenly distributed through the rock with fairly well developed parallel orientation. The green grains occur as irregular platy masses, some of which show a tendency toward hexagonal outline; they have a refractive index of less than 1·600 but definitely higher than the colourless grains, and almost zero birefringence. The hexagonal-shaped plates show a symmetrical extinction, and the very few grains large enough to enable an interference figure to be obtained have a biaxial character with very small negative(?) optic angle. This material may be a penninite chlorite. Scattered through the entire rock are a multitude of rough rod-like grains up to 0·1 mm., but for the most part less than 0·01 mm., in length, of material with a very high refraction and birefringence. The rods are arranged in a rectangular or rhombic pattern, or in parallel or grid-like aggregates that bear no apparent relation to the outward form or crystallographic orientation of the minerals in which they are now embedded. They may be rutile or leucoxene. The original nature of the rock found in these pods is not known.

A distinctive series of phyllites and schists is exposed on the banks of Swannell River about 6 miles from its mouth. The lowest member exposed in this section is a silver-grey-buff, very fine-grained, sericite-calcite schist, in which dark grey and greenish grey prismatic porphyroblasts of zoisite up to 2 mm. long are embedded without any obvious common orientation in a finely granular schistose matrix estimated to contain about 40 per cent calcite, 40 per cent sericite, and 20 per cent quartz. The zoisite porphryoblasts are badly corroded by calcite, sericite, and an unidentified clay-like material. The rock contains parallel bands of slightly coarser quartz and calcite, free from zoisite porphyroblasts, about ½ inch thick and occurring at intervals of 6 inches to several feet, which lie at a slight angle to the schistosity and may represent original bedding planes. The zoisite-bearing rock is overlain by about 100 feet of lustrous, dark grey-green, strongly coherent schist. The groundmass of this schist, which is minutely crumpled, is an exceedingly fine-grained aggregate of quartz and sericite(?) containing a felted mass of minute, needle-like, pleochroic crystals of fairly high relief and birefringence, which are probably tourmaline. Embedded in the fine groundmass are porphyroblasts of carbonate material with very perfect rhombic outlines. They occur in all sizes up to 1·5 mm. long, but are invariably found in simple, rhombic form, almost completely free from evidence of twinning or cleavage. Most of the rhombs are slightly cloudy, probably because of minute inclusions, but they characteristically contain an outer rim of clear carbonate, which preserves the rhombic outline, though in some grains the clear rim is slightly askew to the clouded 'core'. Because of their distinctive rhomic outline, and conspicuous lack of twinning, these porphyroblasts are tentatively identified as dolomite. The rhombic form is further emphasized by a rim of quartz in comb-like grains growing perpendicular to the surface of the carbonate crystal. Accompanying the 'dolomite' porphyroblasts are conspicuous tabular porphyroblasts of dark grey-green chloritoid, up to 4 mm. in diameter and 1 mm. thick. The chloritoid shows well-developed polysynthetic twinning, and contains much included quartz, sericite, and carbonaceous matter, which is arranged in a crude, hour-glass pattern in cross-sections and which, with the twinning, gives a radial appearance to many basal sections. The chloritoid porphyroblasts themselves show some tendency to cluster in radial groups. In general they show no common orientation, and the planes of schistosity of the groundmass are deformed around them. Some beds, rich in chloritoid porphyroblasts, contain no 'dolomite'; and in some beds, coarser than most but still very fine grained, there is much anhedral, twinned carbonate (probably calcite) in the matrix. What may be the same beds, on the southwest side of the syncline passing through Tomias Lake Valley, are poorly exposed near Ravenal Creek about 2 miles south of the Swannell mineral claims.

Minor, fine-grained, clastic, sedimentary rocks observed in the Ingenika group include calcite-sericite-chlorite slate containing felted masses of interwoven tourmaline needles up to 0·05 mm. long; beds composed almost entirely of clinozoisite and epidote; others of zoisite and actinolite; and a calcareous chloritic schist exposed near Ingenika Cone, in which tourmaline crystals up to 2 mm. long arranged in radiating clusters comprise 30 per cent of the rock volume.

Limestones

Textural Features and Mineral Composition. The limestones of the Ingenika group range from rocks consisting almost entirely of calcite to detrital rocks containing as much as 30 per cent clastic quartz and feldspar, or to impure rocks containing much fine clastic material and grading into calcareous argillites and slates. Almost all of the limestones have been recrystallized, so that original sedimentary textures have been in large part destroyed. Many of the limestones are oolitic, with oolites of both radiating and concentric structure. Others contain many small rounded forms up to 5 mm. in length, which may be algal structures. The grain size of the crystalline limestone ranges up to 5 mm. in mean diameter, but in most rocks it is less than 1 millimetre. Any original argillaceous detrital material has, in most of the limestones, been converted to sericite, or to sericite and minor chlorite; and the widespread occurrence of a distinctive ivory-buff or rose-coloured, granular, crystalline limestone containing abundant muscovite flakes up to 1 mm. in length, interbedded with a calcareous chlorite-sericite slate, has already been noted. Most of the limestones contain a few grains of detrital quartz; and some beds, as for example in the Russel and the Espee Ranges, contain up to 25 per cent quartz and 5 per cent plagioclase and microcline feldspar in rounded grains up to 2 mm. in diameter. In these rocks some of the quartz has been slightly recrystallized and shows a tendency toward crystalloblastic outline against the calcite, but the feldspars appear to be essentially unchanged detrital fragments.

Many of the well-bedded limestones have a pronounced purple colour, the intensity of which seems to be independent of the amount of megascopically visible argillaceous or sandy detritus. In thin section, these limestones may be seen to contain minute flakes of what appears to be hematite, fairly regularly distributed and embedded within the recrystallized calcite grains. Their origin, and whether or not they represent an alteration of some pre-existing sedimentary mineral, is not evident. Some beds of blue-grey limestone on Forres Mountain, and east of Pelly Creek, contain much crystalline pyrite.

In several places, as for example east of the mouth of Tenakihi Creek, northeast of Mount Lay, west of Chase Mountain, near Lookout Hill, and east of Pelly Creek, beds of limestone have been locally replaced by siderite to such an extent that they become a siderite-rock. The siderite is typically buff to reddish brown, and generally coarse grained, with, in exceptional instances, rhombic crystals up to 6 inches a side. This rock is apparently developed entirely as a later hydrothermal alteration of the limestone, and is in many places associated with metallic mineralization.

The remarkable degree of brecciation of some of the limestones has already been described. Such structures appear to be best developed in the thick, massive, relatively pure beds. Microscopically, no obvious difference can be seen between brecciated and unbrecciated material, and the fragments in the breccia differ from the matrix material only in their finer crystal size. Coarsely crystalline limestones are best developed in beds 10 to 50 feet thick intercalated with relatively coarse, clastic, sedimentary strata. One such bed on the west side of Espee Range is a white, holocrystalline rock composed almost entirely of very clean, unstrained, untwinned calcite crystals up to 5 mm. long, whose smooth, mutually rounded outlines contrast sharply with the sutured, interlocking borders of less coarsely crystalline limestones, and in which the argillaceous impurities are limited to a few interstitial 'pockets' between otherwise clean-fitting grains.

Stylolitic structures, ranging in size from those with serrations covering a band 2 inches wide to those visible only in thin section, were noted in several places, but are not abundant.

Chemical Analyses. Samples of Ingenika group limestones from various places in the map-area were analysed by R. J. C. Fabry of the Mineralogical Division, Geological Survey of Canada, who reported as follows (a composite analysis of 'average limestone' ("A") is included for comparison):

—	23R	33W	203R	204R	389R	181C	216C	221C	"A"
CaO	54·32	48·86	38·42	49·24	54·82	50·58	52·24	55·30	42·61
CO_2	41·14	39·20	31·64	38·78	43·14	41·06	42·04	42·66	41·58
MgO	0·51	0·34	2·60	0·36	0·21	1·20	1·68	0·20	7·90
$(FeAl)_2O_3$	0·77	2·44	3·86	1·08	0·18	0·92	0·80	0·60	1·35
H_2O	1·58	0·72	1·88	0·68	0·70	1·38	0·88	0·86	0·77
Insol.	2·30	8·50	22·34	9·50	0·76	5·16	2·72	0·50	....
Total	100·62	100·05	100·74	99·64	99·81	100·30	100·36	100·12	

23R. Pale purple and buff-grey, fine-grained, crystalline, poorly bedded limestone, from about the middle of the thick limestone member exposed on the crest of the ridge north of Osilinka River, east of Tenakihi Creek.

33W. Ivory-buff coloured granular limestone containing abundant oriented flakes of muscovite up to 1 mm. long. From the east side of Tenakihi Creek Valley, north of Osilinka River, 400 feet stratigraphically above spec. 23R.

203R. Banded, pale green and silver-buff, sugary, micaceous limestone, containing a multitude of sericite flakes and a few grains of detrital quartz scattered through a sheared, medium-grained, recrystallized calcite matrix. From the northeast side of Swannell River Valley, west of Orion Creek, 1,200 feet stratigraphically above spec. 204R.

204R. Ivory-buff to rose-yellow crystalline limestone, poorly bedded to slaty, with very thin sericitic and chloritic partings. From the northeast side of Swannell River Valley, west of Orion Creek, 400 feet stratigraphically above the top of the main limestone member, 4,100 feet above the base of the Ingenika group.

389R. Light grey, medium-grained, fairly well-bedded, crystalline limestone containing beds and streaks of white, slightly more coarsely crystalline, finely bedded material. From the north end of Butler Range, 3 miles due south of the summit of Ingenika Cone.

181C. Massive to platy, light pinkish grey, fine-grained, crystalline limestone, containing round markings 1 to 3 mm. in diameter, which resemble algal structures. From west side of Swannell River Valley, on crest of ridge 3·2 miles northeast of the summit of Mount Lay.
216C. Compact, fine-grained, finely bedded, grey, crystalline limestone. From south slope of Lookout Hill near shore of Delkluz Lake.
221C. White, moderately coarse-grained, recrystallized, bedded limestone, from near summit of Lookout Hill.
"A". Composite analysis of 345 limestones (H. N. Stokes, U.S. Geol. Surv., Bull. 770, p. 564).

The analysed samples, taken from various stratigraphic horizons in widely scattered parts of the map-area, are believed to be fairly representative of the main varieties of carbonate-rich rocks found in the Ingenika group. It will be noted that despite great variations in physical appearance, the chemical composition of the different rocks is markedly similar, the only significant difference being in the amount of insoluble matter—a difference that may be accounted for by admixed detrital material, chiefly quartz and sericite. All of the rocks have a low magnesia content and most of them a small to moderate amount of iron and alumina. The samples from the thick limestone belts (23R, 289R, 216C, 221C) are all remarkably high in lime; the average of these analyses, recalculated to a total of 100 per cent, is 54·05 per cent CaO (pure calcite has a lime content of 56·00 per cent).

No dolomite rock was recognized among the Ingenika group sedimentary strata, and the foregoing analyses, although too few to warrant a general conclusion, show no tendency for the thick massive limestones, the bedded slaty limestones, or the buff-coloured, impure, micaceous limestones to have a significant magnesia (MgO) content.

Efflorescent Salts

At several localities within the map-area, grey to blue-grey, impure slaty or schistose limestones, and sericitic phyllites and schists of the Ingenika group produce upon weathering a characteristic encrustation of soluble salts.

In the Tenakihi Range south of Mesilinka River, a 5-foot section of impure, dark grey, fine-grained, slaty limestone and blue-grey, very friable, sericitic phyllite is coated along its outcrop on a cliff face for 300 feet with a white soluble salt. The salt apparently forms rapidly, and is as rapidly removed by rainwash; when visited during a period of fine weather in 1945, it coated most of the vertical faces of the beds on which it was formed, so that a white band across the cliff was conspicuous from a distance, and accumulated on small ledges to a depth of 2 inches or more; during a period of wet weather, shortly after the spring snow run-off in 1947, no salt was visible; in the spring of 1948, in the last stages of the snow run-off, the salt was found as a thin coating on the outcrop of the beds from which it is formed. A sample of this material, collected in 1945, was examined by Eugene Poitevin of the Division of Mineralogy, Geological Survey of Canada, who reported as follows:

"This sample is composed of water soluble and insoluble portions. The insoluble portion, which is small, is mainly calcite (lime carbonate). The soluble portion is composed mainly of nitre (nitrate of potash) and appreciable amounts of lime sulphate. The glassy nitrate of potash grains were examined under the microscope, and have all the optical properties of nitre."

Further collections from this deposit, made in 1948, were tested by R. J. C. Fabry of the Geological Survey, who also found the salt to consist mainly of potassium nitrate, with lesser amounts of calcium sulphate. Mr. Fabry noted that the source rock, coated with the salt, contains considerable free ammonia.

The origin of the nitrate in these salts is an enigma. The beds on which the nitre is forming, although too fine grained to allow accurate mineralogical and textural determination, do not appear to be superficially different from other impure limestones and sericite phyllites both higher and lower in the section, and fresh specimens of the nitre-bearing rocks cannot be distinguished (except by taste) from many similar beds that do not form nitre. The most obvious origin, namely, by the reaction of the partly decomposed feldspars in the rocks with nitric acid produced by the decomposition of recent animal deposits, is difficult to accept in view of the location of the salt on an exposed cliff face, the position and topography of the cliff itself, the restriction of the salt to a single thin series of beds, the uniqueness of the deposit in the entire area studied, its persistence through varying climatic conditions, and the apparent lack of any animal deposits. Marmot burrows and one large eagle nest were found on the slope above the cliff, but there is no evidence of nitre forming from the rocks near these, and the present animal population would appear totally inadequate to accumulate deposits that could supply sufficient nitric acid to produce the efflorescence. Nor do the salt-encrusted beds appear to mark the outcrop of a local water-table, and there is no obvious relation between the distribution of the salt and the numerous shears and fractures that must serve as channels for the movement of ground water.

The restriction of the efflorescence to a single thin series of beds, the release of the salt by weathering over an extended period, and its tendency to be removed, rather than formed, near fractures controlling water movement, may suggest that the nitrate is an original constituent of the beds. The beds do not appear to be part of a normal evaporite sequence, for no halite or gypsum, which would invariably be present in much larger amounts than nitre, have been identified in the underlying beds, and the selective leaching of these salts and not of nitre does not seem possible. However, certain beds in several parts of the Ingenika group release calcium sulphate (gypsum or anhydrite) upon weathering (*See* below); and general conditions of aridity at the time of deposition may be indicated by the abundance of clean quartz-pebble conglomerate, the purity and perfection of rounding and sorting of some quartzites, the probable mud-cracks in impure limestone on Forres Mountain, and the paucity of fossils. A further possibility is that the overlying graphitic schists and phyllites, which were probably originally carbonaceous shales, and which may have accumulated under putrescent conditions, contained animal nitrate. But there is no indication of the manner in which the highly soluble nitre could be preserved from early Palæozoic time to the present.

In a canyon of a creek flowing into Mesilinka River from the north about 7 miles east of Blackpine Lake, a white crystalline salt has formed to a depth of about 2 inches on vertical surfaces of sericitic phyllites and schists, and has accumulated on a few protected ledges to a depth of nearly

2 feet. Samples of these salts and their source rocks were analysed by R. J. C. Fabry of the Section of Mineralogy, Geological Survey, who reported as follows:

"Sample 32R (salt from silver-brown weathered schist).
$MgSO_4$ and $CaSO_4$ with some water. In acid solution shows some iron.
"Sample 34R (salt from blue-grey phyllitic schist).
Similar to 32R, but calcium is more abundant than magnesium.
"Sample 36R (from exposed points of grey-brown schist).
Mainly basic ferric sulphate.
"Sample 37R (bulk sample, chiefly from rocks similar to spec. 33R). A qualitative analysis shows this to be a sulphate of magnesium and lime when in aqueous solution. However, in acid solution iron can also be detected.

A quantitative analysis gave the following results:

	Per cent
CaO	1·78
MgO	6·90
Fe_2O_3	4·90
H_2O	20·18
SO_3	12·22
Insol.	54·23
	99·91"

The source rocks were analysed by Mr. Fabry with the following results (a composite analysis of 'average shale' ("B") is included for comparison):

—	33R	35R	"B"
	Per cent	Per cent	Per cent
SiO_2	59·46	44·45	58·10
Al_2O_3	14·15	30·15	15·40
Fe_2O_3	4·44	3·27	4·02
FeO	3·58	3·66	2·45
CaO	0·66	0·42	3·11
MgO	3·54	2·98	2·44
K_2O	2·24	6·12	3·24
Na_2O	1·88	1·06	1·30
H_2O (+)	2·37	4·93	—
H_2O (−)	0·38	0·79	5·00
TiO_2	0·68	0·84	0·65
MnO	0·02	Trace	—
P_2O_5	—	—	0·17
CO_2	6·79	None	2·63
SO_3	0·26	0·89	0·64
S	0·29	0·12	—
Organic	—	—	—
Total	100·74	99·68	—
Less O/S	0·11	0·04	—
	100·63	99·64	99·95

33R. Grey-brown to silvery, fine-grained, very flaky quartz-sericite schist and phyllite, in beds about 6 feet thick, separated by bands of micaceous quartzite up to 12 inches thick. This rock is the source for the salt of sample 32R, and seems to be representative of the rock type yielding the most copious supply of salts.

35R. Blue-grey sericitic phyllite, very soft and friable, in beds up to 25 feet thick. This is the source rock for the salt of sample 34R.

"B". 'Average shale'—composite of many average analyses—F. W. Clarke, U.S. Geol. Surv., Bull. 770, p. 34.

Sample 33R is seen to conform very closely to the chemical composition of average shale as compiled by Clarke. Sample 35R is unusual in possessing a very high content of alumina, with correspondingly decreased silica and relatively high potash content. Neither rock shows any unusual features in its minor constituents, and the reasons why these rocks should produce a copious efflorescence are not apparent. Both calcium and magnesium sulphates, as well as iron sulphates, are, of course, frequently formed in weathered schists and other rocks of similar nature by the action of waters bearing sulphuric acid, usually supplied by the decomposition of iron sulphides in the rock; thin encrustations of this sort are too common to deserve special notice. Whether the salts here described are merely an extraordinarily abundant accumulation of efflorescences of this nature, or whether they may be in part gypsum or anhydrite and epsomite representing a remnant of an evaporite sequence, as discussed for the nitre-bearing salts, is not known.

A similar encrustation is abundant on the walls of a canyon in blue-grey phyllites and slates near the mouth of a small creek entering Mesilinka River from the south, near the eastern border of the map-area. Small cliffs of fine-grained chlorite-sericite schist and chloritic quartzite in Swannell River Valley west of Orion Creek are likewise coated with a white salt. In each occurrence of abundant efflorescence, whether of nitrate or sulphates, the presence of the salt is easily recognized by the conspicuous effect on nearby vegetation; the talus slopes below the salt-encrusted cliffs are sparsely covered with sagebrush (*Artemisia longipedunculata ?*), which contrasts sharply with the sphagnum moss-Labrador tea-dwarf birch undergrowth of the surrounding areas.

Structural Relations

INTERNAL STRUCTURAL RELATIONS

The position of the Ingenika group on the flanks of the major anticlinoria that expose Tenakihi group strata at their cores has been noted. From the northeastern limb of the anticlinorium passing through Chase Mountain, the Ingenika group can be traced northeastward into a major syncline whose axis passes through Tomias Lake Valley and whose northeast limb is overturned (*See* structure-section E-F). The overturned structures may be traced northward along the east side of Pelly Creek Valley, where they may be seen to represent the southwest limb of another major anticlinorium whose crest passes through Barrier Peak and along the Russel Range west of Ed Bird Creek (structure-sections A-B, C-D). The large-scale structural features of the Ingenika group are thus seen to be a series of northwest-trending compound folds, 10 to 15 miles from crest to crest, with, in general, undulating, gently dipping northeast limbs and simple to isoclinally folded, steeply dipping or overturned southwest limbs. The axes of the folds are undulating, and in general plunge gently northwest. These relations have been considerably complicated by faulting on a large and small scale; they are discussed further in Chapter V.

Within these larger structures, the Ingenika group rocks exhibit a great variety of minor structures. The intercalation of thick, lenticular bands of massive limestone; strong, brittle quartzite and conglomerate beds; competent but flexible assemblages of thin beds of limestone and phyllite, schist, or slate; and thick assemblages of weak, incompetent argillites and phyllites has resulted in a great diversity of structural forms, produced in response to what may have been originally simple deforming stresses. On the whole, however, in all rocks south of Ingenika River, and in Tucha Range, the small-scale deformation has been quite gentle, involving deviations of usually less than 30 degrees from the general plane of bedding in any one area, and the deformed beds show little evidence of faulting or rupturing. The entire assemblage of Ingenika group rocks on the north flank of the Mount Lay-Wrede Creek anticlinorium, and in Wrede and Tucha Ranges, is relatively free from small folds, and is only gently flexed into wave-like anticlines and synclines, 500 to 5,000 feet from crest to crest and with closures of from 50 to 600 feet, parallel with the major anticlinorial structure. In places, intercalated medium-bedded micaceous limestones, slates, and phyllitic schists have developed regular parallel folds, and adjacent slates and phyllites have accommodated themselves to the deformation by shearing. The most extreme examples of deformation are shown by the limestone beds. Near the axis of the major syncline that crosses Swannell River near the Swannell mineral claims, impure limestones, together with interbedded calcareous and carbonaceous slates and phyllites, have been bent into isoclinal folds in which single beds up to 2 feet thick have been folded back on themselves for as much as 20 feet, and slightly more open structures have developed a multitude of drag-folds. The relatively pure, thin-bedded, grey limestones exposed on the north face of Forres Mountain show a large number of superimposed folded structures of different scales; on the major folds, about a mile across, are secondary folds 100 to 500 feet across; on these, in turn, are drag-folds up to 25 feet from crest to crest; and these drag-folds carry smaller folds, 1 foot to 3 feet across, which are themselves minutely corrugated. The axial planes of all of these series of folds are essentially parallel with that of the large structures; and it would appear that the entire composite structure was produced simultaneously. It was estimated in the field that the minor folds alone, seen in the cliffs on the south ridge of Forres Mountain, must have required a shortening of beds to less than half their length, exclusive of the shortening occasioned by the development of the large anticlines and synclines. On other parts of Forres Mountain the folds are large and mainly simple.

The thick belt of limestones east of Pelly Creek shows numerous regular isoclinal folds up to 500 feet from limb to limb and more than 1,000 feet from crest to trough. In general, these folds appear to be regular and smooth, free from small-scale drag-folds, although such structures, if present, would be hard to recognize in the massively bedded, uniform limestones. On what appears to be the southern prolongation of this belt, however, in Ingenika River Valley near Lookout Hill and Ferguson and Onward mineral claims, the limestones have been deformed into structures of extreme complexity. Detailed mapping of outcrops, surface strippings, and underground workings in this area has revealed that, around what appears to be the nose of a large, northwest-plunging drag-fold, the limestone has been plastically deformed into infolded, digitate, and fan-shaped structures.

Russel Range shows the greatest complexity of structure of any of the mountain ranges in Aiken Lake map-area. The large, overturned and fan-shaped folds, whose dimensions are measured in miles or fractions of miles, are complicated by numerous local domes, basins, or noses, tens or hundreds of feet in diameter, accompanied in places by drag-folds and minor crenulations whose axial planes, commonly sharply warped, exhibit a wide variety of strikes, with dips ranging from horizontal to vertical and overturned. In places, where the strong, competent quartzite beds outline smooth folds, the interbedded, chloritic, slaty material has been mylonitized and rendered relatively mobile. The mobilized chloritic material is now found as thin 'injected' layers filling joints in the quartzite, or as irregular lens-like bodies that pinch out unevenly along the strike and down the dip, and give the appearance of irregular 'blisters' of chloritic mylonite between beds of quartzite. The origin of these complex structures is not readily apparent, but it appears to be associated with the superposition of the present northwest-trending folds on earlier, nearly west-trending structures. The problem is discussed further in Chapter V.

DETAILED SECTIONS

Sections South of Ingenika River

The following sections are, in a general way, representative of the Ingenika group rocks south of Ingenika River. It was not found possible to correlate individual beds from one mountain massif to another, and the sections given are from fortuitous areas where the strata are most continuously exposed, rather than from areas chosen because of their representative stratigraphic assemblages.

I. Section on Ridge East of Tenakihi Creek, North of Osilinka River, Tenakihi Range

Top of section not observed	Thickness Feet
Sericite schist, dark grey	30
Unexposed	50
Limestone, blue-grey, medium-grained, crystalline, massive to well-bedded; with a few buff-coloured recrystallized beds	310
Poorly exposed; mainly chlorite-sericite phyllite	100
Limestone, blue-grey, well-bedded, crystalline	110
Poorly exposed; scattered outcrops and much float of white to pale purple quartzite, golden brown micaceous quartzite, and lustrous brownish green chloritic phyllite	±500
Limestone, ivory-buff, sugary, sericitic	40
Phyllite, grey-green, fissile, interbedded with quartz-sericite-chlorite schist; with lenses of blue-grey crystalline limestone; archaeocyatha zone (F1R 1946; 15229)	45
Schists, silvery, red, and brownish green, micaceous, in part slaty and phyllitic, in part minutely crumpled; contains a few thin beds of ivory-buff, sugary, sericitic limestone	70
Limestone, blue-grey, partly massive, partly sheared; micaceous limestone, ivory-buff, sugary (analysed specimen No. 33W); thin beds of silver-green-brown sericitic phyllite and fine-grained chloritic quartzite	110

Limestone, ivory-buff to pale rose, micaceous, mainly sugary, non-schistose, in beds up to 5 feet thick; a few beds up to 10 feet thick of brownish green chloritic phyllite	220
Phyllite, lustrous green, chloritic; and schist, very fine-grained, in part minutely crumpled; a few thin bands of dark grey, calcareous, sericitic slate	70
Limestone, light grey to medium blue-grey, fine to coarsely crystalline, in places sheared, slaty, or crumpled, in places massive (analysed specimen No. 23R); part may be removed, or duplicated, by an oblique fault (1,100)	1,700
Limestone, blue-grey, massive; with interbedded buff-coloured, sugary, micaceous limestone	40
Limestone, blue-grey to dark grey, massive to slaty	130
Limestone, blue-grey, massive to slaty, in part highly contorted; with abundant buff-coloured coarsely crystalline beds up to 5 feet thick	110
Limestone, blue-grey, highly sheared, slaty	150
Slate, grey-brown, chloritic; phyllite; chlorite schist; quartzite, fine-grained, schistose, chloritic; slate, blue-grey, calcareous	130
Unexposed	±560
Slate, dark green to grey-brown, chloritic; quartz-sericite-chlorite schist, medium-grained to sugary, pyritiferous	540
Base unexposed.	
Total (4,415)	5,015

II. Section in Tenakihi Range, South of Mesilinka River, North of Jim May Creek

	Thickness Feet
Limestone, blue-grey and buff-coloured, well-bedded, crystalline, in part stylolitic; thin partings of carbonaceous material between some blue and buff beds	130
Limestone, blue-grey, medium-grained, crystalline, mainly well-bedded, with beds $\frac{1}{10}$ inch to 15 feet thick outlined by concentrations of carbonaceous material; irregular bodies of buff-coloured, coarsely crystalline limestone	290
Limestone, buff-coloured to white, coarsely crystalline, poorly bedded; minor blue-grey bedded limestone	170
Limestone, blue-grey, fine- to medium-grained, beds 0·1 to 1 foot thick; some beds near the base are highly sheared	190
Limestone, grey and grey-brown, sheared or slaty, mainly micaceous, chloritic, or sandy; a few beds up to 20 feet thick of poorly bedded, unsheared, blue-grey limestone; partings of chlorite-sericite schist up to 1 foot thick	500
Unexposed	±420
Limestone, grey to grey-brown, sheared or slaty, impure, with up to 20 per cent sericite and chlorite; thin partings of chlorite-sericite schist	370
Unexposed	±2,280
Quartzite, light grey to buff-coloured, impure, consisting of quartz and feldspar grains up to $\frac{1}{10}$ inch in diameter in a fine-grained schistose quartz-sericite-chlorite matrix; interbedded quartz-sericite-chlorite schist, in part calcareous	130
Conglomerate, grey, recrystallized, composed of colourless and light grey quartz and buff-coloured feldspar pebbles up to ½ inch in diameter in a rusty, grey, medium-grained, schistose, chloritic quartzite matrix; some pebbles are coated with a thin layer of chloritic material; minor interbedded quartzite	190
Unexposed	±120
Quartz-sericite-chlorite schist, light grey-green, fine-grained; interbedded quartzite, grey-green to brown, medium-grained, schistose, impure	120

	Thickness Feet
Quartzite, speckled grey-brown, medium- to fine-grained, schistose, impure, in beds 6 inches to 4 feet thick separated by 1 inch to 6 inches of quartz-sericite-chlorite schist	100
Quartz-sericite-chlorite schist, rusty brown to grey-green, slaty	80
Quartzite, grey-brown, medium-grained, schistose, impure, composed of grains up to $\frac{1}{10}$ inch in diameter of quartz, feldspar, chlorite, and an unidentified ferromagnesian mineral now changed to earthy limonite, in a very fine-grained sheared matrix	190
Slate, dark grey and brown; with interbedded quartz-sericite-chlorite schist	70
Quartzite, grey-brown, medium-grained, schistose, feldspathic, with a speckled appearance due to scattered grains of quartz, plagioclase, and chlorite, about $\frac{1}{20}$ inch in diameter in a slightly schistose quartz-sericite matrix	210
Unexposed; float of blue-grey limestone and quartz-sericite schist	±180
Conglomerate, sheared, composed of quartz and feldspar pebbles up to $\frac{1}{2}$ inch in diameter in a slightly schistose quartz-sericite matrix	40
Quartzite, very fine-grained, sheared, sericitic and calcareous; interbedded quartz-sericite-calcite schist	60
Unexposed; float of quartz-sericite schist	±330
Quartz-sericite-chlorite schist, light grey-brown, slaty, in part calcareous; about 10 per cent conglomerate, sheared; thin layers of phyllite, dark silvery grey, carbonaceous	390
Conglomerate, recrystallized, schistose, containing rounded grains of quartz, oligoclase-andesine, alkali plagioclase, and perthite, up to $\frac{1}{8}$ inch long in a quartz-sericite-chlorite matrix	100
Slate, grey-green to dark brown; minor quartz-sericite-chlorite schist	75
Quartz-sericite-chlorite schist, light grey and dark grey, uniformly fine-grained, with banded appearance due to thin layers of increased chlorite content	160
Quartzite, light grey, schistose, chloritic and sericitic; interbedded quartz-chlorite schist, dark grey, fine-grained, partly slaty; minor calcareous beds	280
Unexposed, except for one 15-foot bed of sheared conglomerate, composed of pebbles of quartz up to $\frac{3}{4}$ inch and of quartz and feldspar up to $\frac{1}{2}$ inch in a schistose chloritic quartzite matrix	±100
Quartz-chlorite schist, light grey to grey-green, very fine-grained	280
Unexposed; float of schistose quartzite and quartz-sericite schist	±350
Limestone, blue-grey to dark grey, slaty to phyllitic, sericitic, in beds 1 inch to 3 feet thick, separated by about an equal amount of quartz-sericite-chlorite schist	110
Limestone, blue-grey, slaty to schistose, sericitic, interbedded with slate and phyllite; dark grey, in beds $\frac{1}{2}$ inch to 2 inches thick; quartzite, impure, well-bedded, partly as partings up to 2 inches thick between slate beds; metamorphosed grit and quartzitic conglomerate, partly calcareous, in beds up to 2 feet thick; two distinct beds of sheared, sericitic, calcareous material produce efflorescences of nitre	40
Conglomerate, grey to rusty brown, sheared, composed of rounded quartz and quartzite grains up to $\frac{1}{2}$ inch in diameter, and plagioclase and perthite grains up to $\frac{1}{4}$ inch in diameter in a rusty sericitic matrix, beds up to 12 feet thick separated by partings of slate up to 6 inches thick	35
Slate, dark and medium grey; sheared argillite; a few beds up to 2 feet thick of quartzite, light grey, medium-grained, schistose	60
Quartzite, light grey-brown, slightly schistose, composed of rounded clastic grains and recrystallized 'eyes' of quartz up to $\frac{1}{8}$ inch in diameter, and rounded masses of limonitic matter that apparently represent decomposed ferromagnesian minerals	80
Limestone, dark blue-grey to black, impure, slaty, poorly bedded; slate, dark brown and grey, calcareous; chlorite-sericite schist, calcareous; minor quartzite, sheared, in part crossbedded	130

	Thickness Feet
Schist, grey-green, medium-grained, containing grains up to $\frac{1}{16}$ inch of transparent quartz, light grey feldspar, and amphibole partly converted to chlorite, in a quartz-sericite-chlorite matrix	150
Unexposed; float principally quartz-sericite schist	±200
'Augen' quartzite, grey-green, fine-grained, with quartz 'eyes' up to $\frac{1}{10}$ inch in diameter in a schistose quartz-sericite-chlorite matrix; minor quartz-sericite-chlorite schist, medium- to fine-grained	300
Sericite schist, dark grey, fine-grained, finely wrinkled, carbonaceous	100
Quartz-sericite-chlorite schist, grey-green, fine-grained; phyllite, dark silver-grey to black, lustrous, finely wrinkled; minor quartzitic conglomerate, sericitic, in beds up to 15 feet thick	600
Quartzitic conglomerate, composed of rounded to semi-angular grains up to $\frac{1}{2}$ inch in diameter of quartz and perthitic feldspar, with minor plagioclase feldspar, in a schistose matrix of quartz, muscovite, biotite, and chlorite; about 10 per cent quartz-sericite-chlorite schist, very fine-grained	840
'Augen' quartzite; interbedded quartz-muscovite-chlorite schist, grey-green, uniformly fine-grained; about 10 per cent quartzite, medium coarse, schistose, with scattered flakes of biotite	1,300
Quartzitic conglomerate and 'augen' quartzite, containing rounded and lenticular fragments of feldspar and quartz, most of which look detrital, but some of which are recrystallized and may represent porphyroblasts or porphyroclasts, in a light grey-green matrix consisting of 70 to 90 per cent quartz, 0 to 15 per cent feldspar, 0 to 10 per cent sericitic muscovite and chlorite, and accessory tourmaline, magnetite, calcite	510
Quartzitic conglomerate and quartz-mica schist, in about equal proportions; conglomerate matrix and schist contain 50 to 80 per cent quartz, 0 to 10 per cent feldspar, 0 to 20 per cent muscovite, 0 to 10 per cent chlorite, and 0 to 5 per cent carbonaceous material; minor phyllite, black, carbonaceous, in thin bands	180
Phyllite, black, soft, finely wrinkled, containing about 50 per cent quartz, up to 10 per cent muscovite, and the remainder obscured by carbonaceous matter; a few beds are graphitic schists	40
Quartzitic conglomerate, with pebbles of white feldspar (perthite and albite-oligoclase) up to $\frac{1}{2}$ inch in diameter closely packed in a slightly schistose matrix containing 80 to 90 per cent quartz, 5 per cent feldspar, 5 per cent muscovite, minor chlorite, carbonaceous matter, and calcite, and scattered grains of magnetite up to $\frac{1}{10}$ inch in diameter; minor interbedded quartz-sericite-chlorite schist	190
Quartz-muscovite-chlorite schist, silver-grey-green, with a few beds containing rudimentary garnet porphyroblasts; interbedded quartz-sericite schist and phyllite; quartzite, grey-green and brown, chloritic and sericitic, grading into grit and fine conglomerate, in beds up to 20 feet thick, with a matrix containing 60 to 90 per cent quartz, and up to 10 per cent each of feldspar, biotite, muscovite, and chlorite	580
Quartzite and fine conglomerate, light grey, slightly schistose, containing lenticular fragments of buff and white alkali plagioclase and purplish transluscent quartz up to $\frac{1}{4}$ inch in diameter in a schistose groundmass containing 85 to 90 per cent quartz, 5 to 10 per cent feldspar, 2 to 5 per cent muscovite, and minor biotite	100
Base of Ingenika group—lies conformably on Tenakihi group (See section, page 45).	
Total	13,470

III. Section in Swannell River Valley West of Orion Creek

Limestone, light grey to buff, fine-grained, crystalline; in part sericitic	60
Slate, pale green, slightly crumpled, chloritic	40
Quartzite, light grey, sericitic; minor quartz-chlorite schist	60

	Thickness Feet
Limestone, blue-grey, greenish, and silver-buff, crystalline; in part fine-grained and massive; in part sugary, schistose, and highly sericitic (analysed specimen No. 203R)	200
Slate, pale green, containing quartz, chlorite, and biotite; thin beds of ivory-coloured sericitic limestone	100
Quartzite, white, schistose, slightly sericitic	110
Chlorite-sericite slate, brownish grey; interbedded quartz-chlorite-sericite schist, grey-green	200
Quartzite, grey-brown, schistose, gritty, containing grains of clear quartz up to ⅛ inch in diameter in a schistose, medium-grained, sericitic quartzite matrix	370 (max.)
Quartzite, grey-brown, corrugated, banded, sericitic and chloritic, with layers rich in biotite	40
Unexposed	±240
Slate, pale grey-green, chloritic	80
Limestone, ivory-buff to rose-yellow, sericitic, in part slaty, with partings of chlorite-sericite slate (analysed specimen No. 204R)	100
Sericite-chlorite schist, silvery; slate, pale green, chloritic	80
Limestone, ivory-buff to rose-yellow, sugary, sericitic	60
Slate, grey-green, chloritic; thin beds of sericite schist	170
Limestone, blue-grey to pale grey or buff, crystalline, mainly massive, in part well bedded, in part slaty	680
Quartzitic conglomerate, grey-green, schistose, containing elongated pebbles of white quartzite up to ¼ inch in diameter in a quartz-chlorite-sericite matrix	180
Unexposed	±200
Quartz-sericite schist, speckled grey-brown, fine-grained	60
Quartzite, fine-grained, schistose, chloritic, with thin partings of chlorite-sericite slate	110
Chlorite-sericite slate and slaty schist, pale grey-green; grit, grey-green, schistose; a few beds up to 5 feet thick of schistose quartzitic conglomerate, composed of rounded quartz pebbles up to ¼ inch in diameter, closely packed in a coarse-grained quartz-sericite-chlorite matrix	150
Quartzite, grey, fine-grained, schistose, sericitic	60
Slate, grey-green and grey-brown, chloritic and sericitic	80
Quartzite, grey-brown, schistose, sericitic, with scattered small pebbles of quartz and feldspar	130
Interbedded quartz-chlorite-sericite slate, schist, and quartzite	530
Quartz-chlorite schist, grey-green; minor quartzite, very fine-grained, schistose	350
Quartzite, banded grey-brown, schistose, micaceous, with layers rich in limonitic material; chlorite-sericite schist, silvery grey-green, crumpled, porphyroblastic, with scattered biotite flakes and rough garnets up to ⅛ inch in diameter	960
Grit, grey-green, schistose, with pebbles or porphyroblastic 'eyes' of clear quartz and grey feldspar in a schistose chloritic-sericitic quartzite matrix; interbedded quartz-chlorite-sericite schist	240
Base of Ingenika group—lies conformably on Tenakihi group (See section page 46).	
Total	5,640

IV. Section East of Cutbank Creek

Quartz-chlorite schist, grey-green; quartz-sericite-chlorite schist, brownish green; quartzite, schistose, composed of subangular, well-sorted particles of clear quartz, oriented laths of chlorite, and a few grains of plagioclase; a total of about 1,500 feet is not exposed	7,000
Quartzite, grey-green, nodular, chloritic; interbedded chlorite schist, soft, medium-grained	200
Chlorite schist, fine-grained, slaty	50

	Thickness Feet
Limestone, blue-grey, crystalline, thin-bedded, with partings of chlorite schist	1,800
Quartzite, grey to grey-green, fine-grained, schistose, chloritic	2,500
Quartz-chlorite-sericite schist; interbedded quartzite, schistose, chloritic, containing a few grains of plagioclase	1,200
Quartz-chlorite-sericite schist, grey-green to silver-grey, in small part containing biotite and rudimentary garnets; minor quartzite	2,100
Quartzitic conglomerate, light grey, containing round quartz pebbles up to ¼ inch in a fine-grained quartzite matrix	200
Quartzite, grey-green, chloritic; minor quartz-chlorite schist; a few beds of quartzitic conglomerate up to 10 feet thick	900
Quartzitic conglomerate, composed chiefly of rounded pebbles of quartz and quartzite up to ¾ inch in diameter, with some beds containing many pebbles up to ⅜ inch in diameter of a rock composed mainly of andesine plagioclase; most beds are less than 10 feet thick, separated by partings of chlorite schist and chloritic quartzite, in part containing a few rough grains of garnet	200
Quartz-sericite-chlorite schist; quartz-chlorite schist; minor quartzite	1,000
Quartzite, consisting of poorly sorted, angular to subangular quartz, and about 10 per cent chlorite, which in some specimens has been almost completely converted to biotite; minor quartz-biotite-chlorite schist; a few thin beds of quartzitic conglomerate, consisting of rounded quartzite pebbles up to ¼ inch in diameter in a chloritic quartzite matrix	550
Base of Ingenika group—conformably(?) overlies Tenakihi group.	
Total	17,700

Sections North of Ingenika River

North of Ingenika River, deformation has thickened some beds, thinned others, and in the thick limestone sections caused an unknown degree of repetition of beds by isoclinal folding. Consequently, any estimate of stratigraphic thickness has little meaning in these areas, and, owing to the lenticular nature of some of the deformed beds, the stratigraphic sequence in any single measured section is only representative for a very limited area.

In the following sections, the stratigraphic thicknesses listed are those observed in the field without special regard as to whether any particular bed was measured at a place where it was thinned on the limb of a fold or thickened by drag-folding. They are presented merely to show the relative abundance of the various rock types, and the thickness given may differ considerably from the average thickness of the beds to which they refer.

I. Generalized Section through Russel Range from Mount Tsaydizkun to West of Ravenal Peak (*See* Structure-section C-D)

(Top of Section)	Thickness Feet
Limestone, creamy white to pale grey, blue-grey weathering, massive to poorly bedded, crystalline; much limestone breccia	1,200 to 3,000(?)
Unexposed	±1,800
Interbedded series comprising about 50 per cent quartzitic conglomerate, consisting of white and light grey, rounded pebbles of quartzite up to ¾ inch in diameter, and less abundant, smaller, feldspathic pebbles, all slightly elongated, in a silver to green, phyllitic to schistose, quartz-sericite matrix; about 30 per cent	

	Thickness Feet
quartzite, gritty, feldspathic, containing angular grains of light grey feldspar and quartz in about equal proportions in a schistose, slightly chloritic, quartz-sericite matrix; about 20 per cent quartzite, pale buff to greenish grey, slightly micaceous; a few beds of conglomerate up to 25 feet thick	1,500
Quartz-chlorite schist; quartzite, chloritic, well bedded, in part crossbedded	100
Quartzitic conglomerate, fine-grained, containing rounded quartzite and feldspar-rich pebbles in a micaceous, schistose, quartzite matrix; quartzite, well-bedded, schistose, chloritic and sericitic; quartz-chlorite-sericite schist	2,000
Quartzitic conglomerate, fine-grained; quartz-sericite schist; phyllite, silvery, crumpled	500
Limestone, grey and white, highly contorted, in part slaty; interbedded massive limestone in very lenticular bodies; some beds near top of this unit contain much relatively coarse, rounded, detrital quartz	200 to 700 (?)
Quartzitic conglomerate, fine-grained, schistose, containing rounded pebbles up to $\frac{1}{4}$ inch in diameter of quartz, quartzite, and feldspar, in a fine-grained, schistose, micaceous quartzite matrix	120
Interbedded quartz-sericite schist and phyllite, slaty; quartzite, grey-green, medium-grained, in part calcareous; a few thin beds of limestone, pale brown, fine-grained, sugary to slaty	700 to 1,200 (?)
Unexposed	±700
Quartz-sericite schist, fine-grained, crumpled	500
Limestone, pale brown, coarsely crystalline to slaty; interbedded quartz-sericite schist	300 to 500 (?)
Limestone, dark grey and buff-coloured, sugary to slaty	150
Quartzite, pale brown to buff, medium- to fine-grained, micaceous; slate, pale green, dense, chloritic; minor phyllite, dark blue-grey, calcareous; a few bands up to 50 feet thick of limestone, pale brown-grey and sugary, or mottled blue-grey and massive	500
Quartzite, light grey to buff-coloured, sugary; minor slate	150
Quartzite, light grey, sugary, fairly pure	50
Interbedded series of varied composition; quartzite, grey, banded, in part crossbedded; slate, chloritic and siliceous; limestone, buff-brown, sandy textured, crystalline; various types repeatedly alternate in beds mainly less than 2 feet thick	1,000
Slate, soft, chloritic; interbedded quartzite, fine-grained, banded, slightly micaceous; limestone, reddish brown weathering, coarsely crystalline, in beds up to 5 feet thick	50
Interbedded series comprising about 40 per cent slate, chloritic; 20 per cent quartzite, fine-grained, chloritic; 20 per cent quartzite, slaty; 10 per cent chlorite-sericite slate, brownish grey, pyritiferous; 10 per cent quartzite, buff, pure, fine-grained; and a few thin beds of quartz-pebble conglomerate	1,500 to 2,000
Slate, blue-grey	100
Quartzite, buff, sugary; about 10 per cent interbedded phyllite and slate, blue-grey; minor slate and schist, light green, chloritic	800(?)
Quartzite, buff and grey, in part containing flakes of muscovite; minor slate	120 to 200
Quartz-chlorite-sericite slate, light green, soft, lustrous	40
Quartzite, buff-coloured, light buff-brown weathering, granular, in large part highly sheared; minor chloritic slate	200
About 40 per cent quartzite, orange-buff to light grey, white weathering, relatively pure, composed in part of clear, rounded grains up to $\frac{1}{20}$ inch in diameter in a fine-grained, sugary, tan-coloured matrix, and in part wholly sugary, fine-grained; about 20 per cent slate, blue-black; 10 per cent slate, chloritic; 30 per cent intermediate types of impure, banded, slaty quartzite	800 to 1,200
Quartzite, white, very pure, finely crystalline, mostly without any megascopically visible impurities or stain, but a few beds are	

	Thickness Feet
in places pale buff or green from disseminated chlorite or sericite, visible only under the microscope; a few partings of siliceous chloritic material, mostly less than 1 inch thick and spaced at intervals of from 10 to 500 feet	600 to 1,600
Interbedded quartzite, schist, and slate: about 80 per cent quartzite, light grey to pale orange-buff, very fine- to medium-grained, in beds up to 10 feet thick; about 15 per cent chlorite slate and quartz-chlorite-sericite schist, pea-green, in part mylonitized, in many places distorted into lens-like bodies and 'injected' into joints in the quartzite; minor slate, blue-grey, hard, siliceous; all gradations to impure quartzite	1,000
Bottom of group not exposed.	
Total thickness (approx.)	17,000

II. Section in Espee Range, near North Border of Map-area

Slate or mylonite, dark blue-grey; interbedded greywacke, dark green	200
Limestone, blue-grey, crystalline, non-bedded, slightly sheared	75
Quartzite, white, translucent, medium-grained, well-bedded, very pure except for spots of limonitic material; quartzite, purplish, mottled, slightly feldspathic, possessing only a fair degree of sorting, slightly schistose due to the orientation of the larger grains; interbedded with, and apparently gradational into, pure white quartzite	700
Quartzite, brown, fine-grained, very well sorted, slightly feldspathic, so slightly recrystallized that it is little more than highly indurated sandstone; interbedded greywacke and subgreywacke, greenish brown, heterogeneous	250
Subgreywacke, green, mainly of sand to silt grade; quartzite, feldspathic; limestone, brown, crystalline, in thin beds	300
Conglomerate, containing rounded quartz and quartzite pebbles up to ½ inch in diameter in a matrix of feldspathic quartzite; quartzite, grey-brown, very well sorted, slightly feldspathic; subgreywacke, green, banded, mainly with silty to fine sandy texture, in beds up to 15 feet thick	300
Subgreywacke, green to dark grey, very fine-grained to coarse, sandy textured; minor conglomerate, brown, with quartz pebbles, in beds up to 10 feet thick	400
Quartzite, pale grey to grey-brown, finely crystalline to sugary, feldspathic	100
Slate, chloritic; subgreywacke, bright green, banded	300
Mylonite, blue-grey to purplish, soft, calcareous	200
Limestone, light green, partly slaty, highly contorted, beds about 1 foot thick containing up to 15 per cent detrital quartz and feldspar; interbedded calcareous rock, silty to cherty; interbedded limestone, buff-coloured, coarsely crystalline; includes pods and lenses of compact, green, chlorite-serpentine-leucoxene (rutile?) rock	280
Limestone, ivory-buff, coarsely crystalline, sericitic; thin partings of chlorite slate	20
Slate, greenish grey to purplish, in part calcareous	50
Slate, bright green, with minor purplish calcareous bands	35
Limestone, pale purple, sheared to slaty, in part containing detrital quartz and feldspar; a few partings of chloritic material	15
Limestone, blue-grey to dark grey, massive to finely crystalline; in part oolitic; in part sheared or slaty; in part highly contorted	400
Limestone and calcareous slate, light grey-brown	150
Limestone, blue-grey to dark grey, massive, crystalline, medium- to coarse-grained	600
Base of group not observed	
Total thickness (approx.)	4,400

EXTERNAL STRUCTURAL RELATIONS

The general structural conformity between the Ingenika group and the underlying Tenakihi group has been noted. This relationship holds for all exposed contacts between the two groups in the map-area except on the south flank of Tenakihi Range north of Osilinka River near the east border of the map-area, and west of Swannell River, east of Mount Lay, where in each place the Ingenika group strata have been faulted against Tenakihi group rocks of different structural orientation. The belt of limestones southwest of Chase Mountain may possibly be down-faulted against the Tenakihi group, but the actual contact is nowhere exposed, and outcrops of each respective group, separated by less than 100 feet, show approximately the same bedding plane attitude. The possibility of such a fault is suggested mainly by the lack of conglomerates and quartzites, which form the lower Ingenika group northeast of Chase Mountain, at an equivalent stratigraphic position (with regard to the Tenakihi group) on the southwest side of the anticlinorium, indicating, if faulting does not occur, a pronounced lenticularity of the Ingenika group beds; and by the fact that the contact at this place is marked by an alined series of topographically low areas, in contrast with the known conformable contacts that have no topographic expression.

The upper contact of the Ingenika group is exposed at only one place within the map-area; at its extreme western border, between the two main branches of the south fork of Wrede Creek (*See* Structure-section C-D). At this locality the Ingenika group and the overlying late Palæozoic rocks are strongly sheared, somewhat pyritized, and the bedding relations are obscure. The actual contact is a shear zone about 75 feet wide, striking north 45 to 50 degrees west, and dipping vertically. No evidence indicating the direction of movement along this break was found, but subsidiary parallel shears on the Ingenika group side in chlorite-sericite slate have bent and dragged the beds, suggesting that in these shears the northeast side has moved up and apparently to the west relative to the southwest side.

In an attempt to obtain further information on the relations between the Ingenika group and the overlying rocks, the contact was followed northwesterly to where a good exposure was found. On the crest of the Wrede Range, 7 miles west of the west border of the map-area, and about 13 miles along the contact from the aforementioned exposure, black, calcareous slates, with interbedded blue-grey phyllites and light grey limestones of the Ingenika group, are in definite fault contact against fresh, bedded, andesitic tuffs, included in the lower division of the Takla group, of pre-Lower Jurassic age (Lord, 1948, p. 27). The bedding in the Ingenika group here strikes north 45 degrees west, dips 85 to 90 degrees northeast, and is minutely contorted into folds whose axial planes strike north 30 to 50 degrees east and dip 25 to 45 degrees southeast, and whose axes dip about 60 degrees southeast. The fault plane strikes north 35 degrees west, and dips 80 degrees southwest, and it appears that the northeast side has moved up and to the northwest with respect to the southwest side. This exposure would appear to indicate that, at least on the crest of the Wrede Range, the younger rocks have been faulted against the Ingenika group strata, and also that the Ingenika group rocks have undergone at least one deformation that has not affected the Takla group strata, and has been independent of, oriented differently from, and thus, presumably, older than, the deformation that has produced the present major structures in both groups.

In the southeastern part of the map-area, the contact between the Ingenika and Cache Creek groups lies in the drift-covered valleys of Tenakihi Creek, Osilinka River, and possibly the small creek west of the Beveley group of mineral claims. In each place the rocks of the two groups strike directly toward each other, and in the lack of any indication of sharp folding or nosing, the two groups would appear to be most probably separated by a steeply dipping fault.

Metamorphism

MINERALOGICAL AND TEXTURAL CHANGES

General Sequence of Metamorphic Changes

All the Ingenika group rocks have suffered regional metamorphism. As with the underlying Tenakihi group rocks, the range of metamorphic grade is relatively uniform over all parts of the map-area where these rocks are exposed, and in any one area where the stratigraphic sequence within the group can be established, the grade of metamorphism increases with successively lower stratigraphic horizons. The increase of metamorphic grade with stratigraphic depth is entirely conformable with, and a direct projection of, that observed in the Tenakihi group rocks, and it is at once apparent that the two groups were metamorphosed together.

The metamorphism of the Ingenika group rocks, with the exception of those forming part of the Wolverine complex, is all of low grade. Chlorite, usually accompanied by sericite, is the characteristic metamorphic mineral of the entire assemblage. The degree of metamorphic recrystallization is very slight in the subgreywackes of the uppermost beds exposed in the Espee Range, where the original texture is essentially unchanged and the only authigenic minerals are chlorite and sericite, which are probably a product of diagenetic rather than metamorphic reconstitution. It is highest in the completely crystalloblastic quartzites and quartz-chlorite-biotite-garnet schists near the contact with the Tenakihi group rocks. The Ingenika group rocks present, on the whole, a fairly wide diversity in chemical and mechanical composition; and thus an increase of temperature, hydrostatic pressure, and shearing stress have had different effects on different beds. The metamorphic changes are most pronounced and easily traced in the finer grained, impure subgreywackes.

The least metamorphosed rocks have, for the most part, a sheared, slaty texture. The finest grained pelitic varieties consist of a uniform aggregate of chlorite, sericite, calcite, siliceous material, and indefinite cloudy clay-like matter. In places the whole has a cataclastic appearance. Scattered quartz and feldspar grains are completely unaltered, except for a small amount of replacement by sericite. This fine-grained, partly mylonitic aggregate forms the matrix of the impure siltstones, quartzites, and conglomerate, which differ only in the proportion and size of detrital quartz and feldspar. The purer siliceous sediments interbedded with these rocks are little more than highly indurated sandstones. The limestones show in places a sheared, cataclastic texture, and all those examined have been recrystallized. Many of the rocks contain carbonaceous material. Some carry considerable plrite, probably of diagenetric origin.

With slightly higher metamorphic grade, the main changes observed are the disappearance of the cloudy clay-like material from the groundmass, and a corresponding increase in size and coherence of the flakes of chlorite and sericite. The beginning of recrystallization of the detrital quartz may be observed in these rocks, manifested by the development of sutured borders on the larger grains and a crystalloblastic texture of some parts of the groundmass. A few lenticles of quartz, lying parallel with the poorly developed schistosity, may be entirely crystalloblastic. At this stage the detrital plagioclase feldspar grains appear to remain completely unaffected. Among the minor detrital constituents, grains of garnet may be observed at various stages in the process of alteration to an aggregate of chlorite, sericite, quartz, and magnetite; originally relatively large grains are in places represented by an outer ring of chlorite grading inward to a core of sericite and quartz, with only a few fragments of the original garnet. In many of the rocks of this and all higher metamorphic grades, tourmaline is conspicuous in well-developed, euhedral, prismatic crystals; although many of the grains themselves seem to have been originally detrital, tourmaline may have begun to undergo recrystallization at this early stage. At this stage, also, carbonaceous matter has disappeared, and the pyrite has apparently been completely converted to magnetite or, in some cases, to limonitic material. The rocks of this stage represent true slates, phyllites, quartzites, and quartzitic conglomerates. The requirements for the development of smooth platy slates, as contrasted with minutely crenulated phyllites, are not clear, for the two rock types, although very fine grained, appear in thin section to be alike in mineral composition. In the field, slate and phyllite are intimately interbedded, so that some sedimentary beds have produced slate and others have developed into corrugated phyllites in the same structural and deformational environment. In such cases the controlling factors were probably the grain size and porosity of the original sediment, with the slate representing denser and more compact beds, in which circulation of recrystallizing solutions would be impeded.

The metamorphic changes throughout the middle and most of the lower stratigraphic levels of the Ingenika group consist chiefly of an enlargement of chlorite and sericite grains, and further recrystallization of detrital quartz and feldspar. Few good slates or phyllites are found in the stratigraphically lower half of the group; their place, in beds of equivalent bulk composition, has been taken by chlorite-sericite schists. The schistosity of these rocks is due primarily to the sericite, which has in a few specimens grown into discrete flakes of muscovite; from an early stage in its development this mica occurs in individual lath-like grains, commonly smaller but much more perfectly oriented than the radiating crystals and irregular strings and patches of chlorite. The chlorite grains large enough to be optically identified are the variety clinochlore. The detrital quartz grains are more completely recrystallized, and in the lower horizons the purer quartzites have a uniform crystalloblastic texture. The detrital feldspar grains show much less tendency to recrystallize, and only in the lowermost beds do they enter appreciably into the crystalloblastic texture of the surrounding rock. Thus, in many of the feldspathic quartzites and quartzitic conglomerates, the feldspar occurs as rounded detrital grains or granules interspersed with lenticular masses of quartz that represent recrystallized quartz fragments.

At the lowermost stratigraphic levels of the group, a gradual transition of chlorite into biotite occurs, apparently accompanied by a reaction between chlorite and muscovite. Irregular patches of chlorite, commonly surrounding small grains of quartz, show vague areas of higher birefringence; the fine grains of sericite, which elsewhere permeate the entire rock, are in some cases noticeably lacking in such areas. In some rocks, in which the conversion of chlorite to biotite is well advanced, rudimentary grains of garnet may be observed forming from the remaining patches of chlorite. The first garnets to be seen, as one passes to successively higher metamorphic grades, are very irregular stringy masses, pseudomorphous after chlorite, and completely interstitial to the recrystallized quartz; the schistosity of the rock, as shown by flakes of muscovite and lenticles of quartz, passes uninterruptedly through the skeletal garnet grains. At the lowest levels the feldspars have in many cases become more or less crystalloblastic, but in almost all rocks they retain some trace of their original clastic origin. The degree of recrystallization in the rock as a whole is rarely sufficient to obliterate minor textural differences between adjacent stratification, laminæ, etc. Even the limestones, which are completely recrystallized at an early stage, in places show original bedding by bands of different grain size.

A few departures from this relatively simple mineralogical and textural sequence have been observed. The elliptical bodies of extremely fine-grained, hard, black slate in schistose chloritic quartzite north of Mount Melvin have sharp borders against the well-recrystallized, medium-grained matrix. A black quartzite in the Butler Range contains zoisite and clinozoisite porphyroblasts in an apparently carbonaceous groundmass, so fine-grained that it appears cherty. The very fine texture of carbonaceous rocks compared with associated rocks of low carbon content has been attributed to a direct hindrance to chemical reaction and crystal growth by chemically inert graphite that collects on the surface of growing crystals. Schists and slates containing appreciable or even dominant proportions of tourmaline, zoisite, clinozoisite, epidote, chloritoid, or actinolite occur east of Tomias Lake, near Ingenika Cone, on the lower Swannell River, on Ingenika Crag, and northeast and northwest of Goldeneye Lake. Some, at least, of these minerals may represent material introduced to the rocks during a recrystallization distinct from the regional metamorphism of the Ingenika and Tenakihi groups as a whole; for it may be noted that all of the above mentioned localities, except Goldeneye Lake, are close to the area of the Wolverine complex or to a region of abundant hydrothermal mineralization, and two of the very few dykes observed in the Ingenika group outside of the Wolverine complex area cut the slates and limestones north of Goldeneye Lake.

Large barren quartz veins, similar to those in the Tenakihi group, occur in the Ingenika group strata, but are much less abundant. The veins are commonly colourless or slightly smoky, in contrast with the opaque milky white veins typical of the Tenakihi rocks. Most of them are lenticular, less than 200 feet long, and follow bedding planes in rocks of the more brittle types. Veins less than 2 feet thick are uncommon. As in the Tenakihi group, these veins are thought to be mainly a by-product of regional metamorphism, rather than the result of later hydrothermal processes. Some of the quartz in the veins cutting Ingenika group beds may have been derived from Tenakihi rocks.

RELATION OF METAMORPHISM TO DEFORMATION

That the metamorphism of the Ingenika group rocks occurred mainly prior to the development of the present folded structures is apparent from the general correspondence between the metamorphic grade and stratigraphic horizons, independent of the present attitude of the rocks. If the increase of metamorphic grade is acknowledged to be dependent upon an increase of temperature and pressure determined in part by depth of burial, combined with high shearing stress, then clearly the metamorphism could not have taken place during the time the rocks were being folded to their present positions, nor at any time since they had attained these positions. To cite an extreme example, in the overturned beds on the west flank of the Butler Range, the garnetiferous schists of the Tenakihi group and the quartz-biotite schists of the Ingenika group on the crest of the range lie structurally on top of the chloritic phyllites and slates that are more intensely deformed, but of lower metamorphic grade, at the base of the slope.

The relation between schistosity and bedding in the Ingenika group is similar to that in the Tenakihi group; the general plane of schistosity is parallel with both the limbs and crests of the major and most of the minor folds, but cuts across some of the minor folds. The planes of schistosity and cleavage are for the most part rigorously parallel with the bedding in rocks free from intense local contortion, but where the beds are strongly drag-folded on a small scale, shear and platy cleavage planes parallel the axial planes of the small folds. In some such instances the attitude of the plane of shearing changes as much as 90 degrees within 500 feet. In a few places, where the axial planes of the drag-folds are sharply bent, or where the minor structures are domes and basins superimposed on more regular folds, the rock possesses two sets of shear planes about equally developed—one parallel with the bedding and one parallel with the axial plane of the fold—and the disintegrated rock is an aggregate of pencil-like fragments.

Further evidence that metamorphism and development of schistosity had occurred to some degree before the last major folding of the rocks is afforded by the limestones east of Pelly Creek, which have been folded into isoclinal, digitate folds more than 2,000 feet from crest to trough. Near timber-line on the southwest shoulder of the mountain south of Pelly Lake, a series of such limestones is well bedded, slightly micaceous, with a faint but unmistakable schistosity parallel or nearly parallel with the bedding. The rock is cut by subparallel, nearly plane, calcite veins, mainly less than 6 inches but in places up to 10 feet thick, that are so numerous that on some exposures vein material comprises an estimated 20 per cent of the rock volume. The veins occupy simple fissures, which lie at an average angle of about 10 degrees to the bedding plane (bedding and schistosity strike north 40 degrees west and dip 54 degrees northeast; veins have an average strike of north 15 degrees west and dip 60 degrees northeast); there has been little replacement of the wall-rocks by the veins, and beds can be matched across the veins to show no appreciable displacement parallel with the plane of the vein. There seems no reason to doubt that the veins fill tension cracks developed during the large-scale drag-folding of the limestone; and it is obvious that the schistosity of the recrystallized micaceous limestone antedated the development of the fractures. It would seem inconceivable that non-schistose limestone containing up to 20 per cent vein material could be metamorphosed in such a way that the limestone between the veins was recrystallized to a muscovite-bearing schistose rock with sharp boundaries against the veins while the vein material remained free from muscovite and retained its coarse 'vein' texture; and it is equally hard to visualize a system of stresses that would open the vein fissures at the same time as the schistosity was developed.

Although the main metamorphism of the Ingenika group is thus seen to precede the development of the large folds, there was enough recrystallization during folding to prevent cataclasis and to relieve most internal stresses. Thus crystalloblastic quartz grains, though strained, are clear and unfractured. The dolomite (?) porphyroblasts in some of the chloritoid schists on Swannell River, near the axis of a major syncline, appear to have grown in a sheared rock; during growth they were rotated slightly, and after growth were further moved, allowing quartz to be deposited in spaces formed and protected by the displaced porphyroblasts. The development of these porphyroblasts, and of the nearby zoisite schists, may well be connected with the formation of the syncline, and thus later than the regional metamorphism.

The processes by which schistosity could develop parallel with bedding have been discussed in the description of the Tenakihi group (See pages 51 to 54). The conclusion that most of the metamorphism occurred during a period of relatively gentle deformation earlier than, and independent from, that which produced the present major folds—under directed stresses probably occasioned by large rising or laterally invading intrusive masses, or by forces from a widespread irregular zone of anatexis and migmatic action, accompanied by an increase of temperature gradient due probably to the same intrusive or anatectic sources—applies equally to the Ingenika group. The greater local irregularity of the planes of schistosity in the Ingenika group than in the Tenakihi group is probably due to the greater inhomogeneity of the strata, with lenticular beds of differing competency and varying degrees of ease of recrystallization producing local differences in resistance to stress.

Origin

The Ingenika group is characterized throughout by four dominant sedimentary rock types and their metamorphic derivatives: greywackes and subgreywackes, altered to slates, phyllites, chloritic schists, and chlorite quartzites; sandstones—impure, angular, and poorly sorted, to extremely pure, well rounded and sorted—now represented by the quartzites; conglomerates, which are for the most part fine grained and merely a coarser phase of the subgreywackes and sandstones; and limestones, which in their less-crystalline phases are partly oolitic, and possibly partly algal, and which in many places contain considerable detrital non-carbonate material. All of these sediments suggest shallow-water conditions of deposition throughout the entire sequence of the group. Near-shore conditions are required by the poorly sorted subgreywackes, by the conglomerates and the relatively coarse sandstones, and by the detrital limestones. The crossbedded quartzite, and the possibly mud-cracked limestone indicate shoreline conditions of deposition. If the nitre in Tenakihi Range and the calcium sulphate (gypsum or anhydrite) found in many localities are original constituents of the rocks, their source beds may be the result of isolation and dessication of local basins in an arid climate. The remarkable purity and high degree of rounding and sorting shown by some of the quartzites suggest that they may be reworked wind-blown material. Except for the rare, fossiliferous limestones, which are marine, there is little evidence as to whether the assemblage was laid down in salt or fresh water; but the thickness of the deposit and its uniformity over a large area suggest a sea-coast rather than an inland-basin environment.

The nature of the sediments indicates a greater diversity of conditions of source area than of deposition. Greywackes and subgreywackes are characteristically products of rapid mechanical erosion and short transportation. These sediments, therefore, suggest a near-shore provenance of high relief in which mechanical erosion is dominant; perhaps a rugged archipelago or mountainous coast. The well-rounded, well-sorted, fine conglomerates may have travelled far, but probably require transportation by streams with a relativly high gradient, as from a highland area. The pure quartzites, on the other hand, if not of desert origin, are probably indicative of prolonged erosion in an area of moderate to low relief, with long transportation resulting in reworking, resorting, and rounding of particles. The pure, massive limestones must have been formed during a temporary cessation of clastic deposition over considerable areas.

The intimate intercalation of the various rock types indicates a repetitive alternation of character and quantity of supplied material and of conditions of deposition. It is probable that, in a heterogenous sedimentary sequence like the Ingenika group, there are many intervals of non-deposition in any one section; but no instances of erosion of one bed before the overlying one was deposited were recognized, with the possible exception of 'slump' structures and fillings of contorted argillite in irregularities in some conglomerate beds in the Tenakihi Range near the nitre-bearing beds.

Thus, on the whole, the Ingenika group rocks were laid down under typical geosynclinal conditions of deposition, in which the sinking of the sedimentary basin approximately kept pace with its filling by sediments, through the deposition of an aggregate of up to 18,000 feet of material.

Evidence regarding the lithological character of the source area for the Ingenika group rocks is meagre. On the whole, the rocks are considerably less siliceous than those of the Tenakihi group. The only sedimentary rocks whose bulk composition can be considered at all representative of their parent rocks are the greywackes and subgreywackes. These show, along with the ubiquitous quartz, a relatively high proportion of ferromagnesian material, an abundance of intermediate to slightly sodic plagioclase, and a relative scarcity of potash feldspar. Such material would appear to be possibly indicative of rocks of intermediate composition; if igneous, about in the andesite-diorite-grandodiorite range.

Age

Metamorphism has obliterated most of any fossiliferous material the Ingenika group rocks may have contained, and most of the few structures that are recognizable as the remains of organisms are too recrystallized to be identified. One small lens of limestone surrounded by chloritic phyllites north of Osilinka River, about 4,000 feet above the lowest exposed beds in this section (*See* page 74), and probably much more above the base of the Ingenika group, contains recognizable archaeocyatha. These fossils (Collection F1R (1946) and 15229 (1947) were submitted to Dr. V. J. Okulitch of the University of British Columbia, who reported (Okulitch and Roots, 1947; and personal communication, 1948) on them as follows:

"Faunal list:

Ajacicyathus purcellensis Okulitch
A. clarus Vologdin
A. osilinka n.sp.
Coscinocyathus sp.
Dendrocyathus inexpectans n.sp.
Protopharetra rootsi n.sp.
Archaeocyathus cf. *A. atlanticus* Billings
Cambrocyathus sp.

Age: Lower Cambrian, equivalent to the Donald formation of the Dogtooth Mountains, British Columbia."

No other collections containing definitely diagnostic fossils have been obtained to date. Dr. Okulitch reported[1] on some of the other collections as follows:

"Coll. 15237 (from blue-grey crystalline limestone near the base of the large limestone bluff ½ mile west of the Beveley mineral claims): white patches, possibly archaeocyatha, uncertain.

"Coll. 15238 (from mid-section of limestone bluff west of Beveley mineral claims, about 100 feet stratigraphically above Coll. 15237): archaeocyatha, not identifiable as to genus.

"Coll. 15240 (from top of limestone bluff west of Beveley mineral claims, about 600(?) feet stratigraphically above horizon of Coll. 15238): most likely a coral and not a archaeocyatha; possibly a *Caninia* or a *Cyathophyllum*, but not certain; has a Silurian-Devonian aspect.

"Coll. F6R (1946) (from the summit of a limestone hill 4 miles southeast of Chase Mountain): contains algal remains, similar in appearance to those common with fossils from the Donald formation.

Age: Lower Palæozoic, probably Lower Cambrian." (Similar-appearing algal structures are abundant 3 miles northeast of Mount Lay.)

"Coll. F7R (1946) and Coll. 15222 (1947) (from an open-pit on No. 3 vein, Ferguson property, Ingenika Mines, Limited): contains poorly preserved tubes resembling *Salterella* or *Hyolithes*.

Age: possibly Lower Cambrian.

"Coll. 15242 (from north end of the Espee Range): rounded structures containing what may have been originally sponge spicules, but rock is too strongly recrystallized to allow identification.

"Coll. 15218 (from north end of the Espee Range): not diagnostic, poorly preserved algæ."

[1] Personal communications, 1947, 1948, 1949.

The available evidence thus indicates that the Ingenika group is in part, possibly in large part, of Lower Cambrian age. There is no further evidence to indicate whether all of the rocks mapped in the group are of the same age, or what range of age is represented. If the coral-like fossils found west of the Beveley mineral claims are of Silurian or Devonian age, as tentatively suggested by Dr. Okulitch, the rocks from which they come should not be included in the Ingenika group.

As previously described, the Ingenika group rocks lie with angular conformity on the Tenakihi group rocks, the contact between the two groups being drawn below the stratigraphically lowest unit containing the distinctive conglomerates characteristic of the Ingenika group. The top of the group is nowhere exposed, and the overlying unmetamorphosed rocks of late Palæozoic and younger age are faulted against the Ingenika group beds.

Correlation

The Ingenika group rocks can be traced southeast from Aiken Lake map-area to the valley of Omineca River, where McConnell (1896, p. 24) correlated the conglomerate, quartzites, and slates with the Bow River series of Lower Cambrian and Precambrian age, and the limestones with the Castle Mountain group of Middle Cambrian to Cambro-Silurian (Ordovician) age. McConnell found no fossils, and based his correlation with the type area, some 450 miles to the southeast, on lithological similarity alone.

The archaeocyatha in Tenakihi Range indicate a correlation with the Donald formation, the uppermost Lower Cambrian formation of the Purcell Mountains (Evans, 1933, p. 122), and the equivalent of beds in the lower part of the series of formations now considered to correspond with the Castle Mountain group of McConnell. Okulitch (1949) has summarized the relations between lithological equivalence and fossil correlation of the Precambrian and Cambrian rocks of that part of the Cordillera 300 miles southeast of Aiken Lake map-area, and his suggestion of an eastward-migrating geosyncline in Late Precambrian and Cambrian time, supplied mainly by sediments from a retreating eastern shore of fairly high relief, is compatible with the meagre evidence regarding the origin of the Tenakihi and Ingenika groups.

In the Cariboo Mountains, about 250 miles southeast of Aiken Lake map-area and in much the same regional geological setting, beds of quartzite and limestone contain a Lower Cambrian trilobite fauna (Lang, 1938, p. 14).[1] These beds may be correlative with the Ingenika group beds, and they overlie with apparent conformity the Cariboo series, which may correspond with the Tenakihi group, and which like it is, presumably, of Precambrian age.

In the Toad River-Muncho Lake area along the Alaska Highway, 130 miles due north of Aiken Lake map-area, Williams (1944) and Laudon and Chronic (1949) found a thin series of tan quartzites and sand-

[1]In 1953, archaeocyatha similar to those found in the Ingenika group were collected from similar beds in the Cariboo Mountains by A. Sutherland-Brown of the British Columbia Department of Mines (V. J. Okulitch, personal communication, 1953).

stones, with lesser unmetamorphosed limestones, lying unconformably beneath Silurian beds, and unconformably above a series of quartzites, schists, slates, and basic igneous rocks of probable Precambrian age. This area is within the Rocky Mountains, and the rocks in it show no direct affinities with those of the Western Cordilleran region (Lord, 1947, p. 230), in which the Aiken Lake map-area is included. The tan quartzites have been correlated with the Cambrian Macdougal group of the Mackenzie Plain. The relation of these beds to the Ingenika group is not known; the two assemblages may be in part equivalent, although the Macdougal group is obviously part of a much thinner, possibly foreland facies. The crustal movement that produced the pronounced unconformity below the Silurian beds in this area must also have affected the Aiken Lake region, and evidence of it should be preserved if sedimentary deposition occurred both before and after the disturbance. The lack of any such unconformity in the Ingenika group suggests that all beds assigned to the group are at least pre-Silurian in age.

WOLVERINE COMPLEX

Name and Distribution

The name "Wolverine complex" was given by Armstrong and Thurber (1945, p. 5) to an assemblage of gneisses and schists, with intimately associated granitic rocks and pegmatites, in Wolverine Range of Manson Creek map-area. In Wolverine Range, the rocks are so altered by metamorphism and granitization that it was not found possible to divide the complex into stratigraphic units. These rocks may be traced northwestward into Aiken Lake map-area, where it has been found that they correspond mainly, and probably entirely, to those of the Tenakihi and Ingenika groups. In Aiken Lake map-area the name Wolverine complex has been retained for those rocks of the Tenakihi and Ingenika groups that have been profoundly and distinctly altered by processes of metamorphism and granitization additional to the regional metamorphism suffered by all the rocks of these groups, and for the intrusive and meta-igneous rocks intimately associated with the intensely metamorphosed sediments.

Such rocks occupy an area of about 150 square miles, in a belt 5 to 8 miles wide, running transverse to the strike of the formations, and extending northeast from Blackpine Lake to Tomias Lake and Ingenika Cone. Along its southeast side, where exposed, the belt adjoins typical Ingenika group rocks at a fault contact. The northwest side of the belt grades into Tenakihi and Ingenika group rocks of lower metamorphic rank.

Lithology

The rocks in Aiken Lake map-area assigned to the Wolverine complex consist mainly of feldspathic quartzite, quartz-mica-feldspar schist, gneiss, and migmatite, with lesser amounts of silicated marble, skarn, amphibolite, and amphibolite-gneiss. These meta-sedimentary rocks are invaded by a variety of acidic rocks ranging from granodiorite stocks to narrow pegmatite and aplite dykes and *lit-par-lit* injections. The amount of igneous-appearing material is greatest at the southwest end of the belt of exposed Wolverine complex rocks, where two stocks of granodiorite, about ¾ square mile and 5 square miles in area, respectively, are surrounded by a swarm of sills, dykes, and irregular bodies of leucogranite, pegmatite, aplite, graphic granite, and alaskite. Dykes and stocks are smaller and fewer toward the northeast, and are rare between Ravenal Creek and Tomias Lake; still farther east, and on the crest of Butler Range, they are more abundant.

Feldspathic Quartzite

The common, generally well-bedded, slightly impure quartzites of the Ingenika and Tenakihi group rocks are represented in the Wolverine complex by light grey to golden brown, granular rocks composed of various proportions of quartz, feldspar, biotite, and, rarely, muscovite. The weathered surface of these rocks has a distinct speckled appearance due to the white, opaque coating on weathered feldspars. This type of weathering appears to be more or less unique to the rocks of the Wolverine complex in the area, and was not observed on the less metamorphosed feldspathic sediments of the Tenakihi and Ingenika groups. All such rocks are schistose or gneissic, with the plane of schistosity or gneissosity in all observed cases rigorously parallel with the bedding planes, which are for the most part conspicuously outlined by bands of different biotite content.

In general, these rocks are of somewhat coarser texture than their equivalent beds in the normal Ingenika and Tenakihi groups; most of them are even-granular, with grains up to 1 mm. in average diameter. A few rocks are markedly porphyroblastic, with irregular porphyroblasts of either quartz, feldspar, or biotite up to 5 mm. in diameter.

The quartzites have a wide range of composition, both from bed to bed and within the same bed, due mainly to a varying amount of material added from extraneous sources, and to a reciprocal transfer of matter from bed to bed. In some beds, original differences in the chemical and mineralogical makeup have been emphasized, in others, nearly obliterated. Almost all of the quartzites observed within the Wolverine complex are feldspathic. It is not known whether any of these rocks were originally representatives of the extremely pure quartzites found in the Ingenika group. In several places the conglomeratic phases of the Ingenika group can be recognized within the Wolverine complex, with the original pebbles represented by clots of quartz or quartz and feldspar. The rocks grade, by decreasing quartz content, into quartz-mica-feldspar schists. The feldspar content varies considerably, being generally between 10 and 60 per cent of the rock volume. A rough relation is apparent between the degree of recrystallization and the amount of feldspar; in general the most highly metamorphosed rocks are the most feldspathic. There is much change of feldspar content within distances of several hundred feet in the same bed. With increasing intensity of recrystallization and reconstitution, the feldspathic quartzites grade into quartz-mica-feldspar gneisses and migmatites.

In thin section all the feldspathic quartzites have a completely crystalloblastic texture. Some of the quartzites reveal the effects of crushing, with consequent granulation and recrystallization of fine fragments between larger grains, producing 'mortar structure'.

The feldspar varies greatly in habit, occurring in some rocks as interstitial, stringy masses, and in others as rounded grains with sutured borders, or as small subhedral crystalloblasts. Two distinct kinds of feldspar are represented; albite-oligoclase, and potash feldspar—both orthoclase and microcline. In the less metamorphosed quartzites, which usually contain less than 30 per cent total feldspar, nearly all the feldspar recognized was found to be plagioclase, much of which shows polysynthetic albite twinning. Many of the plagioclase crystals are zoned, and are commonly clouded by fine dust-like inclusions. In more highly feldspathic rocks, which seem to be also coarser and better crystallized, grains of orthoclase appear, and in some sections comprise an estimated 10 per cent of the rock. At higher metamorphic grades, where the rock passes into a quartz-mica-feldspar gneiss, a few crystalloblasts of microcline were observed, but microcline and orthoclase were not both noted in the same thin section of any of the rocks classed as quartzites.

The foliation of the quartzites is due primarily to the flakes of biotite, which in some sections appear to have a nearly perfect planar arrangement. In general, there is no sign of linear structure, and thin sections parallel with the foliation plane show a haphazard pattern of grains. The muscovite shows much less tendency toward a common planar orientation than the biotite, and some relatively large grains have grown with their long axes across the foliation. In many specimens the quartz and feldspar grains are elongated and share in the general foliation.

Needles of sillimanite, commonly grouped in radiating clusters, were observed in about half the thin sections examined, the largest noted about a millimetre long. Most of them are in the biotite flakes; although a few crystals of what appears to be the same mineral occur in quartz.

Quartz-mica-feldspar Schist

The quartz-mica-feldspar schists of the Wolverine complex differ in no essential respect, except in the proportion of quartz, from the feldspathic quartzites with which they are interbedded, and which themselves are either schistose or gneissic. Rocks in which quartz is not a dominant mineral are quite minor, and in the main are restricted to beds, usually less than 3 feet thick, that are correspondingly richer in biotite. Although most of them probably represent beds that were originally among the most fine-grained beds in the assemblage, many are now slightly coarser in texture than the quartzites with which they are interbedded, indicating that they recrystallize with greater ease than the quartz-rich rocks.

Garnetiferous Schist and Quartzite

Garnet-bearing rocks are of relatively restricted occurrence in the Wolverine complex. The abundant quartz-mica-garnet schists of the Tenakihi group apparently suffer a complete breakdown of garnet during alteration to quartz-mica-feldspar schists and gneisses.

The Ingenika group rocks exposed in the syncline passing through Tomias Lake Valley have been metamorphosed to quartz-muscovite-garnet schists and quartzites, and garnet-bearing quartzitic conglomerates, in places feldspathic, in a belt about 8 miles wide trending across the strike of the rocks. Strata 5 miles to the northwest and 2 miles southeast of this belt, which almost certainly represent the same beds as the garnetiferous rocks, are the normal sericitic slates and phyllites, quartz-chlorite schists, and quartz-pebble conglomerates of the Ingenika group. With increasing grade of metamorphism, the garnets apparently disappear, the quartzite pebbles in the conglomerates recrystallize into long lenses of crystalloblastic quartz, the proportion of feldspar increases, and the rocks grade into quartz-mica-feldspar schists and gneisses. Such a sequence of changes is revealed on the ridge due north of Tomias Lake, and on the flank of the mountain southwest of the outlet of the lake.

Quartz-mica-feldspar Gneiss

The beds of feldspathic quartzite and quartz-mica-feldspar schist grade, along their strike, into more coarsely granular rocks in which the individual beds lose their identity, but which possess a pronounced banded structure due to segregated layers rich in biotite or in quartz and feldspar. Most of these rocks are composed mainly of grains 1 mm. or more in size. The tendency toward development of the oriented, elongate grains of quartz and feldspar is much less pronounced in these rocks than in the schistose quartzites from which they were derived, and the foliation of the gneiss is due mainly to the ragged but fairly well oriented flakes of biotite, and to a segregation of the minerals into layers relatively richer in quartz or in biotite.

Most of the gneisses contain about 50 per cent feldspar, apparently mainly albite-oligoclase or microcline. The proportions of these two types vary widely in different specimens. Some rocks are composed almost entirely of biotite and microcline. In one section, an untwinned, optically negative feldspar, probably orthoclase, is associated with the microcline. A few of the gneisses contain conspicuous porphyroblasts of albite-oligoclase, usually zoned, with well-developed albite and Carlsbad twinning, and clouded with inclusions, up to 6 mm. long. The potash feldspar was not observed to be porphyroblastic in habit, but in at least one specimen several smaller grains are collected into irregular, lenticular augen up to 10 mm. long.

Migmatite

There is no sharp distinction between the quartz-mica-feldspar gneisses of the Wolverine complex and those rocks to which the term migmatite has been applied. However, it has been found useful in the field to distinguish those gneisses that contain bands, or, more rarely, irregular patches with vague, gradational borders, of granular crystalline material in which the various constituents are evenly distributed, and which, in hand specimen, have a markedly 'igneous' aspect; such rocks have been called migmatites. They are best developed around the granodiorite stocks southeast of Blackpine Lake, where they may be traced along the foliation through less metamorphosed gneisses into schistose quartzites. A small area of similar rocks is exposed on the ridge east of Tomias Lake.

The migmatites possess the same simple mineralogical composition as the gneisses, quartzites, and schists. Typical specimens consist of quartz, potash feldspar (commonly microcline), sodic plagioclase, and biotite, in about the same proportions as in granite or granodiorite, alternating in all proportions with bands much richer in biotite or quartz or both. In some thin sections it is apparent that the quartz-rich bands, which commonly make up about half the rock, have been the most mobile, and have flowed into subparallel fractures in the feldspathic material; in other cases the outcrop relations seem to indicate that the highly feldspathic bands were actively intrusive, either filling fractures or replacing the original rock; but in most places there is no evidence of rock disturbance or bodily movement of material, and the recrystallization and change of composition seem most easily explained by a quiet pervasion of fluids along the foliation (bedding?) planes.

Accessory minerals are quite minor in the migmatites, as in the gneisses generally, and include sillimanite, apatite, tourmaline, zircon, and magnetite. Some thin sections were observed to contain euhedral grains of scapolite.

Lit-par-lit Gneiss

In places the quartz-mica-feldspar gneisses contain bands or sill-like bodies, commonly between 1 inch and 1 foot thick, of relatively massive, igneous-appearing material of granitic composition. These rocks differ only in degree from the rocks here referred to as migmatites, but the gneisses are commonly finer grained and less well crystallized, the borders of the granitic bands are sharper, and in places the granitic bands cut abruptly across the foliation as seams of quartz and feldspar, suggesting that they have been bodily injected along fractures and planes of weakness. *Lit-par-lit* gneisses of this type are less abundant than the migmatites in the highly metamorphosed rocks northeast of Blackpine Lake, but are more widespread. They are well developed in places near the pass at the head of Ravenal Creek and in the Butler Range east of Tomias Lake.

Silicated Marble and Skarn

Interbedded with the feldspathic quartzites and quartz-mica-feldspar schists are highly metamorphosed calcareous rocks, which range in composition from slightly altered marbles to lime-silicate rocks and amphibolites containing no carbonate material. The rocks to which there has been the least addition of material consist mainly of white, coarsely crystalline calcite, with scattered tan to resin-brown andradite garnet porphyroblasts, and irregular, usually interstitial, grains of clinozoisite. With increasing silicate content the calcite is replaced by plagioclase feldspar and amphibole. A typical rock found on the south slope of the mountain due north of the mouth of Tutizika River is conspicuously banded, with irregular layers up to ½ inch thick alternately rich in brown garnet, green actinolitic amphibole, white tremolite in radiating clusters of needle-like crystals, and grey-green calcite-plagioclase-clinozoisite rock. The development of silicate minerals in these rocks is very irregular; in places the bands end abruptly against patches composed largely of recrystallized calcite, yet nearby almost the whole of the same bed is an aggregate of silicate minerals. In many places, what appear to be the original bedding planes are marked by layers rich in garnet, which either form a fine-grained aggregate of subhedral, rounded grains (garnetite), or, less commonly, individual porphyroblasts up to 10 mm. in diameter with almost perfect dodecahedral forms, and smooth shiny faces. Adjacent to the garnet-rich layer there is in many places an irregular green layer that is seen in thin section to be composed largely of a faintly pleochroic pale green amphibole whose extinction angle of 20 to 26 degrees suggests that it is a form intermediate between actinolite and hornblende; with the amphibole are, nearly everywhere, irregular, poikilitic grains of clinozoisite, and scattered masses of anhedral garnet. This layer, and the still more irregular bands and patches of radiating tremolite, and plagioclase-clinozoisite material, do not appear to be related directly to the bedding planes or visible fractures in the rocks. Their patchy occurrence suggests that they were formed by the action of solutions that travelled mainly along the bedding planes or bed contacts now converted to garnetite, and diffused through the garnet layer without reaction, to the unaltered limestone in the interior of the bed, where they developed crude bands representing approximate planes of equal ease of diffusion.

Where the original limestone has become so replaced by silicate minerals that carbonate is only a minor constituent of the rock, the silicated marbles grade into typical skarns. Several amphibole-garnet-plagioclase-clinozoisite-calcite beds northeast of Blackpine Lake are of this type. Most of them are less than 20 feet thick.

Amphibolite

Several beds intercalated with the quartz-mica-feldspar gneisses and migmatites in the most highly metamorphosed area of Wolverine complex rocks northeast of Blackpine Lake are composed mainly of amphibole and plagioclase, with more or less biotite. Most of them have a strongly developed gneissic texture, and there are all gradations between beds about 10 feet thick of uniform amphibolite and banded quartz-mica-feldspar gneisses with thin layers rich in amphibole and plagioclase.

The dominant mineral of the amphibolites is a dark green to greenish black amphibole, occurring typically in elongated crystals up to 3 mm. long. In thin section, it exhibits bright green to olive pleochroism, and has a maximum extinction angle of about 25 degrees. The mean refractive index appears to be about 1·672.

The plagioclase of the amphibolite occurs mainly as clear, rounded or irregular grains, commonly showing albite and more complex twinning, usually smaller than the hornblende crystals, and within which some grains are poikilitically enclosed. The mean refractive index is close to 1·544; several grains have an optic angle of about 90 degrees, but are apparently optically negative; the composition would thus appear to be in the oligoclase range, about $An_{15\text{-}20}$. Though too few grains were accurately determined to warrant drawing a general conclusion, there seems to be some evidence that the amphibolites contain plagioclase that is slightly more calcic than that in the siliceous gneisses with which they are interbedded. The plagioclase grains in the amphibolite are almost completely free of the many dusty inclusions that cloud the feldspars of the gneisses. Plagioclase is most abundant in the relatively fine-grained amphibolites; bands richer in hornblende are also usually coarser in texture. One thin section contains many grains of what appears to be orthoclase.

Most of the amphibolites contain some biotite, and a few rocks are composed almost entirely of hornblende and biotite. The biotite occurs in elongate, deeply coloured, pleochroic grains that are in part interstitial to, and in part transect, the hornblende crystals, suggesting that it may, in part, have crystallized later than the amphibole. Minor minerals in the amphibolites include quartz, which is relatively rare but occasionally found as very large, poikilitic masses; apatite, which is relatively abundant as spindle-shaped to prismatic grains up to ½ mm. long; and accessory zircon, magnetite, and pyrrhotite.

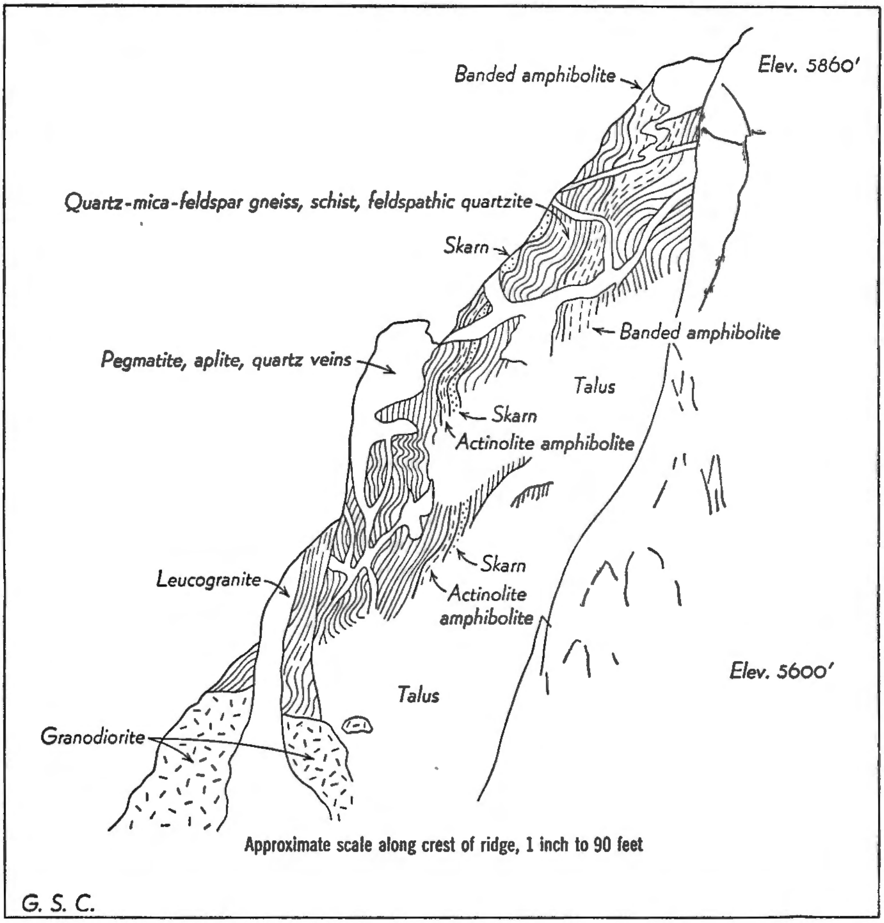


Figure 5. Sketch, looking northwest, of part of the roof of the granodiorite stock exposed on the southwest shoulder of the mountain east of Blackpine Lake.

Like the skarns and silicated marbles, the amphibolites are considered to have resulted from the alteration of limestone beds of the Ingenika group. The development of hornblende-feldspar gneiss and amphibolite from limestone by the action of granitic intrusions is a well-known phenomenon (Adams, 1909; Barth, 1930). The process involves the supply of silica, alumina, iron and magnesium oxides, and alkalis to the limestone by emanations from a 'granitic' fluid, with corresponding abstraction of lime. No example of a transition within a single bed from tremolite-actinolite-clinozoisite-garnet skarn into hornblende-plagioclase amphibolite was found in the Wolverine complex, though such a gradation seems probable and has been suggested (Barth, 1928). North of Blackpine Lake, skarn and amphibolite are both interbedded with quartz-mica-feldspar gneiss, and exist side by side for several hundred feet without noticeable change of composition (*See* Figure 5). It is apparent that the amphibolite is not merely a more highly metamorphosed phase of the skarn; the two rock types seem to represent somewhat different trends of alteration under similar physico-chemical conditions.

Glimmerite

Near the edge of the southwest shoulder of the mountain overlooking Blackpine Lake, and on a serrated arête 3 miles north of this locality, beds up to 3 feet thick composed almost entirely of biotite are intercalated with the quartz-mica-feldspar gneisses. The biotite is in glistening black scales up to 4 mm. in diameter, entirely similar to that found in the biotite-bearing amphibolites. Accessory minerals are those found in the amphibolites: hornblende, quartz, plagioclase, apatite, and sphene.

The glimmerite appears to be merely a phase of the amphibolite extremely rich in biotite.

Pyrrhotite Skarn

In several places the skarns and amphibolites northeast of Blackpine Lake are accompanied by deposits of iron sulphides, dominantly pyrrhotite, with variable amounts of pyrite, chalcopyrite, and arsenopyrite. The deposits range from thin seams of coarsely crystalline sulphides intercalated with the skarns and amphibolites, to bodies up to 25 feet wide and 500 feet long consisting of at least 40 per cent sulphide material. The largest of these bodies, on which the Hope group of mineral claims was staked, is described breifly on page 222. The characteristic association of iron sulphide deposits with contact metamorphosed limestone, in relations that appear directly related to metamorphism rather than to later hydrothermal mineralization, has been noted by many workers (Knopf, 1933, p. 538). Goldschmidt (1911, p. 211) found that in such deposits the iron sulphides were usually partly older and partly younger than the skarn silicate minerals. In the Wolverine complex rocks, the pyrrhotite appears to have formed essentially contemporaneously with the silicate minerals, before the conclusion of intrusive action, for dykes of alaskite crossing bands of pyrrhotite-rich skarn show no evidence of mineralization.

Granodiorite

The most conspicuous feature of the Wolverine complex rocks northeast of Blackpine Lake is a body of granodiorite about 5 square miles in area exposed on the slopes overlooking the lake. Another body about ¾ square mile in area outcrops on the north side of the north peak of the massif northeast of the lake, and smaller bodies of similar material are found on the crest of a ridge 7½ miles south of Chase Mountain. For the most part these bodies are relatively fresh, uniformly coarse grained, slightly gneissic, light grey rocks, the grain size of most specimens averaging from 2 to 5 mm.; a few rocks are composed chiefly of grains about 8 mm. in diameter. Thin sections of representative specimens show the rock to contain about 30 per cent quartz; 45 per cent oligoclase-andesine (An_{15-35}), commonly twinned and zoned; 0 to 20 per cent potash feldspar, mainly microcline, but some sections show many grains of orthoclase; and up to 10 per cent dark minerals, mainly biotite or, occasionally, hornblende. Accessory minerals are magnetite, sphene, and apatite. No systematic difference in composition or texture between the centre and borders of the various bodies could be discerned.

The granodiorite bodies have relatively smooth, sharp contacts against the schist they intrude, and in general have the shape of steep-walled stocks, fairly regular in plan outline, with irregular but relatively flat roofs. The prominent southwest shoulder of the massif northeast of Blackpine Lake appears to consist of a relatively thin roof or capping of gneiss, much intruded by pegmatite, resting on the granodiorite, which is exposed on three sides almost up to the top of the shoulder. In the entire, excellently exposed upper contact of the largest body northeast of Blackpine Lake, which was examined in detail, no apophyses of granodiorite into the gneiss were found. In many places the contact between the granodiorite body and the gneiss is occupied by a quartz-feldspar-muscovite pegmatite dyke, which shows intrusive or replacement relations against both rocks. Elsewhere, the contact is invariably sharp, but not everywhere knife-edged; in places the distinctive layers of strongly banded gneiss lose their individuality and give way to uniform granodiorite within about half a centimetre. No difference could be noted between the granodiorite truncating bands of amphibolite and that intruding quartz-mica-feldspar gneiss; and the foliation of the granodiorite is not oriented in any apparent relation to the bedding foliation of the schist, gneiss, and migmatite. Inclusions of gneiss within the granodiorite appear to be lacking, with the possible exception of a few relatively large bodies near the margins of the stocks, which could be interpreted as roof pendants.

The foliation of the larger granodiorite body northeast of Blackpine Lake is in most places inconspicuous, and is not uniformly developed; many exposures appear massive. In general the planes of foliation are relatively flat-lying, though quite variable, near the roof, and somewhat more steeply dipping at levels 3,000 feet lower. In plan, the foliation appears to form broad sweeping curves that roughly parallel the face of the rounded mountain spur on which the rock is exposed, and curve into the mountain at the east and north contacts. The contact relations suggest that the granodiorite body is a more or less regular dome-shaped body, of which somewhat more than half the upper part is exposed, and which is nowhere deeply eroded. Within the dome the planes of foliation appear to be crudely concentric, forming shells roughly paralleling the contact.

Leucogranite

A medium-grained, light brown, granitic rock occurs as numerous sills, dykes, and irregular bodies in the feldspathic quartzites and quartz-mica-feldspar gneisses between Blackpine Lake and the headwaters of

Ravenal Creek. Similar material forms irregular bodies and small dykes in the upper part of the granodiorite stocks near the lake. The rock is mostly massive, with a smooth porcellaneous appearance, imparted by the pale brown feldspar, in which rounded to ragged elongated grains of colourless quartz are conspicuous. In thin section, the rock has a pronounced crystalloblastic texture, and a confused arrangement of grains suggestive of many normal metamorphic rocks. It contains about 25 per cent quartz, 40 per cent orthoclase (much may be microperthite) in large, anhedral, partly interstitial grains, 30 per cent plagioclase (about An_{20}), a few grains of microcline, and usually not more than 5 per cent dark minerals, mainly biotite, with a few ragged grains of amphibole. It is thus a typical leucogranite.

The rock has sharp contacts against the granodiorite. In the gneisses it is found partly as distinct dykes and sills up to 20 feet thick, partly as bands in some of the *lit-par-lit* rocks, and partly as irregular masses within the migmatites.

In places it is possible to trace an apparent gradation along a single bed from feldspathic quartzite through gneiss and migmatite into leucogranitic material, which appears in every respect similar to that in the distinct sills and dykes, except for the presence of biotite-rich patches. Beds showing this transition were examined carefully in three localities. Near the Hope group of mineral claims, on the ridge between the north and south peaks of the massif northeast of Blackpine Lake, the change from slightly schistose feldspathic quartzite, in beds about 6 inches thick separated by quartz-mica-feldspar schist, to leucogranitic rock takes place within about 150 feet. No sharp boundaries can be drawn between the various rock types. On the west side of the shoulder overlooking Blackpine Lake, distant about 100 feet from the upper contact of the main stock of grey granodiorite, a similar change takes place in a single bed within 4 feet. On the south side of this shoulder, about 7,000 feet directly up the slope from the Mesilinka River crossing on the Aiken Lake winter road, the transition from gneiss to rock apparently identical with nearby leucogranite dykes is achieved in about 50 feet. The changes involved in such transitions are chiefly textural and structural, and are much more conspicuous in outcrop or hand specimen than in thin section. Microscopic study of specimens from the same bed shows that the first change entails the breaking down of elongated, sutured grains of quartz into bands of small irregular grains. Coincident with this process is an increase in feldspar content, at first in elongated grains, commonly arranged in strings or bands, and then, as the rock passes from a gneiss to a migmatite, in irregular grains whose haphazard distribution destroys the heretofore well-developed foliation of the rock. The biotite appears to play a passive role in these changes, although it is the mineral primarily responsible for the outward appearance of foliation; it seems to be recrystallized to accommodate the changes of texture of quartz and feldspar. Finally, the rock has no noticeable banding or preferred orientation of individual minerals, and is a confused hypidiomorphic granular aggregate, of about the same grain size, and containing perhaps twice as much feldspar, as the original feldspathic quartzite.

Such leucogranitic material comprises nearly one-third of the rock volume over areas of several acres around the small granodiorite stock exposed on the north peak of the massif immediately northeast of Blackpine Lake, and between this peak and the shoulder overlooking the lake. About half occurs in definite dykes and sills; the remainder grades into migmatites. No instance was noted of a continuously exposed body of leucogranite grading into migmatite at one place and forming clean-cut dykes and sills at another. However, the two types appear identical except for their field occurrence. It seems reasonable to conclude that they are of the same ultimate origin, and that in one case the granitic material consolidated in situ, whereas in the other it became mobilized and travelled along fractures and foliation planes before solidifying. Some dykes of leucogranite cut across bodies of pegmatite and graphic granite; others are cut by pegmatite.

Alaskite

Many dykes and irregular bodies in the gneisses and migmatites surrounding the granodiorite stocks east of Blackpine Lake are composed of cream-coloured, moderately coarse-grained alaskite. Typical specimens contain 25 to 45 per cent quartz, 10 to 40 per cent potash feldspar, in about equal proportions of microcline and what appears to be microperthite and orthoclase, and the remainder albite-oligoclase feldspar, much of it untwinned. Some thin sections show no dark minerals except scattered grains of magnetite; others contain a few flakes of biotite. Accessory minerals include muscovite and sillimanite. The rock has an irregular texture, with much intergrowth of the various minerals. Mortar structure, and strain fractures in feldspar healed by quartz suggest that the alaskite consolidated during a time of pronounced rock movement.

At least some of the alaskite dykes appear to be the youngest of all the Wolverine complex rocks exposed, for they cut across pegmatite and aplite dykes, and quartz veins.

Graphic Granite

Cream-coloured, coarse-grained, graphic granite occurs in irregular bodies up to 100 feet in diameter among the gneiss-migmatite roof rocks above the grey granodiorite exposed on the southwest shoulder of the massif northeast of Blackpine Lake. The feldspar of this granite is in large, irregular crystals, some of which are several inches long. The quartz is colourless, arranged in characteristic cuneiform structures up to ½ inch long. The rock contains about 70 per cent microperthite (?), 5 per cent twinned sodic plagioclase, and 25 per cent quartz. The only accessory minerals noted in thin section were fine, powdery, iron oxides. The graphic granite grades into quartz-feldspar pegmatite.

Pegmatite

Small bodies of pegmatite are abundant above and around the stocks of grey granodiorite northeast of Blackpine Lake. Swarms of dykes are found at intervals along the ridges between these stocks and Chase Mountain. Elsewhere they are very scarce, but appear in some abundance on the crest of Butler Range, at the extreme east border of the map-area.

The pegmatite is found only as dykes and sills, commonly sharply curved, usually less than 10 feet thick and 500 feet long. In places the pegmatites form a reticulate network, which may occupy nearly 50 per cent of the rock volume over an area ½ mile square.

The pegmatites are of simple mineralogical composition; almost all are composed principally of quartz, in both opaque white and smoky transparent forms, microcline microperthite, and muscovite. Other minerals, rarely observed to comprise more than 5 per cent of the rock volume, are sodic plagioclase, biotite, actinolite, garnet (almandine ?), magnetite, sphene, sillimanite, and zircon. The pegmatites have the variable texture characteristic of bodies of this type, showing much mutual replacement and intergrowth. Muscovite, which is the only quantitatively important mineral possessing a tendency to euhedral form, occurs in pseudo-hexagonal books as much as 5 inches in diameter and 3 inches thick. Pockets in the dykes up to 10 feet across, in which nearly half the rock is composed of muscovite crystals more than 2 inches in diameter, have been found. A few dykes contain biotite crystals up to 2 inches in diameter and 1 inch thick.

Most of the pegmatite bodies have obviously replaced the rock in which they lie. Inclusions within the pegmatite bodies retain the same orientation as the wall-rock, and large, regular and irregular bodies cut the quartzite and banded gneiss without producing any offset of contorted structures (*See* Figure 5). One of the most remarkable features of the pattern so produced is the apparent disregard for the banded structure of the host rock; true sills are much less common than irregular, curving bodies crossing the foliation at all angles. The contact between the pegmatite and the wall-rocks is in most places gradational across widths of about ½ inch. An exception to the common replacement pattern is shown by a few pegmatites in the grey granodiorite stock; here they occur as narrow, straight-walled dykes with knife-edged contacts, and appear to fill fractures.

The areas containing much pegmatitic material commonly also contain many quartz veins, and the two rock types are probably genetically related, although no gradational phases were observed. There are two distinct types of quartz veins in the highly metamorphosed rocks northeast of Blackpine Lake: one of white, milky, opaque quartz, almost completely devoid of any other minerals, and one of bluish to smoky transparent quartz, commonly rusty weathering and containing scattered grains of arsenopyrite and chalcopyrite. The white quartz veins are the more numerous, and larger, though bodies more than 3 feet thick and 200 feet long are rare; they both cut and are cut by the pegmatites. The bluish transparent veins are rarely more than a foot thick, and were only observed to cut the pegmatites. Within the pegmatite bodies themselves, the smoky, transparent quartz is found mainly as isolated pockets.

The pegmatites are associated with, and in places grade into, bodies of aplite.

Aplite

Bodies of aplite are much fewer than bodies of pegmatite in the Wolverine complex rocks. They are restricted to areas where pegmatites are abundant, and occur as narrow, fairly regular dykes, or as vaguely defined, fine-grained bodies. They have essentially the same mineral composition as the pegmatites, from which they appear to differ only by reason of their fine-grained, sugary, interlocking texture, and, in many places, by their regular, apparently chiefly fracture-filling form. Some of the aplites are composed almost entirely of quartz and potash feldspar, with little or no mica. A few contain scattered grains of pyrite, arsenopyrite, and pyrrhotite.

Granophyre Porphyry

The largest stock of grey granodiorite near Blackpine Lake is cut by numerous dykes, and irregular bodies, up to 600 feet in diameter, of light buff-grey fine-grained porphyry. The rock contains about 20 per cent oligoclase phenocrysts up to 3 mm. long, much altered to sericite, and about 5 per cent ragged green hornblende, commonly accompanied by clinozoisite, in a quartz-feldspar groundmass, with well-developed granophyric texture. Accessory minerals are mainly magnetite and zircon. There is much evidence of repeated corrosion and recrystallization of feldspar, and clots of non-granophyric feldspar, in semi-polygonal outline surrounded by a rim of clinozoisite grains and containing a core of corroded euhedral hornblende, are common; these may be the result of alteration and replacement of original pyroxene phenocrysts.

Granophyric porphyries were not found in the gneisses and migmatites surrounding the granodiorite stock. Their presence in the granodiorite may be purely fortuitous, as they appear to be identical with the small granophyre intrusions in the Tenakihi and Ingenika group rocks in the Tenakihi Range and on Chase Mountain (*See* page 108).

Andesite Dykes

A few thin dykes of fine-grained andesite porphyry cut the granodiorite stocks and the quartz-mica-feldspar gneisses northeast of Blackpine Lake. All observed are less than 5 feet wide, of uniform width, and are remarkably straight for lengths up to 500 feet. The rock contains scattered altered hornblende phenocrysts about 2 mm. long in a groundmass composed principally of chlorite, clinozoisite-epidote, and cloudy decomposed feldspar. The dykes have chilled contacts and a well-developed foliation parallel with the walls. In detail the dyke walls are irregular, and show numerous apophyses into the adjoining rocks; xenoliths of the wall-rocks are found in the dyke margins.

All andesite dykes observed are steeply dipping, and most of them strike northeasterly. In one place, the hornblende phenocrysts show a fair lineation trending directly down the dip. The dykes cut granodiorite, leucogranite, and pegmatite.

Origin

It is readily apparent that the term 'Wolverine complex' as here used applies primarily to the products of a condition of metamorphism and rock replacement rather than to an assemblage of rocks of any particular age range or lithologic character. In Aiken Lake map-area the sedimentary rocks involved belong to the Tenakihi and Ingenika groups, and all gradations are represented, from recognizable sedimentary strata that have suffered low- to medium-grade regional metamorphism, to high-grade gneisses, migmatites, and rocks of granitic aspect. It is also apparent that the intensity of the "additional" metamorphism and replacement increases progressively toward a centre now represented by the grey granodiorite bodies northeast of Blackpine Lake, and toward a less well-defined, less intensely altered centre in the Butler Range at the east border of the map-area. Thus the processes that produced the Wolverine complex bear no direct relation to the regional metamorphism of the surrounding rocks.

The changes involved in the development of the Wolverine complex are essentially those by which quartzites, schists (originally subgreywackes and greywackes), and limestones are converted into a rock that is identical, mineralogically and texturally, with a normal igneous granitic rock; the process is one of granitization (Read, 1943). The granitization has been accomplished by high-temperature solutions, which circulated mainly along foliation planes, from which they have intimately pervaded the pores of the rock itself, have selectively added or subtracted various chemical constituents, and have facilitated recrystallization and reconstitution of the material already in the rock. The nature of these solutions, their ultimate origin, and method of reaction, are fundamental questions in the entire problem of granitization and the origin of granites, and have given rise to much controversy and a voluminous literature (Gilluly, 1948, and numerous references therein). Reynolds (1946) has discussed the sequence of chemical changes that take place during such a process of granitization; the changes producing the "Wolverine complex" rocks appear to follow this sequence quite closely. According to this sequence, the quartzites are progressively feldspathized, with a marked increase in the alkali content of the rock, and a somewhat less pronounced enrichment in lime, magnesia, and iron oxides. The schists are first desilicated, with concomitant increase of alkali and lime, magnesia, and iron content; at a later stage, when feldspathization is more advanced, silica is added, and lime, magnesia, and iron oxides are removed. The limestones are likewise altered in two stages: first, toward a rock of ultrabasic composition (i.e., amphibolite), by addition of iron oxide, magnesia, alkalis, and alumina, together with a subtraction of lime and carbon dioxide; and then the ultrabasic rock is granitized by addition of silica and alkalis. All of these changes can be observed in the rocks northeast of Blackpine Lake. It is difficult to escape the conclusion that the leucogranite is an end product of the granitization of the Ingenika group sediments, and that, farther northeast, Tenakihi group rocks are trending toward the same end product.

The grey granodiorite appears to be of a different immediate origin. Its contact with the sediments, and with the leucogranite supposedly derived from the sediments, is invariably sharp; and it shows no difference in character against rocks of different chemical composition. The outward form of the bodies, and the internal structure as revealed by planes of foliation, are apparently independent of the structure of the surrounding rocks. The stocks of grey granodiorite thus appear to have the characteristics of actively intrusive bodies, but there is no evidence that the margins of the bodies have been chilled, and there is a puzzling lack of dykes of granodiorite into the surrounding rocks, or of inclusions of these rocks within the granodiorite.

The general pattern of occurrence of migmatite and leucogranite, and, especially, the distribution of the pegmatite and aplite dykes, would seem to indicate strongly that much of the alleged granitizing solutions and the pegmatite-forming fluid was distributed from the space now occupied by the grey granodiorite. It would seem to follow that the granitizing solutions, the material that formed the pegmatite and aplite bodies, and the 'magma' that consolidated into grey granodiorite are genetically connected, and are all products of a common syntectic (or igneous) activity that developed in a relatively narrow zone trending northeast through the Tenakihi and Ingenika group rocks. This activity has taken place at relatively higher levels at each end of the zone, so that erosion has revealed more highly granitized rocks near Blackpine Lake and in the Butler Range.

A tentative sequence of events resulting in the production of the Wolverine complex rocks might be summarized as follows:

(1) The first stage of the processes unique to the Wolverine complex involved the emplacement and consolidation of the grey granodiorite. The material forming the stocks was apparently actively intrusive into the Ingenika and Tenakihi group sediments, which were probably already regionally metamorphosed. The intrusion probably caused severe local deformation of the rocks, resulting in the confused structures found within the Wolverine complex rocks, but no pronounced regional stresses were active during the time of intrusion and consolidation, and the granodiorite solidified with an internal structure controlled mainly by its external form and method of intrusion. The contact action of this intrusion on the surrounding rock is not known, but there was apparently very limited mutual reaction or gradational assimilation between the granodiorite and the intruded rocks.

(2) After, or perhaps partly contemporaneous with the later stages of, consolidation of at least the upper part of the granodiorite stocks, fractures within the granodiorite and along its contact admitted solutions of great chemical activity, which travelled distances of several thousand feet, and perhaps miles, into the adjacent older formations. The solutions selectively attacked the regionally metamorphosed sediments and made them over toward granitic material. Only near the granodiorite bodies, in and around which were located the feeding channels, were the solutions abundant enough or potent enough to complete the process of granitization; there they formed leucogranites, some of which consolidated in situ, others of which were mobilized and travelled along foliation planes and fractures in the partly granitized sediments to form sills and dykes.

At greater distances from the feeding channels, the intermediate rock types represented by the migmatites, quartz-mica-feldspar gneisses, feldspathic quartzites, and schists formed from the clastic sediments, and amphibolites, skarns, and silicated marbles, formed from the limestones, were produced. The solutions carrying magnesia, iron, alkalis, and lime travelled farthest; they were followed by less mobile, or perhaps less plentiful, solutions that introduced alumina, more alkalis, and redistributed silica. There is no evidence of appreciable deformation due to local or regional stresses during at least the latter part of the period of granitization; the leucogranite sills and dykes, which apparently fill fractures and thus imply rock movement in the earlier stages, but which also should have recorded the effects of any deforming stresses active during their consolidation, are mostly structureless.

(3) In the wake of the highly selective granitizing solutions came others which, by contrast, were capable of wholesale, indiscriminate replacement of rocks of various compositions and textures. These solutions, apparently, had only limited power to replace the grey granodiorite, and large quantities may have passed through narrow fractures now represented by thin seams; but they were able to dissolve the granitized rocks to a remarkable extent. They did not permeate the pores and foliation planes of these rocks, which were, apparently, more or less sealed by granitization, but they appear to have followed a multitude of fractures, perhaps contraction joints, in the relatively brittle migmatites and gneisses. These fractures seem to have been enlarged by simultaneous, indiscriminate replacement of the wall-rocks, the material of which was, apparently, completely removed, and substituted by a variable, generally coarsely crystalline aggregate of quartz, microcline microperthite, and muscovite. In places, possibly because of a local loss of volatile content accompanying the sudden opening of a fracture the coarse, variable crystallization did not obtain, and a fine, sugary aplite resulted; in other places, typically in irregular 'pockets' formed by the intersection of several sets of fractures, a 'pool' of the pegmatitic fluid seems to have been able to crystallize quietly, or the growing crystals to have suffered uniform, crystallographically controlled replacement (Spencer, 1945), to form patches of graphic granite. The net result has been the development of an intersecting system of pegmatite and aplite dykes, bodies of graphic granite, and high-temperature quartz veins, which occupy as much as 50 per cent of the exposed rock over large areas lying within a shell 1,000 feet or so thick surrounding the granodiorite stocks (*See* Figure 5). The pegmatites have apparently been emplaced by removing, in solution, the rock whose space they occupy, without effecting any appreciable over-all increase in the volume of the rock.

The pegmatite-forming solutions were obviously highly siliceous, and rich in potash. At irregular intervals they carried small quantities of iron and magnesium, forming irregular clusters of biotite and other minor minerals. There is much evidence of deposition, solution, and redeposition of material within the dykes. The final solutions in many places carried little but silica and a small amount of iron and copper; these formed pockets of clear quartz within the dykes, and veins of transparent to smoky quartz containing a few metallic sulphides transecting the dykes. What peculiarities of the solutions or conditions of the invaded rock caused the solutions to follow lines of mechanical weakness, such as fractures, rather than enter the foliation planes and whatever pore spaces remained in the granitized rocks, and yet enabled them to completely replace those rocks more or less independently of their composition and texture, are unsolved problems.

(4) After the cessation of pegmatite-forming activities, the intruded, granitized, pegmatite-bearing rocks suffered three periods of normal dyke

intrusion along regular fractures. In these periods the alaskite, andesite, and granophyre dykes were formed. The relation of the alaskite to the andesite and granophyre was not observed, but on the basis of its chemical and mineralogical similarity to the leucogranite, pegmatite, and graphic granite, the alaskite is believed to be closely connected with the sequence of granitization and pegmatite formation. The alaskite could represent a late-stage up-welling of granitic material similar to that which had given rise to, or perhaps which had been produced at depth by, the granitizing and pegmatite-forming solutions.

(5) The andesite dykes were emplaced. These rocks have been observed to cut all of the rock types of the Wolverine complex except the alaskite, and are themselves cut by the granophyre porphyry. The andesite dykes observed are found in long straight fractures that appear to be due to regional, rather than local, deformation. Somewhat similar dykes are found in much younger, less metamorphosed rocks in several places within the map-area; consequently, they are not considered as products of the peculiar processes that produced the 'Wolverine complex'.

(6) The stocks and dykes of granophyre porphyry were formed. These rocks are younger than the andesite dykes, and like them, their presence within the area of Wolverine complex rocks appears to be fortuitous.

Age of the Granitizing Activity

There is little definite evidence regarding the time of operation of the processes producing the Wolverine complex rocks. The process has affected Ingenika group strata, and is thus post-Lower Cambrian. Apparently, it occurred later than the regional metamorphism, and almost certainly later than at least one episode of folding (post-Lower Cambrian, pre-Mississippian) of the Ingenika group rocks.

The dominant period of igneous activity in north-central British Columbia is represented by the Omineca intrusions, which are associated with orogenic activity extending from late Jurassic through most of Cretaceous time. However, in no place are these intrusions known to have produced metamorphic effects similar to the effects of the processes that produced the Wolverine complex, and there does not seem to be any evidence on which this complex and the Omineca intrusions could be inferred to be genetically connected (Armstrong, in Gilluly, 1948, p. 123; and Armstrong, 1949, p. 28). The fact that the processes producing the Wolverine complex are not known to have affected Mississippian and younger rocks suggests that they may have ceased operation before the Mississippian rocks were laid down. A bed of conglomerate in the rock assemblage containing strata of Mississippian to probably Permian age, exposed in the Lay Range 24 miles northwest of Blackpine Lake, contains boulders of grey granodiorite mineralogically and texturally similar to the granodiorite of the Wolverine complex, in a matrix made up largely of fragments of quartzite, some of which are feldspathic, micaceous, and gneissic (*See* page 115). This conglomerate suggests that granitic and high-grade metamorphic rocks had formed, and had been exposed by erosion, by late Palæozoic time. The granitizing activity producing the Wolverine complex rocks thus seemingly occurred in post-Lower Cambrian, probably pre-Mississippian, time.

POST-LOWER CAMBRIAN PORPHYRY INTRUSIONS

Granophyre and Quartz-feldspar Porphyry

Small distinctive bodies of granophyre and feldspar-quartz porphyry of dacitic and rhyolitic composition cut the Tenakihi and Ingenika group strata in several places. They are most abundant in Tenakihi Range, where they form an irregular stock about 2,000 feet in diameter south of Jim May Creek, and many sills and dykes, mostly less than 50 feet thick, in the surrounding rocks. North of Mesilinka River rocks of this type occur as dykes and small irregular masses in the grey granodiorite stock northeast of Blackpine Lake, and as sills up to 30 feet thick and small stocks less than 10 acres in exposed area in the Tenakihi group rocks on Chase Mountain.

All of these rocks are very similar in appearance and composition. They are medium grey, weathering a light pinkish grey to grey-brown, almost all porphyritic, with grey to buff-coloured feldspar phenocrysts up to 2 mm. long. The proportion of feldspar, phenocrysts ranges from about 10 to nearly 100 per cent. About half of these rocks contain scattered grains of quartz up to 1 mm. in diameter. Some rocks contain up to 15 per cent of smaller phenocrysts of a ferromagnesian mineral, which in some specimens is hornblende, and in others biotite, partly to completely altered to chlorite. The groundmass is light grey, with a dull, earthenware-like appearance, and is seen in thin section to be a fine-grained aggregate of quartz and feldspar, much of it in a granophyric intergrowth. All the rocks are somewhat altered, despite their fresh appearance in outcrop; the feldspars are so clouded with sericitic and kaolinitic material that it is difficult to determine their composition. All the feldspars examined have a mean refractive index of less than 1·544; many exhibit good polysynthetic twinning, and a few appear to show perthitic intergrowths. The phenocrysts are probably oligoclase, orthoclase or microcline, and perthite. The granophyric intergrowths in the groundmass are commonly exceedingly fine grained, and where best developed form more or less spherical shells with a semi-radiating structure around rounded grains of quartz. Ferromagnesian minerals, represented by hornblende and biotite, make up less than 10 per cent of any of the specimens examined, and are generally found only as small phenocrysts; the groundmass of most specimens appears to be free of dark minerals, except for a little magnetite and secondary chlorite. Secondary minerals include sericite, chlorite, clinozoisite, and unidentified cloudy clay-like material in the feldspars.

None of the rocks examined showed any preferred orientation or flowage textures. All exhibit sharp, commonly chilled borders against the rocks they intrude.

The feldspar-quartz porphyries and granophyres cut the grey granodiorite northeast of Blackpine Lake, and were, therefore, intruded later than the period of formation of the Wolverine complex rocks. Though altered, they show no evidence of metamorphic recrystallization, and are thus presumably later than the metamorphism of the Tenakihi and Ingenika group rocks. They are younger than some of the shear zones that cut the metamorphosed rocks. The rocks resemble some of the early Tertiary, Kastberg intrusions of McConnell Creek map-area to the west (Lord, 1948), and may be related to them; somewhat similar intrusions in Fort St. James map-area to the south are probably of Eocene or Oligocene age (Armstrong, 1949).

Diorite(?) Porphyry

Two dykes, 400 and 100 feet wide, respectively, of highly altered green porphyry cut impure Ingenika group limestones on the lower slopes of the mountain east of Pelly Creek, south of Zygadine Creek. The present rock is a confused aggregate of chlorite, sericite, altered feldspar, and carbonate. It originally consisted of phenocrysts of plagioclase feldspar up to 5 mm. long in a fine-grained matrix that was probably of intermediate to relatively basic composition. Clots of chlorite in this groundmass may represent altered ferromagnesian phenocrysts. The rock contained as much as 2 per cent ilmenite or titaniferous magnetite, in euhedral grains up to 2 mm. in diameter, which is now largely altered to leucoxene. The original rock may have had a composition close to that of a diorite.

The dykes are steeply dipping. The contact relations are obscured by shearing. There has been no noticeable contact metamorphic effect on the adjacent limestone, but some rocks in the immediate vicinity are unusually rich in tourmaline.

These large, isolated dykes are of interest chiefly because they are the only igneous bodies known in the entire one-third of the map-area north of Chase Mountain. No dykes quite comparable to these have been found elsewhere in the map-area, with the possible exception of some coarse, feldspar porphyry bodies close to the Hogem batholith, and the small andesite dykes described cutting the granodiorite northeast of Blackpine Lake.

LATE PALÆOZOIC SEDIMENTARY AND VOLCANIC ROCKS

General Statement

A thick assemblage of interbedded volcanic and sedimentary rocks outcrops in a belt 6 to 10 miles wide stretching northwesterly across the map-area from east of Uslika Lake to the headwaters of Lay Creek. This belt includes two distinct mountain groups separated by about 20 miles of relatively low country where outcrops are confined to isolated ridges and stream canyons. The apparently conformable rock assemblage, grouped into one map-unit, consists of andesitic and basaltic flows intercalated with tuff, greywacke, limestone, sandstone, conglomerate, and chert.

Lithology and Stratigraphic Sections

ROCKS IN THE SOUTHERN MOUNTAIN GROUP

The southern mountain group composed of these rocks lies east of Osilinka River, east and northeast of Uslika Lake, and west of Osilinka River between Vega and Tenakihi Creeks. The succession in these mountains consists of at least 11,000 feet of strata. The characteristic rocks are fine- to very fine-grained, well-bedded, grey-green to green tuffs that weather various shades of light grey, yellow-green, green, and reddish brown, with a conspicuous banded appearance on outcrops. These tuffs, which can be seen under the microscope to be composed principally of chlorite, epidote-clinozoisite, saussuritized plagioclase, and pyroxene largely or completely altered to amphibole, were probably originally of andesitic or perhaps in part of basaltic composition. The flows interbedded with the tuffs are grey-green, massive to porphyritic rocks, and are composed of about the same minerals altered to about the same degree as in the tuffs. The porphyritic varieties contain phenocrysts of altered andesine plagioclase, amphibole, or pyroxene, up to $\frac{1}{4}$ inch long. A relatively few rocks, found as flows and as fragments of flow rocks in the tuffs, are amygdaloidal, with quartz, chalcedony, chlorite, and carbonate amygdules up to $\frac{1}{4}$ inch in diameter. Some layers that appear to be flows, intercalated with the tuffs, are less than 10 feet thick. One exposure of andesite north of Vega Creek shows excellent pillow structure.

In about the middle of this assemblage, a series of tuff beds with a stratigraphic thickness of about 100 feet is sharply cut by bodies of fossiliferous arkosic grit and conglomerate up to 40 feet wide and 200 feet long. The bodies strike almost at right angles to the bedding of the tuff, against which they have knife-edged, undulating contacts. The conglomerate is composed of well-rounded to angular fragments up to 1 inch diameter of red and green tuff and andesite, grey-green porphyritic andesite, blue-grey limestone, and white quartz in a gritty matrix composed principally of angular white feldspar grains up to $\frac{1}{16}$ inch long, in a fine, sandy groundmass of quartzite grains cemented by limonite. The arkosic grit is similar to the matrix of the conglomerate, and like it contains many fragments of crinoids and bryozoa. These bodies appear to represent some sort of marine canyon or crack fillings in the tuffs. The overlying tuffs are not disturbed. Two such bodies are exposed north of Vega Creek on the east side of Osilinka River Valley, and a similar, smaller body is found on the east side of Conglomerate Mountain, west of Wasi Lake.

Uniformly banded tuffs constitute the lowermost 600 feet of the section exposed north of lower Vega Creek. Overlying them are about 400 feet of uniformly banded tuffs with minor black slaty argillite; and these in turn are overlain by at least 6,000 feet of banded tuffs, with minor, intercalated, grey-green, massive to porphyritic andesitic flows and a few small bodies of gritty arkose and greywacke. Above the highest recognized flow are about 3,500 feet of uniform, very fine-grained, banded tuffs. One continuous exposure shows no bed more than 6 inches thick in a stratigraphic section of 300 feet. The youngest rocks exposed in this section consist of about 800 feet of argillite, grit, greywacke, and banded tuffs.

An isolated bluff of conglomerate on the bank of Vega Creek, about $1\frac{1}{2}$ miles below the Vega mineral claims, may belong to this assemblage and may represent a considerably higher horizon in the section. The conglomerate consists of rounded pebbles of light and dark grey chert, quartz, micaceous and feldspathic quartzite, brown, fine-grained sandstone, grey-green and reddish andesites, banded tuff, red jasper, and black cherty argillite up to 6 inches diameter, in a strong, sandy to gritty matrix composed mainly of grains of quartzite cemented by limonite. The conglomerate is fairly well sorted, with beds ranging from a pea-conglomerate to a coarse rock with most pebbles more than 2 inches in diameter.

ROCKS IN TUTIZIKA RIVER VALLEY

In the relatively low area extending northwest from the southern mountain group to the southeast end of Lay Range, most outcrops show banded tuffs and intercalated flows. Probably more than twice as much tuff as flow rock is exposed. The section exposed in the valley of Tutizika River reveals a relatively large proportion of argillaceous rocks. An observed section on the north bank of the river and along one of its small tributaries is as follows:

(Top of Section)	Approximate thickness Feet
Andesite, sheared, serpentinized, carbonated	100
Banded tuff; minor agglomerate; a few bands of highly altered flow breccia	1,200
Argillite, dark grey to black, slaty, in part graphitic, pyritiferous, calcareous	400
Argillite; intimately intercalated greywacke; altered tuff; andesitic flows	500
Chert(?), pale grey; minor tuff; argillite	100
Slate and argillite, blue-grey to black, in part calcareous, in part tuffaceous; minor chert	1,200
Banded tuff; about equal amounts of andesite flows, in units 25 to 100 feet thick	1,000
Total thickness	4,500

The highest members in this section are sheared, and local alteration has developed much serpentine in the andesitic rocks and graphitic or ankeritic material in the argillaceous or calcareous sedimentary rocks.

ROCKS IN THE NORTHERN MOUNTAIN GROUP

The most complete exposures of this map-unit are found in the northern mountain group, which includes the entire Lay Range except for an area of about 25 square miles near its southeastern end, occupied by an ultramafic stock. Here, as elsewhere to the southeast, the strata of this map-unit are characterized throughout by conspicuously banded tuffs. In the Lay Range, however, they contain in addition a greater variety of non-banded tuffs, greywacke, and non-volcanic sedimentary material. Two typical sections, one in the southeastern and one in the northwestern part of the range, are about as follows:

Section at Polaris Creek

(Top of Section)	Approximate thickness Feet
Banded tuff; interbedded argillite, black, slaty	500
Banded tuff; minor andesitic flows	2,000
Banded tuff; minor argillite	600
Banded tuff; minor andesitic and basaltic flows	4,500
Limestone, blue-grey; tuff, red, massive; banded tuff; conglomerate; sandstone; grit; greywacke (includes *Lithostrotion* horizon)	1,200
Banded tuff	1,600
Banded tuff; interbedded agglomerate; minor andesitic and basaltic breccia; greywacke	2,500
Banded tuff; intercalated porphyritic andesitic flows	4,000
Total thickness	16,900

Section North of Lay Creek, Near West Border of Map-area

(Top of Section)	Approximate thickness Feet
Andesite; intercalated banded tuff (upper 2,000 feet poorly exposed)	5,000
Banded tuff; grit; limestone; conglomerate	1,500
Basalt and andesite flows and breccias; banded tuff; conglomerate	1,200
Conglomerate	340
Sandstone; grit; banded tuff; andesite; limestone; impure greywacke	550
Banded tuff; minor limestone, cherty, relatively pure, in thin lenticular beds; greywacke	1,200
Limestone	200
Banded tuff; intercalated andesite flows; greywacke	2,000
Banded tuff; very fine-grained, uniform; minor andesite flows	1,000
Banded tuff, fine-grained; andesite flows	400
Total thickness	13,500

Volcanic Rocks

Few of the rocks of volcanic origin are fresh enough to enable their original composition to be determined. Most of them, whether flows, breccias, or fragments in agglomerate or tuff, are finely porphyritic, with phenocrysts of altered feldspar from 0·25 to 5 mm. long, showing evidence of having been zoned and polysynthetically twinned. Determination of the mean refractive index and extinction angles of fragments of phenocrysts from three of the fresher specimens indicated an average composition in the andesine range. The original occurrence of phenocrysts of feldspar is represented in some specimens by rectangular patches of sericite, epidote-clinozoisite, and chlorite. Many flows contain phenocrysts of dark minerals: orthopyroxene (hypersthene), clinopyroxene (diopside), and amphibole have been recognized. The pyroxene phenocrysts are in a few places replaced by a single pseudomorphic grain of chlorite or serpentine. It is difficult to determine how much amphibole is a primary mineral; almost all rocks contain fresh needles of secondary amphibole. In general, the total amount of dark minerals among the larger grains is not more than 20 per cent. The groundmass of these rocks is, like the phenocrysts, composed of plagioclase and ferromagnesian minerals, altered to an aggregate of amphibole, chlorite, epidote-clinozoisite, sericite, and calcite. Some rocks contain much leucoxene, presumably the result of alteration of sphene or ilmenite. Amygdules are quartz, calcite, chlorite, and occasionally calcite and biotite. The high proportion of feldspar, and the observation that the plagioclase of the phenocrysts, which is commonly the most calcic plagioclase in the rock, is andesine in some specimens, suggest that most of the rocks are andesites rather than basalts.

In contrast with the widespread, green, highly altered andesites, a few flows have a bright purple-brown colour and a fresh appearance in hand specimens and in thin section. These flows were seen only in the northwestern part of the Lay Range, where there are at least six bodies, 50 to 250 feet thick, separated by stratigraphic intervals of 200 to 3,000 feet. All are more or less amygdaloidal, with quartz, calcite, and chlorite amygdules up to $\frac{1}{4}$ inch in diameter. In most of these rocks the plagioclase phenocrysts are relatively fresh, and occur as well-developed prismatic crystals of andesine up to $\frac{1}{4}$ inch long, whereas the phenocrysts of dark minerals (probably mainly pyroxene) are completely altered to antigorite. The groundmass is very fresh, with minute laths of feldspar arranged in conspicuous flow lines, curving around the phenocrysts.

Tuffs

Most of the rocks here called tuffs are undoubtedly water-lain, and some of the material may be a product of erosion of nearly contemporaneous volcanic flows, rather than of strictly pyroclastic origin. They are composed of angular but well-sorted fragments and broken crystals representative of all the types of flows with which they are interbedded. In many rocks the degree of heterogeneity within a single bed is considerable; fragments of various rock textures and mineralogical combinations (all apparently within the andesite range) are intimately mixed in the finest laminæ. Other rocks are composed almost entirely of individual crystals and fragments of crystals of feldspar in a very fine-grained, uniform matrix. Some may be true crystal tuffs, formed predominantly of crystals blown out from volcanic vents as separate individuals. Unless they are well bedded, some of these rocks cannot be distinguished in hand specimens or under the microscope from porphyritic flows. One distinctive rock of this type is buff to greenish grey, with a curious spotted appearance due to an abundance of fresh, idiomorphic, doubly terminated prisms of oligoclase-andesine, about the size and shape of grains of rice, in a uniform, very fine-grained, chlorite-sericite-feldspar matrix. In a few places, immediately underneath beds of limestone, highly hematitic, siliceous material forms the matrix and coats the fragments of the tuff, producing a brilliant red jasper-like rock.

The individual layers of the banded tuff range from a fraction of an inch to a foot or more in thickness. Most layers show a pronounced gradation from coarse to fine grain. At one carefully checked locality on the ridges west of Swannell River, this gradation is repeated about ten times per foot through a stratigraphic thickness of more than 450 feet.

Greywackes

With the appearance of fragments of non-volcanic origin, and the development of a recognizable sedimentary groundmass, the tuffs grade into greywackes. Except for a few beds rich in carbonate of organic origin, the proportion of non-volcanic material in these rocks rarely exceeds 25 per cent, and there does not appear to be a gradation from the predominantly volcanic greywackes into the arkosic sandstones and grits. Most of the greywackes are somewhat coarser in texture, and much less well sorted, than the tuffs. In many beds, fragments up to $\frac{1}{4}$ inch in diameter are abundant, and subangular pieces of rock up to 1 inch long are not uncommon. The non-volcanic material consists of fragments of black argillite, rounded grains of quartz, flakes of muscovite and quartz-mica rock, and carbonate material, much of which is in the form of disks of crinoid stems and fragments of bryozoa. The groundmass of some greywackes is largely crystalline carbonate; of others, it is a pasty, partly opaque, exceedingly fine-grained aggregate of indeterminate composition.

A few beds, up to 15 feet thick, contain as much as 50 per cent carbonate, largely in the form of organic remains, intimately mixed with, and mainly forming a matrix to, the subangular fragments of volcanic rock. In many specimens, the carbonate is dark brown or green, and so impure with finely disseminated volcanic matter that it is difficult to recognize in hand specimen. The carbonate matter consists mainly of recrystallized fragments of crinoids, bryozoa, brachiopods, corals, and other animal remains.

Limestones

The limestones vary from brown to green, impure rocks containing up to 50 per cent non-carbonate clastic material, to light grey, massive beds composed almost entirely of calcite. Most of the limestone beds are markedly lenticular, and pinch out between conformable beds of greywacke and banded tuff. The largest body exposed is 400 feet thick in the centre and 8 miles long; others, up to 100 feet thick, are less than 1 mile in length. All of the larger bodies of limestone contain many cherty layers or patches, and most of them carry relatively abundant, poorly preserved, organic remains.

Shales and Argillites

The shales and argillites in the Lay Range vary from chocolate-brown to blue-grey, massive to finely bedded rocks, to jet-black, graphitic slates. With increasing grain size they grade into siltstones, some of which may be seen in thin section to consist mainly of semirounded quartz and quartzite fragments in a very fine-grained highly carbonaceous quartz-sericite-chlorite matrix.

Sandstones and Grits

Sandstones and grits form distinctive, though minor, units in the Lay Range, and comprise a total thickness of about 2,500 feet, mainly in assemblages less than 100 feet thick, interbedded with the tuffs and andesites in the upper part of the assemblage west of the headwaters of Swannell River. The typical fine-grained sandstone is light brown, with a very clean, porous appearance. It is composed of about 75 per cent semiangular well-sorted grains of quartz, with minor fragments of crystalloblastic quartzite, calcite, carbonaceous material, and flakes of mica, in a limonitic matrix. Coarser varieties of this rock are less well sorted, and grade into a grit composed of angular fragments up to $\frac{1}{8}$ inch in diameter in a highly hematitic, clayey matrix. It is noteworthy that in the predominantly volcanic assemblage exposed in the Lay Range, there are many sandstones and grits containing no obviously volcanic material. In these rocks, all the grains, except fragments of vein quartz and a few cleavage rhombs of calcite, are of recrystallized metamorphic rocks. A typical grit exposed west of the headwaters of Swannell River comprises at least 95 per cent granules of quartzite. Some of the granules are of relatively pure quartzite; others are strongly feldspathic; still others are rich in muscovite and approach quartz-mica schists; and a few contain some graphitic material.

Conglomerate

Conglomerate is relatively rare in the Lay Range. The largest body is exposed on the highest peak between the headwaters of Swannell River and Lay Creek. Here a body at least 340 feet thick consists entirely of conglomerate, with rounded pebbles and boulders up to 14 inches in diameter, in a hematitic, gritty matrix. The conglomerate is well bedded, with several bands up to 2 feet thick of pea-conglomerate and coarse grit. The pebbles and boulders are all well rounded; most of the matrix is relatively angular and poorly sorted. For the whole body the following types and approximate proportions of pebbles are represented:

25 per cent coarse-grained, massive to slightly gneissic, grey, buff, and weathered grey-brown granodiorite, with minor granite(?), in well-rounded stones up to 1 foot in diameter, and averaging 2 to 4 inches (a representative specimen of the granodiorite contains: 25 per cent quartz in crystalloblastic, patchy grains; 35 per cent plagioclase feldspar in twinned, partly poikilitic grains zoned from about An_{35} to An_{17}, 15 per cent microperthite or orthoclase, in large, very irregular grains, and about 20 per cent hornblende);

30 per cent white, buff, or pale grey quartzite, partly micaceous and feldspathic, in boulders up to 14 inches in diameter and averaging 2 to 3 inches;

10 per cent dark grey to nearly black quartzite, quartz-mica schist, and chert(?); average diameter about 2 inches;

15 per cent green, grey-green, and chocolate-brown andesite, massive and porphyritic; some andesite breccia; average size ½ inch to 2 inches;

10 per cent dark grey to nearly black, deeply weathered, schistose rock; looks like decomposed gneiss; mostly less than 1 inch in diameter;

5 per cent banded grey-green tuffs; much altered to epidote-rich material; average 1 inch to 3 inches in diameter; and

Minor, splintery fragments of black slaty argillite.

The matrix of this conglomerate constitutes about 20 per cent of the rock volume, and is a semiangular grit composed mainly of fragments of quartzite in a hematitic groundmass.

This conglomerate body is overlain by at least 700 feet of sheared, shattered rock, intensely epidotized and very heavily coated with reddish purple hematite. The original composition of this rock is doubtful, but some parts at least were conglomerate bearing granitic pebbles. The outcrop of conglomerate is 2½ miles long. Exposures at apparently equivalent stratigraphic horizons 1 mile to the northwest and 2 miles to the southeast show no conglomerate, and what may be the same band of shattering, rich in hematite, lies in normal andesite breccia and tuff.

Smaller bodies of conglomerate are found at higher horizons in this section. None is known to contain granitic pebbles. Many of these beds are similar to the conglomerate exposed on Vega Creek at the west edge of the southern mountain group of this map-unit.

Chert

A few beds of chert are intercalated with the tuffs and sandstones. Some are dull grey to nearly white; others are bright red jasper. All beds observed are less than 10 feet thick. Some of these rocks, which may be seen in thin section to be composed of very fine-grained siliceous material and chloritic matter, may be siliceous volcanic rocks.

Structure

With the exception of small faulted blocks east of Osilinka River and west of Uslika Lake, all of these late Palæozoic rocks strike northwest and dip to the southwest at angles ranging from 30 to 90 degrees and averaging about 60 degrees. The tops of beds, as shown by grain gradation in almost all exposures of banded tuffs, consistently face southwest. At the west edge of the map-area, a few banded tuffs strike north to north 15 degrees east, with a vertical dip. Local folds and drag-folds are rare, and are best developed in beds of argillite such as those exposed on Tutizika River (*See* Plate VIII A). Some of the tuffs show small, local slump structures. The minor variations of strike and dip are due principally to the lenticular nature of the beds.

A series of northwest trending, steeply dipping faults has divided the rocks of this group, in their southern mountain area, into slices about 2 miles wide; the slice northeast of each fault appears to have been lowered relative to its neighbour to the southwest. The Uslika formation has apparently been emplaced along two of these faults, which in places nearly coincide with the bedding planes (*See* page 188). All of these rocks and structures have been offset by a transverse fault along Osilinka River Valley. The west side of this fault moved northward about 1½ miles relative to the east side. As a result of these fault movements, a block about 2 square miles in area northeast of Uslika Lake has been tilted to the east, with dips ranging from 25 to 70 degrees; and another, considerably shattered part of the map-unit, exposed on Thane Creek, has a westerly strike with dips of 10 to 60 degrees south.

The upper part of the map-unit exposed on Tutizika River is highly sheared parallel with the bedding, and some shears may represent southwest dipping faults of considerable displacement (*See* Plate VIII A). These faults all indicate that the rocks on the southwest side have dropped and moved to the south with respect to those on the northeast side, and they may be subsidiary breaks of a large compound fault zone forming the contact between this map-unit and the overlying Takla group rocks.

Apparently, few faults occur in these rocks in the Lay Range, and no appreciable displacement was observed on any that cross the bedding. About forty carbonatized shear zones were noted in the entire range. Most of these are less than 5 feet wide, and parallel the bedding. The largest carbonatized zone is about 100 feet wide and at least 3 miles long, and cuts obliquely across the beds, striking about north 10 degrees east, near the west border of the map-area. Beds are, apparently, not offset along this zone. The hematite-impregnated shatter zone above the large conglomerate body between the headwaters of Swannell River and Lay Creek does not seem to have been the locus of significant net movement. Shear zones up to 100 feet wide, generally parallel with the bedding and heavily impregnated with pyrite and pyrrhotite, were observed at the northwest end of Lay Range and in the canyon on Polaris Creek.

The rocks of this late Palæozoic map-unit are adjoined to the southwest by volcanic flows and intercalated sedimentary rocks of the Takla group, which is Upper Triassic and Jurassic in age. The division between the two map-units is based mainly on structural considerations, for individual outcrops of each group are in many instances lithologically similar. In the southern part of the map-area the contact has been placed below a band of conglomerate exposed west of Uslika Lake and on Thane and Vega Creeks, and containing pebbles of banded tuff and of intrusive rock not unlike that composing some of the pebbles in one of the bodies of conglomerate in the Lay Range. In other respects these conglomerates are not at all similar. The conglomerate west of Uslika Lake lies above a fault or a pronounced angular unconformity. On Tutizika River, and down almost the entire length of Lay Creek Valley, a well-exposed fault zone is believed to mark the contact.

Metamorphism

Almost all these late Palæozoic rocks are composed in part or entirely of volcanic material; the andesitic flows, breccias, tuffs, and greywackes have been altered by the processes of chloritization, propylitization, and saussuritization to aggregates of chlorite, sericite, epidote-clinozoisite, clay-like matter, and minor calcite and pyrite. The change appears to have been essentially one of introduction of water, with some sulphur and carbon dioxide, to the rocks. The dark minerals have been most severely altered; in nearly all rocks the pyroxenes have been almost completely changed to amphibole, or chlorite, or both, and in many specimens the original presence of phenocrysts of pyroxene or amphibole can only be recognized by the occurrence of crudely polygonal clusters of chlorite, needle-like amphibole, and grains of clinozoisite. The feldspar crystals are more resistant to alteration in these rocks, and in a few specimens are quite fresh; most of them, however, are partly to completely saussuritized. In most rocks phenocrysts and groundmass appear to have been about equally altered.

The intensity of this alteration does not appear to be related to any of the recognized shear and fault zones, or to the numerous bodies of intrusive rocks, but is mainly restricted to volcanic material, and seems to be a normal autometamorphic process (propylitization) consequent on consolidation and cooling of the volcanic matter. The presence of propylitized fragments of andesite and tuff in greywackes containing recognizable organic remains suggests that the alteration took place in each flow and tuff bed individually, as it consolidated, before its fragmentation and transportation to the greywacke bed. That the alteration was facilitated by solutions that circulated along joints in the rock is indicated by the abundant coating of serpentine-like material, some of which is typical antigorite, on fracture surfaces. The larger fractures apparently did not serve as channelways for widespread movement of the solutions; very few shear zones are serpentinized.

The rocks of non-volcanic origin are fresh. All the limestones are partly recrystallized. The sandstones and grits are composed mainly of metamorphic materials, and have been unaffected by any processes to which the rock in which they are now found has been subjected. In the highly sheared areas, some of the argillaceous rocks have been metamorphosed into slates, with the development of considerable graphitic material.

Origin

The late Palæozoic rocks are predominantly of volcanic origin, characterized throughout by a high proportion and even distribution of pyroclastic rocks of remarkably uniform character. Most of the tuffs were laid down in marine waters, and are fine grained, and well sorted. Thus, the assemblage is also predominantly clastic. During most of its period of accumulation, a large part of what is now the Aiken Lake map-area was a marine basin, situated relatively near a volcanic centre from which immense quantities of pyroclastic material of uniform composition were supplied. At irregular intervals minor eruptions of andesitic lava took place within the Aiken Lake map-area itself.

During lapses in volcanic activity, the basin continued to sink, thereby allowing the deposition of detritus from the recently deposited, easily eroded surrounding rocks to form greywacke. In restricted areas, and for relatively short periods, clastic deposition stopped or became very slow, permitting the formation of local deposits of relatively pure limestone. At intervals, particularly in the latter half of the period of formation of this map-unit, volcanic activity ceased entirely, and medium- to coarse-grained detritus of crystalline and metamorphosed rock (most probably from the Ingenika or Tenakini group or their equivalents) was the only material supplied to the basin, forming beds of sandstone, grit, and conglomerate. All of the varieties of granitic rock noted in the conglomerate body between the headwaters of Swannell River and Lay Creek can be matched by the granitic rocks of the Wolverine complex.

Age

Organic remains, including sections of crinoid stems, bryozoa, sponge spicules and casts, brachiopod and gastropod shells, cirriped plates, and corals, are abundant in many of the greywackes of this map-unit. Almost all are so fragmentary, or so crushed by compaction of the relatively coarse-grained sediments in which they are most numerous, that they are of no use for stratigraphic identification. The lowest horizon in which identifiable fossils were found is a bed of limestone 200 feet thick exposed on the ridges of Lay Range between the headwaters of Polaris Creek and Swannell River, at least 5,000 feet stratigraphically above the lowest exposed beds in this section. Fossils from this bed were examined by Dr. E. C. Stumm of the University of Michigan, who kindly reported as follows:

Collection 15221. "One of the species present in large numbers is a species of *Lithostrotion* very close to or possibly cospecific with *Lithostrotion whitneyi* Meek from the Carboniferous. The *L. whitneyi* type is known from the upper Mississippian Brazer limestone in Idaho, from Upper Mississippian or Lower Pennsylvanian strata in the Wasatch Mountains (Colorado), and from Carboniferous (Rundle) strata in the Banff region."

Many collections of fossiliferous material from the 3,000 feet immediately overlying this bed have been made. None contains diagnostic fossils well enough preserved to be identified[1]. Professor B. F. Howell of Princeton University has summed up the evidence from some of the collections as follows:

Collection 15225: "Most of the fossils in this greenish fragmental rock are segments of crinoid stems. Some of these segments are very large, like some of those from collection 15219. There is also a small snail, coiled almost in a single plane, a few impressions of bryozoans and one impression of a small brachiopod that is probably a Rhyncospirid (possible *Eumetria,* which is a Mississippian genus); and there is one specimen that may be an *Archimedes*-like bryozoan. *Archimedes* is a Mississippian and Pennsylvanian genus; and these beds must be Carboniferous, I think, perhaps more probably Mississippian than Pennsylvanian."

Collection 15223: "As far as I can determine from a study of these crinoids the rock is probably Carboniferous or Permian. None of the crinoid stems is as large as are some of those in the limestone from locality 15219, so it is probable that bed 15223 is Mississippian rather than Pennsylvanian or Permian."

Collection 15219 (grey crystalline limestone containing detrital quartz sand): "Most of the fossils are crinoids, but there is a small snail, coiled almost in a single plane (but not a Bellerophontid), a phosphatic worm tube, traces of two types of articulate brachiopods (one of which may be a Productid), and what may be a small inarticulate brachiopod. There is one fossil that may be a wide hinged spiriferid brachiopod (which would indicate a probably Mississippian age if it were really such)."

Collection 15224 (grey limestone containing pebbles of volcanic rock): "Possibly Permian. One large, vase-shaped fossil is almost certainly a sponge. So is a small, tubular fossil. Other smaller spherical bodies may be sponges. The presence of pebbles, and sponges, probably indicate shallow water deposition of the limestone. As sponges are abundant in the shallow water limestones of Permian age in the southwestern United States, such evidence as the sponges from this locality afford indicates a probably Permian age for these beds. The crinoidal material might well be the remains of a Permian crinoid."

Thus the evidence available indicates that this map-unit includes beds from Mississippian to possibly Permian age.

Correlation

Correlation of these late Palæozoic rocks with formations elsewhere on the basis of palæontological evidence is unsatisfactory. The only fossil identified with any assurance indicates a correlation of the enclosing strata with the late Mississippian Brazer formation of Idaho, and the Rundle formation of the Lake Minnewanka area, Alberta (Shimer, 1926; Kelly, 1942).

On the basis of general lithology and structural and stratigraphic position, much of this map-unit probably corresponds with parts of the Asitka group of Permian and (?) earlier age, exposed in the McConnell Creek map-area to the west (Lord, 1948). However, as the stratigraphic limits of neither map-unit are precisely defined, and as there are, in places, marked dissimilarities in lithology and faunal communities, it is thought

[1] The writer is indebted to Dr. A. E. Wilson, Mr. L. D. Burling, and Dr. P. Harker of the Geological Survey; Dr. B. F. Howell and Dr. S. K. Fox of Princeton University; Dr. E. C. Stumm of the University of Michigan; Dr. V. J. Okulitch of the University of British Columbia; Dr. M. A. Fritz of the University of Toronto; and Dr. T. H. Withers of the British Museum for their kindness in examining this material.

best, on the basis of present knowledge, not to include this map-unit in the Asitka group, although it is recognized that in part the two units are probably correlative.

Similarly, the meagre palæontological data provide evidence for correlating at least part of this map-unit with the Cache Creek group of Permian and partly Pennsylvanian age. The relations between the Cache Creek group and either the Asitka group or the map-unit here under discussion are not known; the Cache Creek group is probably mainly younger, but the ages of all three units may overlap considerably.

On the basis of their geographic position and general lithology the banded tuffs of the southern mountain group appear to be in part a continuation of some of the volcanic and sedimentary rocks that have been mapped as the lower part of the Takla group of Upper Triassic and later age in the Takla and Manson Creek map-area (Armstrong and Thurber, 1945; Armstrong, 1946b). However, the rocks of this unit in Aiken Lake map-area contain abundant fragments of corals, which are not known in the definitely Upper Triassic rocks of the map-area to the south, and do not contain the molluscs typical of the Takla beds.

In summary, this map-unit is thought to be entirely or almost entirely of late Palæozoic, probably mainly or entirely Carboniferous, age, and to include beds that correspond with beds of the Asitka group, and possibly also with beds of part of the Cache Creek group.

CACHE CREEK GROUP

Distribution

Rocks assigned to the Cache Creek group are exposed in the south-eastern part of the map-area, south of Osilinka River, east and west of Wasi Lake. A few outcrops, part of a large body of Cache Creek rocks exposed in the adjoining McConnell Creek and Takla map-areas, are found in the extreme southwest corner of the map-area, southwest of Omineca River.

Lithology

ROCKS IN THE SOUTHEASTERN PART OF THE AREA

The Cache Creek group rocks in the southeastern part of the map-area fall into three main divisions: one predominantly massive limestone, one composed mainly of volcanic rocks, and one consisting mainly of argillite, with slate, chert, minor volcanic rocks, and limestone. The divisions are arranged from east to west in the order named.

Limestone Division

The dominant rock in this division is massively bedded, blue-grey weathering, light grey and dark grey limestone. Most of it is free from clastic material, finely crystalline, and of a compact uniform texture, with a smooth conchoidal fracture. In places, units up to 100 feet thick are creamy to white, buff weathering, and relatively coarsely crystalline. Some beds, best exposed on the slopes of Osilinka River Valley just east of the east border of the map-area, are dull black to dark brownish grey, with a white or yellowish weathered coating, and emit a sulphurous, fetid odour when pulverized. A sample from one of these beds produced a yellow precipitate, indicating the presence of phosphatic material, when dissolved in nitric acid and added to an ammonium molybdate solution. A few beds contain considerable argillaceous matter.

Greenstone Division

Green and grey-green flows, with minor pyroclastic rocks, comprise about three-quarters of this division. The most common rock is a fine-grained, slightly porphyritic, propylitized andesite composed of zoned plagioclase feldspar and pyroxene phenocrysts rarely more than 1 millimetre long, more or less altered to chlorite, sericite, amphibole, and clinozoisite, in a matrix of the same material. A few of the flows are remarkably fresh. Some flows, up to 50 feet thick, appear to be completely aphanitic; a few have a porcellaneous or slaty appearance. Chilled, partly vesicular and amygdaloidal contacts show that some flows are less than 20 feet thick. Some exhibit excellent ellipsoidal or pillow structures, with the pillows outlined by darker, aphanitic rock, or by concentric layers of amygdules. Breccias are common. Dark grey-purple and dark brown flows are found near the extreme southeast corner of the map-area. The rocks in areas up to ½ mile wide are highly sheared, and are altered to fine-grained, chloritic and amphibolitic gneiss and schist. They have been referred to in general as greenstone.

Pyroclastic rocks include massive to well-bedded tuff, and a few beds up to 10 feet thick of agglomerate. In most places the pyroclastic rocks are in units 200 feet or less thick, interbedded with the flows and non-volcanic sedimentary material.

The non-volcanic rocks of this division are mainly chert, argillite, and limestone.

Argillite Division

The most abundant rocks of the argillite division are thin-bedded, dark grey to black, rusty weathering, carbonaceous argillites. These rocks range from soft, intensely fractured, shaly beds to hard black slates and lustrous phyllites, but most of them are dull, soft but relatively strong rocks, sheared into plates $\frac{1}{20}$ to $\frac{1}{8}$ inch thick. Interbedded with these rocks, and composing about one-quarter of this division, are blue-grey to cream-coloured cherts. Some of the chert occurs as thin-bedded, crumpled 'ribbon chert' consisting of contorted beds of chert ¼ inch to 2 inches thick, separated by fine partings of argillite. A few strong, massive beds of chert up to 8 feet thick are found in the upper part of the division. Other rock types include relatively coarse, poorly sorted greywacke, consisting of fragments of volcanic rock, argillite, and chert; beds of white, crystalline limestone up to 300 feet thick; and volcanic rocks, almost all highly sheared and altered to greenstone.

ROCKS IN THE SOUTHWESTERN PART OF THE AREA

The Cache Creek group rocks exposed in Omineca River Valley are argillites and sheared greenstones.

Structure

The three divisions of the Cache Creek group in the southeastern corner of the map-area are separated by well-exposed faults. The easternmost, or limestone, division, has a thickness within the map-area of about 1,500 feet, and dips gently to the southwest. Investigation of the geology immediately east of the map-area has shown that the limestone overlies a unit, apparently about 9,000 feet thick, composed largely of argillaceous rocks and chert in the upper part, and volcanic rocks, chert, and argillites in the lower part, which in turn overlies another limestone member at least 800 feet thick. The greenstone division in the map-area appears to be about 6,000 feet thick, unless there has been repetition of strata by faulting. In general, the rocks of this division strike about north 15 degrees west and dip steeply southwest, but several large- and small-scale irregular folds give individual outcrops a wide variety of attitudes. The structures of the greenstone division are about parallel with those of the argillite division to the west. This feature, together with the observation that the upper members of the greenstone division become progressively richer in sedimentary material, and that most of the volcanic material of the argillite division is in its lower members, suggests that there may not have been much stratigraphic displacement along the fault separating the two divisions, which may, therefore, be parts of an essentially continuous section. However, the boundary fault is not quite parallel with the bedding planes of either division; strata on both sides appear to have been truncated; and there has been some, and possibly much, omission or duplication of beds by the fault movement.

The argillite division is more intensely deformed than the limestone or greenstone divisions, and drag-folds and local folds up to 500 feet across are common. In most places the shears and slaty cleavage traverse the contorted argillites and ribbon cherts without producing noticeable offset of the beds. A section of this division measured south of Wasi Lake has an apparent thickness of about 4,000 feet.

The lower east slopes of Conglomerate Mountain, west of Wasi Lake, are intersected by innumerable faults and shear zones, with a wide range of attitudes. A study of the direction of slickensides and order of movement of these breaks, the pattern of the associated systems of joints and quartz veins, and the position and form of drag-folds, suggests that the structures could have been produced by compression acting along an axis that now strikes northeast and plunges to the southwest at an angle of about 50 degrees.

On the basis of the lithology and general structure of the Cache Creek group rocks exposed within and east of the map-area, it is suggested, tentatively, that the greenstone division is the oldest unit; that it is overlain by the argillite and limestone divisions respectively; and that it is underlain by another belt of limestone, which is not exposed in the map-area, but which is widespread in the unmapped region to the east. The total thickness of the group is postulated to be not less than 10,000 feet. It should be noted, however, that in the Stuart Lake belt of Cache Creek rocks of Fort St. James map-area to the south, to which the rocks in the southwest corner of Aiken Lake map-area belong, a lithological division comprised mainly of greenstone appears to be the youngest of the group (Armstrong, 1949).

The Cache Creek group rocks are not known to be in exposed contact with any other rock unit in Aiken Lake map-area. They strike directly toward the Ingenika group rocks on the north side of Osilinka River Valley, and are probably separated from them by a fault. They are in places parallel with, and in places in marked discordance with, the banded tuffs and andesite flows of the late Palæozoic map-unit to the west. In part these two map-units are almost certainly separated by a fault, but it is possible that they may be in part conformable, or even parts of the same Cache Creek group assemblage, in spite of a lithological dissimilarity. The structures within the Cache Creek group rocks west of Wasi Lake, near the contact of the group, are consistent with the possibility that the banded tuffs and other rocks to the west could have been thrust up relative to the Cache Creek beds, into their present position along an essentially dip-slip fault striking north 15 degrees west and dipping about 50 degrees southwest.

Age

Fossils have been collected from the massive blue-grey limestones east of the Weber group of mineral claims, on the east boundary of the map-area, and from the lower limestone belt exposed 5 miles east of the map-area. These fossils have been examined by P. Harker of the Geological Survey, who states that the precise identification and assignment of definite stratigraphic horizons must await further studies of the late Palæozoic fauna of northwestern Canada as a whole, but that the collections include productid brachiopods of undoubted Pennsylvanian or Permian age.

The rocks southwest of Omineca River are part of an assemblage that, in the Fort St. James map-area to the south, includes foraminifera of Middle Permian age (Armstrong, 1949).

Correlation

The Cache Creek group, named by Selwyn (1873, pp. 60-62) from its typical occurrence around Cache Creek, near Ashcroft, in southern British Columbia, and to which Selwyn (1877, p. 78) and Dawson (1878, p. 55) assigned the limestones near Stuart Lake in the Fort St. James map-area, has been redefined by Armstrong (1949, p. 50) as: "a very thick assemblage of interbedded sedimentary and volcanic rocks, mainly of Permian age, but also probably in part of Pennsylvanian age. The whole of the Permian period may be represented. Foraminiferal limestones and ribbon cherts are characteristic of the group".

The rocks in the southeastern corner of Aiken Lake map-area are the northwesterly continuation of strata that, in the Manson Creek map-area to the southeast, have been correlated by Armstrong and Thurber (1945) with the Cache Creek group on the basis of lithology and stratigraphy. The beds and flows in the southwest corner of the map-area belong to an assemblage that contains typical Pennsylvanian(?) and Permian foraminifera.

The rocks mapped as Cache Creek group in Aiken Lake map-area are believed to be mainly younger than those of the map-unit, characterized by banded tuffs, and also of late Palæozoic age, that adjoins them on Conglomerate Mountain and in Osilinka River Valley. It is possible, however, that parts of this map-unit correspond with parts of the greenstone division of the Cache Creek group east of Wasi Lake.

ULTRAMAFIC AND RELATED ROCKS (TREMBLEUR INTRUSIONS ?)

General Statement

Several bodies of ultramafic rock intrude late Palæozoic sedimentary and volcanic strata east of Wasi Lake and in the Lay Range. These bodies are provisionally correlated with the Trembleur intrusions of Fort St. James map-area to the south (Armstrong, 1949). They consist of sills and stocks of peridotite, dunite, and pyroxenite, and their serpentinized and uralitized equivalents. Associated with these bodies are masses of hornblendite, and rocks of gabbroic and dioritic composition that are believed to be, at least in part, hybrid rocks.

Rocks of basic and ultrabasic composition are also found at many places within and near the Hogem batholith. These rocks appear to differ in several respects from the ultramafic rocks cutting the late Palæozoic formations, and in this report they are considered to be basic and ultrabasic phases of the Omineca intrusions, unrelated to the strictly ultramafic Trembleur intrusions (*See* page 164-174).

The largest body of ultramafic rocks in the map-area is a stock about 25 square miles in area exposed in the south end of Lay Range, east and south of Polaris Creek. This stock is composed predominantly of serpentinized peridotite, with lesser amounts of dunite, pyroxenite, and possibly hornblendite, and is bordered by relatively extensive areas of hornblende-rich hybrid rock. The ultramafic mass apparently extends under relatively shallow cover to the northwest, where an additional area of about 20 square miles contains several sills and bosses of ultramafic rock, and much hybrid material.

A sill-like body of serpentine about 200 feet thick lies along what may be a fault zone in the north end of the Ingenika Range. Four bands of serpentinized peridotite, with minor associated material of gabbroic composition, cut highly sheared Cache Creek sedimentary strata along and near a fault southeast of Wasi Lake.

Ultramafic Rocks

MEGASCOPIC DESCRIPTION

By far the most common ultramafic rock is a serpentinized peridotite that was originally composed essentially of olivine and pyroxene, with small amounts of chromite. This rock grades into nearly pure dunite, by decrease of pyroxene, and into pyroxenite by decrease of the olivine content. Many of the peridotites are so highly serpentinized that few textural or mineralogical features can be observed in hand specimens, but the less altered parts show a wide variety of grain sizes and textures. Almost all are relatively coarse grained, with crystals from $\frac{1}{20}$ inch up to 2 inches or more long. Most of the rocks are composed mainly of rounded, anhedral grains with a seriate texture; but in parts of the stock east of Polaris Creek where textural differences have not been obliterated by serpentinization, there is a distinct variety consisting largely of crystals of pyroxene 2 to 5 inches long. The large crystals are markedly poikilitic, including numerous rounded individual grains and reticulated networks of grains of olivine up to $\frac{1}{4}$ inch in diameter. On outcrops and in hand specimens these coarse peridotites may be recognized by the reflection of light from similarly oriented cleavage surfaces, which show the presence of skeletal pyroxene grains that are otherwise very difficult to distinguish. Some of the rocks of this type appear to have very little groundmass; the whole rock seems to be an aggregate of coarse, poikilitic pyroxene crystals, and essentially all the olivine, which may comprise much more than half the rock volume, occurs as inclusions in the pyroxene. In other varieties, the large poikilitic pyroxene grains are scattered through a finer grained matrix; in places, clusters of olivine grains in the matrix have been completely serpentinized and, on exposed surfaces, largely removed by erosion, so that outcrops of this rock have a distinctive pock-marked appearance, with more or less equidimensional pits up to 2 inches in diameter and 2 inches deep, spaced two or three to the square foot.

In general the olivine-rich peridotites are finer grained than the rocks containing more abundant pyroxene. Many of these rocks show a type of glomeroporphyritic texture, with clusters of relatively large pyroxene grains in a granular, pyroxene-free olivine matrix. In some rocks of this type the texture seems to be porphyroclastic, with the more easily crushed olivine suffering a greater degree of granulation than the pyroxene.

Rocks that appear in hand specimen to contain only granular olivine have the equigranular, sugary texture and, when fresh, the pale olive-green colour common to dunites. Dunites (peridotites containing more than 95 per cent olivine) are probably rare in these rocks, at least in those sufficiently fresh to enable their minerals to be determined; but peridotites containing more than 85 per cent olivine are widely distributed, and constitute perhaps one-fifth of the area of the relatively fresh ultramafic rocks exposed east of Polaris Creek. A typical variety of this rock consists of elliptical clusters up to 3 inches in diameter of relatively coarse pyroxene grains scattered at intervals of 1 foot to 3 feet in a granular matrix consisting almost entirely of olivine. It may be that dunite was relatively more abundant in those parts of the stock now more completely serpentinized for, in general, the olivine-rich peridotites are more altered than those containing less olivine. The dunite and olivine-rich peridotite occur characteristically in irregular bodies a few tens or at most a few hundreds of feet in greatest dimension. No systematic form of the bodies or pattern of their distribution could be recognized. In many individual outcrops the olivine-rich bodies seem to be roughly tabular, but when the contacts were carefully followed the bodies were invariably found to be completely irregular and haphazard in outline.

Pyroxene-rich peridotite and pyroxenite (peridotite containing more than 95 per cent pyroxene) are likewise of very irregular distribution, but appear to be relatively less abundant in the interior than at the edges of the stock east of Polaris Creek, and if, as is possible, some of the hornblendites are in part uralitized pyroxenite, there is evidence of a definite zone of originally pyroxene-rich material along the margins of the stock. In these places the pyroxene-rich rocks exhibit a great variety of textures, modes of occurrence, and mineralogical relations, which are probably related to, and are described with the 'hybrid' rocks (page 136). One distinctive type of pyroxene-rich peridotite is highly brecciated, and the original aggregate of coarse pyroxene crystals now contains a network of seams and veinlets of fine-grained pyroxene, pyroxene and olivine, or hornblende, which transect and surround the larger grains. The coarse grains and the network of finer grains have in many places reacted differently to serpentinization; in some places the fragments, in other places the veinlets, have been more intensely altered. In the coarsest pyroxene-rich rocks, the pyroxene crystals, up to 14 inches long, commonly show good prismatic form and appear to be quite free of any inclusions except a few grains of magnetite (or chromite?). Such rocks are limited to the margins of the ultramafic body; in the central parts of the body the pyroxene grains are, as previously noted, strongly poikilitic.

Many of the peridotites contain a little biotite, and near the borders of the larger masses, and throughout some of the smaller bodies, biotite may comprise as much as 30 per cent of the rock. Even in the interior of the larger ultramafic bodies, where direct contamination by the wall-rocks is not likely, flakes of biotite are scattered sparsely through many of the peridotites, and some of the rocks that approach dunite in composition contain biotite associated with scattered grains of pyroxene. Where abundant, the biotite is in large book-like grains of about the same size as the pyroxene, and, like the pyroxene, is poikilitic, enclosing olivine and magnetite.

The contacts between rocks of the various types are all sharp, or at most gradational across a few inches. Any one rock composition, and in most places any one texture, is remarkably constant, and changes between the various rock types and textures take place across intrusive contacts between units that are uniform in themselves, rather than by a regular gradation of rock composition and texture. There appears to be a complete lack of system to the intrusive relations between the various rock types; in places olivine-rich rocks cut olivine-poor rocks, or fine-grained peridotite cuts coarser peridotite; in other places the reverse is true.

As in most bodies of ultramafic rocks, chromium-iron oxides are abundant, but no large concentrations were found in the map-area. Chromite was noted chiefly in the serpentinized peridotites, where it occurs as individual, subhedral grains about $\frac{1}{50}$ inch in diameter, both evenly distributed through the rock and as layers that vary from a string of single grains to lacy networks covering a square yard or more, and to dense masses 6 inches or more thick and several feet long. The largest single mass of chromium-iron oxides observed is about 12 feet long, with a maximum thickness of 5 inches. In addition, much chromite occurs as irregular, interstitial masses forming an integral part of the fabric of the olivine-rich peridotites.

The most striking feature about the chromite layers is their unsystematic arrangement over any large area. Individual layers are almost always curved, and festoon- or garland-like patterns are common. In the southeast part of the stock many layers were seen to be arranged in concentric, canoe-shaped or basin-shaped shells; in other places the layers appear to form a series of small basins, a few inches to 5 feet or more deep, whose upper rims, over an area 100 feet or more square, lie in a roughly horizontal plane. In all such structures the lowest layers of a series are the most irregular and have the sharpest curvature; the layers are farthest apart and, in general, thickest in the bottom of the 'basins' or 'festoons', and close together or in places missing at the rims or nodes (*See* Figure 6).

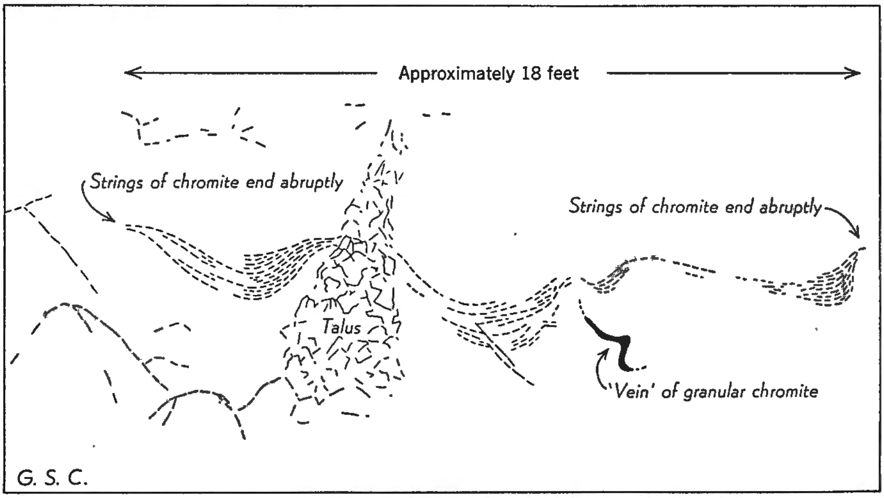


Figure 6. Festoons of chromite-rich layers in serpentinized peridotite near south end of ultramafic stock east of Polaris Creek, as seen on a vertical face.

Almost all the layers of chromite terminate abruptly. In several places they stop at a serpentine-filled seam that probably represents a small fault or slip joint, but in many other places no fracture can be observed, and relatively large layers end abruptly, in some cases leaving a faint 'tail' of grains to suggest that they have been truncated by shearing (*See* Figure 7).

Some lenses and vein-like bodies of granular chromite change in thickness abruptly upon a sharp change of direction, in such a way as to suggest that they fill openings created by slight movement along irregular fractures (*See* Figure 6). In a few places irregular masses occur at intervals in a network of fine, lacy bands.

PETROGRAPHIC DESCRIPTION

The ultramafic rocks are for the most part coarse textured, and except in the highly serpentinized varieties textures and mutual relations between rocks can be seen to best advantage on outcrops and in hand specimens. Thin section study is of value mainly in determining the composition, range of composition, minor textural features, and relative proportions of the individual minerals.

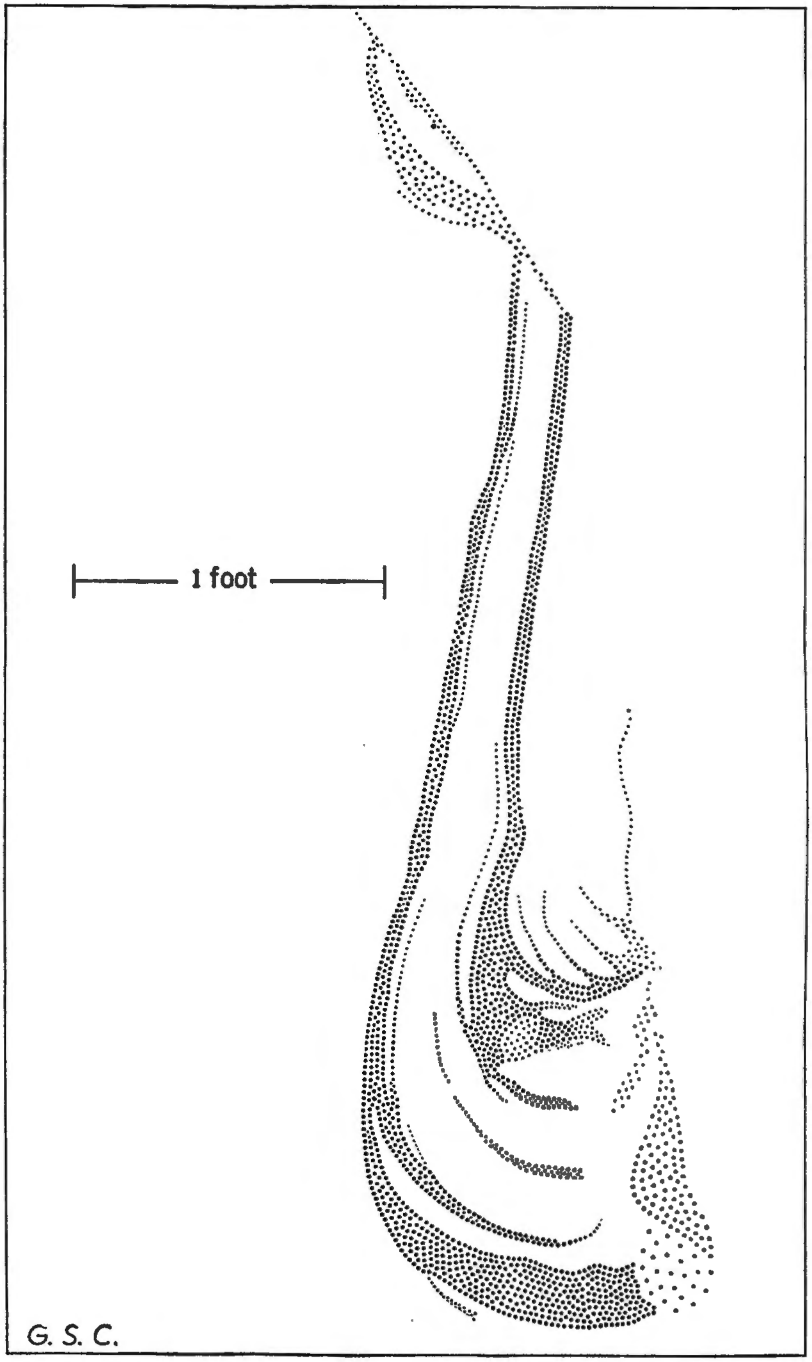


Figure 7. Pattern of chromite-rich bands in peridotite.

Constituent Minerals

The following minerals have been observed in the ultramafic rocks tentatively assigned to the Trembleur intrusions in Aiken Lake map-area.

Olivine. This mineral, which comprises nearly 100 per cent of the dunite and which is, or was originally, present in all the other ultramafic rock types except the rare, purest pyroxenites, occurs mainly in smooth, anhedral grains 1 to 4 mm. in diameter. In a few rocks the grains range to 10 mm. Most specimens show a seriate texture, but at least one slide contains olivine grains of two distinct sizes, with the smaller grains clustered into aggregates whose over-all dimensions are approximately equal to those of the larger grains. The grain boundaries are mainly smoothly interlocking but not sutured, although several specimens of dunite and olivine-rich peridotite were observed to contain amoeboid grains of olivine that lie interstitial to, and poikilitically surround, crystals of pyroxene and rounded grains of olivine of different optical orientation. Euhedral grains are rare. The optical properties indicate a composition ranging from 87 to 96 per cent of the Mg_2SiO_4 (fosterite) molecule. No difference could be detected in either the range of composition or the average composition of the olivines in the olivine-rich rocks as compared with those of the olivine-poor rocks. In addition to the common alteration to serpentine, which proceeds from the rim of the grains and from a network of random fractures, the olivine has in many thin sections been partly converted to iddingsite, which appears as a brown, foliated ring outlining the original grain.

Pyroxene. The pyroxene of the ultramafic rocks varies widely in grain size and texture. In the dunites and many of the peridotites it occurs as rounded anhedral grains of about the same dimensions as the olivine grains. Other peridotites, as has been described, have irregular but usually elongated poikilitic pyroxene grains up to 5 inches long, which enclose olivine and, less commonly, other pyroxene grains. Many grains have an amoeboid habit, with irregular projections into the surrounding pyroxene and into olivine, in such a manner as to suggest that the pyroxene replaced the olivine. The rocks richer in pyroxene show a general tendency toward more regular grain shape, and euhedral crystals are found in many of the pyroxenites. Some of these crystals are more than a foot long.

Nearly all the pyroxene in these rocks is monoclinic, uniformly colourless to very pale green in thin section, and essentially non-pleochroic. They are optically positive with an optic angle of 50 to 60 degrees, and a maximum extinction angle ranging, in different slides, from 38 to 50 degrees. These clinopyroxenes are thus mainly augite, of a variety intermediate between normal augite and diopside. In general the pyroxenites, particularly the coarser varieties, contain pyroxenes with a smaller extinction angle and larger optic angle, and thus presumably a more diopsidic composition, than the peridotites. In some peridotites, large, irregular, poikilitic grains of non-pleochroic pyroxene surround rounded grains of faintly pleochroic pyroxene; this may suggest that the earlier formed mineral is augite, and the later, interstitial and poikilitic grains are nearer to diopside in composition.

Several thin sections, all from peridotites containing 40 per cent or more olivine, contain grains of orthorhombic pyroxene. This mineral comprises more than 10 per cent of a small sill in the northwestern part of the Lay Range, and of a similar body near Wasi Lake, but in all other ultramafic rocks examined it appears to be rare. The grains are colourless, non-pleochroic, anhedral, and similar in size to the associated clinopyroxene. The optical properties are those of relatively pure enstatite.

In most of the olivine-rich bodies, the pyroxenes show various stages of alteration to serpentine, with characteristic numerous thin plates of magnetite oriented along cleavage planes. In the non-serpentinized rocks, many of the pyroxene grains contain a multitude of small amphibole grains, which represent the products of incipient uralitization. Specimens showing successive steps in the transformation of pyroxene into actinolitic amphibole can be found, but in most of the non-serpentinized pyroxene grains the process has not gone beyond the initial stages, and highly uralitized pyroxenites appear to be uncommon.

Biotite. Biotite occurs in many of the ultramafic rocks in the Lay Range. It is particularly abundant, and is locally the principal mineral, at the southeast border of the stock east of Polaris Creek, where book-like crystals up to 2 inches across were seen. In these places, its presence may probably be ascribed largely to contamination of the consolidating ultramafic body by the intruded rocks; but a few flakes of biotite occur well within and throughout the ultramafic mass in quite pure, almost monomineralic dunite, where possibility of direct contamination by fragments of the wall-rocks seems remote. Such biotite, which was observed in only about 5 per cent of the peridotites and even there rarely comprises as much as 1 per cent of the rock, is commonly in irregular tabular grains, about the same size as the associated pyroxene grains and commonly interstitial to them; but a few peridotites contain skeletal or poikilitic crystals with a crude pseudohexagonal outline.

It does not seem probable that this biotite is an alteration product connected with serpentinization or uralitization of the olivine or pyroxene, for gradational phases are lacking, and biotite is no more abundant in the highly altered than in the freshest peridotites. The biotite is of the normal brown, pleochroic variety. It does not appear to be affected by serpentinization, and is conspicuous on both the weathered and the fresh surfaces of serpentinized peridotite. A few flakes of chlorite have been recognized in some of the uralitized peridotites; these may be the result of alteration of biotite. The biotite of the hybrid and contaminated rocks near the margin of the stock east of Polaris Creek has been in part altered to a bronze-coloured material; some small masses have the properties of vermiculite.

Amphibole. Only the larger bodies of the ultramafic rocks contain amphibole, and in them it is restricted to a marginal zone a few thousand feet thick. The occurrence of actinolitic amphibole resulting from the uralitization of peridotite and pyroxenite has been alluded to above. Such alteration, usually resulting in irregular felted masses of dark green bladed crystals, is, however, relatively minor, and of erratic distribution; on the whole it appears that the amount of amphibole developed by alteration from pyroxene is small. More abundant, and much more widespread, is black hornblende, which has all the appearances of having crystallized as a primary mineral in the peridotite. Some fresh-appearing rocks are composed almost entirely of hornblende and olivine; others contain hornblende, olivine, and pyroxene. In most of these rocks the hornblende occurs in rounded to irregular, in some instances interstitial, grains, with smooth, sharp contacts against the adjacent minerals. One distinct rock type has a pronounced porphyritic texture, with subhedral, black hornblende crystals up to 15 mm. long evenly distributed through a pale olive-green fine-grained matrix of fresh pyroxene and minor olivine. Other rocks, best described as hornblende-bearing pyroxenite, consist of fresh, anhedral pyroxene grains among large, irregular hornblende grains. The 'primary' hornblende is strongly coloured, pleochroic brown to green in thin section. No unusual optical properties have been observed. The fresh 'hornblende peridotites' in the eastern part of the stock east of Polaris Creek contain hornblende grains with a maximum extinction angle of 17 degrees, an optic angle of about —80 degrees, and a mean index of refraction (average of only four grains) of 1·670. These properties suggest a relatively high Mg/Fe ratio and an average Ca/Na ratio as compared with most of the common hornblendes.

Chromite. Chromite occurs in two distinct forms in the ultramafic rocks. Most common, but inconspicuous, are irregular, cuspoidal or shard-shaped masses interstitial to olivine and pyroxene. These masses are distributed throughout almost all the dunites and peridotites, and show a tendency to be concentrated in bands less than a foot thick. In the richest of such bands, chromite comprises about 5 per cent of the rock. Chromite also occurs in rounded to octahedral grains up to 3 mm. in diameter, either as individual inclusions within olivine and pyroxene crystals, or grouped into the layers, lenses, and lacy networks that are conspicuous on outcrops and in hand specimens (*See* Figures 6 and 7). The composition or range of composition of the chromite is not known. Most grains show a brown streak, and many are coffee-brown in thin section. Those tested with the blowpipe showed the presence of chromium. Some of the layers rich in chromite strongly affect a compass needle, but whether this is due to the chromite alone or to magnetite developed in the rock as a result of serpentinization is difficult to determine; specimens of the chromite lenses do not appear to be appreciably magnetic. It may be that some of the material here called chromite has such a low Cr_2O_3 content that it would be more accurately termed spinel (picotite) or even magnetite; but in order to avoid confusion with the magnetite that is formed in the same rocks during serpentinization, all the primary metallic oxides, many of which contain chromium, of these ultramafic rocks are here referred to as chromite.

Serpentine. Like most bodies of similar composition, the ultramafic rocks in the Lay Range and near Wasi Lake have been partly to completely serpentinized. About one-tenth of the outcrop area of these rocks is underlain by material so completely converted to serpentine, with accessory magnetite, iddingsite, picotite, and chromite, that no evidence of the original rock type remains; fully half is underlain by rocks so highly serpentinized that almost no original minerals are preserved, though the original rock type can be inferred from the various forms and structures of serpentine present; the remainder of the ultramafic rocks show varying degrees of serpentinization. Unserpentinized ultramafic rocks, although widely distributed and useful in determining the nature of the serpentinized material, are insignificant in amount; they probably do not occupy a total of more than about 200 acres in the 25-square mile stock east of Polaris Creek.

No generally acceptable classification of the different varieties of serpentine has yet come into general use. The terms used in this report are essentially those proposed by Lodochnikow (1933), modified by Leech (1953), and are used in a descriptive sense only. They include chrysotile, the microscopically fine fibrous variety of serpentine, with fibres, of either positive or negative elongation, usually oriented perpendicular to the walls of the veinlet or lens (*See* Plate VIII B); antigorite, in bladed or lamellar grains, with positive elongation, commonly arranged in three mutually perpendicular planes and presenting a reticulated appearance in thin section; serpophite, the apparently structureless rounded masses that form the cores in an interlacing network of chrysotile or antigorite; and bastite, the product of pseudomorphous serpentinization of pyroxene. All of these types are represented in the serpentinized ultramafic rocks of the Lay Range. Their occurrence and distribution is described in connection with the discussion of the process of serpentinization (*See* pages 140-144).

Sepiolite (Meerschaum). Several of the fractures in the serpentine and joint surfaces in the serpentinized peridotite contain fillings of a pale greyish white or green, very compact, smooth textured, light, soft material, which is probably mainly sepiolite. Much of this material shows a delicate, scroll-like banding. The largest pieces seen in place were plate-like masses about 1 inch thick and up to 3 feet long, but masses more than 1 foot thick have been reported by prospectors, and the writer was shown a trimmed fragment, about 3 inches cube, of pure white meerschaum from the stock east of Polaris Creek.

Magnetite. Magnetite is a by-product of the process of serpentinization of olivine and pyroxene, and as such occurs in all ultramafic rocks in the Lay Range and near Wasi Lake, as minute grains along the grain boundaries of olivine and pyroxene, and in the cleavage plane cracks and fractures of the altered minerals. In the completely serpentinized rock the persistence of trains of magnetite grains in such positions affords an indication of the nature of the original minerals. In some otherwise fresh-appearing pyroxene the first conspicuous indication of serpentinization is the development of plates of magnetite along cleavage planes in the interior of the crystal.

Corundum. Corundum is the principal constituent of some white dykes cutting the pyroxenite and peridotite. It occurs as an aggregate of fine, rounded masses, and as elongated grains with hexagonal cross-section, up to 0·4 mm. in greatest dimension, which in places show a tendency to form radiating groups. The grains are colourless, and almost isotropic, with the high refractive index and length-fast character typical of corundum. They are embedded in a serpentinous or clayey matrix and, as is common with this mineral, appear deceptively soft; but a fragment of the corundum-bearing rock will scratch quartz crystals.

Talc, Brucite. Some shear zones contain white, palpable material that may be talc or brucite. It is noteworthy that, unlike many ultramafic bodies, and unlike the type bodies of the Trembleur intrusions to the south (Armstrong, 1949, p. 89), no known masses of ultramafic rock in Aiken Lake map-area have altered to talc.

Nomenclature

The different varieties of ultramafic rocks in Aiken Lake map-area originally represented aggregates of the primary minerals described above, mixed in apparently continuous series. Different rock types are recognized merely as proportions, variable within certain limits, that are relatively more abundant than other proportions of the same minerals. All are feldspar-free rocks; most of them are olivine-bearing, and they are, thus, peridotites (Johannsen, 1938); and the remainder are olivine-free and, therefore, perknites. With the possible exception of hornblende-bearing varieties found near the borders of the stock east of Polaris Creek, all the known rocks are believed to have originally been essentially mixtures of olivine, monoclinic pyroxene, and lesser orthorhombic pyroxene. These rocks range from the pure olivine peridotite, dunite, at one extreme to pure pyroxenite at the other. Nearly all are of intermediate composition; most of them are olivine-augite or olivine-diopside rocks, probably best described as wherlites. A few contain both orthopyroxene and clinopyroxene, and so come under the definition of the variety lherzolite. The distinctive olivine-hornblende peridotites found east of Polaris Creek probably correspond with the rocks generally called cortlandtite.

These different varieties of original rock have been subjected to various degrees of serpentinization, and at least half of the exposed ultramafic rocks in the map-area are serpentinized to such an extent that the original composition is indeterminable, or must be inferred from the varieties and textures of the serpentine minerals. The term serpentinite (Lodochnikow, 1933; Selfridge, 1936) is used in this report for rocks, now composed dominantly of serpentine minerals, whose original composition is obscure.

Contact Rocks

The ultramafic rocks in the Lay Range and near Wasi Lake are emplaced into andesitic flows and tuffs, medium- tò fine-grained greywacke, and minor argillite and limestone of the late Palæozoic sedimentary-volcanic assemblage believed to be of Cache Creek and earlier age. The smaller sill-like or lenticular bodies have in most cases had no noticeable effect on their wall-rocks, and any effect of these rocks on the ultramafic material has been masked by intense serpentinization. Around the large stock in the Lay Range east of Polaris Creek, however, there has been extensive reciprocal reaction between the ultramafic body and the intruded rock, and the stock is rimmed by a large variety of contaminated, hybrid, and contact-metamorphic rocks, which in places represent all gradations from normal ultramafic intrusive material to unaltered volcanic or sedimentary rocks.

The contact zone of the ultramafic stock east of Polaris Creek varies in width from less than 1,000 to 8,000 or more feet around the southeast lobe, where, as seen from its trace across topographic irregularities, the contact is nearly vertical. At the northwest end of the stock, where the upper contact is observed to be gently dipping, contaminated, hybrid, and contact-metamorphic rocks are found abundantly but erratically distributed over an area of about 20 square miles, including a few small sill-like masses of ultramafic material, and lead to the inference that an extension of the large stock underlies this area at relatively shallow depth.

CONTACT WITH ARGILLITES AND SILTSTONES

The type of contact-metamorphic product appears to be controlled mainly by the type of rock into which the ultramafic body has been intruded. Where serpentinized peridotite lies against dark grey to black, sheared, slaty argillite, contact-metamorphic action has been least conspicuous. At such contacts, which are well exposed at several places along the northeast border of the stock east of Polaris Creek, the argillite has been recrystallized to a coarser porphyroblastic texture, with prismatic porphyroblasts of andalusite (chiastolite) up to ¼ inch long. Some of the rock has a waxy lustre due to microscopic seams of serpentine. Slightly coarser sedimentary strata, which 2,000 feet or more from the contact are normal carbonaceous siltstones or fine sandstones, are in places intimately veined and permeated with serpentine, but show no conspicuous development of new minerals. If these rocks are viewed in thin section, it appears that the contact-metamorphic action has resulted mainly in a 'cleansing' of the originally heterogeneous siltstone or subgreywacke, leaving fresh detrital quartz grains in a uniform, carbonaceous matrix containing much serpentine. Where rocks of this type are close to but not directly in contact with the exposed ultramafic mass, being separated from it in plan by tuffaceous or volcanic material, some of the argillites have been recrystallized into slightly sugary hornfels, without any apparent significant mineralogical change, and the siltstones do not appear to have been altered at all. The ultramafic body at the contacts with argillite, siltstone, and subgreywacke is in all places represented by a band, 120 to 400 feet wide, composed entirely of waxy green, black, or glossy chocolate-coloured serpentine. Little 'structure' can be recognized in these bands of serpentinite; although in many places they resemble dyke-like bodies intercalated between the intruded rocks and the main ultramafic mass, their invariable occurrence adjacent to clastic sedimentary beds suggests that they are probably a distinctive reaction product of this type of contact. Like other totally serpentinized bodies in the area, they contain numerous irregular patches, vein-like masses, and fracture-surface coatings of straw-coloured, bright green, blue, and bluish white serpentine minerals and sepiolite. In several places, brecciated veins of white, coarse-grained calcite, containing angular fragments of, and cut by veins of, serpentine were observed in the band. In most cases this belt of serpentinite abuts sharply against the dull orange-brown weathering, dark greenish brown to black serpentinized peridotite that comprises most of the stock; but in several places 100 feet or more of hornblende-rich rock, which grades (?) into pyroxenite, intervene.

CONTACT WITH VOLCANIC AND PYROCLASTIC ROCKS

'Pseudo-diorite' and Injected Feldspathic Material

The most common rock types into which the ultramafic rocks have been intruded are well-bedded, very fine- to medium-grained tuffs, thin porphyritic flows, and minor agglomerates, of andesitic composition. Between such rocks and the ultramafic body there has been interchange of material across several thousand feet. The intruded rocks, which away from the influence of the ultramafic bodies consist mainly of saussuritized plagioclase and chlorite, are, in the outer zone of contact metamorphism, recrystallized and selectively reconstituted to a strong, hard, gneissic rock composed largely of biotite and feldspar. The bedding of the tuffs is made more conspicuous by a relative coarsening of the coarser beds, and minor features such as graded bedding and crossbedding are emphasized. Nearer the contact, this process becomes more pronounced, and although the bedding is still well preserved, individual beds approach the composition and texture of a biotite diorite. In all cases it is the coarsest tuffs that are the most profoundly affected; some of the very fine-grained tuffs and porphyritic flows are not noticeably altered. Where selective reconstitution is well advanced thin seams and sill-like bodies of white feldspar appear here and there between bedding planes; most of these are nodular but very persistent, and seams averaging less than $\frac{1}{8}$ inch thick may be followed along the same bedding plane for more than 100 feet. These sill-like bodies become more numerous nearer the ultramafic body, to where they may constitute as much as one-quarter the rock volume. In many of the highly recrystallized tuffs it is difficult to distinguish some 'pseudo-diorite' recrystallized tuff beds from the injected feldspathic material, but the latter do not show graded bedding, and numerous dyke 'feeders' that connect the sill-like masses appear to demonstrate conclusively that the tabular feldspathic bodies are injected, even though they are of nearly the same composition as the beds between which they lie. Where they crosscut the bedding, the dykes have in places produced a zone of finer grain size, in appearance much like a chilled zone, but with reverse structural relations, in the 'pseudo-diorite' recrystallized intruded rocks. The dykes themselves appear to be unchanged at their contacts. The feldspar of many of these bodies is coarse grained, and remarkably resistant to weathering, so that on many outcrops the interstitial material has been etched away, leaving a crust of coarse anhedral grains standing in relief.

This feldspar, together with that of the 'pseudo-diorite' and recrystallized tuffs, is, despite its fresh outward appearance, so highly altered that its composition is not determinable. Most of the feldspathic material has been changed to a white, nearly opaque, clay-like aggregate in which the original feldspar grains cannot be distinguished in thin section. Accompanying the clay-like material is much clinozoisite and epidote, mostly very fine grained and more or less evenly disseminated, but some rocks contain irregular masses 1 mm. or more in diameter. A few thin sections of this material contain zoisite. The fragments of feldspar grains tested have a relatively low refractive index (about 1·540 to 1·542) suggesting, along with the general mineralogical association, a sodium-rich plagioclase, but all feldspars are so altered that the measurements are not reliable. It is not known whether albitization of an originally more calcic feldspar has been part of the alteration process.

The injected feldspathic material is relatively mobile, and not entirely confined to the tuffs; a few small bodies are found in the metamorphosed siltstones, where, however, it does not form regular sill-like masses, but thin irregular bodies that wander erratically across the bedding in a manner suggestive of replacement. Similar material is found sparingly in the serpentinized ultramafic rock as much as a mile from the exposed contact of the body (although possibly close to the original roof). These rocks, which constitute one of the varieties of 'white dykes', are for the most part less than 10 feet wide, and are flanked by bands of massive serpentinite.

Where the injected feldspathic material becomes most abundant, tabular and lenticular bodies of relatively coarse hornblende make their appearance. Farthest from the ultramafic contact, the hornblende bodies have much the same habit as the feldspar, appearing first as seams between bedding planes and as replacement bodies in the injected feldspathic material or in favourable beds in the tuff; but closer to the contact, where the proportion of feldspathic material decreases sharply, the hornblende rapidly becomes more abundant, and appears as irregular masses or uniform disseminations, in places with sharp, and in places with gradational, contacts. No dyke-like 'feeders' of hornblende, similar to those of feldspathic material, were found. Finally, the highly metamorphosed 'pseudo-diorite' tuff passes into or abuts sharply against rocks in which no evidence of the original structures is preserved, and the zone of hybrid rocks is reached.

Hybrid Rocks

The hybrid rocks of this contact zone include all the rocks situated between the ultramafic body and the intruded, older formations that are neither parts of the normal ultramafic series and its alteration products nor recognizable altered older rock. Such rocks occur alongside the ultramafic bodies east of Wasi Lake and are well developed around the stock east of Polaris Creek, where they occupy an area half as large as the stock itself. Most of these rocks are relatively resistant to erosion, and form many of the prominent peaks and ridges surrounding the stock. Many rock types are represented. Almost all have textures similar to normal igneous rocks and typical intrusive structural relations. In general the various hybrid rocks belong to two main classes: those in which hornblende is an essential mineral, and those characterized by biotite.

Hornblende-bearing Hybrid Rocks. These range in mineral composition from slightly hornblendic pyroxenites and peridotites to hornblendite, hornblende meladiorite, and hornblende diorite.[1] A fairly abundant rock type, found adjacent to normal serpentinized peridotite, is a medium-grained, highly pyroxenic peridotite containing stout prismatic crystals of black hornblende up to 1 inch long. Where best developed in this rock the hornblende makes up about one-third of the rock volume in individual crystals of relatively uniform size evenly spaced through a medium-grained, light green, diopside-olivine matrix, resulting in a rock of conspicuous spotted appearance. In several places a breccia-like rock consists of fragments of very coarse-grained pyroxenite in a matrix of finer grained ($\frac{1}{4}$ inch long) hornblendite. Examples were found both of small dyke-like bodies of

[1] It may be debatable whether these terms, which commonly carry the implication of origin by direct crystallization of an igneous magma, should be used for the hybrid rocks in question. They are here applied in a descriptive sense only, with no intended genetic connotation, although on the grounds that the rocks have all the appearances of having crystallized from a high temperature, mobile, intrusive medium, the terms may perhaps be justified in a genetic as well as descriptive sense. The degree of impurity allowed before a contaminated magma, if contamination takes place while it is essentially mobile, ceases to be a "magma", and the rock formed from it ceases to be "igneous", is largely a matter of arbitrary definition.

hornblendite cutting pyroxenite and peridotite, and of fine-grained, granular, diopsidic pyroxenite cutting hornblendite. In general the hornblende-bearing ultrabasic rocks are not strongly serpentinized.

The most widespread types of hornblende-bearing hybrid rocks constitute a series ranging from pure hornblendite to a rock composed mainly of plagioclase with minor hornblende, characterized by prismatic, commonly elongated hornblende crystals and saussuritized plagioclase feldspar. In thin section, the hornblendites may be seen to be composed almost entirely of very fresh, green-brown, pleochroic hornblende. Many crystals enclose numerous octahedral crystals of magnetite, some of which are surrounded by and contain irregular 'cores' of what appears to be a calcite-clinozoisite-amphibole aggregate. Minor and accessory minerals, almost entirely confined to interstices, are penninite chlorite, calcite, clinozoisite, hematite, garnet, and possibly corundum. Pure hornblendites are relatively rare, although patches an acre or more in extent contain essentially no feldspar; but there are extensive areas of feldspathic hornblendite containing 10 to 20 per cent feldspar. The most remarkable feature of these hornblende-rich rocks is their extremely coarse average grain size. Most of the crystals in many of the rocks composed dominantly of hornblende are more than 2 inches in length; crystals 6 inches long are common; and one 70-foot cliff west of the boundary of the stock east of Polaris Creek appears to be composed almost entirely of crystals more than 1 foot long. The largest crystal seen measured 38 by 18 inches in the cliff face; euhedral crystals, with well-developed terminal faces, more than 2 feet long and 1 foot mean diameter are not uncommon, and are in places grouped in clusters.

The more highly feldspathic hornblende-bearing rocks include a distinctive type in which elongated prisms of hornblende form a reticulated network, to which white to pale rose-grey or greenish saussuritized feldspar, rarely in distinct grains, is interstitial. One of the characteristic features of many of the coarser varieties of these rocks is the presence of one or more triangular or polygonal prisms of feldspar within, and parallel with the long axis of, the prismatic hornblende crystals. Some of the finer grained varieties of this rock type have much the same appearance as normal intrusive diorite, but most of them have a distinctive texture of acicular hornblende crystals and interstitial plagioclase. Diopside, tremolite, epidote, and biotite are locally abundant in these rocks.

Veinlets of epidote, usually less than 1 inch wide, are fairly common in some of these rocks. Most of them have sharp borders, and they appear to occupy fractures. Most of the epidote (some may be clinozoisite) is a fine-grained network of elongated crystals, producing a rock that is massive in hand specimen; but coarsely crystalline, vuggy veins are not rare. Prismatic, striated crystals of epidote up to 2 inches long have been collected from these.

Biotite-bearing Hybrid Rocks. These are nearly all of basic or ultrabasic composition, and most of them seem to be normal peridotites and pyroxenites that have become contaminated with sufficient extraneous material to develop abundant biotite, in many places accompanied by hornblende. A few small bodies composed almost entirely of biotite were observed, but most rocks of this type consist of an aggregate of serpentinized olivine and pyroxene, and fresh hornblende and biotite. The hornblende and biotite are in most cases by far the coarsest components of such rocks. Some of the 'biotite' in these rocks may be phlogopite (Johannsen, 1938, p. 410).

CONTACT WITH LIMESTONES

A distinctive series of metamorphic rocks has developed where the ultramafic stock contacts massive late Palæozoic limestones of the Lay Range. It was not found possible to trace a gradation from unaltered into altered limestone. However, a body of what was originally limestone outcrops over an area about 1,000 feet by 500 feet on the west side of the stock east of Polaris Creek, lying between serpentinized peridotite to the southeast and hornblendite and 'pseudo-diorite' to the west and north, and thus forming the wall and part of the roof of the ultramafic body. About half of the altered limestone is a dull white, pale bluish green and yellow-grey rock containing irregular patches up to several feet across of darker yellow-grey material. Both the patches and the rock surrounding them vary greatly in appearance; both show relict bedding, outlined by colour bands and by texture. The texture of this rock varies within wide limits, from very fine grained, almost cryptocrystalline, to coarse and sugary, and to a felted mass of prismatic crystals up to 0·5 mm. long. In several places it can be seen that the boundaries between areas of unlike texture are independent of, and cut across, the boundaries of the colour patches. Microscopic study shows parts of this rock to be recrystallized limestone, composed almost entirely of irregular interlocking grains of calcite with a few grains of detrital quartz, and other parts to be composed entirely of white or pale grey diopsidic pyroxene. No thin sections showed a transition phase between these two rock types. Both types apparently vary widely in grain size, and as both are more or less serpentinized, with the development of pale yellow-green massive serpentine (serpophite), the difference in physical properties between the two is not always evident. It proved very difficult to distinguish between the marble and the diopside-rock in the field, and the structural relations between them are not known. The irregular colour patches in this rock appear to be the result of development of serpentine, and are to some extent independent of the rock composition and texture.

Much of the rest of the metamorphosed limestone has been altered to serpentine. Some of the serpentine forms seams of fibrous chrysotile, but most of it occurs as irregular bands or patches of massive toffee-yellow serpentine in a pale yellow, serpentinized, limestone matrix. Microscopically, the yellow serpentine is seen to be mainly finely fibrous chrysotile, in part embedded in a massive serpophite matrix. Some of the yellow rock contains porphyroblasts of olivine, apparently quite pure forsterite, which have been highly serpentinized and are visible in thin section as remnants with an optically positive character and an optic angle close to 86 degrees. Where most uniform, the partly serpentinized limestone has a crystalloblastic texture, and consists of about 70 per cent calcite in masses of small grains (0·10 to 0·05 mm. in diameter), cut by rude bands of fairly clean, regular grains up to 2 mm. in diameter. The larger grains of calcite in the groundmass are poikilitic, and enclose smaller grains of calcite and masses of serpentine. The remainder of this rock is composed of rounded grains of apparently massive serpentine, mostly in blebs 0·01-0·05 mm. in diameter within and between the calcite grains. A few flakes of talc are present.

About one-fifth of the altered limestone is conspicuously porphyroblastic, with pale honey-yellow dodecahedral crystals of grossular garnet up to 3 mm. in diameter. In addition, a few specimens contain rounded, in part skeletal, porphyroblasts of a garnet that is probably close to andradite in composition. In thin section, both types of garnet are seen to be packed with inclusions of calcite and clinozoisite. Many of the grossularite crystals are zoned. The remainder of the rocks is mainly recrystallized calcite and massive or fine fibrous serpentine, with much clinozoisite, many minute rounded grains of garnet, and, in some sections, masses of forsterite. Small irregular masses of this rock are relatively rich in clinozoisite-epidote, resulting in an apple-green and bright bluish green, fine, sugary rock containing yellow and pink-brown garnet porphyroblasts. Some of this rock contains a few crystalloblasts of what may be diopside.

'White Dykes' (Plumasites)

The pyroxenite and peridotites are cut by a few dyke-like bodies of pale creamy grey or almost pure white material, which stands out in conspicuous contrast with the orange-brown or olive-green surface of the surrounding rocks. These bodies are quite distinct from, and apparently in no way connected with, the dyke-like bodies of feldspathic material and the apophyses of hybrid rock that cut the contaminated borders of the ultramafic body. The feldspathic bodies are restricted to the margins of the ultramafic mass, from which many can be traced into the surrounding hybrid rocks and reconstituted older formations, and they exhibit a wide variety of textures and proportions of their constituent feldspar and hornblende; whereas the 'white dykes' referred to in this section were only observed within the interior of the ultramafic body in apparently normal (though commonly highly serpentinized) pyroxenites and peridotites, and, where observed, they are of apparently uniform composition, with no minerals except a little serpentine material identifiable in the hand specimen.

Five such bodies were found cutting the stock east of Polaris Creek. All are between 3 and 10 feet wide; the longest can be followed in outcrop and on felsenmeer for about 600 feet. Those best exposed are curved and 'wandering', and do not seem to bear any obvious relation to the joint patterns of the surrounding rock. All those observed dip fairly steeply. Some of the shear planes in the wall-rocks cut through the bodies, but in no place was the body itself seen to be offset. The different bodies, and different parts of the same body, are uniform in outward appearance. All are very fine grained, and contain minute needle-like crystals of high lustre. They have a peculiar brecciated appearance, due in part to irregular masses, with concentrically banded borders, of material of different serpentine content and commonly of different texture, and in part to the presence of many very thin, open, irregular fractures and seams, which do not follow any particular pattern and are commonly not connected.

Microscopic examination shows that these bodies are composed almost entirely of corundum. The only other material, occurring as a patchy groundmass or as vein-like bands surrounding masses of almost pure corundum, is a semi-opaque, almost isotropic, white material that probably contains serpentine, clinozoisite, and perhaps clay-like matter resulting from the hydrothermal alteration of feldspar.

The corundum-bearing rocks have been found cutting both the serpentinite and the slightly serpentinized pyroxenite and peridotite. No change in composition or texture of the bodies could be discerned at their borders. The walls are in all observed places lined by a thin selvedge of dark brown mica. In one place this selvedge is backed by a zone of coarse black hornblende crystals. The wall-rocks of the other bodies either consist of serpentinized peridotite or grade through a foot or more of grey-green, very fine-grained, altered material that may be an aggregate of amphibole, talc (?), and serpentine minerals. The total width of this 'reaction zone' in the wall-rock varies from about 1 inch to 3 feet, and was observed to be almost the same on each side of the body. However, there appears to be an increase in intensity of serpentinization of the ultramafic rock in a band 5 to 20 feet wide on each side of the bodies.

Corundum-bearing dyke-like bodies have been found in ultramafic rocks in many localities, and have given rise to much speculation regarding their origin. Most of them consist essentially of oligoclase and corundum, a combination to which the name plumasite has been given. Most of the plumasites described are associated with, or grade into, rocks consisting mainly of oligoclase. Larsen (1928) has summarized the descriptions of many of these occurrences and the hypotheses regarding their origin. He emphasizes the similarity of the 'reaction zones', usually consisting of concentric layers of dark mica, amphibole, and talc, which frequently bear no relation to the width of the dykes, and postulates that the corundum-bearing bodies are not true dykes but deposits formed by alumina-rich hydrothermal solutions. Du Toit (1918, 1928) and many other workers have considered that the plumasites represent normal aplitic and pegmatitic dykes that have been desilicated by the surrounding ultrabasic rock, with the reaction zones resulting from the progressive transfer of silica, potash, and fluorine from the dyke to the serpentinized wall-rock. The corundum-rich 'white dykes' of the stock east of Polaris Creek may not be normal plumasites; their 'reaction zones' are more poorly developed than those described by Larsen and du Toit. The specimens collected are much richer in corundum than those described from other localities, but the samples taken may not be representative of the dykes as a whole. Their narrow (in places lacking) 'reaction zones', relatively uniform width and tabular shape, and restricted occurrence suggest that these bodies are most probably altered dykes rather than hydrothermal deposits. They may be similar to some of the 'white rock' of the Coquihalla serpentine belt (Cairnes, 1930), but are more regular in form.

Alteration to Serpentine

In common with almost all ultramafic bodies, the peridotites, dunites, and pyroxenites in the map-area are partly to completely altered to serpentine. The sill-like bodies east of Wasi Lake and in the northwest part of Lay Range are so completely serpentinized that their original composition is obscure. At least 80 per cent of the large stock east of Polaris Creek is highly serpentinized. The most abundant serpentine, which uniformly pervades most of the peridotites, is a very dark bluish green to black, dull to waxy lustred material that weathers a bright orange-brown to a depth of ½ inch or more. In thin section, this material is seen to consist mainly of bladed, lamellar antigorite, in an irregular, very fine-grained aggregate. Many sections contain fine fibrous chrysotile, which forms networks in massive serpentine (serpophite) or surrounding masses pseudomorphous after pyroxene (bastite). In common with most serpentinized bodies, this bright orange-brown weathering serpentine is exceedingly infertile, owing to traces of chromium and nickel in the derived soils (Robinson, *et al.*, 1935), so that the main part of the ultramafic stocks are almost completely devoid of plant life, either in the form of sub-alpine forest and meadowland at lower elevations or of lichen above timber-line; because of its barrenness and distinctive weathering colour the outlines of the stocks are conspicuous from a distance.

The successive steps in the process of progressive alteration of fresh ultramafic rock into serpentinite can be observed in thin section. As is usually the case, the olivine crystals are more susceptible to serpentinization than the pyroxene, and a thin band of what appears to be lamellar antigorite appears along crystal and fracture faces of olivine in rocks that otherwise appear fresh. In some rocks iddingsite (or bowlingite) develops around the olivine at this stage. When the process is farther advanced, the bands of antigorite(?) around and within the olivine crystals are in many cases seen to be flanked by zones of bladed and fibrous serpentine; and at the same time layers of exsolved magnetite in the cleavage planes of the pyroxene grains indicate the beginning of a gradual replacement of that mineral by bastite. The alteration of the pyroxene, although commencing somewhat later than that of the olivine, is apparently a relatively rapid process. Some sections show that the pyroxene has, apparently, been completely replaced by bastite, whereas the adjacent olivine crystals have been merely divided into a number of fragments separated by a network of serpentine and fine-grained magnetite. The magnetite is commonly expelled to the centre of each widening vein, marking the position of the original fracture or crystal boundary. In several sections it appears that the olivine alters to chrysotile, which is in turn replaced by antigorite, and that the zone of fibrous serpentine migrates toward the centre of the grain or fragment as serpentinization proceeds. The last remnants of the olivine grains seem to be replaced by a massive, structureless, nearly isotropic serpentine (serpophite).

Bastite and chrysotile are not common in the serpentinites. This is no doubt partly because the rocks originally containing relatively more pyroxene and thus capable of developing relatively more bastite are uncommon, and less susceptible to serpentinization than other peridotites, and it may also indicate a general tendency for antigorite to replace bastite and chrysotile.

In addition to the pervasive, black, orange weathering serpentine, a great variety of serpentines and related minerals occur in smaller amounts. Bands up to 120 feet wide composed almost entirely of dark green to black, very glossy serpentine are found along some contacts between ultramafic and sedimentary rocks, and flanking the rare corundum-bearing 'white dykes' in the peridotites. In part this material is a reticulated aggregate of bladed antigorite; in part it has a mesh structure, with areas that appear massive in thin section (serpophite) surrounded by minute fibres (chrysotile). Irregular areas up to 25 feet in diameter of chocolate-brown serpentine, with a compact glassy appearance, are found at several places within the mass, not obviously related to any compositional or structural features. Most of the joints are filled or coated with pale grey-green to dark green, fibrous and long columnar chrysotile. The columnar crystals commonly grow at an acute angle to the faces of the joints in which they lie, so that fracture faces have a 'shingled' appearance. The serpentine of the joints is commonly more resistant to erosion than the surrounding rock, so that the joints stand out on weathered surfaces as a network of serpentine veinlets. In places, highly serpentinized peridotite, consisting mainly of greenish black, massive serpentine, contains dyke-like bodies up to 3 feet wide of straw-yellow, bladed to fibrous serpentine. The fibres are oriented directly across the dykes, which contain lenses of black massive serpentine. In thin section, the long parallel fibres of these bodies show an over-all lamellar structure perpendicular to their length, caused by small variations in orientation and irregularities of growth of parts of the fibres. This 'lamination' is nearly always parallel with the walls of the major fissure occupied by the chrysotile body; in places it branches around, and in other places abuts, inclusions within the body and walls of subsidiary fissures. The pattern of this lamination within the masses of fibres indicates that the chrysotile fills fractures whose walls were spread apart, and does not represent replaced bands in the serpentinite; that the fibrous chrysotile developed almost simultaneously with the spreading apart of the walls; and that the fibres grew outward, in places from both walls and in places from only one wall (*See* Plate VIII B). A few thin bands of grey, flexible, asbestiform chrysotile were found in the west-central and southeastern parts of the stock east of Polaris Creek. Much of the serpentine east of Wasi Lake is bright yellow-green, apple-green, and pale green-grey in colour. It does not weather brown. Bodies of this type of serpentine are found near the peripheral parts of the stock east of Polaris Creek. In a few cases they contain isolated, ball-like masses of chromite up to 2 inches in diameter.

Bright blue, pale leaf-green, and pure white serpentine minerals are widely distributed in small amounts. A porcellaneous, nearly white material, commonly with a contorted, delicate colour banding, is quite common as seams up to 1 inch thick. Some of this is probably sepiolite (meerschaum).

The areal distribution of serpentinization, and the variation of its intensity within any one area, is in general haphazard. Many of the small ultramafic bodies are almost completely, uniformly, serpentinized (to serpentinite). There is a general tendency toward a uniform, pervasive serpentinization within the interior of the large bodies, with a corresponding greater variation in type and intensty of serpentinization near the borders, but the intensity of over-all serpentinization is no greater in the interior than at the borders of the bodies, and small unserpentinized masses occur at random. The contact with sedimentary rocks is generally a zone of intense serpentinization in both large and small bodies. Dykes, and fault, shear, and major joint planes within the ultramafic bodies are likewise loci of locally intense alteration. Around the stock east of Polaris Creek, serpentine has developed sparingly within the adjacent greywacke and limestone for several hundred feet from the contact, but no serpentine minerals occur in the 'pseudo-diorite' tuffs or in the hornblende-bearing hybrid rocks.

The process of serpentinization is essentially a conversion of magnesium silicates stable at high temperatures (olivine, pyroxene) into forms stable at low temperature (serpentine) in a system containing excess water (Turner, 1948, p. 130). There has been controversy as to whether this conversion is essentially an autometamorphic or deuteric process, effected by solutions that were largely contained within the rock-forming material at the time of crystallization, or whether the process is hydrothermal, with the serpentinizing solutions derived from outside the ultramafic mass (Bowen and Tuttle, 1949). In Aiken Lake map-area, all of the small ultramafic bodies mapped lie along observed or possible faults or shear zones, and all are intensely serpentinized. Within the large stock east of Polaris Creek, which is not emplaced along or bordered by a known fault or shear, the most complete serpentinization is found along the contact with argillite and greywacke and along minor fracture zones and dyke borders within the mass. In these places it seems difficult to entertain the hypothesis of serpentinization by means of solutions within the ultramafic body. Contacts, fractures, and other lines of tectonic weakness would be expected to form channels of circulation of solutions within the mass; and although these might be expected to facilitate the process of serpentinization in some places, they should also serve as lines of escape of serpentinizing solutions if these originated within the ultramafic body, and the rock near them should in places be less altered than the unfractured rock. On the other hand, if the serpentinization was effected by waters from an extraneous source, the greatest intensity of alteration would be expected adjacent to such channels of circulation.

A 'pervasive' type of serpentinization, however, seems to have reached an approximately uniform intensity over relatively large areas, apparently independent of the main joints and shear zones of almost pure serpentine. This type of alteration has resulted from attack on each individual grain by an interstitial liquid, which in the initial stages of serpentinization corrodes uniformly from crystal faces, fractures, and cleavage planes. If the solutions are postulated to have come from an outside source, it is difficult to explain how they become so evenly distributed through the pores of the rock, in part unrelated to any visible fracture. On the other hand, if serpentinization is held to be an autometamorphic process, brought about by solutions contained within the medium from which the rock consolidated, it is equally difficult to explain how small areas, haphazardly distributed within the main ultramafic mass, and with no apparent peculiarities of composition, could have remained fresh and unserpentinized.

Thus the evidence recognized in the ultramafic bodies in Aiken Lake map-area suggests that both autometamorphic and hydrothermal processes have played a part in the alteration to serpentine. The former process seems to explain best the relatively uniform 'pervasive' serpentinization of at least 60 per cent of the ultramafic masses, whereas the joint fillings and veins of pure serpentinite that branch into veinlets and capillary-like networks of seams of serpentine in less pure serpentinite and serpentinized peridotite suggest that hydrothermal serpentinizing solutions travelling along joints and cracks achieved a very intimate penetration of the ultramafic bodies.

The relative lack of intense serpentinization in the contaminated ultramafic rocks near the border of the stock east of Polaris Creek, and rarity of serpentine in the ultrabasic hybrid rocks of the border zone itself, and the absence of any large-scale alteration to talc, suggest that in these places the water contained within the crystallizing ultramafic mass may have entered into hornblende, biotite, and other high-temperature hydrous silicates, leaving little water available for either deuteric or hydrothermal alteration when the relatively lower temperature range of serpentine formation was reached, and virtually none for the subsequent development of talc (Turner, 1948, p. 132).

Alteration to Quartz-Carbonate Material

In places, along bands that are apparently steeply dipping shear zones, the ultramafic rock has been altered to an aggregate of quartz and ankeritic or dolomitic carbonate, with lesser amounts of mariposite and pale grey-green serpentine. Most of the bands are about 100 feet wide, although some as much as 600 feet wide were encountered in the stock east of Polaris Creek. Bands less than 10 feet wide have been found in the smaller ultramafic bodies and, rarely, in the roof rocks. They show both sharp and gradational contacts against serpentinized ultramafic rock.

The principal mineral in most of this material is cream-coloured carbonate, which usually weathers a conspicuous buff or orange. Associated with the carbonate is a siliceous mineral, usually of a crypto-crystalline, chalcedonic habit, but in some instances in well-formed, transparent, pyramidal quartz crystals. Some specimens contain much opaque, white, clay-like matter, part of which is brucite and talc. Minor minerals, each locally abundant, include serpentine, bright green mariposite, red, earthy, and silvery specular hematite, and flat rhombohedral crystals of white calcite. The texture is variable in the extreme. Most of the rock has a massive, stony appearance, and in thin section is seen to be a very confused aggregate of extremely fine-grained material, in which few individual grains can be discerned. Other parts of the quartz-carbonate zones are relatively coarsely crystalline, with cleavage faces of a carbonate up to 1 mm. across; some are delicately banded, with very contorted, concentric, and volute patterns of carbonate and silica; still others are vuggy, with well-developed carbonate and quartz crystals.

The microscope is of little assistance in identifying the minerals in the quartz-carbonate rocks. The most common carbonate mineral, probably ankerite or ferrodolomite, does not effervesce in cold dilute acid, and an iron content is indicated by the uniform development of a limonite coating upon weathering. Similar, but white weathering, pale buff, porcellaneous material is thought to be mainly magnesite. The mariposite was not checked for optic properties. Green micaceous minerals are found in many quartz-carbonate zones in ultramafic rocks; not all are mariposite. The quartz-carbonate zones associated with the major faults and the Trembleur intrusions in the adjacent Fort St. James map-area, however, contain mariposite; and, in particular, X-ray studies have shown the conspicuous green mineral found in a quartz-carbonate zone associated with a belt of serpentine on Ominicetla Creek, 10 miles south of the southwest corner of Aiken Lake map-area, to be mariposite[1].

Alteration to Amphibole

The abundance of hornblende in the contact zone of the ultramafic bodies and in the hybrid rocks surrounding the contact has been noted. This hornblende appears to be an 'original' mineral formed during the crystallization of the completely reconstituted rock. Within the ultramafic bodies themselves, some of the hornblende is likewise probably a primary constituent of the rock, in that it appears to have developed, mainly in the contaminated border zone, at the time of the consolidation of the original rock-forming medium, but part may have had a secondary origin and may have resulted from the uralitization of pyroxene. In a few places, rims of fresh hornblende surround cores of what appears to be altered pyroxene. Various stages of the process of uralitization can be observed in thin section. In most of the sections showing this transformation a single crystal of pyroxene has been replaced by several bladed or lath-like crystals of amphibole, whose orientation bears no relation to the original crystal. No true pseudomorphs of amphibole after pyroxene were noted. The process of uralitization, however, appears to be more or less confined to the border (including the roof) areas of the ultramafic bodies, and is only developed in the highly pyroxenic rocks, which are relatively less susceptible to serpentinization.

Minor amounts of tremolite and actinolite are found near the contact of the ultramafic rocks east of Wasi Lake and east of Polaris Creek. These minerals appear to have resulted mainly from the alteration of hornblendites related to the hybrid rocks, but some may have developed by alteration from pyroxenites of the ultramafic bodies.

Structural Relations

EXTERNAL STRUCTURAL RELATIONS

All of the bodies of ultramafic rock in the map-area except the large stock east of Polaris Creek are essentially single units emplaced along lines of apparent tectonic movement more or less parallel with the surrounding rocks.

The stock east of Polaris Creek is, like the other ultramafic bodies, elongated parallel with the strike of the older rocks in which it lies. However, it definitely transects these rocks; the tilted, late Palæozoic sedimentary strata and volcanic flows trend directly into the ends of the stock for 3 miles, measured across the strike, and along the flanks of the stock preserve their general regional orientation without regard to the attitude of the contact cutting obliquely across them. The hybrid rocks also have discordant contacts, and occur as dyke-like forms, small irregular bosses, or large lenticular masses with irregular projections; basic and ultrabasic varieties intrude each other in a very confusing manner. Sills, dykes, and

[1] Armstrong, J. E.: personal communication, 1947. Unpublished investigations by J. E. Armstrong and J. B. Thurber, Geological Survey of Canada, 1944-45. Material collected by E. F. Roots, 1944.

irregular apophyses of the hybrid and remobilized contact-metamorphic rocks have worked their way as much as a mile into relatively unaltered rocks, and show sharp, intrusive, crosscutting contacts against the sedimentary strata. Inclusions, ranging in size from a few inches to several hundred feet across, of relatively unmetamorphosed rocks have been found in the hybrid zone close to the main ultramafic body, but are rare, although some anomalous pockets of dioritic material in hornblendite may represent altered inclusions.

The contact zone of the main ultramafic mass is well exposed around all parts of the stock except the north boundary, where serpentinized peridotite passes under glacial drift on the floor of Swannell River Valley. Topographic relief is sufficient to indicate the dip of the contact over a vertical interval of 500 to 2,500 feet. At many places on the northeast and southwest flanks the contact dips outward at observed angles of 50 to 90 degrees. Around the south and east borders the contact of the main ultramafic mass appears to dip nearly vertically, as exposed by 600 feet of relief, but a broad area of metamorphosed rocks containing hybrid and 'pseudo-dioritic' material and scattered outcrops of serpentinized ultrabasic rock suggests that the contact flattens abruptly, and that the ultramafic mass extends to the southeast at a comparatively shallow depth.

The inclination of the northwest contact of the ultramafic stock is well shown on the parallel ridges separating a series of hanging valleys draining into Swannell River. As may be seen from the map, the entire ridge southeast of the third creek entering Swannell River from the southwest below the mouth of Orion Creek is composed of ultramafic rock. The ridge between the second and third creeks is composed, for the middle two-thirds of its length, of ultramafic material continuous with the main stock to the southeast. At both the northeast and southwest ends of this ridge, the ultramafic mass is overlain by ultrabasic and dioritic hybrid rock, succeeded in turn by relatively unaltered, older, sedimentary and volcanic rocks. The next ridge to the northwest—the ridge between the first and second creeks entering Swannell River from the southwest below the mouth of Orion Creek—exposes a mixture of unaltered late Palæozoic sedimentary and volcanic rocks, intrusive 'pseudo-diorite', hornblende-plagioclase hybrid rock, hornblendite and related ultrabasic rocks, and minor serpentinites along its crest. On both flanks of the ridge, however, at elevations of 800 to 1,600 feet below the crest, a band of cliffs exposes normal serpentinized peridotite and dunite for a distance of nearly 1½ miles. The relations can be clearly seen on the southeast flank of this ridge, as viewed from the next ridge to the southeast. The ultramafic rock exposed on the lower slopes of the flank of the ridge is almost certainly a part of the main ultramafic mass that outcrops to the southeast, and its upper surface is seen to be a fairly regular arch at least 2 miles wide (*See* Figure 8) dipping about 10 degrees to the northwest. The hybrid and contact-metamorphic rocks invariably found enveloping the ultramafic body outcrop over an area of about 20 square miles to the northwest of the main stock, and suggest that an extension of the stock underlies the area at a relatively slight depth. Over all this area the roof rocks appear to be essentially undisturbed; on both flanks of the ridge shown in Figure 8 they are preserved in the regional southwest-dipping attitude to where they are obliterated by hybrid rock within 500 feet of the contact with peridotite.

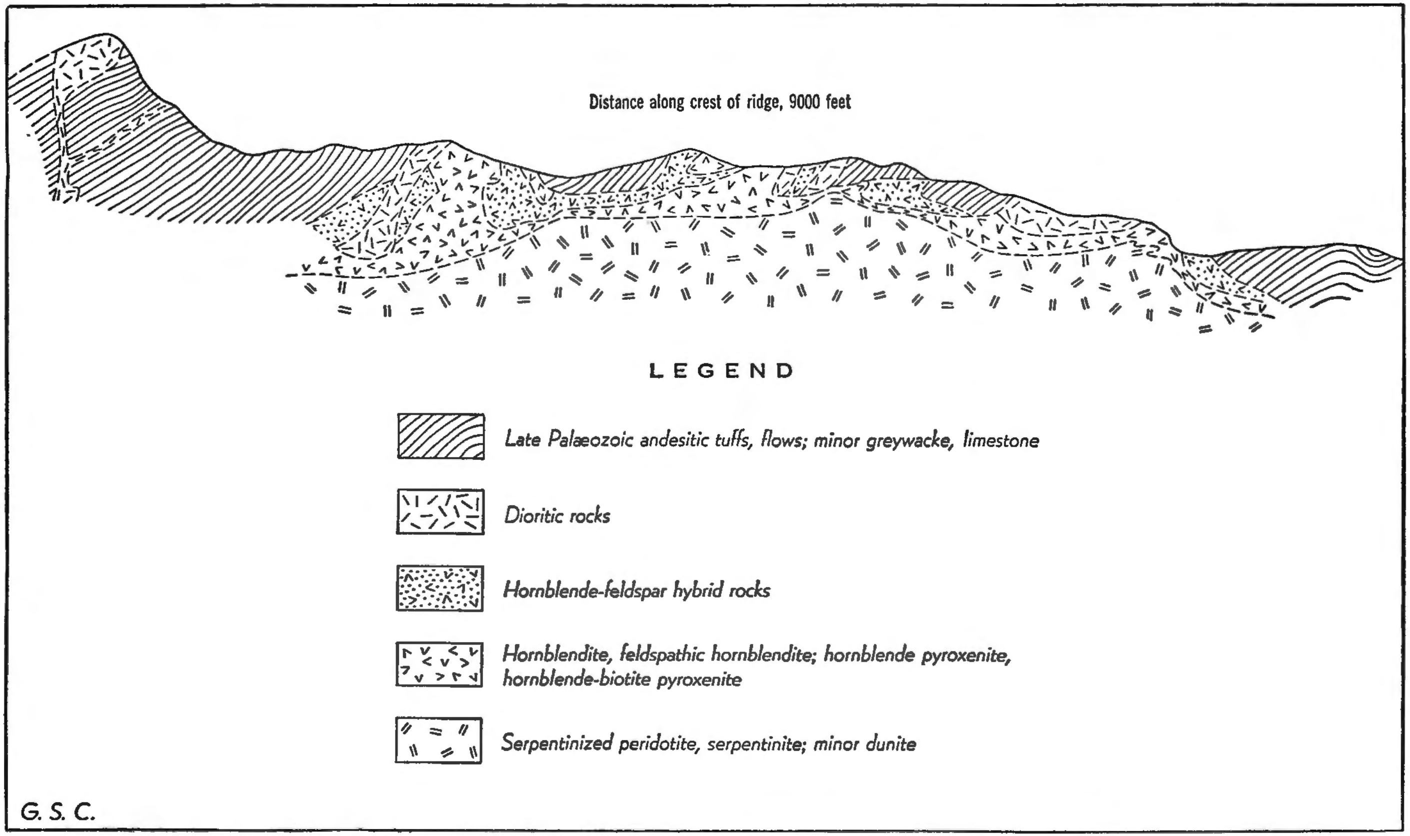


Figure 8. An interpretation of outcrop relations shown on ridge in Lay Range, 2 miles south of the mouth of Orion Creek; drawn on hypothetical vertical section through the crest of the ridge.

INTERNAL STRUCTURAL RELATIONS

The internal structural relations of the stock east of Polaris Creek are obscure. No order to the position of the different varieties of peridotite, dunite, and pyroxenite, suggesting a structural arrangement of different rock types, could be recognized. A regular banding was noted in the peridotite in only one place. Near the south summit of the mountain forming the north lobe of the stock, fresh, coarse-grained peridotite containing about 10 to 20 per cent pyroxene alternates in bands 1 inch to 8 inches thick with medium-grained peridotite containing 30 to 40 per cent pyroxene. The bands are straight and nearly horizontal, and the finer, relatively pyroxene-rich layers have sharp lower contacts but their upper surfaces grade across ½ inch or more into the coarser, relatively dunitic bands. About ten pairs of coarse and fine bands were observed, one above the other; the bands were traced 70 feet along strike. The banded rock is underlain and overlain by heavily serpentinized, apparently uniform peridotite.

The tendency for festoons and basin-shaped layers of chromite to lie in a more or less flat plane suggests that parts of the stock have not been greatly disturbed since consolidation of the rock; but the curved and twisted shape and sharp truncation of other chromite layers, the multiplicity of serpentine-lined breaks, which bring different rock types into juxtaposition, and the apparent protoclastic structure of some rocks suggest that much of the mass has suffered considerable dislocation while in a semi-solid state.

The main body of the ultramafic mass east of Polaris Creek is fractured into semi-equidimensional or slab-like blocks, which in any one area exhibit a relatively uniform size. In most places the joints usually lined with chrysotile serpentine form one or two conspicuous systems. The rock breaks to an even cover of felsenmeer on all smooth ridges and gentle slopes; the range of size of talus and rock-glacier blocks from serpentinized peridotite is shown in Figure 2. Almost all of the main joints are lined with serpentine. It was not found possible to differentiate between shear and tension joints, except in a few individual cases, and it is quite probable that many fractures have experienced more than one period and direction of movement.

The attitudes of the fractures and joint systems traversing the interior of the southeast lobe, the central part, and the northwest lobe of the stock east of Polaris Creek were analysed statistically by plotting on stereographic projections. In each place, flat-lying or gently northwest dipping joints are overwhelmingly predominant. These joints are roughly parallel with the observed or inferred upper contact or roof of the stock; joint systems in the interior of the stock, parallel with the steep or vertical side contacts, are lacking or rare. The contact rocks are so diversely fractured that attempts to record the joint systems systematically were abandoned. Unlike the interior parts of the stock, however, there is no preponderance of flat-lying joints. The general joint pattern thus seems to be roughly related to the outlines of the intrusive body, with a steeply dipping zone of highly shattered, irregularly jointed rock near the flanks, and predominantly gently dipping fractures throughout the interior of the stock, approximately parallel with its nearly flat roof. There does not seem to be any recognizable relation between the present tilted attitude of the older, intruded rocks, or the stresses that must have produced such tilting, and the fracture pattern in the ultramafic stock. The fracture pattern would seem to indicate that the stock has not taken part in the rock movement that resulted in the regional deformation of the older rocks; rather, it was most probably intruded when the surrounding rocks were in essentially their present positions. The fracture pattern itself appears to be related primarily to the stresses within the stock accompanying its intrusion.

Origin and Mode of Intrusion

The ultramafic bodies in Aiken Lake map-area appear to possess some features suggesting an origin directly from parent material of ultramafic composition (Hess, 1938), and other features that are more compatible with an origin by differentiation from a normal basic magma (Bowen, 1928). In common with the type bodies of the Trembleur intrusions in Fort St. James map-area to the south (Armstrong, 1949), the bodies in Aiken Lake map-area are intruded only into late Palæozoic rocks, and are not found cutting the younger Takla group; whereas the widespread acidic intrusive rocks of the Omineca intrusions, which are the only exposed rocks that could be supposed to represent the acidic complement of the ultramafic material, intrude the Takla group and thus appear to be younger than the Trembleur intrusions. The only acidic intrusive rocks cutting the late Palæozoic rocks in the Aiken Lake area are a few porphyry dykes, totally inadequate to account for the material that would be produced if the ultramafic rocks were the product of differentiation of an originally basaltic magma. The dykes are similar to many acidic rocks cutting the Takla group. No evidence of gradation in composition, within the ultramafic rocks themselves, toward a less basic material near the contacts could be found, except perhaps in places where the contact zone has apparently been contaminated by older rocks. As is commonly the case with ultramafic bodies of this type, intense serpentinization along the contacts has obliterated any chilled zone that, if present, might have served as an indication as to whether or not the body consolidated in its present position, and if so, from what type of material it crystallized. The roof is still in place over large parts of the stock east of Polaris Creek. In this body the peridotites and dunites persist without apparent change over a vertical range of about 2,500 feet, directly up to the sharp contact with the contaminated and hybrid rocks of the roof zone; and it seems certain that the ultramafic rocks cannot be, in their present position, accumulations of crystals that have settled out of a differentiating magma, whose higher, less basic products have been removed by erosion. The manner in which the regionally tilted but locally undeformed strata forming the roof are truncated by the ultramafic stock suggests that the latter was actively intrusive, and capable of removing or replacing, rather than displacing, material from the space it now occupies.

These characteristics of the ultramafic bodies in Aiken Lake map-area indicate that the bodies cannot be simple accumulations of early formed crystals settled to their present position from a differentiating basaltic magma. The evidence seems convincing that the bodies have consolidated from material that, when intruded into its present position, was essentially of the same composition as the present rock.

On the other hand, these bodies possess some features not strictly in accordance with most bodies held to be formed directly by consolidation of material of ultramafic composition. The most outstanding of these features is the envelope of altered and hybrid rocks. Ultramafic bodies not associated with basaltic magma typically have a very slight metamorphic effect on their wall-rocks; in general much less effect than the rocks formed from basaltic magma (Hess, 1938, p. 325). This seems to be the case with all of the smaller ultramafic bodies within the map-area, except possibly the westernmost band near Wasi Lake, where coarse, recrystallized sedimentary rocks 1,000 feet from the contact may owe their altered condition to the intrusion of the ultramafic body. The large stock east of Polaris Creek, however, is, as described above, surrounded by a broad zone of altered rocks. The alteration has been especially profound in the volcanic and related pyroclastic rocks of approximately andesitic composition, and appears to consist for the most part of a recrystallization and a rheomorphic remobilization of the older rocks, rather than an appreciable addition of material of distinctive composition. These features suggest that the material from which the ultramafic rocks were formed was capable of producing metamorphism by virtue of its temperature and its control of mineralizing solutions in the adjacent rocks, rather than by any special chemical composition of the material itself.

It is suggested that the smaller, almost completely serpentinized ultramafic bodies near Wasi Lake and in the northwest part of Lay Range may have been emplaced at a relatively low temperature, perhaps in a plastic or semi-solid state, along fault or shear zones.

Age and Correlation

Bodies of ultramafic rock are widely distributed in northern British Columbia and southern Yukon (Armstrong, 1949; Hanson and McNaughton, 1936; Hedley and Holland, 1941; Lees, 1936; Lord, 1948). The most carefully studied bodies are those of Fort St. James map-area, where they have been named the Trembleur intrusions. The ultramafic rocks of Aiken Lake map-area have been provisionally correlated with these intrusions on the basis of their lithology, geographic position, and structural setting.

The type bodies of the Trembleur intrusions are confined to and cut Middle Permian and older rocks. On the north shore of Pinchi Lake, in Fort St. James map-area, Freeze (1942) found pebbles of serpentine and grains of chromite, together with pebbles of Cache Creek group rocks, in fossiliferous Upper Triassic (late Noric) strata of the Takla group. From such evidence, Freeze (1942) and Armstrong (1949) determined the Trembleur intrusions to be partly or wholly of post-Middle Permian, pre-Upper Triassic age.

The observed contact relations of the ultramafic rocks in Aiken Lake map-area are in accord with these conclusions, but afford little supporting evidence. The bodies near Wasi Lake intrude strata that have been assigned to the Cache Creek group, and thus are post-Pennsylvanian, and probably post-Middle Permian, in age. The bodies in Lay Range can only be said with certainty to be of post-Upper Mississippian age. No definite indication of a younger age limit has been recognized, but ultramafic rocks have not been found cutting Takla group or younger formations, and the basal Takla group conglomerate west of Uslika Lake contains serpentinized pebbles that may have come from the contaminated or hybrid rocks (*See* page 153). Thus, in the absence of definite evidence to the contrary, the ultramafic rocks of Aiken Lake map-area have all been assigned to the Trembleur intrusions. There is some evidence that the large stock east of Polaris Creek was intruded into previously strongly tilted strata. If such was the case, a period of crustal disturbance between the Middle Permian and Upper Triassic may be indicated.

PRE-JURASSIC ACIDIC INTRUSIVE (?) ROCKS

Fragments of orange-pink fine-grained feldspar porphyry are embedded in Takla group lavas exposed by the underground workings on the Vega mineral claims, and in carbonatized breccia or tuffs in trenches and outcrops in the vicinity. The fragments are subangular to rounded, up to 2 feet in diameter in the flow rocks and up to 4 inches in the breccia or tuff.

All fragments are more or less altered. They consist of zoned and twinned plagioclase phenocrysts, mostly less than 1 mm. but in some specimens up to 3 mm. long, now largely saussuritized, and less abundant augite phenocrysts, altered to amphibole, biotite, chlorite, and magnetite, in a fine-grained feldspathic matrix. In part the matrix contains lath-like feldspar crystals with an interwoven felsitic texture. The rock is estimated to have a composition similar to monzonite.

In the hand specimen and under the microscope, the rock appears to have an intrusive, rather than typically volcanic, texture. No flow rocks of similar composition or texture are known in the Takla group. This rock is, therefore, thought to be most probably part of a small intrusive body, although the possibility of its having had a volcanic origin cannot be entirely eliminated.

A bed of argillite interbedded with the tuffs and lavas containing these fragments has supplied fossils of early Lower Jurassic age. The feldspar porphyries are, therefore, of pre-Jurassic age. They may be related to the post-Permian, pre-Jurassic Topley intrusions of Fort St. James map-area. Their relation to the post-Lower Cambrian granophyre and feldspar porphyry found elsewhere within the Aiken Lake map-area is not known (*See* Structure-section G-H).

Pebbles with a composition similar to these fragments, together with pebbles of a coarser feldspar porphyry and of quartz syenite, are found in a conglomerate bed, west of Uslika Lake, that is considered to be the basal bed of the Takla group, and thus of Upper Triassic age (*See* pages 117, 153).

A pink feldspar porphyry, similar in appearance to these rocks, forms three stocks, too small to be shown on the map, on the south fork of Thane Creek. The actual contact between these bodies and the adjacent rock is nowhere exposed, but at least one stock is closely flanked and overlain by Takla group lavas in what may well be an unconformable relation. It is possible that these stocks represent part of the pre-Jurassic bodies that supplied the fragments found in the Takla group lavas. Breccias and greywackes intercalated with the flows in the vicinity, however, do not contain fragments of this porphyry; and microscopic study shows the stocks to be about granodiorite in composition, containing considerable quartz, and more ferromagnesian minerals than the fragments embedded in the Takla group rocks. These stocks may be related to the Omineca intrusions.

TAKLA GROUP

The Takla group consists of a thick assemblage of volcanic and intercalated sedimentary rocks of Upper Triassic and Lower Jurassic age. It was named from its abundant occurrence in Takla map-area, which adjoins Aiken Lake map-area on the south (Armstrong, 1946).

Distribution

In the Aiken Lake area, formations of Takla group occupy a northwesterly trending belt, 3 to 10 miles wide, extending from Uslika Lake to Aiken Lake and beyond.

The stratigraphic limits of the group are nowhere accurately recognized. The rocks of the Takla group are in part lithologically similar to those of the underlying groups, and in many places it is difficult to determine to which group the rocks of individual, isolated outcrops belong. Because of this lithologic similarity, together with the paucity of fossils and general conformity of major structures, separation of the Takla group from underlying formations is indecisive. What is thought to be the base of the group is exposed on Thane Creek about a mile west of Osilinka River Valley at Uslika Lake. Elsewhere in the map-area, the lower limit of the Takla group is provisionally placed in highly sheared rocks exposed in the valley of Tutizika River 5 miles from its mouth, and along a prominent fault down the valley of Lay Creek. The upper limits of the group are not exposed in Aiken Lake map-area, being in all places obliterated by the Hogem batholith or its satellitic intrusive bodies.

Lithology

FIELD OCCURRENCES AND MEGASCOPIC DESCRIPTION

The Takla group exposed in Aiken Lake map-area is predominantly a volcanic assemblage. At least 60 per cent of the exposed rocks are grey, green, and black, porphyritic and non-porphyritic, andesitic and basaltic lavas. Intercalated with the lavas are coarse, angular breccias and black, grey, and green tuffs. Sedimentary rocks not of direct volcanic origin include argillite, greywacke, and small lenses and discontinuous beds of impure limestone, chert, and conglomerate.

In the southern part of the map-area, the base of the Takla group has been drawn at a bed of conglomerate at least 100 feet thick exposed on Thane Creek about 3,300 feet upstream from the Aiken Lake winter road crossing. What appears to be the same conglomerate is exposed on two creeks on the west side of Osilinka River Valley above Uslika Lake, and in a ravine leading into Vega Creek from the south, about a mile west of the Aiken Lake winter road. The conglomerate nowhere shows definite bedding, but the distribution of outcrops seems to indicate a nearly northerly trend; thus it appears to rest with angular discordance against the older rocks to the east, which have a local easterly strike on Thane Creek near the contact. This contact may be a fault. The basal conglomerate exposed on Thane Creek consists of well-rounded pebbles up to 8 inches in diameter of volcanic, intrusive, and sedimentary rock types in a grey-green, sandy to gritty, greywacke matrix containing considerable organic matter. About 35 per cent of the rock, by volume, is composed of pebbles larger than 3 inches in diameter. Of these, about half are coarse-grained or coarsely porphyritic igneous rock, consisting of a feldspar porphyry with white feldspar phenocrysts up to ½ inch long (seen in thin section to be altered albitized plagioclase) in a grey-green medium-grained groundmass approaching diorite in composition, and light brown-grey quartz syenite or quartz diorite. Many of these pebbles resemble those in a late Palæozoic conglomerate in Lay Range (*See* page 115). The remainder of the large pebbles are mainly grey-green, fine- to medium-grained, porphyritic and non-porphyritic andesite, now largely altered to an albite-chlorite-epidote-amphibole greenstone. The smaller pebbles are a mixture of the above-mentioned rock types with lesser amounts of: purple-brown porphyritic basalt, containing white feldspar phenocrysts; dark green, serpentinized, coarse-grained rock of gabbroic to ultrabasic composition, possibly recrystallized greenstone, but conceivably derived from some of the contaminated or hybrid rocks associated with the ultramafic intrusions; light to dark grey, uniform and finely banded, fine-grained quartzite; brilliant red cherty tuff; and many coaly fragments. The coaly material is hard, has a high lustre and conchoidal fracture, and is easily ignited. The largest lens of such material observed in this conglomerate is about 4 inches by 2 feet.

Thane Cr.
BC 94D
Takla Gp.
(basal)
U. Trias

Above the basal conglomerate in the southern part of the map-area, the Takla group is composed mainly of porphyritic andesites and andesite breccia, with intercalated tuffs and minor greywacke, limestone, and slate. Recognizable horizon markers are scarce, and different parts of the group, separated by wide stratigraphic intervals, show remarkable lithological similarity; these factors, together with abundant faults of both large and small displacement, in many places too numerous to be shown on the present map, make it impossible, on the basis of the work done to date, to establish a general stratigraphic sequence or to estimate the over-all thickness of the Takla group in this region. In general it is estimated that about 60 per cent of the outcrop area in this vicinity consists of grey-green to dark green andesite and andesite breccia. Megascopically, the andesite appears quite uniform in mineral composition and texture. Almost all is porphyritic, with relatively abundant, somewhat inconspicuous grey or greenish grey feldspar, and less numerous green-black hornblende or pyroxene phenocrysts 1 to 2 mm. long in a moderately fine-grained to aphanitic groundmass. The rock weathers light greenish grey to reddish grey. The characteristic breccias associated with these porphyries consist of angular fragments averaging about 4 inches to 1 foot in diameter, with exceptional blocks up to 18 feet long, of andesite generally similar to that of the non-brecciated flows, in a matrix of the same material. In many places the fragmental character of the breccias is visible only on the weathered faces of outcrops, fragments and matrix being almost indistinguishable on freshly broken surfaces. In a few places a faint chilling of the matrix against the fragments is visible. Most of the breccias appear to be parts of normal flows. Some of the breccias exposed on the south fork of Thane Creek and on the ridges north of Vega Creek contain fragments considerably darker and coarser than the matrix in which they are embedded or than any of the normal flow rocks found in the vicinity. In hand specimens, these fragments appear to be coarse-grained basalts. Some are markedly amygdaloidal, with calcite amygdules up to ¼ inch in diameter. The flows exposed at the Vega mineral prospect contain rounded boulders up to 2 feet long of feldspar porphyry (*See* page 151).

Flow contacts are inconspicuous in many of the Takla group andesites. Large areas of outcrop, and cliff faces as much as 300 feet high, have, in places, been carefully examined in unsuccessful attempts to determine the thickness and attitude of the flow. However, bands of breccia, which are themselves as much as 120 feet thick, and intercalated tuffs indicate that in this area the flows range between 15 and 300 feet in thickness.

The sub-parallel mountain ridges between Vega and Kliyul Creeks afford good rock exposures approximately normal to the regional strike of the Takla group. Between Vega Creek and Tutizika River, the rocks of this group consist of about equal proportions of porphyritic andesite and andesite breccia, and bedded tuff and greywacke. Numerous shear and fault zones, and lack of distinctive marker strata or assemblages of strata, have made it impossible to form a satisfactory concept of structures in this region or to establish a useful stratigraphic sequence. In a very general way the sequence east of Matetlo Creek contains, at the lowest limit of continuous exposure, a series of grey-green porphyritic andesites, for the most part consisting of phenocrysts, 1 to 3 mm. long, of hornblende or zoned plagioclase, or both, in an aphanitic matrix. A few layers in this series of flows are coarser in texture, and appear less porphyritic, with an apparently holocrystalline matrix composed mainly of hornblende and plagioclase grains 0·5 to 1 mm. long. These coarser layers are from 6 inches to 10 feet thick, and in places are repeated at intervals of 3 to 50 feet. They appear to grade abruptly into normal porphyritic andesite, and may represent unusually well-developed flow banding. Otherwise, the andesites in general contain no obvious textures or structures that could be attributed to flowage. Overlying the andesites is an assemblage of very fine-grained to moderately coarse, well-bedded tuffs and greywackes, with minor amounts of argillaceous slate and porphyritic andesite. This assemblage has an apparent thickness of at least 3,000 feet; however, it contains two shear zones along which there may have been enough movement to produce an omission or a repetition of a considerable number of the beds. The typical tuff is a dark green-grey to dark grey rock, weathering light grey-green or brownish grey, conspicuously banded on weathered surfaces. All gradations are represented between dense, dark beds that appear identical with the slightly metamorphosed cherty argillite, and relatively coarse beds that are distinctly fragmental in hand specimens, with angular fragments up to 1 inch across. Most beds are composed principally of fragments about a millimetre in diameter. The uniformity of bedding and degree of sorting suggest that many of the rocks here called tuffs are water-lain, and no sharp distinction can be drawn between them and the greywackes.

Above the tuff-greywacke assemblage is a sequence of interbedded, banded, sedimentary beds and grey-green andesitic flows. The flows or groups of flows are in units 50 to 150 feet thick, and comprise about one-third of this part of the section, which has a total thickness of 1,000 to 2,000 feet. Overlying the interbedded tuffs and flows is a thick series almost entirely composed of andesite, with minor breccia and very minor sedimentary rocks. The andesites are uniformly porphyritic, with phenocrysts of hornblende or pyroxene, or occasionally both. Scattered, light grey feldspar phenocrysts occur in most of the flows, and are in a few places the predominant mineral observed in hand specimens. Amygdaloidal texture was observed in only a few places, and is confined chiefly to the brecciated tops of flows. Flow banding or coarser layers are not conspicuous in these rocks. The thickness of this uppermost exposed unit of the Takla group in the Matetlo Creek area is estimated to be between 3,000 and 7,000 feet. The upper members of this unit are intruded by the Hogem batholith.

The mountains between Tutizika and Mesilinka River Valleys expose what may be a nearly complete section of the Takla group, but outcrops are not continuous, and several fault or shear zones, together with interruptions and disturbances by numerous intrusive bodies, make it difficult to obtain a satisfactory picture of the sequence or structure. The easternmost outcrops in this area, believed to represent the lowest part of the Takla group section, are chiefly porphyritic andesite and breccia, partly amygdaloidal, similar to the rocks found on Thane Creek and near the Vega mineral claims. Some of the breccias contain conspicuous, relatively dark-coloured, coarse-grained, amygdaloidal fragments. A few narrow bands of slate and small lenses of blue-black, argillaceous limestone are the only sedimentary rocks found in this area. The greater part of the mountains north of Tutizzi Lake is composed of porphyritic andesite, with comparatively little andesite breccia. Bedded tuffs are almost lacking in the eastern and central parts of the main mountain massif between Tutizzi Lake and Abraham Creek, but become more abundant toward the west and northwest. Due west of the upper end of Tutizzi Lake, the Takla group rocks in contact with the Hogem batholith are mainly bedded tuffs and porphyritic andesite or andesite breccia with pyroxene phenocrysts. In Abraham Creek Valley and in the mountains immediately to the south, tuff and greywacke and partly calcareous slaty argillite are interbedded with the porphyritic andesite, comprising perhaps one-third of the rock volume.

Mount Elsie, due south of Aiken Lake, exposes a typical mixture of andesite, andesite breccia, and tuff, with minor interbedded argillite and limestone. About 70 per cent of the rock volume is bright grey-green, dull grey weathering, porphyritic andesite, with abundant black hornblende phenocrysts up to 2 mm. long, and less numerous white feldspar phenocrysts up to 1 mm. in a fresh appearing, fine-grained to aphanitic, grey-green matrix. The tuffs are for the most part confined to units of less than 100 feet, but, together with argillite and greywacke, comprise a sedimentary assemblage at least 1,500 feet thick near the middle of the sequence exposed on the north face of Mount Elsie. The tuffs are well sorted, and range from thick, dark grey and black beds composed of fragments averaging about 2 mm. in diameter, to very fine-grained, minutely laminated, dark grey and greenish grey rocks. The argillite is confined to beds rarely more than 1 foot thick; most of it is black and slaty, and in some places it is rich in plant material. The limestone is confined to lenses, mainly less than 10 feet thick and 50 feet long, or to bands of brecciated greywacke. In some places, angular fragments of greywacke, which are themselves composed principally of angular fragments of andesite, are embedded in a dark grey, impure limestone matrix, forming layers that appear to be sedimentary beds up to 150 feet thick; in other places fragments of the limestone are embedded in the greywacke.

An assemblage very similar to that on Mount Elsie is exposed about 4 miles to the west, where the Takla group andesites, tuffs, and argillites outcrop over an area of approximately 3 square miles in what appears to be a large roof pendant in the border of the Hogem batholith.

North of Mesilinka River, the Takla group contains, on the average, a somewhat higher proportion of sedimentary material than most of the rocks of this group in Aiken Lake map-area. The outcrops west of Aiken Lake, in the canyon on Kliyul Creek and on the mountain between Mesilinka River and Kliyul Creek, show an increasing amount of tuff, argillite, and limestone at progressively higher levels in the section. At the highest stratigraphic levels exposed, close to the contact with intrusive bodies near the west boundary of the map-area, thick beds of impure, dark grey, buff-brown, and light green limestone are intercalated with porphyritic andesite and tuff. The mountains between Kliyul Creek and Lay Creek are composed of about equal proportions of volcanic and sedimentary rocks. An assemblage at least 1,000 feet thick, extending northward from west of the Granite Basin mineral claims to Lay Creek Valley, is composed almost entirely of sedimentary rocks in the following estimated proportions: grey to black, very fine-grained argillite, grading to grey-green water-laid tuff and blue-grey calcareous shale, 50 per cent; light to dark grey, brown weathering, slightly recrystallized limestone, in part crinoidal, 20 per cent; grey-brown compact siltstone, 15 per cent; blue-grey to greenish greywacke and calcareous breccia, 10 per cent; and minor pale brown arkosic sandstone.

PETROGRAPHIC DESCRIPTION

Volcanic Rocks

The lithology of the volcanic rocks of the Takla group exposed in Aiken Lake map-area is remarkably uniform. Almost without exception, the rocks are porphyritic, with plagioclase, hornblende, or pyroxene phenocrysts in a very fine-grained holocrystalline groundmass. The plagioclase phenocrysts are for the most part well formed, euhedral, and mostly between 0·25 and 1 mm., exceptionally up to 4 mm. long. Broken crystals are common. The plagioclase is almost invariably zoned, usually in a simple gradation from a relatively calcic core to a more sodic rim, although a few crystals show reversals and interruptions of zoning. The extreme range measured in the apparently fresh plagioclase phenocrysts is from a core of labradorite (An_{60}) to a rim of oligoclase (An_{15}). As the composition of only the larger phenocrysts is determinable, the average composition of the phenocrysts is not known, but it is probably in the oligoclase-andesine range, approximately An_{35}. An irregular rim of clear, fresh-appearing albite is conspicuous on many crystals; this material is generally easily distinguished from the original feldspar grain, which is almost invariably cloudy with clinozoisite or epidote. Both the albite rims and the clinozoisite-epidote material within the phenocrysts are thought to be products of the saussuritic alteration that has to some extent affected all the rocks of the Takla group.

Phenocrysts of ferromagnesian minerals may comprise as much as 25 per cent of the rock. In some flows, hornblende crystals up to 6 mm. long are conspicuous, but the average size is between 0·5 and 2 millimetres. About two-thirds of the flow rocks examined contain what appear to be primary hornblende phenocrysts; in the remainder, diopside and augite are the primary dark mineral phenocrysts. In addition, most of the rocks contain grains of amphibole that are probably uralite, developed during alteration of the lava. The primary hornblende is for the most part in well-developed elongate crystals, usually bounded by regular prism faces relatively free from inclusions, and pleochroic from olive-green to green-brown. Some of the phenocrysts are fragments of broken crystals. No hornblende thought to be of primary origin was observed in the rocks bearing pyroxene phenocrysts. The latter are colourless, non-pleochroic crystals, in typical stout prismatic forms, and many are conspicuously zoned. Most of them are probably close to diopside in composition, but nearly all are partly altered to secondary hornblende (uralite), with minor aggregates of chlorite, calcite, clinozoisite, and epidote. No orthopyroxenes were identified in the thin sections studied.

The groundmass of the typical Takla group andesites is holocrystalline, but in most specimens is too fine grained to permit accurate mineralogical determination. Much of the feldspar is in elongate or tabular grains 0·005 to 0·02 mm. long, which in some thin sections show a trachytic, subparallel arrangement. Some of the ferromagnesian minerals in the groundmass are up to 0·1 mm. long, distinctly larger than the feldspar grains. Almost all thin sections show some amphibole in the groundmass; most of it is probably secondary. Two varieties of pyroxene can be distinguished in many sections; one with a moderate to large optic angle, probably augite or diopside, and one nearly uniaxial, probably pigeonite. Accessory minerals include zircon in prismatic grains up to 0·5 mm. long, apatite, sphene, and magnetite; all of these occur as inclusions in the phenocrysts as well as in the groundmass. Irregular grains of quartz were observed in several sections. Some of these may represent original constituents of the flow, but it appears more probable that most, if not all, are of later origin.

Flow rocks with glassy matrix are apparently rare in the Takla group. The only rocks found to be of this nature are fragments in breccias from near Vega Creek and from north of Tutizika River, which can be seen in thin section to consist principally of lath-like feldspar crystals about 0·05 mm. long in a dark brown, glassy or cryptocrystalline mesostasis with fluidal texture.

As with most volcanic rocks, the fine-grained nature of the groundmass precludes accurate determination of the mineral composition of the rock. In all sections examined, however, the primary feldspar and auxiliary minerals are estimated to form between 50 and 95 per cent by volume of the total components. The composition of the feldspar grains could be accurately determined only for the larger phenocrysts, but taking into consideration that in such rocks the phenocrysts, if they differ at all, are generally more calcic than the feldspar of the groundmass, the average composition of the plagioclase is probably in the range albite (An_{10}) to oligoclase (An_{30}). No significant amount of undisputedly primary quartz or potash feldspar was recognized in any of the thin sections studied. All the rocks thus appear to be normal andesites, and to represent variations between pyroxene-bearing hornblende andesite and hornblende-bearing pyroxene andesite.

Amygdaloidal or vesicular rocks constitute only a small percentage of the Takla group andesites. They are found mainly in breccias on Thane Creek, and north of Tutizika River, and in fairly fresh flows west of Lay Creek. In some of these rocks amygdules up to 4 mm. in diameter, composed of aggregates of chlorite, clinozoisite, calcite, and strained quartz, are fairly abundant. In general the amygdaloidal rocks are brown, in contrast with the normal grey-green colour, owing to finely disseminated ferric oxides in the groundmass.

Sedimentary Rocks

Most of the sedimentary rocks of the Takla group are composed predominantly of volcanic material. The most abundant type appears to be tuff, but there are all gradations to greywacke deposits composed mainly of fragments resulting from erosion of consolidated rocks. The typical tuffs are grey-green, very fine to medium grained, and well bedded, with layers ranging from about $\frac{1}{50}$ inch to 5 or more feet thick. Tuffs with fragments more than $\frac{1}{10}$ inch in diameter are rare. Most of the tuffs are altered, and show a smooth green surface due to the development of chlorite, epidote, and clinozoisite; some have a glossy, serpentine-like appearance. Others are partly carbonatized, and weather a light rusty orange, although on fresh surfaces the appearance of the rock is little changed. A few beds have been highly silicified and have a cherty appearance. In thin sections, the tuffs are seen to consist of various proportions of broken crystals of feldspar, usually highly altered to clinozoisite, sericite, and kaolinitic material; pyroxene, probably both pigeonite and augite; hornblende, in places altered to epidote; and angular masses of fine-grained volcanic rock composed of the same minerals. In addition, masses or individual crystals of chlorite (pennine), clinozoisite, epidote, biotite, quartz, and calcite are abundant in some tuffs; these minerals are thought to be mainly or entirely secondary. Likewise, it is probable that some of the feldspar is an alteration product. The fragments of volcanic rock are typical of the various types of andesites observed as flows in the Takla group. No glassy fragments were observed in these tuffs, but several sections show irregular masses of very fine-grained or amorphous, partly isotropic, dark brown material that could represent partly devitrified glass. What might be small spherulitic structures are abundant in one tuff bed near the Vega mineral claims.

The greywackes consist, like the tuffs, almost entirely of fragments of volcanic rocks and of individual crystals of plagioclase, hornblende, and pyroxene, with an average composition close to that of the andesite flows. Most of the fragments of the greywackes are subangular to semi-rounded, embedded in an indeterminate paste-like groundmass apparently consisting principally of finely comminuted particles of the same material as the larger fragments, with a fairly high proportion of sericite and calcite. On the whole, the greywackes are fresher in appearance than the tuffs. In thin section they can be seen to contain considerable clinozoisite-epidote and chlorite, but they have undergone considerably less carbonatization than the strictly pyroclastic rocks.

Sedimentary rocks not composed predominantly of volcanic material are relatively rare in the Takla group. An assemblage of banded, light green to dark grey rocks west of Kliyul Creek, which might best be termed calcareous tuffs, is composed primarily of fragmental volcanic material in a groundmass of granular calcite. Beds of apparently this composition have been metamorphosed near intrusive bodies to garnet-calcite-epidote rocks. The typical Takla group limestone is dark grey, impure, massive to poorly bedded, with a silty texture. In some places, small-scale slump structures are well developed. Thin sections from beds of this type west of Lay Creek contain 50 to 80 per cent calcite in anhedral, equidimensional grains, 10 to 30 per cent plagioclase feldspar in subrounded to angular grains or broken crystals, and 10 to 30 per cent fragments up to 1·5 mm. long of very fine-grained volcanic rock, with minor amounts of biotite, muscovite, iron oxides, and iron sulphides.

Other sedimentary rocks—black, slightly slaty carbonaceous argillites, and compact, poorly bedded, grey to brown siltstones—show no distinctive petrographic characteristics.

Structural Relations

The maximum exposed thickness of the Takla group within the map-area appears to be more than 10,000 feet.

The formations of the group have been deformed in accordance with the general pattern of northwesterly trending structures developed chiefly during the period of orogeny with which the emplacement of the Omineca intrusions was associated. Deformation has been on a large scale, but has not been severe; dips at all angles from horizontal to 90 degrees have been recorded, but the folds are relatively broad and open, though in many places steeply plunging; and although faults and shear zones are abundant, there seems to be no evidence of great dislocations within the Takla group itself. South of Abraham Creek Valley, the exposed Takla group rocks have a general northwest strike and a dip of 30 to 70 degrees southwest; between Abraham Creek and Mesilinka River the entire group is deflected to a northerly trend around a series of plunging folds whose axes dip steeply west; north of Mesilinka River the folds are less regular, but a northeast to north strike, with a northwest to west dip, is common. The entire belt of Takla group rocks within the map-area appears to lie on the east limb of a major synclinal structure, whose axis, largely obliterated by the Hogem batholith, is partly exposed in the McConnell Creek area to the west.

There is relatively little small-scale deformation within the Takla group rocks. In places, exposures up to a mile in length exhibit quite regular attitudes. Except within the closely faulted area south of Vega Creek, there is little angular discordance on each side of the various faults and shear zones.

Faults and shear zones are numerous in the region between the south border of the map-area and Vega Creek—too numerous to be adequately shown on the present map. Most of them are steeply dipping, highly fractured zones 5 to 50 feet wide, along which both horizontal and vertical movements have occurred. The breaks trend in many directions, but three main sets can be recognized: strike north 10 to 30 degrees east, dip nearly vertical; strike north 30 to 50 degrees west, dip 45 degrees southwest to vertical; and strike approximately east, dip 60 degrees north to 70 degrees south. Some of the breaks, in particular those with a northeast trend, show evidence of at least two periods and directions of movement. All of them have served as channelways for the circulation of quartz-carbonate solutions, which have altered the adjacent rocks for distances up to 300 feet to a conspicuous light orange-brown colour, and have filled the fractures themselves with deposits of ankeritic carbonate and banded chalcedonic quartz. In places the quartz-carbonate rocks contain much finely divided hematite. Similar quartz-carbonate mineralization is found, but is much less abundant, in shear ones in the Takla group rocks in other parts of the map-area.

Alteration and Metamorphism

Virtually all the Takla group rocks have been saussuritized, sericitized, or carbonatized to some degree. The original rocks, which, whether as andesite flows, tuffs, or greywackes, were composed essentially of plagioclase feldspar, hornblende, and pyroxene, have been more or less completely altered to aggregates of clinozoisite, epidote, sericite, chlorite, and ankeritic carbonate, with some regeneration of relatively sodic feldspar and uralitic hornblende. In most rocks, the original textures, and many of the original minerals or larger fragments, can still be recognized, although the groundmass and smaller fragments are almost completely changed. In some of the quartz-carbonate shear zones, as for example those exposed on Thane and Vega Creeks, the original rock may be totally unrecognizable, the original texture obliterated, and the whole rock converted to an indistinct aggregate of shreds and irregular patches of carbonate, cryptocrystalline to granular quartz, with minor chlorite, altered feldspar fragments, etc. Except for these quartz-carbonate shear zones, the degree of alteration is relatively uniform over the entire exposed area of the Takla group, and does not seem to be related to the position in the stratigraphic section or to the proximity of intrusive bodies. The conclusion seems warranted that the whole group has been subjected to low-grade metamorphism involving some metasomatic change; a change that may be partly autometamorphic, connected with the consolidation of the original rock.

Throughout the entire length of its exposure in Aiken Lake map-area, the Takla group is invaded by various bodies of the Omineca intrusions, chief among which is the Hogem batholith. Despite the intimate association with intrusive rocks, contact metamorphic effects traceable to these bodies are almost negligible. Careful field observation and study of thin sections has shown no change in any of the Takla group rocks to within 300 feet of the contact with the batholith, and in many places there is no discernible change right up to the sharp contact. Undoubtedly, one of the factors that account for the general lack of contact metamorphism is the predominantly volcanic nature of the Takla group, with an over-all chemical composition relatively similar to, though probably less siliceous than, that of the average intrusive rock.

The detailed contact relations of the Hogem batholith are described elsewhere in this report (*See* page 181). The most significant change noted in the Takla group andesites near the contact has been a recrystallization of the rock within 50 feet of the contact. This phenomenon is well illustrated on the ridge east of the east fork of Matetlo Creek, where the andesite, still retaining its normal porphyritic texture, has a slightly denser appearance in the hand specimen. In thin section this rock is seen to have a well-developed crystalloblastic texture of rounded grains with sutured interlocking contacts. About 60 per cent of this rock is fresh-looking hornblende, pleochroic olive-green to green-brown, in poikilitic grains up to 2 mm. in diameter. These grains are commonly clustered in masses, up to 5 mm. long, with more or less equidimensional outlines, which have the appearance of altered pyroxene phenocrysts. Approximately 30 per cent of this rock is feldspar, present in two distinct varieties: (1) much altered, subhedral grains largely replaced by sericite and epidote, rarely showing good twinning but almost invariably zoned; and (2) fresh-appearing, polysynthetically twinned, unzoned, poikilitic, but free of fine cloudy alteration products and minute inclusions. In addition, the rock contains considerably more magnetite than the average andesite of the area. In this case the contact metamorphism seems to have consisted of the alteration of an original pyroxene andesite through uralitization of the pyroxene, producing hornblende and magnetite, and through clearing the feldspar by absorption of the sericite and epidote developed in previous (diagenetic ?) incipient alteration, accompanied by a partial re-combination of the albitic feldspar and epidote, previously developed by saussuritization, to form new albite-oligoclase. The contact metamorphism observed east of Matetlo Creek has been just sufficient to reorganize the rock material into a rock with poikilitic crystalloblastic texture. This appears to be a straightforward instance of thermal metamorphism of a relatively basic rock.

The impure calcareous tuffs west of Kliyul Creek have undergone a distinctive contact metamorphism against the intrusive bodies. The normal rock, to within about 300 feet of the contact, is a grey-green, bedded tuff containing up to 30 per cent granular calcite, which appears to be part of the original groundmass of the tuff, distinct from the shreds and irregular patches of carbonate developed during later alteration. Adjacent to the contact, no change of colour is apparent, but the rock becomes harder, with a slightly more granular texture. In thin section, the rock at the contact is seen to consist almost entirely of calcite, garnet, and epidote. The bedding is well preserved, outlined in the contact metamorphosed rock by segregated bands of different mineral composition. Some bands consist primarily of anhedral, semi-equidimensional grains of calcite up to 0·1 mm. in diameter, with minor quartz and much epidote and clinozoisite in very minute, rounded grains. Other bands contain up to 80 per cent garnet, in ragged elongate masses up to 2 by 4 mm., crowded with small, rounded inclusions of calcite and epidote or clinozoisite. The masses of garnet are separated by elongated areas of granular quartz and calcite. Still other bands are composed of at least 90 per cent epidote, in very irregular, poikilitic grains. Here again the contact metamorphic changes appear to have been the results of the normal response of an impure calcareous rock to increased temperature.

The quartz-carbonate alteration along fault and shear zones in the southern part of the map-area, already referred to, is particularly well illustrated near the Vega mineral showings. There, the original plagioclase-pyroxene rock has been more or less completely altered to an aggregate of chlorite, sericite, and clinozoisite (or epidote), with recognizable relict crystals of feldspar but no remaining pyroxene. This aggregate has been partly to completely permeated by carbonate-bearing iron-rich solutions, which replaced and veined the chlorite-clinozoisite aggregates with irregular masses and shred-like patches of ankeritic(?) carbonate and fine, granular hematite. After the deposition of carbonate and hematite, the shear zones must have been traversed by siliceous solutions, for very small, irregular grains and sutured aggregates of quartz, in angular, stringy, or platy patches and clear cryptocrystalline masses, invade all the other minerals. The resulting rock is conspicuously variegated. In places it is spotted, with yellow-green calcite-sericite-clinozoisite patches in a purplish grey matrix. In other places it is delicately banded in scroll-like and concentric layers; other specimens show numerous spindle-shaped crystals of feldspar(?) now altered to clinozoisite, and quite different in shape from the less conspicuous, larger, complexly twinned plagioclase in the same rock. All of these rocks weather, to a depth of nearly 1 inch, to a light orange-brown, in which veins of crystalline calcite and chalcedonic quartz stand out sharply.

Age

Fossils are relatively rare in the Takla group rocks. Poorly preserved belemnite casts were found in the tuffaceous greywackes in many places, and collections have been taken from near the camp buildings at the Vega mineral prospect, on Mount Elsie, and west of Lay Creek. Several small lenses of limestone southwest of the Granite Basin mineral claims contain abundant crinoid remains. Fragments of wood and leafy matter have been noted on Thane Creek, Vega Creek, Mount Elsie, and west of Lay Creek. None of these remains, however, has been found well enough preserved to be generically identified.

Diagnostic fossils were collected from the Takla group rocks in two localities only, and were identified by F. H. McLearn of the Geological Survey as follows:

"(1) Limy lens in andesite outcropping on south wall of cirque at Granite Basin mineral claims, contains:

Halobia or *Daonella*
Pleuromya sp.
Juvavites (*Anatomites*) sp.
Juvavites ? sp.

Age: Triassic, probably Upper Triassic

"(2) From a ground-sluice exposure at Vega camp, a specimen of *Arnioceras* sp. The age of the Arnioceras is the Sinemurian of the Lower Lias of England, that is, early Lower Jurassic."

Little is known of the stratigraphic position within the Takla group of the beds from which these fossils were obtained. In the vicinity of Vega Creek, faulting is so prevalent that any reconstruction of the original stratigraphic sequence is impossible on the basis of present information. The horizon from which the Upper Triassic fossils were obtained near the Granite Basin claims lies at least 5,000 feet from the base of a continuously exposed section more than 12,000 feet thick without any recognized duplication of beds. Thus, the only conclusion based on information gathered in Aiken Lake map-area that can be drawn regarding the age of the Takla group is that it includes Upper Triassic and early Lower Jurassic beds.

Correlation

In its type area in Takla map-area, the Takla group has been defined (Armstrong, 1946) as "an apparently conformable succession of interbedded volcanic and lesser sedimentary rocks, ranging in age from Upper Triassic to Upper Jurassic". The group has been found to be widely exposed in Manson Creek map-area (Armstrong and Thurber, 1945) to the east of Takla map-area, and in McConnell Creek map-area (Lord, 1948) adjoining Aiken Lake map-area on the west. In Takla map-area, rocks of the Takla group have provided marine fossils of Upper Triassic and Lower and Middle Jurassic age; in Manson Creek map-area, of Upper Triassic age; and in McConnell Creek map-area, the group can be separated into two divisions, of which the lower is unfossiliferous, and the upper contains fossils indicating Lower, Middle, and mid-Upper Jurassic horizons. The belt of Takla group rocks exposed in Aiken Lake map-area connects the exposures in Takla and Manson Creek, and McConnell Creek map-areas.

OMINECA INTRUSIONS

General Statement

The name Omineca instrusions has been applied to the numerous bodies of intrusive rocks of Upper Jurassic or Lower Cretaceous age that are exposed in the Omineca and Cassiar Mountains. These bodies range in size from sills and dykes to batholiths, and in composition from pyroxenite and hornblendite to granite and syenite. Granodiorite, quartz diorite, and adamellite (quartz monzonite) are the most common rock types.

The largest known body of these rocks is the batholith that extends from Nation Lakes northwest across Manson Creek, Takla, Aiken Lake, and McConnell Creek map-areas. This body, generally known as the Hogem batholith (Armstrong, 1949, p. 98), occupies about 400 square miles in the southwest corner of Aiken Lake map-area. It is a composite body comprising a wide range of rock types, and contains many minor intrusive bodies within the main mass. It probably represents a prolonged period of intrusion of a differentiating magma.

Stocks, dykes, and sills, satellitic to the Hogem batholith, are abundant in the surrounding Takla group and late Palæozoic rocks. All are relatively small.

The various kinds of intrusive rocks composing the Omineca intrusions within Aiken Lake map-area fall, on the basis of their composition and mode of occurrence, and thereby also their age, into two divisions. The oldest division, comprising about one-sixth of the exposed area of the Hogem batholith and related stocks, consists mainly of melanocratic rocks containing little or no quartz. Included in this division are hornblende syenite, syenodiorite, hornblende diorite and meladiorite, pyroxene diorite, appinite, hornblendite, pyroxenite, and biotite-pyroxenite.[1] Hornblende diorite and meladiorite, almost everywhere containing small masses of appinite or hornblendite, are the most common members of this series. The second and younger division includes rocks that rarely contain more than 30 per cent ferromagnesian minerals, and are thus predominantly light in colour, and in which quartz is a significant and usually conspicuous constituent. The predominant rock types in this division are granodiorite and adamellite-granite; true granite, quartz diorite, and diorite occur in lesser amounts. Associated with these rocks are numerous dykes and small irregular bodies of leucogranite, alaskite, quartz-microperthite pegmatite, and aplite.

Melanocratic, Quartz-free Rocks

DISTRIBUTION

Rocks of this division are found chiefly in the northern part of the Hogem batholith exposed in Aiken Lake map-area. They form a belt 1 mile to 3 miles wide along the eastern edge of the batholith from Tutizzi Lake to Mesilinka River, and north of the Mesilinka at the extreme west edge of the map-area. Similar rocks compose a stock about 10 square miles in area in the Takla group rocks east of Croydon and Kliyul Creeks, and two small bodies totalling 3 square miles in Kliyul Creek Valley; and they compose a complex body occupying about 20 square miles within the main body of the batholith, west of the headwaters of Abraham Creek. All of these bodies may be parts of a single unit of batholithic dimensions, extending from Tutizzi Lake to Croydon Creek (*See* Figure 9). Each of the exposed bodies, however, has somewhat unique characteristics. Many small masses of similar material, a few square yards to ½ square mile in extent, are found as inclusions elsewhere within the batholith.

LITHOLOGY

Constituent Minerals

All of these rocks are of simple mineralogical composition. In most of them, plagioclase and amphibole appear to be the only 'original' essential minerals. Accessory minerals include magnetite (composing several per cent of the volume of some specimens) and apatite, with very minor sphene. Other minerals, present in some areas in small amounts and locally conspicuous, are pyroxene, biotite, microcline, and quartz. Epidote-clinozoisite, clay-like material, chlorite, and sericite are the common secondary minerals.

In most of the melanocratic, quartz-free rocks, the plagioclase is too highly altered to enable its composition to be determined, and in many it is so completely converted to an aggregate of fine, dusty, nearly opaque, white material, with varying amounts of clinozoisite and epidote, that the original grains cannot be recognized. In a few places, structures that may

[1] *See* definitions on page 165.

be due to polysynthetic twinning or zoning suggest that the original material might have been relatively coarse in texture. Some specimens contain lath-like aggregates of saussuritic matter, that may once have been single feldspar crystals, as much as 2 inches long. The few fragments of recognizable feldspar that were tested have a refractive index of about 1·538, indicating albite; it is probable that albitization has been one of the processes of alteration of the plagioclase. Many of the altered feldspathic masses are a delicate pink colour, due to finely disseminated hematite.

Most of the amphibole is fresh, green-black hornblende. The hornblende is invariably the best crystallized mineral in the rock, and ranges in habit from slender needles to stubby prisms, from about $\frac{1}{20}$ inch to 8 inches long. In any one rock, the shape and size of hornblende crystals are relatively constant, and in many places two rocks with apparently identical minerals or proportions of minerals, but differing in size and crystal habit of the hornblende, show definite intrusive relationships. In all observed instances the feldspars are interstitial to the crystals of hornblende.

A few rocks contain a ragged green amphibole, in part of coarse, fibrous habit, and probably close to actinolite in composition. It is probably secondary, resulting from the alteration of both green-black hornblende and, in some rocks, pyroxene. Some rocks northwest of Tutizzi Lake contain a little pale grey-green, coarse, fibrous tremolite.

Composition of Various Rock Types

The rocks composed of the above minerals range from highly feldspathic types, which appear to be hornblende monzonites or sodic hornblende diorites (although the feldspar is too altered to enable its composition to be accurately determined) to hornblendite. Most of the rocks contain more than 40 per cent hornblende, and in general the term appinite, a group name for melanocratic varieties of syenite, monzonite, and diorite, which are rich in hornblende (Holmes, 1928), is appropriate. In this report, rocks containing less than 60 per cent hornblende are called hornblende diorite or hornblende meladiorite[1]; those with 60 to 90 per cent hornblende are called appinite; with more than 90 per cent hornblende, but some visible feldspar, feldspathic hornblendite; and the term hornblendite is reserved for rocks with no visible feldspar in hand specimens.

DESCRIPTION OF INDIVIDUAL BODIES

Croydon Creek Body

The stock exposed in the Takla group andesites and sedimentary strata east of Croydon and Kliyul Creeks and on the lower part of Croydon Creek is composed of hornblende diorite of variable texture, with lesser hornblende-rich varieties and minor hornblende-pyroxene diorite. The most abundant rock is light grey-green and moderately coarse grained, and contains about equal amounts of fresh hornblende

[1] Meladiorite is the name given by Johannsen (1937, III, p. 159) to diorites containing more than 50 per cent dark materials. The distinction between diorite and meladiorite is not made in this report except in the few instances where it seems advisable to refer to rocks that appear to have affinities with the normal diorites rather than with the appinites, but which are rich in dark minerals.

and altered, pale green, creamy, or pink feldspar. In places the feldspar has been intensely epidotized, and some rocks are composed mainly of hornblende and epidote. The average length of hornblende grains is from $\frac{1}{10}$ to $\frac{1}{4}$ inch, although crystals up to 1 inch are common and a few reach 8 inches. The grain size is relatively uniform in any one specimen, but changes rapidly across distances of a few feet. No systematic pattern could be observed of the bodies of different texture.

The hornblende diorite contains numerous bodies up to 500 feet across of rocks much richer in dark minerals. The oldest of these rocks are of ultrabasic composition. The dominant mineral is hornblende, but some bodies contain considerable dark green, ragged actinolite, and a few specimens contain pyroxene, probably augite, which may be seen in thin sections to be in various stages of alteration to amphibole.

Rocks of various textures and containing various proportions of feldspathic material intrude each other in a very intricate manner, and in a definite succession, so that much of the stock is a confusing mixture of dyke-like bodies and inclusions. The order of intrusion of the different rocks is definite and, in the outcrops studied, apparently invariable, with younger rocks progressively more feldspathic. The succession is as follows, beginning with the oldest rock:

(1) Hornblendite, with minor pyroxene-bearing hornblendite and actinolite-amphibolite; average size of larger grains $\frac{1}{4}$ inch to 1 inch.
(2) Feldspathic hornblendite and appinite, containing up to about 15 per cent feldspar; hornblende crystals average 1 inch to 2 inches, many up to 4 inches.
(3) Medium-grained appinite, containing 15 to 25 per cent feldspar; hornblende crystals about $\frac{1}{8}$ inch long.
(4) Pegmatitic appinite and hornblende diorite, containing 15 to 40 per cent feldspar; hornblende crystals up to 8 inches, average more than 2 inches in length.
(5) Fine-grained appinite, containing about 20 per cent feldspar; hornblende crystals less than $\frac{1}{10}$ inch long (relatively rare).
(6) Medium-grained appinite and hornblende diorite, containing about 40 to 50 per cent feldspar, with hornblende crystals averaging about $\frac{1}{4}$ inch long.
(7) Dark grey, fine-grained hornblende diorite, containing about 50 per cent feldspar; hornblende crystals less than $\frac{1}{8}$ inch long; this rock contains much less epidote than any other feldspar-hornblende rock in the area, although, like the other rocks, its feldspar is almost completely altered.
(8) Coarse-grained hornblende diorite containing about 50 per cent feldspar; hornblende crystals up to 6 inches, average about 1 inch long, commonly in clusters with a poorly developed radial structure.
(9) Fine- to medium-grained hornblende diorite, containing 50 to 80 per cent feldspar, grain size $\frac{1}{10}$ to $\frac{1}{8}$ inch; this rock composes about half the stock

All of these rocks are cut by dykes of epidotized feldspar (some may be true veins of epidote), which in turn are cut by fresh feldspar porphyry dykes of dioritic, syenitic, and granitic composition.

The various rock types composing the stock are found in all parts of the body. It appears, however, that the lower, western part of the stock is more heterogeneous, and contains more ultrabasic material than the eastern part, which is some 3,800 feet higher.

The contacts of the stock with the surrounding sedimentary and volcanic rocks of the Takla group are sharp, and are characterized in places by large numbers of short, thick, irregular dykes or apophyses of hornblende diorite, and by abundant inclusions of Takla group rocks within the margins of the stock. The only change noted in the intruded rock that might be attributed to the action of the intrusion is the development of abundant epidote. In places, rocks that were probably andesite flows have been almost completely converted to epidote minerals.

Kliyul Creek Bodies

Two stocks of basic and ultrabasic rock, with a total exposed area of about 3 square miles, lie respectively north and south of Kliyul Creek on the extreme west border of the map-area. Parts of each of these bodies extend into the McConnell Creek map-area to the west. The bodies are very similar in appearance and composition, and are characterized by a biotite-rich peridotite with biotite-amphibolite, hornblendite, appinite, and hornblende meladiorite. The biotite-peridotite occurs in irregular bodies up to 1,000 feet in diameter, cut by all the other rocks of the stock. It is a medium- to coarse-grained (average diameter of larger grains, 1 to 4 mm.), dark brown to bluish black, slightly serpentinized rock of relatively uniform composition and texture. Microscopic study shows average specimens to contain about 35 per cent olivine (Fo_{90}), 10 per cent orthopyroxene (bronzite), 15 per cent clinopyroxene (augite ?), and 35 per cent biotite, with which is associated considerable magnetite. The biotite occurs as rounded, amoeboid grains that apparently replace the olivine and to a lesser extent the pyroxene; as rectangular to ragged, tabular grains, equal in size to the olivine and pyroxene, and apparently forming an integral part of the original rock fabric; and as irregular, ragged grains interstitial to olivine, pyroxene, and other grains of biotite. Some of the large grains of clinopyroxene contain irregular inclusions of biotite, all of which have the same optic orientation. It appears that much of the biotite is the latest of the main minerals in the rock, and has replaced pyroxene, and to a lesser extent olivine. An interesting feature of the biotite is that the grains associated with, and replacing, pyroxene are rimmed with magnetite grains, but are themselves free of magnetite, whereas the grains intimately associated with olivine contain large, coherent masses of magnetite within their interiors, but none at their margins.

Some of the hornblendites and appinites from these stocks contain grains of altered monoclinic pyroxene; the hornblende has a ragged, confused texture, is full of inclusions of apatite and biotite, and is altered irregularly to clinozoisite-epidote and chlorite. It seems probable that much of this rock is a uralite amphibolite, developed by alteration of a pyroxenite or biotite pyroxenite. The feldspars of the rocks south of Kliyul Creek are somewhat less altered than those of most rocks of this series, and in one specimen, containing about 40 per cent feldspar, 30 per cent hornblende and pyroxene largely altered to chlorite and 15 per cent biotite, with abundant calcite, epidote-clinozoisite, etc., the feldspar appears to be andesine-labradorite, about An_{55}. If this specimen is representative, many of the rocks are probably gabbros.

Both of the stocks near Kliyul Creek are extensively intruded by the acidic, younger phases of the Omineca intrusions.

Abraham Creek Body

General Description. An irregular body of extreme structural and lithological complexity outcrops over an area of about 20 square miles west of the headwaters of Abraham Creek. At its northeast side this body is in contact with andesites and andesitic tuffs of the Takla group. The rest of the body lies within, and is intruded by, the various acidic phases of the Hogem batholith.

Like several other bodies of this phase of the Omineca intrusions, the Abraham Creek body is composed almost entirely of hornblende, plagioclase, and magnetite, with accessory apatite and much epidote-clinozoisite of secondary origin. The body is unique in the map-area, however, in its extreme degree of differentiation into rocks of widely different textures and mineralogical proportions, and in the remarkably complicated structural relations between these rock types. The rocks range in composition from hornblendite to hornblende diorite containing only about 30 per cent hornblende (a few dyke-like bodies are composed entirely of feldspathic material), and in grain size from pegmatitic rocks in which most crystals are more than 3 inches long to material in which none of the grains can be distinguished with a hand lens.

About half the rock of this body contains more than 60 per cent dark minerals. One of the most common rock varieties is an appinite composed of stout, prismatic crystals of black hornblende $\frac{1}{4}$ inch to 1 inch long, in a groundmass of light grey to pale pink, saussuritized andesine feldspar. The feldspar, which comprises about 10 per cent of most of these rocks, is completely interstitial to the euhedral hornblende. With decrease in the amount of feldspathic material, this type of appinite grades into feldspathic hornblendite and hornblendite, in which the hornblende crystals lose the highly developed euhedral habit seen in the appinite. Most of the hornblendite shows no preferred orientation of its constituent crystals, but in a few outcrops the elongated crystals are arranged more or less parallel with each other, forming bands or sheets 1 inch to 5 inches wide lying perpendicular to the long axes of the crystals. The sheets, which were only observed to be vertical or steeply dipping, lie side by side, with occasional bands of non-oriented crystals, across distances of as much as 6 feet, and can be traced 50 feet up a steep slope. A few of these sheets are composed of crystals not quite perpendicular to the general plane of layering, so that the resulting rock has a 'herringbone' appearance. Adjacent sheets differ slightly in feldspar (or epidote) content, and in texture. Some of the hornblendite contains isolated, straight bands up to 1 foot thick that are coarser grained, and richer in feldspathic material.

Another widespread type of appinite and feldspathic hornblendite is characterized by clusters and knots of feldspathic material in otherwise feldspar-free hornblendite. This texture, called synneusis (swimming together) texture by Vogt (1921, p. 321), has developed to a remarkable degree in some of the appinites, which, consequently, have a conspicuous 'starred' appearance, with clusters $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter of white or pale grey feldspathic material evenly distributed at intervals of $\frac{1}{2}$ inch to 4 inches in black hornblende rock containing almost no interstitial feldspar (*See* Plate IX A). In thin section the 'stars' are seen to be irregular aggregates of rounded grains of twinned andesine, generally smaller than the hornblende crystals, against which they show, in places, mutually interfering contacts. In the best-developed synneusis texture, segregation has been very complete, with no feldspar in the hornblende-rich rock and almost no hornblende within the feldspathic 'stars'. A few outcrops show the 'stars' arranged in lines or bands up to 3 inches thick, separated by bands of the same thickness containing fewer 'stars'.

The remainder of the Abraham Creek body consists, so far as a generalization can be made, of about 30 to 60 per cent dark minerals. Most of the numerous varieties of rock within this composition range can be classed as hornblende diorite and hornblende meladiorite. One variety of the hornblende diorite appears to be merely a feldspathic phase of the coarse appinite, and consists of euhedral prisms of hornblende up to 4 inches long, scattered irregularly, or arranged in rude bands of more or less radiate clusters, in a saussuritized feldspar matrix. Some varieties of this rock are so confused and variable in texture and composition that they are best referred to as 'appinite-hornblende diorite mixed rocks'. Many of the diorites, however, are markedly different from the typical appinites and their feldspathic equivalents, as shown in this and the Croydon Creek bodies. In these diorites the hornblende does not occur in the fresh, black, stout prisms characteristic of the appinites, but forms ragged grains, rarely more than ½ inch long, of dull green hornblende, commonly considerably altered to epidote minerals and serpentine material. Some specimens contain bundles of slender prisms of amphibole scattered through the whole rocks, included within and replacing the grains of feldspar. Other diorites contain fine needle-like crystals of fresh black hornblende up to ½ inch long, in a groundmass of plagioclase and smaller, anhedral, rounded grains of black hornblende. A few dyke-like bodies contain phenocrysts of both slender needles and stubby prisms of fresh black hornblende in about equal proportions. In all the diorites examined, the feldspars fresh enough to be determined have a composition within the andesine range (An_{40-48}), about the same as those in the appinite. A few small bodies of diorite are extremely fine grained.

Almost all the diorite has some degree of foliate or linear structure, due mainly to the orientation of elongate hornblende crystals and the innumerable inclusions of more basic material with which most of the rocks are charged. Some of the rocks are conspicuously and regularly banded, with layers $\frac{1}{16}$ inch to 1 inch or more thick alternately richer in hornblende and feldspar. The best observed exposure of this structure contained forty pairs of bands, gently curved but almost flat-lying, within a total thickness of about 15 feet.

Small bodies of pegmatitic hornblende-feldspar material occur as veins or dykes, and as irregular pockets in diorite, appinite, and hornblendite. These bodies consist of prismatic, usually fresh green or black hornblende crystals up to 4 inches long in a light grey to pink matrix of coarse, altered feldspar. Many of these rocks resemble the 'appinite-hornblende diorite mixed rocks', but differ from them in their mode of occurrence and their commonly more feldspathic composition. A few of these bodies are almost pure feldspar. Most of them do not show any foliation or flow structure, but some are concentrically banded, with layers of different composition repeated symmetrically on each side of a central parting plane.

The hornblendite, appinite, most of the varieties of hornblende diorite, and the small bodies of pegmatitic diorite are cut by numerous dykes of strikingly banded rock consisting of fresh hornblende, and of feldspar that has been almost entirely altered to epidote. These dykes are quite distinct in appearance from the numerous appinite and diorite dykes common in the area, although there is probably a gradation between them and the normal diorite dykes. In some respects these bodies have the characteristics of veins rather than dykes. They form masses up to 25 feet wide, usually straight or gently curving for distances of 300 feet or more. The most pronounced feature of these dykes is their remarkable banded character (*See* Plate IX A). The bands consist of layers of hornblende and saussuritized feldspar (or, in some cases, nearly pure epidote) in almost every possible proportion and texture. The boundaries between the bands are generally sharp, and bands only one crystal thick may be traced more than 100 feet. In some places bands composed almost entirely of hornblende prisms lying in comb-like arrangement perpendicular to the plane of the band are adjacent to bands of hornblende crystals with their long axes parallel with the band. Layers of feldspar-epidote material, with minute differences of colour and texture, preserve their identity for many tens of feet. One dyke about 4 feet wide was found to contain thirty-five recognizable bands. Eighty feet away, the same dyke contains thirty bands, of which at least twenty-four are considered to be the same bands, in the same arrangement, as those examined at the original locality. The dykes do not show a symmetrical arrangement of bands, but in some places a series of several bands within a single dyke appears to have a symmetrical arrangement about one or more planes. A few of the dykes contain inclusions of appinite and hornblende diorite, which can be matched with older rocks somewhere within the Abraham Creek body, but some of which are not of the same type of material as the immediate walls of the dyke. The banding of the dykes flows smoothly around most of these inclusions. In places the banding is confused and contorted by minor shear zones, and dragged by small faults. Some dykes are terminated abruptly at small, epidote-filled seams that do not appear to represent fault fractures.

Many pegmatite and aplite dykes of the younger, acidic phase of the Omineca intrusions cut the Abraham Creek body near its borders, but virtually none was found in the interior of the body. The central part of the body, however, contains several large quartz veins, mineralized with pyrite, chalcopyrite, and galena, which may be related to this later phase of igneous activity.

Relations of Different Rock Types. The contacts between the various rock types of the Abraham Creek body are almost all sharp, with intrusive, crosscutting relations. The only examples of gradation of rock types within a single body are found between some of the appinites and hornblendites. However, most of these rocks, and all the other compositional varieties, occur in relatively small bodies of apparently uniform composition and texture, separated by sharp contacts from other bodies of different (in some cases very slightly different) composition and texture.

In a general way the rocks have been intruded in the order from most basic to most feldspathic, and from coarsest to finest grain. What appears to be the oldest rock in the body is a dark green, soft, apparently altered, coarse-grained amphibole rock, composed entirely of amphibole close to hornblende in optical properties but distinctly different from the black, fresh-appearing hornblende of the rocks that brecciate it. This rock, which may be uralite amphibolite, is found only as rounded, apparently partly resorbed, fragments up to 10 feet in diameter in the hornblendite, appinite, and diorite (*See* Plate IX B). The next younger rocks are fresh hornblendite, feldspathic hornblendite, and appinite. These occur mainly in irregular areas up to several acres in extent with intimate, interlocking, commonly sharp contacts, rather than as crosscutting dykes and stocks, although dykes of coarse-grained appinite are not uncommon. In general the appinite bodies are younger than the pure hornblendite, although a few exposures show hornblendite apparently cutting appinite. Most of these rocks are non-directional in texture, but some of the smaller appinite dykes show pronounced flow structure.

All of the rocks mentioned above are intruded by the diorites. In general, the coarse, hornblende-rich meladiorites are older than the medium- to fine-grained, relatively feldspathic varieties. The oldest diorite intrusions seem to have formed simple dykes in straight or zigzag fractures that have later been deformed by plastic flowage of the rock. The formation of these dykes was followed by at least two general periods of emplacement of irregular bodies that replaced all older rocks over areas ranging from a few square inches to several acres, separated by an episode of fracturing and dyke formation. The small bodies of pegmatitic diorite were formed by replacement or recrystallization of diorite, appinite, and hornblendite at some time during this stage. Following the consolidation of what appears to have been the youngest generation of major diorite bodies formed by replacement of older diorite, appinite, and hornblendite, the banded dykes were formed along relatively straight, steeply dipping fractures. Many of the dykes appear to be vein-like structures, formed mainly by replacement along a favourable fracture by solutions supplied through other fractures that were not favourable to replacement, thus developing the dykes with abrupt terminations at inconspicuous fractures, but others must have been injected more or less bodily into simultaneously opened fissures, carrying inclusions of unassimilated older rock with them. The delicate banding, presence of layers of slender hornblende crystals oriented at right angles to the plane of the band, and remarkable persistence of bands of minor textural and mineralogical differences, suggest that the present texture was achieved in a non-flowing medium, and that uniform physical-chemical conditions were reached over a considerable length of dyke. It seems reasonable to suggest that the banded dykes were originally formed with a texture different from that which they now possess, and that they have been recrystallized, acquiring their banded nature in response to particular conditions of diffusion, solution, or recrystallization, which were reached simultaneously in a plane lying more or less parallel with the walls of the dyke.

Whatever their process of formation, these bodies had attained their banded character before the next recorded episode in the history of the Abraham Creek body, which took the form of a slight deformation of the rocks. In part this movement was absorbed by flowage of the apparently still plastic appinites and diorites. By such movements the banded dykes were contorted and pinched, with the individual bands still partly recognizable in the deformed areas. In part the movement occasioned definite faults and shears along which the semi-plastic dykes were offset and dragged.

After complete consolidation of the banded dykes, they and all the older rocks were shattered, injected, and partly remobilized during the emplacement of gneissic, relatively feldspathic hornblende diorite of great mechanical activity. This diorite, which now composes nearly one-quarter of the Abraham Creek body, was apparently injected as a relatively viscous material that had little power to absorb or react with the adjacent rocks. In places the amount of bodily motion of the injected material, after it was viscous enough to 'carry' inclusions, was small; and in these places the adjacent rock was shattered, the small fragments removed, and the resulting fractures filled with diorite. In other places, bodily movement of the pasty diorite magma must have been considerable; the diorite is charged with a mixture of inclusions of all the different varieties of older diorites, appinites, and hornblendites through which it must have passed, some of which have been carried hundreds, and more probably thousands, of yards. In some places small bodies of this diorite are almost 'choked' with inclusions; one 10-inch dyke in diorite, about 300 yards from the nearest outcrop of appinite or observed banded dyke, contains inclusions almost 10 inches in diameter of appinite, hornblendite, and fragments of banded dyke, which constitute more than half the volume of the dyke.

Flowage structures are well developed in this diorite. The irregular-shaped inclusions are mostly well oriented and alined in short bands, and the hornblende crystals of the diorite itself are arranged in linear patterns that stream around inclusions and follow irregularities of the contacts of the bodies. In places, conspicuous swirls and eddies have developed.

The youngest of all the common rocks of the Abraham Creek body itself is a fine-grained to almost aphanitic, dark grey diorite containing about 50 per cent hornblende. This rock has been found only as dykes, less than 10 and commonly less than 3 feet wide, which are simple fracture fillings. Most of these dykes dip steeply. Those near the east side of the Abraham Creek body were observed to strike north and northwest; those near the west side of the body commonly strike north and northeast. None of the dykes is strongly gneissic, but the margins of most show a slight foliation parallel with the contacts. Some of the dyke borders show swirls and 'drag-folds' as if there had been movement of the walls while the dyke was in a semi-plastic condition. On the southeast side of the Abraham Creek body, the west (hanging-wall) side of several of the dyke fractures apparently moved north relative to the east side. In addition, many dykes contain numerous oblique, subparallel layers richer in feldspar or hornblende; these are interpreted as fractures produced and healed at a late magmatic stage (cf. Figure 12). Unlike any of the intrusive contacts of the other rock types of the Abraham Creek body, the contact zones of these dykes have been chilled against the intruded rock. These fine-grained diorite dykes are apparently considerably younger than the main sequence of diorite intrusion of this body, and as they show evidence of having been intruded during a period of stress, they may be associated with the emplacement of the younger, acidic phases of the Hogem batholith.

Body West of Mount Elsie

Hornblende diorite, appinite, and hornblendite are exposed for about 1½ miles along the crest and flanks of the ridge between Abraham Creek and Mesilinka River, 3 miles west of Mount Elsie. This body appears to be very similar to the Abraham Creek body, of which it may be a part; and the intervening 3 square miles of Takla group rocks may be an isolated roof pendant. Compared with most of the Abraham Creek body, the body west of Mount Elsie is less complex, and consists essentially of a central band of hornblendite and appinite, intruded by dykes of various types of hornblende diorite, flanked by areas up to ½ mile wide of relatively uniform, medium- to coarse-grained hornblende diorite. Some of the hornblende in these rocks occurs as ragged green crystals and felted networks of elongated prisms; it may represent alteration in place from pyroxene. A bluff overlooking Abraham Creek Valley includes a rock containing about 30 per cent hornblende in black, elongated, prismatic crystals up to 14 inches long, distributed with apparent random orientation in an interstitial groundmass of saussuritized plagioclase.

Tutizzi Lake Body

A body about 5 square miles in area northwest of Tutizzi Lake is composed of highly altered pyroxenite and diorite, cut by numerous diorite and feldspar porphyry dykes. About half the mass is of very basic or ultrabasic composition, and seems to have originally been mainly pyroxenite. The remainder of the body is diorite containing 30 to 60 per cent dark minerals.

The freshest pyroxenite is a dark olive-green to dull grey, mainly coarse, uniform-grained rock composed of augite crystals about ⅛ inch long. Small parts of this rock are relatively fine grained; and very coarse, pegmatitic varieties were not observed. The rock has been severely sheared and altered, and about half of it has been more or less completely changed to ragged, impure grains of uralitic amphibole. In other places the pyroxene has been reduced to an indefinite dark bluish grey material, which is seen in thin section to be a confused aggregate containing amphibole, carbonate, serpentine, epidote, magnetite, and much unidentifiable matter. Still other altered rocks appear to be mainly serpentine, with lesser fine-grained amphibole. One distinctive alteration product, found in many shear zones up to 50 feet wide, is a light grey or green tremolite rock composed of uralite largely to completely converted to a felted mass of fibrous tremolite. Semi-flexible fibres of tremolite up to 1 inch long were encountered, accompanied in places by calcite, which also has a fibrous habit. Some of the pyroxenite has apparently suffered considerable movement during shearing, and fragments of subrounded, coherent, altered pyroxenite are embedded in wide bands of highly sheared altered pyroxenite.

The most abundant diorite is a moderately coarse-grained pyroxene diorite, consisting of about equal proportions of saussuritized feldspar and uralitized pyroxene. No rocks were found to contain feldspar sufficiently fresh to enable its composition to be determined. The diorite clearly intruded the altered pyroxenite, in which it is found as irregular fingers and dykes, with sharp contacts. Much of the diorite contains inclusions of uralitized pyroxenite and meladiorite. The diorite varies considerably in composition and texture from place to place within the body, but the different varieties grade irregularly into one another, and seem to be parts of a single, heterogeneous intrusion rather than representatives of a series of intrusions, each of slightly different composition.

Both the pyroxenite and the diorite are cut by numerous fresh diorite and feldspar porphyry dykes up to 200 feet wide. One of these dykes lies in a shear in which the pyroxenite has been altered to serpentine and tremolite, but the porphyry dyke is not sheared; thus it is later than at least some of the shearing, and presumably later than some of the alteration of the pyroxene and diorite. The dykes are probably associated with the younger phases of the Omineca intrusions.

The Tutizzi Lake body intrudes the Takla group andesites in many dykes and irregular tongues. It has altered the andesites to an epidote-amphibole rock for distances of several hundred feet from the exposed contact, and in highly sheared areas it is difficult to separate the intrusive rock from its host. In the best exposure observed, however, the contact between the two rocks is sharp, and it appears that the pyroxenite-diorite stock was in part intruded forcibly, with much shattering of the Takla group strata.

Although it is much more basic in average composition, the Tutizzi Lake body has many features that resemble the basic border phases of the Hogem batholith in Fort St. James map-area to the south, particularly the syenodiorites of the Duckling Creek district, and the gabbros and pyroxenites near Indata and Tchentlo Lakes (Armstrong, 1949).

ORIGIN

The hornblendite-appinite-hornblende diorite series, together with biotite pyroxenite and related rocks, constitute a distinctive intrusive rock assemblage of wide distribution. Such assemblages, to which the melanocratic, quartz-free rocks of the Omineca intrusions belong, are typically found in orogenic regions, and generally occur marginally to granitic batholiths or as inclusions within acidic rocks (Reynolds, 1935). Most workers have considered such rocks to be the product of an ultrabasic or basic magma intruded at high temperature and with an abnormally high volatile content. Such a magma is capable of profound reaction with the intruded rocks, and with earlier formed phases of the intrusive rock, resulting in the extreme and abrupt variation of texture and composition, with numerous pegmatitic phases and evidence of repeated "self-intrusion' characteristic of the entire series. There is evidence that many of these rocks may have resulted from 'hybrid' or strongly contaminated magmas (Reynolds, 1935). The biotite pyroxenite rocks appear to represent a more alkalic series than the hornblendite-appinite rocks. Rocks very similar to those found in and near the Hogem batholith occur within and close to many of the batholiths of the Coast intrusions in western British Columbia and southeastern Alaska. Buddington (Buddington and Chapin, 1929) recalculated the hornblende from one of these rocks in terms of anhydrous minerals, and found it to be the equivalent of an olivine gabbro. He states (page 249):

> "hornblendites may have resulted from the crystallization of a magma of a composition which would usually have produced an olivine gabbro, but which in the presence of a relatively high content of volatile material, particularly water, formed hornblendite."

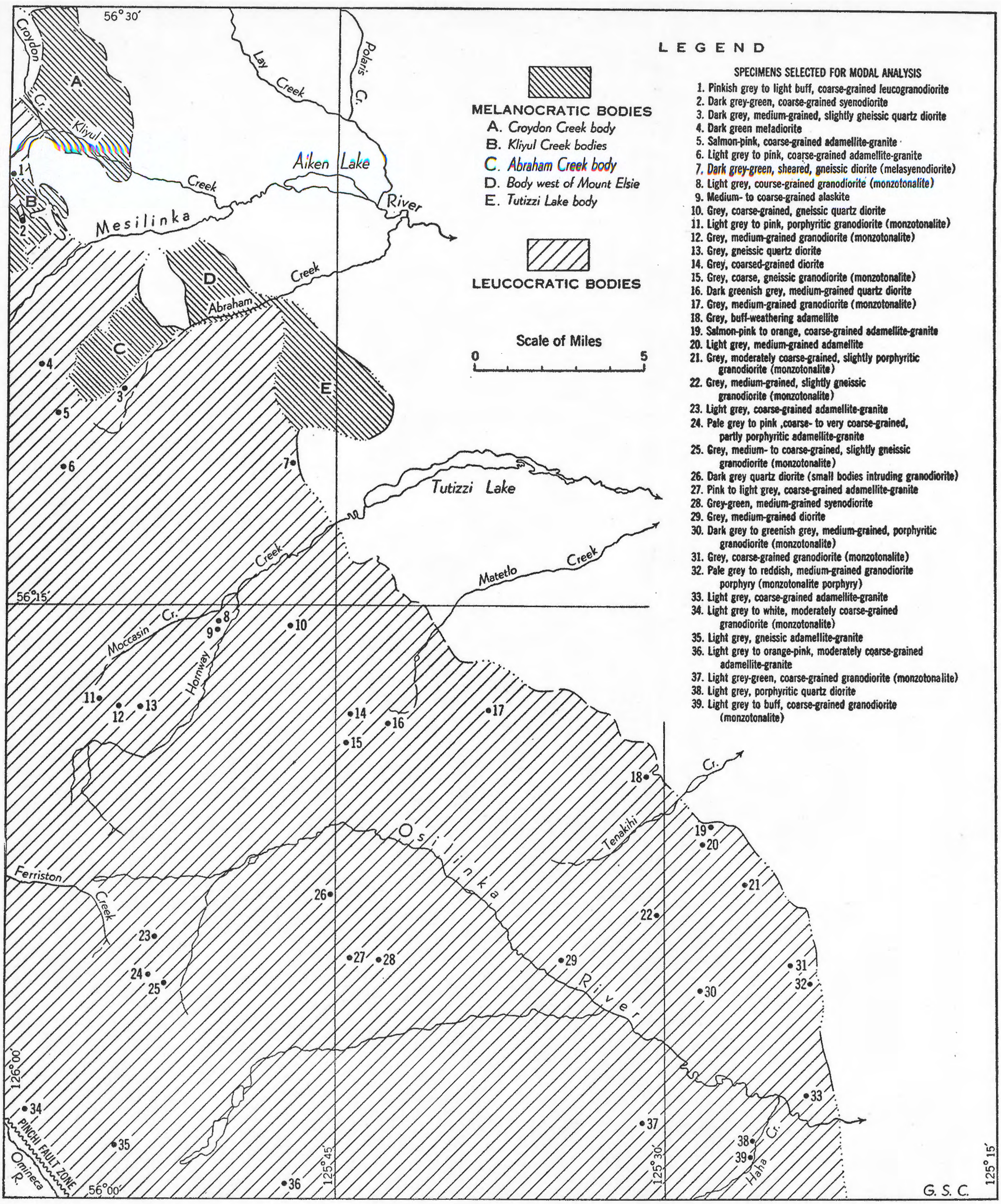


Figure 9. Diagram of Hogem batholith, showing position of the largest melanocratic bodies, and distribution of specimens selected for modal analysis (*See* Table I).

Koschmann (1935) has considered that most of the even-grained hornblendites in rocks of this type in Alaska crystallized first as pyroxene-rocks, and then were converted to hornblende by volatile-rich solutions that also precipitated the pegmatitic hornblendite directly. The evidence from the Aiken Lake area suggests that most of the coarser hornblende is a primary mineral, but that the magma from which it crystallized was strongly and variably contaminated by included and absorbed older (mainly Takla group ?) rocks.

Leucocratic, Mainly Quartz-bearing Rocks

DISTRIBUTION

This division embraces all the rocks of the main mass of the Hogem batholith, with the exception of the Abraham Creek body and the Tutizzi Lake body described above. Most of the large number of dykes and the few small stocks in the Takla group and late Palæozoic rocks are also probably associated with this younger, major phase of the Omineca intrusions.

LITHOLOGY

General Statement

The Hogem batholith is a composite body, composed of masses mainly uniform in themselves but differing from each other in composition and texture within moderately wide limits. In most places it is rare to find the composition or texture uniform over more than 3 square miles.

The principal rock types range from granite to diorite. Most of the rocks are medium to coarse grained, and light grey, buff, pinkish, and pale salmon-brown. About two-thirds are even grained; the rest are more or less porphyritic, with orthoclase, or less commonly hornblende or actinolite, phenocrysts up to $2\frac{1}{2}$ inches long in a matrix of grains about $\frac{1}{10}$ inch in diameter. A few uniformly coarse-grained varieties are composed mainly of grains more than $\frac{1}{4}$ inch in diameter. Most of the rocks appear very fresh in the hand specimen, although in thin section many are seen to be more or less altered to sericite, saussurite, and chlorite.

Petrographic Description

The leucocratic, quartz-bearing rocks contain the following principal minerals: quartz (in part in myrmekitic intergrowths), orthoclase, microcline, perthite, plagioclase (generally zoned), hornblende, actinolite (probably in part secondary), augite, biotite, and muscovite. Accessory minerals include magnetite, apatite, rutile, sphene, leucoxene, zircon, and sillimanite. In almost all the rocks the feldspars have been more or less saussuritized, with the production of epidote-clinozoisite, sericite, and calcite. Some of the pyroxene has been converted to uralite, and all of the ferromagnesian minerals have, in places, been altered to chlorite.

Most of the various rocks may be divided into four main types, easily recognized in the field. The most acidic and lightest coloured of these is a pale grey, buff, or pink rock containing 10 to 25 per cent colourless quartz distributed through a holocrystalline aggregate of white to salmon-pink orthoclase and light grey plagioclase. The ferromagnesian minerals are commonly fresh black hornblende and brown biotite. In hand specimens most of these rocks look like normal granites. Microscopic examination shows that few or none of the common varieties of this rock contain sufficient potash feldspar to be classed as true granites, although most of them lie close to the granite-granodiorite boundary. All have the composition of adamellite or quartz monzonite.

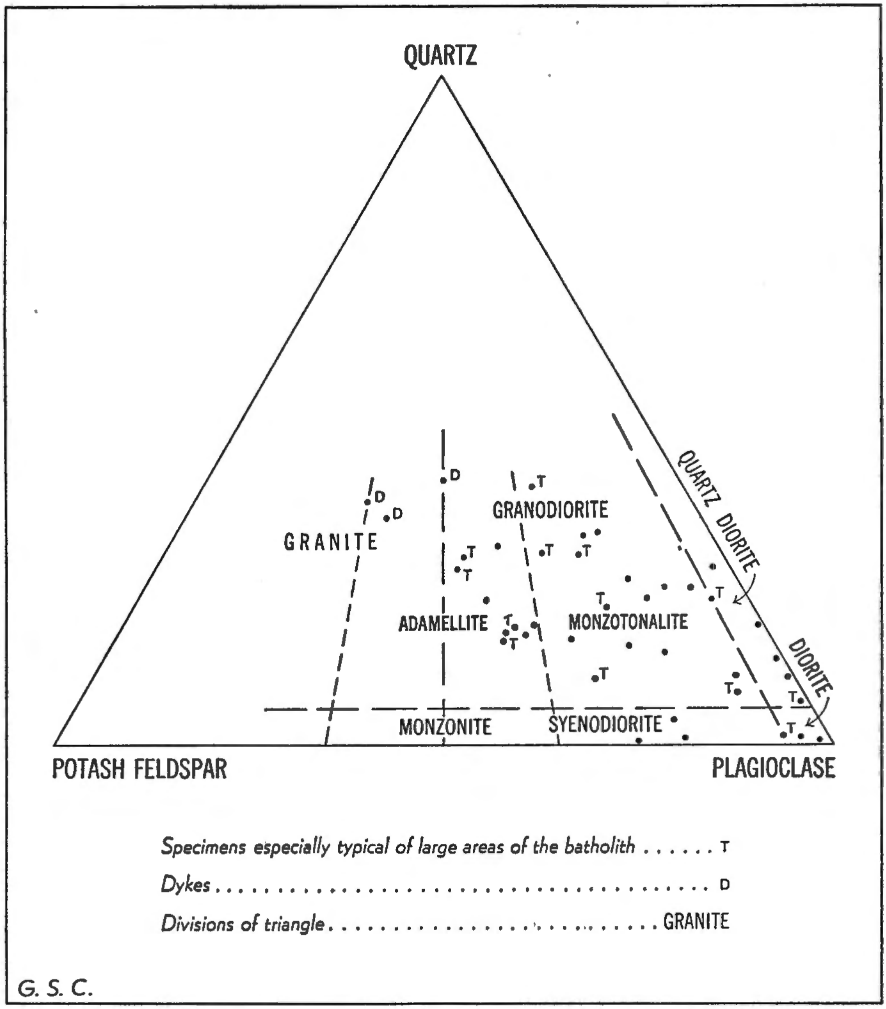


Figure 10. Modes of thirty-nine specimens of the Hogen batholith and three typical dyke rocks.

Generally somewhat darker in colour, less quartzose, and more variable in texture and composition than the granite-like rocks are the normal granodiorites, which differ from the adamellites by reason of their lower potash feldspar content and correspondingly greater proportion of grey plagioclase. Most of these rocks have a mineral composition equivalent to an orthoclase-bearing quartz diorite, or monzotonalite.

Rocks with still less orthoclase and quartz pass into typical quartz diorites, and finally into dark grey syenodiorites and true diorites. The typical diorite of this series consists of about 60 per cent dark grey or greenish plagioclase and 40 per cent augite or amphibole. A few small bodies of pyroxenitic and amphibolitic material are associated with the diorites. These may represent remnants of engulfed older rock or parts of the earlier, melanocratic phase of the Omineca intrusions.

Approximately 234 miles of outcrop of these rocks in the Hogem batholith were traversed within the map-area. Along the lines so investigated, the adamellite-granite rocks occupy 35 per cent of the batholith, in bodies with an average estimated diameter of 4,000 feet; the largest body encountered was 28,000 feet across. The granodiorite (monzotonalite) constitutes 37 per cent of the rocks traversed, in bodies with an average intercept of about 3,000 feet; the largest single body recorded was 7,500 feet across. Rocks that appear to be best described as quartz diorite make up 22 per cent of the total within the main body of the batholith; the average diameter of masses of this rock is about 3,400 feet, and the largest single body observed has a diameter of 12,600 feet. Diorite and syenodiorite, with very minor pyroxenitic and amphibolitic rocks, constitute 6 per cent of the rocks traversed, in bodies about 2,000 feet across.

The modal (mineral) composition of thirty-nine specimens of these rocks, distributed as shown in Figure 9, is presented in Table I and plotted on Figure 10. The rocks appear to represent all stages in a progression from diorite toward relatively quartz-rich, orthoclase-poor granite.

Bodies of pegmatite composed mainly of quartz and microcline-microperthite are found as dykes and irregular masses up to 1,000 feet by 500 feet in all parts of the batholith, and in some of the Takla group rocks near the contact. Most of the pegmatites are salmon-pink or orange-brown, and contain about equal amounts of feldspar and quartz, commonly in graphic or myrmekitic intergrowth. They are associated with a smaller number of dykes of aplite, alaskite, and leucogranite. A few of these dykes are remarkably straight and persistent; one exceptional body of leucogranite about 150 feet thick may be traced from Detni Creek to the ridge south of Klakring Creek, a distance of 11 miles.

Structural Relations

MUTUAL RELATIONS OF THE VARIOUS INTRUSIVE BODIES

contrast Bill Bacon in Sechelt - Jervis Inlet Area!

The individual igneous bodies that compose the Hogem batholith and its satellites are almost all separated by sharp, intrusive contacts. As has been described, the melanocratic, quartz-free, hornblendite-appinite-hornblende diorite series of rocks forms separate bodies within or adjacent to the batholith. Among the other rock types the sequence of intrusion is in most places fairly apparent, and although widely diverse in detail, was found to show a more or less constant trend in all parts of the batholith from which information was obtained. It is not meant to be inferred, however, that all bodies of similar-appearing rocks are directly related. The general trend of successively younger rocks is from diorite, through quartz diorite and granodiorite, to adamellite-granite. Evidence

Table I

Modal Compositions of Intermediate and Acidic Rocks of the Hogem Batholith in Aiken Lake Map-area

Specimen number	1*	2	3	4	5*	6	7	8*	9	10*	11*	12	13*
Quartz	33·5	...	14	...	22	16	2	17	28	7	24	26	21
Myrmekite	...	...	...	...	7	5		5	5	...	...	...	...
Total quartz (quartz + ½ myrmekite)	33·5	...	...	...	25·5	18·5	...	19·5	30·5	...	...	...	...
Microcline	0·5	15			18	16	8	13	2?	...	...	12	
Orthoclase	16·8	...	?	...	...	...	?	...	...	...	16	...	3
Perthite	?	...	...	...	5	9		...	63	...	...	...	
Total potash feldspar (microcline + orthoclase + ½ myrmekite + ½ perthite)	17·3	15	...	...	24	23	...	15·5	36	...	16	12	3
Plagioclase (percentage in rock)	38	47	59?	45?	32	46	32?	53	...	60?	46	44	37
Percentage A_n in plagioclase (average)	18	35	26	43	28	38	38?	23	...	35?	22	18	15
Total plagioclase (plagioclase + ½ perthite)	38	47	59	45	34·5	50·5	32	53	31·5	60	46	44	37
Ferromagnesian minerals plus accessories	2·2	38	27	55	16	8	58	12	2	33	14	18	39
Amphibole	...	x↑	...	x	x	x	x	...	...	x↑	x	x	x
Pyroxene	...	...	x	...	...	...	...	...	...	...	...	...	...
Biotite	x	x	x	...	x	x	...	x	x	x	x	...	x
Muscovite	x	...	...	...	x	...	...	...	x	...	...	...	...
Magnetite	x	x	x	x	x	x	x	x	x	x	x	x	x
Apatite	...	x	x	x	x	x	x	x	...	...	x	x	x
Rutile	...	...	x	...	x	...	...	...	...	...	...	...	...
Sphene and leucoxene	x	...	...	...	...	x	...	x	...	...	...	...	x
Zircon	...	x	...	...	...	x	...	x	...	...	x	...	...
Sillimanite	...	...	...	...	x	...	...	...	...	...	...	...	...
Tourmaline	...	...	...	...	...	...	...	x	...	...	...	...	...
Rock type, according to Johannsen's classification	127PP (leucogranodiorite)	2211 (syenodiorite)	228 (quartz diorite)	3212 (meladiorite)	227PP (adamellite)	227PP (adamellite)	3211 (melasyenodiorite)	227P (monzotonalite)	116 (alaskite)	228 (quartz diorite)	227P (monzotonalite)	227P (monzotonalite)	228 (quartz diorite)

Specimen number	14*	15*	16	17	18	19	20	21	22	23*	24*	25	26
Quartz	...	5	8	11	14	34	16	18	12	21	14	10	13
Myrmekite	...	8	...	...	...	...	...	...	20	4	4	...	...
Total quartz (quartz + ½ myrmekite)	...	9	...	...	...	...	...	...	22	23	16	...	...
Microcline	?	...	?	?	...	...	...	...	...	12?	28		...
Orthoclase	...	...	...	...	23	38	31	11	...	...	...	16	?
Perthite	...	...	...	15?	...	...	...	...	...	12?	...		...
Total potash feldspar (microcline + orthoclase + ½ myrmekite + ½ perthite)	...	4	...	7·5	23	38	31	11	10	26	30	16	...
Plagioclase (percentage in rock)	82	61	66	66	41	24	43	59	53	33	45	32	57?
Percentage A_n in plagioclase (average)	42	34	35	28	25	20	23	20	15?	30	22	18	35?
Total plagioclase (plagioclase + ½ perthite)	82	61	66	73·5	41	24	43	59	53	33	45	32	57
Ferromagnesian minerals plus accessories	18	26	22	8	22	4	12	12	15	18	9	42	30
Amphibole	x	x	x↑	x	x	x	x	x	x	x	x	x	x↑
Pyroxene	x	x	x	...	...	...	...	...	...	...	x	...	...
Biotite	...	x	...	x	...	...	x	...	...	x	...	x	...
Muscovite	...	...	...	...	...	...	...	...	x	...	...	...	...
Magnetite	x	x	x	x	x	x	x	x	x	x	x	x	x
Apatite	x	x	x	x	x	...	x	x	x	x	x	x	x
Rutile	...	...	...	...	...	...	...	...	x	...	...	...	...
Sphene and leucoxene	...	...	...	x	x	...	...	x	...	x	x	x	...
Zircon	...	...	...	...	...	...	...	...	...	x	...	x	...
Sillimanite	...	x	x	...	...	...	...	...	...	...	...	x	...
Tourmaline	...	...	...	...	...	...	...	...	...	...	...	...	...
Rock type, according to Johannsen's classification	2212 (diorite)	227P (monzotonalite)	228 (quartz diorite)	227P (monzotonalite)	227PP (adamellite)	226PP (adamellitic granite)	227PP (adamellite)	227P (monzotonalite)	227P (monzotonalite)	227PP (adamellite)	227PP (adamellite)	227P (monzotonalite)	228 (quartz diorite)

Specimen number	27*	28*	29	30	31	32	33	34*	35	36*	37	38	39
Quartz	27	...	...	7	17	22	23	9	12	13	10	20	18
Myrmekite	...	...	...	...	...	...	...	...	...	...	5	5	...
Total quartz (quartz + ½ myrmekite)	...	...	...	...	...	...	...	...	...	...	12·5	22·5	...
Microcline	32	...	...	...	...	...	...	?		...	...	...	?
Orthoclase	...	10?	...	5?	5?	12	...	22	18	32?	10?	...	
Perthite	...	...	...	...	...	...	20	...		...	...	...	...
Total potash feldspar (microcline + orthoclase + ½ myrmekite + ½ perthite)	32	10	...	5	5	12	10	22	18	32	12·5	2·5	?
Plagioclase (percentage in rock)	36	46?	60?	53?	51?	38	40?	53	25	44?	55	60	60?
Percentage A_n in plagioclase (average)	20	?	38?	30?	25?	25	30?	28	23	18	30?	32	30?
Total plagioclase (plagioclase + ½ perthite)	36	46	60	53	51	38	50	53	25	44	55	60	60
Ferromagnesian minerals plus accessories	5	34	40?	35?	27?	28	17	16	45	11	20	15	15
Amphibole	x	x	x	x	x↑	x	x	x	x	x	...	x	x
Pyroxene	...	x	...	?	...	...	...	...	...	x	x	...	...
Biotite	...	...	...	...	...	...	...	...	...	...	x	...	x
Muscovite	x	...	...	...	...	...	...	x	...	...	...	...	...
Magnetite	x	x	x	x	x	x	x	x	x	x	x	x	x
Apatite	x	...	x	x	x	x	x	x	x	x	x	x	x
Rutile	...	...	x	...	...	...	...	...	x	...	...	...	...
Sphene and leucoxene	x	...	...	x	x	...	x	x	x	x	...	x	...
Zircon	...	...	...	x	...	x	...	...	...	...	...	...	...
Sillimanite	...	...	...	...	...	...	...	...	x	...	x	...	...
Tourmaline	...	...	...	...	...	...	...	...	...	...	...	...	...
Rock type, according to Johannsen's classification	227PP (adamellite)	2211 (syenodiorite)	2212 (diorite)	227P (monzotonalite)	227P (monzotonalite)	227P (monzotonalite)	227PP (adamellite)	227P (monzotonalite)	227PP (adamellite)	227PP (adamellite)	227P (monzotonalite)	228 (quartz diorite)	227P (monzotonalite)

NOTE: The proportions of the minerals shown in this table are more or less approximate for some sections, owing to the alteration of feldspar to saussuritic minerals and the ferromagnesian minerals to chloritic and amphibolitic material.

The symbol (?) after the percentages indicates that the measured proportion of that mineral was revised to include altered material, or, in highly altered sections, estimated by eye. In all other sections, the percentage composition is based on the mineral proportions encountered in a total traverse length of at least 50 millimetres for each specimen.

Specimens marked * are especially typical of large areas of the Hogem batholith.

x, denotes presence, but not quantitative abundance of ferromagnesian or accessory mineral. Total abundance of all minerals marked x gives percentage figure for ferromagnesian minerals plus accessories.

↑, broken arrow from pyroxene to amphibole indicates that amphibole may have formed from pyroxene.

of a few minor but definite reversals in this sequence has been observed. A typical succession, exposed on the Horn Peak massif, is as follows, beginning with the oldest rock.

(1) Medium-grained, dark grey, gneissic diorite, containing inclusions of meladiorite and amphibolite that probably represent still older intrusive rocks but may be metamorphosed fragments of pre-batholithic formations;
(2) Grey, relatively coarse-grained, gneissic quartz diorite, whose foliated structure parallels the contacts of the dykes and fingers transecting the planes of gneissosity of the older rock;
(3) Fine-grained, dark grey quartz diorite, darker, finer grained, more uniform, and less gneissic than the rock it cuts;
(4) Light grey, medium-grained granodiorite, showing no pronounced foliation; rock of this type composes about half the Horn Peak massif;
(5) Light grey, medium-grained granodiorite, in part containing biotite, and in part containing amphibole; mostly in relatively small (1,000 feet or less in diameter), slightly gneissic bodies that differ from each other slightly in texture, and in kind and abundance of ferromagnesian constituents;
(6) Light grey to pink, medium- to coarse-grained, strongly porphyritic granodiorite;
(7) Orange-buff to pink, coarse-grained adamellite-granite, in part porphyritic;
(8) Pegmatite, aplite, and leucogranite dykes, some of which may grade into the adamellite-granite.

Exceptions to the general trend toward rocks richer in silica and poorer in lime, magnesia, and iron are found on the massif between the two branches of Osilinka River. Here, large bodies of grey-green syenodiorite intrude light grey granodiorite. Both rocks are cut by dykes of dark grey quartz diorite-porphyry, and the whole assemblage is cut by coarse, pink adamellite-granite. Similar, post-granodiorite dykes of dark, quartz diorite-porphyry are found south of Kliyul Creek, east of Ferriston Creek, and south of Detni Creek.

The relations of all of these rocks to the melanocratic, quartz-free phase of the Omineca intrusions is not entirely clear. The only representative of the latter rocks whose contacts with the acidic rocks are well exposed is the Abraham Creek body. All of the quartz-free rocks of this body are intruded by light grey and orange-pink granodiorite and adamellite-granite. Part of the youngest rock type of the Abraham Creek body proper (the gneissic diorite) is superficially similar to some of the diorite forming the oldest recognized unit exposed west of Etschitka Creek, on Horn Peak, and east of Detni Creek. Thus the two 'divisions' of the Omineca intrusions, as here separated on the basis of lithology, may overlap in age; or the Abraham Creek body may be composed of rocks that are all older than any of the series of acidic rocks. The fine-grained granodiorite dykes that cut and have chilled borders against the gneissic diorites of the Abraham Creek body are similar to many small dykes cutting the diorites and some of the quartz diorites elsewhere in the batholith.

INTERNAL STRUCTURE OF THE HOGEM BATHOLITH

About half of the leucocratic rocks of the Hogem batholith possess a recognizable planar or linear structure. These structures are due primarily to a subparallel orientation of the non-equidimensional ferromagnesian minerals in the rock, and to a lesser extent to the arrangement of large crystals or phenocrysts of feldspar. A few of the rocks are excellent gneisses.

The gneissic structure of the various rock masses that comprise the Abraham Creek body shows no recognizable common orientation. It is apparent that the foliation of each separate intrusive mass in this body is mainly dependent on the local shape of the body, and bears little relation to the outlines of the body as a whole. The foliation planes of some of the rocks may have been plastically deformed during intrusion of younger rocks.

In the younger, acidic rocks of the Hogem batholith, planar structure is best developed in the diorites and quartz diorites; almost every carefully examined outcrop shows rocks with some degree of foliation. Although a few of the granodiorites and adamellite-granites are strongly gneissic, most of them possess no recognizable foliation, and at first sight appear massive. However, close investigation of these rocks commonly reveals a vague but definite lineation, which is so obscure that much of the batholith was traversed before it was recognized.

These planar and linear structures are not oriented uniformly for the different bodies in which they occur, and most of them bear no obvious relation to the structures of the rocks that cut them, although several 'sills' of quartz diorite, parallel with the plane of gneissosity of the diorite in which they lie, are exposed west of Etschitka Creek. At most contacts the planar or linear structure of the older rock is sharply truncated by a younger rock with structures of different orientation. It appears that most of the oriented structures are more or less unique to each body in which they are found, and, therefore, that they were developed at the time of the original consolidation of the rock rather than by later intrusive or tectonic action[1]. In a few cases the directions and patterns of these structures have been modified by subsequent intrusion and rock movement, as is seen, for example, in contorted inclusions of gneissic quartz diorite embedded in nearby structureless adamellite-granite.

The foliation planes of all the large gneissic bodies observed are steeply dipping, with commonly a broadly curving horizontal trace. In a few places, such as west of Etschitka Creek, the planar structure parallels the steeply dipping contact with older gneissic rocks. The lineation in the non-gneissic granodiorite and adamellite-granite appears to vary considerably in different parts of the same body. The only detailed information regarding the orientation of lineation was obtained from the region at the headwaters and to the east of Abraham Creek, where a mass of adamellite-granite about 3 miles by 1 mile shows a faint lineation in the shape of a segment of a dome; most of the lineation strikes northeast or north, is flat-lying in the southwest part of the body, and dips 20 to 40 degrees to the northeast in the north and northeast parts.

Thus, the evidence at present available suggests that the foliation and lineation are mainly related to the outlines of the individual bodies in which they occur. The structures suggest that the material that consolidated to form the bodies of intrusive rock was, while partly crystalline, capable of bodily movement or of circulation within an enclosed chamber now represented by the space occupied by the foliate or linear-structured rock.

[1] This generalization seems to apply to all the acidic rocks studied, but it does not hold for part of the Abraham Creek body (*See* page 171).

The present joint pattern of the Abraham Creek body commonly bears no apparent relation to the local gneissic structures of the body or of the surrounding younger phases of the Hogem batholith, or to the attitudes of the myriad dykes, stringers, and healed fracture systems by means of which many of the different rock masses were emplaced. There is ample evidence that most of the rock has been through a condition of plasticity, which appears to have completely relieved stresses connected with the formation of the Abraham Creek body itself. The stresses producing most of the present fractures are clearly of later origin, and may be related to the intrusion of the acidic phases of the Hogem batholith. The attitudes of four hundred and sixty-six dominant joint sets from this body were plotted (*See* Figure 11). It can be seen that most of these joints dip very steeply to vertically with a southeast, east, and northeast trend. Analysis of the relation of the shear and tension joints in this pattern, assuming the easiest relief to be vertically upward, leads to the suggestion that the main fracturing has been in relief of forces that were directed to the northeast, upward at an angle of 5 to 25 degrees.

CONTACT RELATIONS AND MANNER OF INTRUSION OF THE HOGEM BATHOLITH

The only melanocratic, quartz-free body in the Hogem batholith whose contact with the Takla group is well exposed is the Tutizzi Lake body, whose relations suggest a forcible invasion of a heterogeneous, apparently viscous magma into much shattered andesites and tuffs. The actual contact of the Abraham Creek body with the Takla group to its northeast is nowhere exposed, but outcrops of each rock unit close to the contact show that the contact plane is relatively regular and steeply dipping for a vertical interval of at least 2,400 feet.

The more widespread, light-coloured, younger rocks show a variety of types of contact, both against Takla group rocks and against the older phases of the Hogem batholith. Contacts with Takla group rocks are well exposed on the ridges between Thane and Kliyul Creeks, and are of three main types, two of which appear to be related in a general way to the composition of the intruding rock.

Gradational Contacts

The first type of contact is that shown by a few, relatively dark granodiorites and quartz diorites, and is typically developed on the ridges on each side of the east branch of Matetlo Creek. In these places the batholith has been emplaced in comparatively coarse-grained porphyritic andesite, against which there is no sharp contact with the lighter coloured coarse granodiorite. Across a distance of about 300 feet, the granodiorite becomes progressively finer grained and darker, and passes into a slightly sheared, sugary, grey-green rock in which 'phenocrysts' of feldspar are vaguely visible, and which in turn grades into saussuritized porphyritic andesite. All the observed contacts of this type are sheared, but no single fault, bringing rocks of noticeably different nature into contact, was found. East of Matetlo Creek, the planes of shearing strike parallel with the contact and dip about 45 degrees towards the batholith; the contact itself, as shown by its trace over a vertical interval of 2,500 feet, is nearly vertical. Slickensides on the shear planes trend directly down the dip and

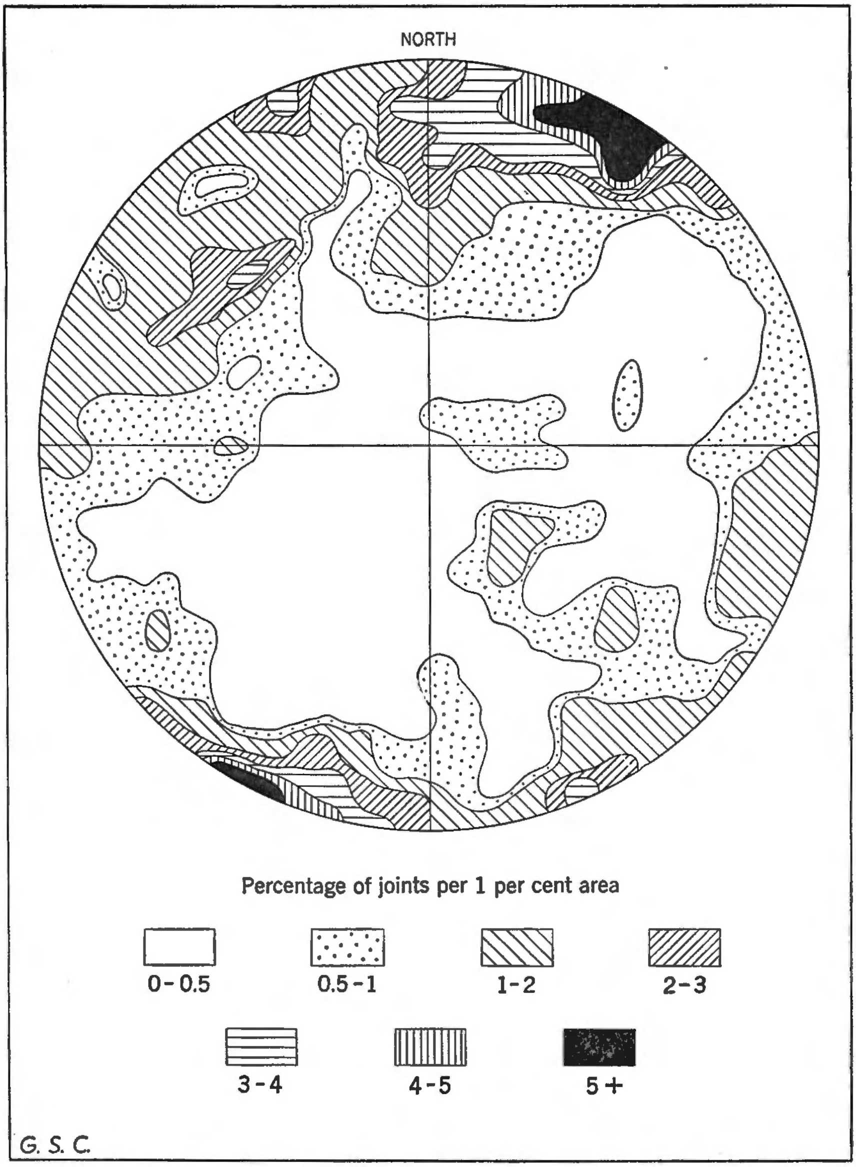


Figure 11. Diagram illustrating attitudes of joint sets in the Abraham Creek body of the Hogem batholith, prepared by plotting the perpendiculars to 466 joint faces on an equal-area stereographic projection.

show that in the last movement the northeast (Takla group) side moved up relative to the southwest side. This type of contact was observed only where the 'intrusive' rock and the rock it intrudes appear to be very similar in composition; and it may indicate a gradual assimilation and recrystallization of the andesite, facilitated by solutions or emanations from a magma in the interior of the batholith, until it has become an igneous-appearing quartz diorite or granodiorite.

Sheared or Fault Contacts

The second type of contact is illustrated north of Thane Creek, west of Tenakihi Creek, and west and northwest of Tutizzi Lake. In these places the contact is a single fault or shear zone, 3 to 100 feet wide, bringing medium-grained granodiorite against apparently unaltered or slightly recrystallized Takla group rocks. None of the observed contacts of this type appear to represent major faults along which large masses of rock have moved; instead, the breaks seem to be minor adjustments to a crowding caused by the batholith. All of the known fault or shear contacts are curved. The best exposed contact of this type, west of Tenakihi Creek, consists of an S-shaped shear zone about 3 feet wide, which curves back upon itself so that its strike changes by approximately 120 degrees within 100 feet. The shear plane dips steeply toward the older rock, and the shear movement has been directly along the line of dip. In this locality the granodiorite appears to have moved upward with respect to the Takla group rocks. At the contact northwest of Tutizzi Lake, the last movement on the shear has displaced the Takla group upward relative to the batholith.

Contact Zones Characterized by Myriad Dykes

The third, and apparently the most common, type of contact of the Hogem batholith is that shown by most of the leucocratic granodiorites and adamellite-granites, and to a lesser extent by representatives of all the other rock types. Excellent exposures of this type of contact are found where adamellite-granite cuts Takla group andesites, tuffs, and argillites east of Tenakihi Creek, and east of Etschitka Creek. At such places the rocks surrounding the batholith are cut by numerous orange and buff granitic or granodioritic dykes. These are in sharp contact against the Takla group rocks, are very irregular in outline, and run in many directions. They crosscut one another in such a pattern as to indicate that at least some occupy fractures whose walls have spread apart, whereas others must occupy space from which the original rock has been removed. They occur in increasing abundance to where they comprise most of the rock volume, and the older rock is found only as inclusions within a tangled network of mainly intrusive material. The number of inclusions diminishes rapidly on approaching the batholith, and the transition from Takla group rocks containing only a few dykes to typical adamellite-granite of the Hogem batholith takes place within a horizontal distance of about 500 feet. In such contact zones, several of the larger dykes can be followed into the batholith proper for distances up to 1,000 feet. It is apparent that the dykes are not simple apophyses from the outermost layer of the batholith, but intrusions from the interior of the igneous mass that have broken through an outer solidified shell. But this outer shell itself appears to be nothing more than a coalesced network of dykes and apophyses; and the precise contact between batholith and Takla group can rarely be drawn. The whole arrangement suggests that in the final stages of intrusion there was little sideward advance of the magma, but rather repeated fracturing and minor intrusion, with little change in the position of the walls of the batholith.

This same type of contact, but developed between an intrusive body and its roof rocks, rather than its walls, is spectacularly shown at the headwaters of Abraham Creek. There, coarse-grained pink adamellite intrudes overlying, older, dark grey, gneissic quartz diorite, and still older dark green-grey hornblende diorite of the Abraham Creek body. The cliffs west of the tongue of the large glacier at the head of Abraham Creek present a vertical section about 1 mile long and as much as 2,300 feet high, across which the contact runs obliquely. The process of stoping is well displayed. The contact between the adamellite and the diorite is knife-edged, and is irregular both in detail and on a large scale. The plane of the contact commonly follows a zigzag pattern of epidote-filled fractures in the diorite. Most of these fractures do not cut the adamellite. Many apophyses of coarse- to medium-grained adamellite, varying in size from fingers ½ inch thick to cupolas 700 feet across, cut the diorite, and several inclusions of diorite are found in the adamellite near the contact. Most of the inclusions are between 1 foot and 20 feet in diameter, and are close enough to the contact that their original position in the diorite roof is evident; it can be seen that many of them have dropped bodily, in some cases with slight rotation, into the adamellite mass. What appears to be an unusually large inclusion of this type forms a conspicuous boss projecting into, and forming a small icefall in, the west side of the glacier. The exposed boss is about 600 by 500 by 300 feet; its upper surface lies about 400 feet below the projected plane of the contact in this locality; and the orientation of the gneissic structure of the boss differs from that of the roof rocks by about 40 degrees. The boss must be either a contorted roof pendant or a large, detached, rotated fragment.

In this area the adamellite is gneissic at its contact with the quartz diorite and hornblende diorite. In most places the gneissosity parallels the details of the contact and curves sharply to enter large and small apophyses. The gneissic structure of the diorite is unchanged up to, and is truncated by, the contact.

The adamellite exposed on the east side of Abraham Creek Valley, about 2 miles from the nearest exposure of diorite, contains many rounded inclusions of dark grey dioritic material. Most of the inclusions are 2 to 10 inches in diameter, with gradational margins.

Pegmatite Dykes

A plethora of pegmatite dykes cuts across the contact and through the roof rocks near the headwaters of Abraham Creek. It is estimated that in a carefully examined area of about 2 square miles, about 15 per cent of the rock is pegmatite. A single serrated arête ½ mile long exposes several hundred individual dykes. Most of the dykes are less than 5 feet thick, although bodies up to 100 feet thick and 700 feet long were observed. The dykes cut the adamellite near its contact with the diorite roof rocks but several good examples of a gradation between adamellite and pegmatite were observed 700 feet inside the contact. None of the apophyses of adamellite was observed to pass into a pegmatite dyke.

Although most of the pegmatite dykes appear to have been emplaced by replacement of the rock whose space they now occupy, they are mainly relatively smooth tabular bodies. They occur in three main sets, of which the youngest, flat-lying or gently southwest-dipping set is most prominent. The flat-lying dykes were evidently guided by subparallel fractures in consolidated roof rocks, which here consist of medium-grained quartz diorite, hornblende diorite, and numerous fine-grained diorite dykes that appear to be the youngest of the series of rock types connected with the Abraham Creek body (*See* page 172); but it is evident from the contorted attitude of small connecting dykes that the diorite was plastic and undergoing deformation during or shortly after the period of dyke formation. Figure 12 shows the relations between these small pegmatite dykes and gneissic diorite (*See* Plate X A). It appears that the entire rock mass was more or less plastic, and that stresses were relieved by shearing and flowage localized along the lines of fine-grained diorite dykes. The deformation has resulted in a local re-orientation of gneissosity in the diorite. The fine-grained diorite dykes have suffered considerable flowage, and in places where the amount of deformation has been too great to be accommodated by plastic movement have developed a series of *en échelon* shear fractures, along which aplitic quartz-feldspar material has been deposited (*See* Figure 12). Most of the structures of this type in the Abraham Creek district show that the underlying side of the nearly flat to gently southwest dipping shear planes has moved to the northeast, with respect to the overlying, southwest side.

Orientation of Deforming and Intruding Forces

The general direction of relative movement indicated by the pegmatite dyke patterns in the Hogem batholith is compatible with that deduced from the joint pattern in the Abraham Creek body (*See* page 181). It seems probable that the roof rocks of the adamellite body were subjected to an outward, northeast-directed pressure that was resisted by a southwest-directed pressure acting at a somewhat higher level. Such a force couple would tend to produce movement between beds in the reverse direction to that which must have occurred during the development of the large syncline of Takla group rocks, along whose axis the Hogem batholith has been emplaced. It would seem to follow that the Takla group rocks were folded prior to the final intrusion of the granodiorite and adamellite rocks of the batholith, and that the intrusion itself, or at least the consolidation of the intrusions, was accompanied by forces of a different nature from those that produced the regional folding.

Age

Rocks representing the oldest, melanocratic phases of the Omineca intrusions cut Takla group beds several thousand feet stratigraphically higher than the horizons from which Upper Triassic fossils were taken. They thus can scarcely be older than very late Triassic. The granodiorite of the Hogem batholith cuts beds containing fossils indicating a Lower

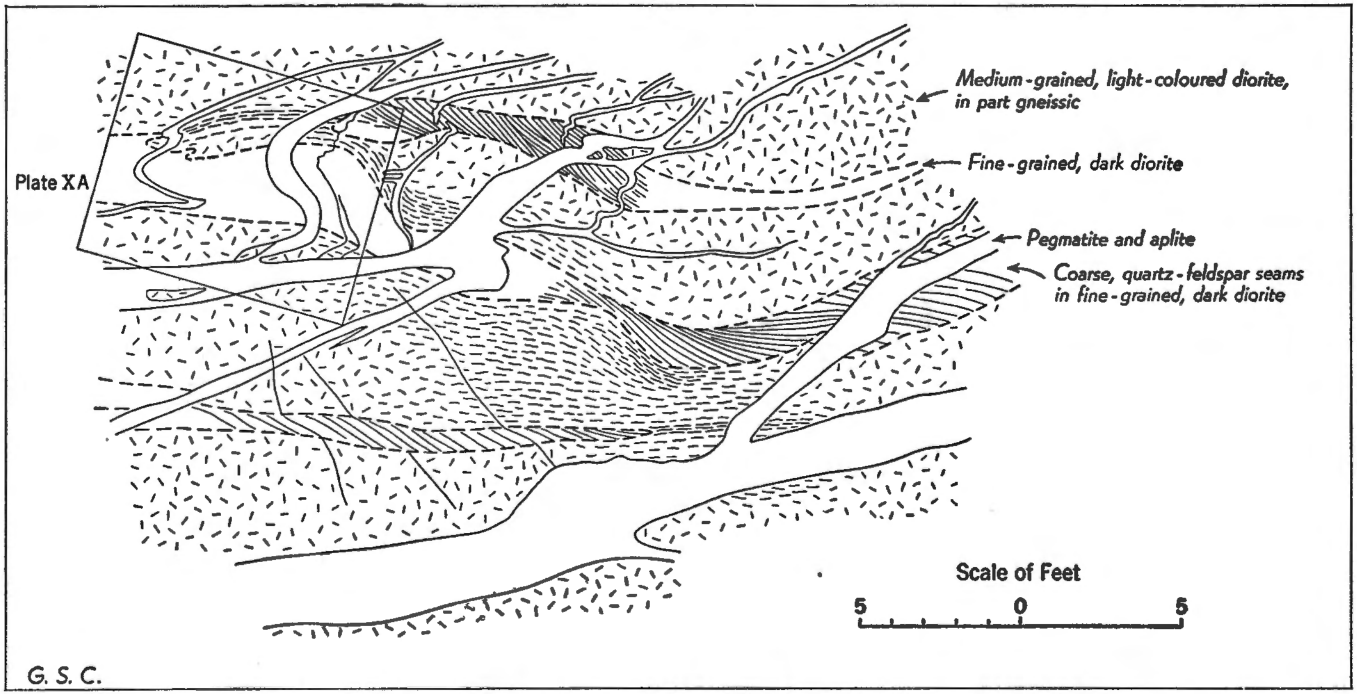


Figure 12. Sketch illustrating relations between diorite and pegmatite near headwaters of Abraham Creek.

Jurassic horizon. In the McConnell Creek map-area to the west, the Takla group contains Upper Jurassic beds, which, however, were not observed to be cut by the Omineca intrusions. But as no important unconformity has been recognized within the Takla group, and as the whole group appears to have been deformed as a unit prior to the intrusion of the major part of the Hogem batholith, it seems probable that all of the Omineca intrusions are younger than the entire Takla group; that is, not older than late Jurassic.

Bodies of these intrusions were unroofed to supply abundant cobbles and pebbles to the Uslika formation and to the Sustut group strata. The Uslika formation is tentatively assigned a late Lower Cretaceous age. The Sustut group contains early Upper Cretaceous fossils. The Omineca intrusions were, therefore, emplaced between late Triassic and late Cretaceous time, and probably between late Jurassic and early Cretaceous time.

USLIKA FORMATION

General Statement

The Uslika formation includes a single body of conglomerate exposed east and north of Uslika Lake, together with faulted, contiguous blocks south of Conglomerate Mountain and in the lower part of Vega Creek Valley. Beds of black argillite and chert-pebble conglomerate that outcrop on Vega Creek, just west of, and in apparent conformable relations with, the main mass of conglomerate, are also tentatively assigned to this formation.

Lithology

The main conglomerate mass consists of well-rounded pebbles and cobbles up to 10 inches in diameter in a heterogeneous, grey-green to brown, sandy to gritty, greywacke matrix. The most abundant stones are of volcanic rocks, mainly grey-green and green, finely porphyritic andesites, with lesser purple andesite or basalt, and andesite breccia. Somewhat less plentiful, but forming almost all the cobbles, and the predominant material in zones whose aggregate thickness is about one-third of the total, are rounded fragments of a great variety of plutonic rocks. All of the types of plutonic rocks found in this conglomerate are similar to rocks of the various bodies of the Omineca intrusions, although, in general, diorites, syenodiorites, and quartz-poor porphyritic granodiorite are proportionally more abundant in the conglomerate than in the Omineca intrusions now exposed. Leucocratic, relatively quartz-rich granodiorite and adamellite-granite, which are the most abundant rocks in the Hogem batholith at the present level of erosion, are relatively rare as boulders in the Uslika formation.

→ 10"

qtz-poo clast

Other rock types widely distributed as pebbles in the conglomerate include: fine-grained, well-bedded andesitic tuffs; pale grey, in part micaceous, quartzite; white vein quartz; and blue-grey chert. Less abundant rock types, found mainly in small (less than 1 inch) pebbles, include: black and grey argillaceous limestone; blue-grey cherty limestone; red chert or jasper; quartz-mica schist and quartz-mica-feldspar gneissic rock; and fine-grained brown sandstone. Almost all of the fragments except those of flaky rocks, such as the argillaceous limestones and the schists, are well rounded.

In many places the matrix of the conglomerate has been impregnated with hematite, which forms a smooth, shiny coating on pebbles that are otherwise mostly fresh and unweathered.

Much of the conglomerate is poorly sorted. In places, however, lenticular units 10 to 200 or more feet thick and up to 1,000 feet long are of relatively uniform texture. These units range from rocks of which more than 70 per cent of the volume is composed of cobbles larger than 3 inches diameter, to rocks in which most fragments are less than $\frac{1}{4}$ inch in diameter. The different units have both gradational and sharp, crosscutting and conformable contacts. The matrix of the conglomerate has an average grain size of about $\frac{1}{16}$ inch, and constitutes about 20 per cent of the volume of the rock. The few small sandy and gritty lenses are composed of material apparently identical with the matrix of the conglomerate.

In some areas, a compositional 'sorting', most conspicuous in the larger fragments, is evident. Beds in which most of the cobbles are of volcanic material alternate with those in which plutonic rocks predominate. Still other, less common, beds contain abundant pebbles of vein quartz. Beds containing much plutonic material are most common near the middle of the exposed stratigraphic section of the Uslika formation.

The argillite exposed on Vega Creek consists of two bodies, about $\frac{1}{2}$ mile apart, of black to dark blue-grey, crumbly to slaty rock containing much woody material. A fine conglomerate, containing subangular fragments of black chert or silicified argillite, white quartz, jasper, and altered green volcanic rock up to $1\frac{1}{2}$ inches in diameter in a dark grey silty matrix is interbedded with the argillite.

Structural Relations

Bedding is poor in most of the Uslika formation. It is best shown by layers of grit and fine conglomerate interbedded with the normal, relatively coarse conglomerates. Such fine-grained layers, however, are quite rare, and are lenticular, rarely more than 5 feet thick and 50 feet long. For the most part, the conglomerate is a uniform, massively jointed rock (*See* Plate X B), in which the only suggestion of bedding is given by the orientation of the inequidimensional pebbles and boulders. In a few places, cross-sections of channel fillings have been observed. By these various features it can be seen that the composite of lenticular bodies forming the Uslika formation has a general northwest strike and southwest dip. The dip is moderate at the west edge of the body and steep to vertical at the eastern margin, so that the main mass of conglomerate appears to represent the east limb of a large, curving, northwest-trending syncline. Faulted segments of this body on the south slope of Conglomerate Mountain and in Vega Creek Valley exhibit a wide range of attitudes. No evidence of small-scale deformation within the body itself has been noted.

The total stratigraphic thickness of the main conglomerate mass is in excess of 4,200 feet. The exposed thickness of the argillite and chert-pebble conglomerate on Vega Creek is about 300 feet.

Rocks of the late Palæozoic sedimentary and volcanic series outcrop on each side of the Uslika formation, and their attitude is essentially conformable with that of the adjacent conglomerate body. The only extensive exposure of the contact is on the northeast side of the conglomerate body, due east of the outlet of Uslika Lake, where outcrops distributed over more than a mile show the contact to be a curving fault whose plane is nearly parallel with the bedding of the conglomerate. The conglomerate is highly sheared along the fault, and pebbles have been deformed into elliptical disks and cigar-shaped bodies, for widths of 3 to 20 feet from the contact. The deformation of the pebbles and the direction of slickensides on the fault planes show that the last important movement was one in which the Uslika formation moved upward and to the east-southeast relative to the older rocks to the northeast.

Any postulated sequence of rock movements that would produce the structural relations shown by the Uslika formation appears to involve two separate fault movements, with the plane of the later fault intersecting that of the earlier one. The following explanation is hypothetical, but is compatible with the geometry of the structures and the observed evidence of faulting (*See* structure-section G-H). It is suggested that the conglomerate, previously folded into a synclinal structure, was carried bodily eastward and stratigraphically lower across the tilted Takla group strata and onto the late Palæozoic rocks by a flat thrust from the southwest. This thrust curved up more steeply at its eastern end to form the present exposed east and northeast contact of the conglomerate, and placed the beds of both units in a roughly parallel position. After the movement on the first thrust fault had ceased, a steeper fault, whose plane crossed that of the older break, developed. Motion on the later fault relatively raised the entire region west of Conglomerate Mountain, and moved the late Palæozoic strata onto the west side of the Uslika formation, where again the beds are roughly parallel. This later, relatively steeply dipping reverse fault may be related to the subparallel faults that separate the divisions of the Cache Creek group to the east. According to this hypothesis, the Uslika formation must represent an isolated mass, a *klippe*, underlain by a spoon-shaped thrust plane whose extension to the west, in a block now relatively uplifted, has not been recognized or has been removed by erosion. The *klippe*, if such it is, has been complicated by at least two later periods of faulting.

Alternative hypotheses, based on a normal movement on the eastern contact of the conglomerate, bringing the Uslika formation down to its present position from the northeast, may be made to explain the observed structural relations of these rocks. Such hypotheses, however, involve movement in a direction opposite to the observed evidence of the direction of the last movement of the eastern contact. The size and abundance of granitic pebbles in the conglomerate suggest that the formation was deposited relatively close to the Hogem batholith, which must have been less widely exposed when the Uslika formation was laid down than it is at present. For these reasons it is considered more probable that the Uslika formation was brought to its present position by a warped thrust from the southwest than by a normal fault from the northeast.

Age

The main body of conglomerate is almost completely devoid of organic material. Plant fossils were collected from the argillites on Vega Creek, and were reported on by W. A. Bell of the Geological Survey as follows:

"Collection F1R5:
Cladophlebis virginiensis forma *acuta* Fontaine
Coniopteris brevifolia (Fontaine)
Upper Jurassic or Lower Cretaceous; a Lower Cretaceous age is considered more probable.

Collection 3695:
Sagenopteris sp.
Nilssonia (?) sp. (too poorly preserved to be certain this is not *Taeniopteris* sp.)
Pagiophyllum sp. (? *Elatides curvifolia* (Dunker))
This florule is clearly Mesozoic, and is tentatively considered more probably Aptian or Albian (late Lower Cretaceous) than earlier.

Collection 3838:
Cladophlebis virginiensis forma *acuta* Fontaine
Cladophlebis parva ? Fontaine
Nilssonia cf. *densinervis* (Fontaine) Berry
Elatides n.sp.
An Aptian age, equivalent to that of the Luscar formation of Alberta, is indicated.

Collection 3839:
Cladophlebis virginiensis forma *acuta* Fontaine
Cladophlebis parva (?) Fontaine
Ruffordia goepperti (Dunker) Seward
Gleichenites gieseckiana (Heer) emend. Seward
Gleichenites porsildi Seward
An Aptian age, equivalent to that of the Luscar formation or Alberta, is indicated."

The Uslika formation conglomerate contains fragments that have clearly been derived from bodies of the Omineca intrusions and from almost all older rocks within the map-area. The relations between the main body of conglomerate and the argillite beds of Aptian age on Vega Creek are not precisely known, but the close spatial association of the two rock masses in an area surrounded by rocks of markedly different type, and their apparent structural conformity, suggest that they may be of about the same age. The formation is, therefore, provisionally considered to be of late Lower Cretaceous age.

SUSTUT GROUP

Sifton Formation

Pale pinkish buff to grey, blue-grey weathering conglomerate outcrops in long parallel ridges in the floor of the Rocky Mountain Trench in the northeast corner of the map-area. The largest body, northeast of Ed Bird and Estella Lakes, is about 3 miles long and ½ mile wide. Other bodies are found south of Isola Creek, near the eastern boundary of the map-area, and east of Mount Tsaydizkun.

The conglomerate consists of subangular to well-rounded pebbles, cobbles, and boulders, with an average diameter of about 1½ inches, but in exceptional cases up to 14 inches, of limestone, sandstone, schist, slate, and quartz, closely packed in an impure silty matrix. Water-worn, subangular stones up to 14 inches in diameter of blue-grey or buff-coloured crystalline limestone, mostly well bedded, comprise about 70 per cent of the rock. About 15 per cent consists of pebbles of brownish grey to buff-coloured, medium- to fine-grained, well-bedded calcareous sandstone. Minor constituents include pebbles of white quartz and quartzite, blue-grey chert or highly silicified limestone, and a bright red, soft, sheared rock that may be a ferruginous limestone or slate or a weathered volcanic rock. The matrix, commonly quite minor in amount, is shaly to silty, highly calcareous, and locally ferruginous.

The conglomerate is moderately well sorted, but bedding attitudes could be obtained only locally. These are relatively uniform in all bodies examined, and indicate a strike of north 70 to 80 degrees west, trending diagonally across the Rocky Mountain Trench, and a moderate dip to the northeast. The long ridges, 50 to 450 feet high, formed by the conglomerate, strike parallel with the axis of the trench. No information about the thickness of the conglomerate was obtained.

The Sifton conglomerate appears to be part of the belt of clastic sedimentary rocks mapped by McConnell (1896, p. 35C) along the Rocky Mountain Trench from the mouth of Ingenika River to Sifton Pass and beyond. Plant remains collected from these rocks from Deserters Canyon, 2 miles east of Aiken Lake map-area, were identified by Sir William Dawson as of upper Laramie age. Upon re-examination, W. A. Bell of the Geological Survey reports that these plants are of late Cretaceous or Paleocene age. The northern continuation of this belt, in Kechika River Valley, was examined by M. S. Hedley and S. S. Holland (1941, p. 42) for the British Columbia Department of Mines. They gave the name 'Sifton' to the formation, and collected plant fossils, which were identified by W. A. Bell as of late Cretaceous or possibly Paleocene or Eocene age. No fossils were found in these rocks in Aiken Lake map-area. The formation is regarded as a part, probably an upper part, of the Sustut group of areas to the west. The possibility that the Sifton formation has been downfaulted into its present position in the floor at the Rocky Mountain Trench is discussed on page 195.

Undivided Sustut Group Rocks

A body of conglomerate, sandstone, shale, and coal, about 1 mile long and 1,500 feet wide, is exposed on the west side of Osilinka River Valley south of Uslika Lake. It is surrounded by andesitic flows, tuffs, and breccias.

Conglomerate, consisting of well-rounded pebbles and cobbles up to 5 inches in diameter, of light brown granitic rock, black chert, green andesite or tuff, white quartz, brown sandstone, and minor shale, schist, and argillite, in a light brown sandy to gritty matrix, comprises the lowest unit of the assemblage. The conglomerate is overlain by beds of brown and grey massive shale, coarse micaceous sandstone, containing many woody fragments, and thin seams of coal and coaly shale. A log of fossil wood, 22 inches in diameter at the butt and 7 feet long, was noted. The largest observed coal seam, free of shaly partings, is 18 inches thick. The total exposed thickness of this assemblage is of the order of 400 feet.

11 80

Plant remains from these beds were examined by W. A. Bell of the Geological Survey, who reported on them as follows:

"Collection 3841:

Elatocladus (*Taxodites* ?) sp.
Pagiophyllum sp.
Menispermites ? sp.

The plant remains are too few, fragmentary, and poorly preserved to indicate any particular age except late Lower Cretaceous (Albian) or later.

Collection 3840:

Podozamites lanceolatus (Lindley and Hutton)
Pityophyllum sp.

The age might be anywhere from Aptian (late Lower Cretaceous) to Upper Cretaceous inclusive.

Collection 3844:

Sphenopteris stricta ? Newberry

If actually *stricta*, the age is probably Upper Cretaceous.

Collection 3842:

Sequoiites langsdorfii Brongniart
Unidentifiable dicotyledenous leaf

The age might be either Upper Cretaceous or early Tertiary.

Collection 3843:

Equisetum sp.
Trochodendroides arctica Heer

An early Tertiary rather than an Upper Cretaceous age is favoured.

Collection 3845:

Trochodendroides ? *arctica* ? Heer
Viburnum ? sp.

These leaves are too fragmentary and poorly preserved for identification, but an early Tertiary age seems most likely.

Collection 3697:

Equisetum sp.
Sequoia langsdorfii (Brongniart) Heer
Alnus carpinoides ? Lesquereux

This florule is too small for judgment as to precise age, but it is considered to be Tertiary and probably post-Paleocene."

This assemblage is tentatively correlated with the Sustut group of McConnell Creek map-area to the west. In the type area the Sustut group includes beds ranging in age from lower Upper Cretaceous to Upper Paleocene.

This small block of Sustut group rocks must have been faulted into its present position. It is in contact with late Palæozoic rocks to the east across an intensely shattered zone, heavily impregnated with hematite. The shattered zone lies just east of the southern projection of the steep, southwest-dipping contact between the late Palæozoic rocks and the Takla group. As stated on page 153, the contact may be a fault; if so, movement on the fault may have relatively lowered and preserved the block of Sustut group rocks. If the Uslika formation represents part of a *klippe* broken by later faulting, as suggested on page 189, it is possible that these Sustut group rocks on the west side of Uslika Lake Valley are part of the same structure, and are underlain by a fragment of the same once-extensive thrust plane (*See* Structure-section G-H). The west contact of these rocks truncates the beds of the block and is also probably a fault; such a fault may be roughly parallel with, and related to, the steeply dipping thrust postulated along the west side of the Uslika formation. According to this view, both the Uslika formation and this block of Sustut group rocks have reached their present infaulted positions among older rocks by a similar, and presumably related, sequence of thrusting.

CHAPTER V

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The major structural features of the various formations in Aiken Lake map-area combine to give a general picture of long, relatively narrow, northwest-trending belts of folded rock, separated by mainly steeply dipping faults, along which the principal movement has been in the direction of the dip. In places the structures are offset by large transverse faults that strike east, northeast, and north. The regional structures are dominated by two, nearly parallel, northwest-trending features: the strong belt of rocks embracing the Omineca intrusions and the rocks reinforced by them, and the zone of weakness and dislocation represented by the Rocky Mountain Trench about 50 miles to the northeast.

ORDER OF DEVELOPMENT OF THE MAIN STRUCTURAL FEATURES

The relations between the various fault and fold structures are complex, and evidence regarding the development of the structures is in part contradictory. The following events in the structural history, however, are suggested by what appear to be reasonably well-established relations.

(1) The Tenakihi and Ingenika groups apparently suffered deformation before the late Palæozoic formations were laid down. The evidence for this Palæozoic deformation is: the widespread lineation and crumpling independent of the present major structures of the Tenakihi and Ingenika groups; the 'trains' of anomalous structures in the present folds of the Tenakihi group; the domes, noses, and 'blisters' in the Ingenika group beds of the Russel Range; and the difference in orientation of minor folds on either side of the fault contact between Ingenika group and younger rocks in the Wrede Range. These early folds had a more northerly trend than the present major structures.

It seems probable that some or all of this deformation took place prior to, or coincident with, the intrusive and metamorphic activity that resulted in the Wolverine complex. The granodiorite stocks appear to have been emplaced, and the granitizing processes carried on, in rocks that were already folded to a broad arch between what are now the positions of Blackpine and Tomias Lakes.

(2) The late Palæozoic rocks of the Lay Range may have been tilted before the intrusion of the pre-Upper Triassic ultramafic (Trembleur?) intrusions. The mapping to date shows that the ultramafic stock east of Polaris Creek, which intrudes rocks now dipping 50 to 70 degrees southwest, has a fairly symmetrical, steep-sided, flat-roofed cross-section in its present position. Small, chromite-rich segregations and bands of distinctive lithological composition in this stock are roughly horizontal. There is nothing in the joint pattern (*See* page 148) to suggest that the stock has been strained by regional stresses. It is difficult to see how the stock could have these characteristics if, subsequent to emplacement, it had been bodily tilted 50 to 70 degrees.

(3) A major orogeny between Upper Jurassic and late Lower Cretaceous time resulted in severe rock deformation in response to regional compression from the northeast and southwest. The deformation found expression in large, compound, northwest-trending folds, with undulating but more or less horizontal axes. The axial plane of each fold in the series dips, in general, to the northeast, at a successively flatter angle than that of the neighbouring fold to the southwest (*See* Structure-sections C-D, E-F). Local deformation has been much more severe on the shorter, steeper, southwest limb of each compound fold. The shortening due to compression was greatest in the northern part of the area, and developed thrust faults and large, recumbent, digitate, overturned structures (*See* Structure-section A-B). The earlier folded structures of the Tenakihi and Ingenika group beds were overwhelmed by these asymmetrical anticlinoria and synclinoria. The late Palæozoic and Takla group rocks in the southwestern half of the area form the northeast limb of a large synclinal structure along whose axis the Hogem batholith was intruded. The fracture and dyke pattern within the batholith suggest that the younger, major part of the batholith was emplaced after the rocks had been folded and at a time of little or no regional compressive stress.

(4) A period of widespread flexure in response to compression from the southwest followed the deposition of the Sustut group rocks. This deformation is recorded in the synclinal structure of the Uslika formation and the oblique tilting of the beds of the Sifton formation. Evidence from the McConnell Creek map-area to the west, where the Sustut group has been more widely preserved (Lord, 1948, p. 33), suggests that this folding was, on the whole, comparatively gentle, with much variation in local intensity. The effect of this post-Paleocene folding on the previously folded Jurassic and older rocks was probably slight, and no structures produced by it, superimposed upon earlier structures, have been recognized.

(5) The major faults in the area probably formed at widely different times, but the main displacements on all have post-dated the folding of the rocks in which they occur. In general it seems that the most important movements on nearly all the main faults took place in post-Paleocene time. The contacts between the Tenakihi and Ingenika group rocks east of Mount Lay and south of Jim May Creek may be, in part, folded faults. As described on pages 189 and 192, the Uslika formation and the small block of Sustut group rocks southwest of Uslika Lake appear to have reached their present position among older rocks by two, separate, post-Paleocene thrusts.

CHARACTER AND INFLUENCE OF THE ROCKY MOUNTAIN TRENCH

The Rocky Mountain Trench is almost certainly underlain by great faults that bring the formations of the Rocky Mountains on the northeast into discordant contact with those of the Omineca and Cassiar Mountains on the southwest. The line of the trench has marked the apparent westward limit of sedimentation in the Rocky Mountain geosyncline at intervals since early Palæozoic times, and at other times has been the locus of an abrupt change in lithological character and thickness of rocks deposited to the east compared with those deposited to the west. So far as known, it represents the northeast limit of the late Jurassic or early Cretaceous orogeny, of all earlier (post-Silurian) periods of deformation, and of all post-Cambrian igneous activity in central and northern British Columbia. The trench was an active structural feature during the post-Paleocene deformation that affected most of northeastern British Columbia west of the Interior Plains. No direct connection has yet been established between the structures of the northern Rocky Mountains and the contemporaneous, much milder structures produced by post-Paleocene deformation west of the trench. The Rocky Mountain Trench thus appears to have been a major depositional, lithological, and structural boundary throughout much of the recorded history of the Cordillera.

That part of the Rocky Mountain Trench in and near Aiken Lake map-area is apparently characterized by closely spaced, parallel, steeply dipping faults. The movement on these faults has been partly, and probably mainly, vertical, and has resulted in the lowering and preserving of long narrow slices of the Sustut group (Sifton formation) in the present valley floor. The southwest wall of the trench, as represented by a 1,500-foot shear face on Mount Tsaydizkun and a line of lower cliffs preserved at intervals for 15 miles to the southeast, may well be a fault or a fault-line scarp.

EMPLACEMENT OF THE SIFTON FORMATION AND OLDER ROCKS IN THE ROCKY MOUNTAIN TRENCH

Fault movements within the Rocky Mountain Trench appear to have resulted in the down-dropping and preservation of long slices of the Sifton formation, which now form narrow ridges striking parallel with the axis of the trench. The beds on several of these ridges have a uniform orientation, striking northwest, obliquely across the ridges, and dipping northeast. It is difficult to conceive of movements by which nearly flat-lying sediments laid down in the valley floor could have been tilted to the northeast and obliquely cut through by north-northwest-striking faults, and it appears more reasonable to suggest that the Sifton formation is a part of the Sustut group rocks, which were deposited at a level considerably above the present erosion surface. The formation is thought to have been involved in the post-Paleocene deformation that affected Sustut group rocks elsewhere, and then faulted into long thin blocks, some of which were lowered to their present position with an unknown, but probably small, amount of further tilting.

The amount of downfaulting suffered by the rocks in the floor of the trench cannot be measured in Aiken Lake map-area, but 30 miles to the northwest, relatively flat-lying, apparently Sustut group, strata cap the massif known as Finlay Mountain, approximately 4,700 feet above similar appearing sediments in the valley floor at the foot of the mountain[1].

[1] These rocks were examined, and their relations brought to the writer's attention, by Mr. E. Bronlund of The Consolidated Mining and Smelting Company of Canada, Limited. Finlay Mountain may be seen from neighbouring peaks and from the air to possess the distinctive topography of mountains capped by Sustut group strata; rocks of the Sifton formation type are reported by McConnell (1896) to lie in the valley floor at this point.

As it is probable that only the lower part of the Sustut group is exposed on Finlay Mountain, and that the Sifton formation may be an upper part of the group, the actual vertical displacement may be much in excess of the above figure.

An island in Finlay River about 5 miles east of the map-area is reported to expose altered green volcanic rock over an area of about 5 acres.[1] If these outcrops represent a block of late Palæozoic or Takla group volcanic rocks downfaulted to their present position, it follows that the Ingenika group rocks now flanking the trench were overlain in this region by late Palæozoic or Takla group strata that were in turn overlain by the Sustut group. If such is the case, the amount of downfaulting suffered by the rocks in the floor of the trench may be tens of thousands of feet.

TOMIAS LAKE SYNCLINORIUM AND PELLY CREEK THRUST: THE 'PELLY CREEK LINEAMENT'

The overturned synclinorium whose axis passes through Tomias Lake Valley (*See* Structure-section E-F), and is exposed on Swannell River, becomes progressively more compressed toward the north, and develops into a thrust fault in Pelly Creek Valley. North of the mouth of Tucha Creek the plane of this thrust may be seen to dip about 40 degrees to the northeast, passing under the overturned anticlinorium of the Russel Range (*See* Structure-sections C-D and A-B). The comparatively more symmetrical series of folds of the Espee Range and Forres Mountain, themselves separated by a fault that is probably a northeast-dipping branch of this thrust, have been relatively lowered, and possibly rotated so that they strike northwesterly and abut against the more northerly striking folds of the Russel Range.

The thrust along the line of Pelly Creek Valley appears to be the result of horizontal shortening, caused by northeast-southwest compression, that was greater in the north than in the south, and it must have formed during the same period of deformation as the folds along the same structure to the south. It, therefore, antedates all the known steeply dipping faults in the area.

Pelly Creek and Tomias Lake Valleys form part of a straight, narrow, topographic depression, more than 300 miles long[2]. This depression, which might be termed the 'Pelly Creek lineament', diverges from the Rocky Mountain Trench, in Parsnip River Valley, at the northern end of an irregular area that separates the trench itself into distinct northern and southern parts. It continues, as a valley occupied successively by Omineca River, Mesilinka River, Carina Lake, Tomias Lake, Pelly Creek, Obo River and Lake, Frog River, Dall River and Lake, to Deadwood Lake, west of the north end of the Rocky Mountain Trench proper (Hedley and Holland, 1941). In part, it marks the division between Finlay Ranges and Swannell Ranges (Bostock, 1948, p. 43). Throughout its entire length this depression maintains a strike of about north 34 degrees west. The Rocky Mountain Trench strikes north 31 degrees west at this latitude, and the two lineaments are probably genetically related. The evidence from the Aiken Lake area suggests that, locally at least, the Pelly Creek lineament represents an east-dipping plane of weakness, which has formed the axial plane

[1] Bronlund, E.: personal communication, 1948.

[2] Well shown on National Topographic Series map, Sheet 94SW., Finlay River (8 miles to 1 inch).

of an overturned fold, or, where movement is greater, an underthrust fault that meets the major faults of the Rocky Mountain Trench at depth. Compression, acting mainly from the west, may have relatively lifted the Russel and Butler Ranges as a wedge, and produced their crumpled and overturned west borders (*See* Structure-sections A-B, C-D). Where movement was relatively greater, the structures west of the lineament are brought into discordant contact with those to the east, producing relationships of the type shown by Espee Range and Russel Range. Somewhat similar explanations have been advanced by Evans (1933, p. 167) and Link (1935, p. 1466) for the development of the underthrust and overturned structures on the east side of the Rocky Mountain Trench in southeastern British Columbia.

TRANSVERSE FAULTS

The general fold structures and thrust blocks of the map-area are cut across by faults on which there has been important horizontal displacement. All of these transverse faults appear to be older than, and are truncated by, the large, through-going, longitudinal faults. The largest transverse faults are essentially tear faults, in which most of the movement has been parallel with the strike of the fault.

A tear fault along Zygadine Creek Valley has shifted the structures of the southern part of the Russel Range about 5 miles to the east, relative to those of the northern part. There has been no appreciable vertical displacement. This fault may have been formed at the time of the development of the overturned synclinorium and the underthrust of the Pelly Creek lineament. It may be that Butler Range and the southern part of Russel Range yielded to some extent to compression from the southwest and were moved bodily northeastward contemporaneously with the development of the synclinorium. In so doing the southern part of the Russel Range appears to have been torn free, along the Zygadine Creek tear fault, from the northern part, which may have been a more rigid, resistant block. The deforming forces, incapable of displacing the northern part of the Russel Range, apparently broke under it in a thrust fault. The Zygadine Creek tear fault may, therefore, be tentatively considered the northern limit of the Tomias Lake synclinorium. North of this fault the synclinorium has been broken to form an underthrust.

The western part of the anticlinorium of Ingenika and Tenakihi group rocks south of Ingenika River has been displaced a total of nearly 10 miles to the south, relative to the eastern part, within a north-trending zone about 6 miles wide along Swannell River Valley and near the Mount Lay massif. This zone contains three well-exposed transverse faults, and it is probable that a master tear fault underlies the floor of Swannell Valley. The possibility that the offset nature of the present structures is, in part, a feature inherited from an earlier deformation of these rocks, rather than entirely the result of post-folding faults, must, however, be considered. The faults in this part of Swannell Valley strike toward, and may be in part a continuation of, branch faults from the Pelly Creek lineament.

It is possible that the Tenakihi Range anticlinorium and the Chase Mountain anticlinorium are parts of the same structure, displaced by a large fault in Mesilinka River Valley. An observed fault parallel with this valley, about 4 miles north of the river, brings normal Ingenika group strata against rocks of the Wolverine complex, and Wolverine complex rocks derived from the Ingenika group against those derived from the Tenakihi group.

The late Palæozoic rocks and the Uslika formation in the southeast part of the map-area have been offset by a tear fault along Osilinka River Valley. This fault has carried the structures on the west side about a mile to the north relative to those on the east. The tear fault has offset the faults that have emplaced the Uslika formation and the diagonal and small longitudinal faults in the late Palæozoic rocks, but has been itself truncated by the major longitudinal fault that forms the boundary between late Palæozoic and Ingenika group rocks.

LONGITUDINAL FAULTS

Steeply dipping, through-going, subparallel longitudinal faults, so called because they trend parallel with the regional structure, have recorded the last important deformational movements in the map-area. The largest of these faults divide major rock units or older structures. It is probable that movement has occurred along most or all of them at several different times, but a large part of the movement has post-dated one or more periods of earlier, though post-Paleocene and later than the last folding, faulting. The direction of movement on these faults has probably been complex, and it is rarely possible to locate faulted extensions of older transverse faults or of folds. The net movement appears, however, to have been mainly vertical, and although evidence is scanty, most faults appear to have the characteristics of high-angle thrusts rather than normal faults.

Two of these longitudinal faults form contacts between major map-units. One brings Takla group rocks on the southwest against late Palæozoic rocks to the northeast. The crustal movements represented by this fault may be connected, through the subparallel faults in the southeast corner of the map-area, with those of the Manson fault zone (Armstrong, 1949, p. 118). The other, which may be an extension of the Wolverine fault to the southeast (Armstrong, 1949, p. 119), brings late Palæozoic, including Cache Creek group, rocks on the southwest against Ingenika and Tenakihi group strata to the northeast. Where exposed, these faults are sheared and schistose zones up to several hundred feet wide, and are generally accompanied by subsidiary, more or less parallel faults, comprising a disturbed zone as much as 1,500 feet across (*See* Plate VIII A).

The Omineca fault (Lord, 1948, p. 50) or Pinchi fault zone (Armstrong, 1949, p. 117), a major structure extending more than 200 miles from Carp Lake map-area (Armstrong, Tipper, and Hoadley, 1947) to McConnell Creek map-area, passes through Omineca River Valley in the southwest corner of Aiken Lake map-area. At this place it forms the contact between the Cache Creek group and the Hogem batholith.

A fault of slightly different character appears to diverge from the thrust in Pelly Creek Valley (part of the 'Pelly Creek lineament'), down the line of the canyon near the mouth of Pelly Creek. Shearing on the canyon walls suggests that the latest movement was one in which the west side moved down and to the south, with respect to the east side. This fault may join with the fault zone in Swannell River Valley east of Mount Lay.

CHAPTER VI

ECONOMIC GEOLOGY

PLACER DEPOSITS

Placer gold may be panned from many streams in the map-area, and in particular from the bars of the larger rivers, but has been found in workable quantities at only two localities. Jim May Creek, a tributary of Osilinka River, has been worked intermittently since 1899, but recovery has never been large. The paystreak lies in gravels 5 to 12 feet above bedrock, and appears to represent mainly re-sorted glacial debris, although some gold has been recovered from a buried preglacial channel, now being exposed at various points by the rapidly down-cutting stream. The gold is mainly fine and relatively rounded, although a nugget weighing 1·35 ounces was recovered in 1939. Several bars on Ingenika River have been worked from time to time, but returns have not warranted continuous operations. The most productive stretch of the river has been that part between the mouths of Wrede and Pelly Creeks. In addition, small placer operations have been carried out on Vega and Wrede Creeks.

It may be noteworthy that although the only significant amount of placer gold recovered to date in the map-area has come from streams eroding the highly metamorphosed Lower Cambrian and late Proterozoic rocks, no lode gold deposits of importance have been found in these rocks. The younger rocks exposed to the west, in which gold-bearing deposits have been discovered, have, on the other hand, produced no known local placer deposits within the map-area, except perhaps on Vega Creek, but have supplied much of the glacial material mantling the stream valleys now containing placer gold.

LODE DEPOSITS

The lode deposits in the map-area may be broadly classified on the basis of geological occurrence as follows: (1) deposits in the highly metamorphosed late Proterozoic and Lower Cambrian rocks, and in the Cambrian and late Palæozoic (Cache Creek group) limestones; (2) deposits in, or grouped around and apparently related to, the Omineca intrusions; and (3) deposits in post-Paleocene faults.

Deposits in the Proterozoic and Lower Cambrian Rocks, and in the Late Palæozoic Limestones

Mineral deposits in the Lower Cambrian and late Proterozoic rocks, and in the late Palæozoic (Cache Creek group) limestones, are, with the exception of relatively unimportant pyrometasomatic pyrrhotite deposits at the contact of a small stock, typically of the silver, silver-lead, and silver-lead-zinc types.

As noted in Chapter IV, although the Cambrian and Proterozoic rocks have been subjected to intense metamorphism and local granitization, the only apparently definitely intrusive body of any size is a granodiorite stock east of Blackpine Lake. Along the borders of this body, associated with typical diopside-garnet-tremolite skarn and feldspathized gneissic quartzite, are several deposits of pyrrhotite containing minor amounts of pyrite, arsenopyrite, and chalcopyrite. The deposits, as for example those of the Hope group, do not appear to have any commercial significance.

The Ruby prospect, on Jim May Creek, is in quartz-mica schists of the Tenakihi group near small feldspar porphyry and granophyre stocks and sills. Here a northeasterly trending, silicified fault zone is erratically mineralized by sphalerite, pyrite, galena, tetrahedrite, ruby silver, and arsenopyrite. Similar minerals have been found in the Tenakihi group rocks east of the head of Jim May Creek.

Small veins in Tenakihi quartzites and schists south of Mount Lay contain galena, tetrahedrite, and ruby silver.

The deposits of the Orion group, in Tenakihi quartz-mica schists on Orion Creek, consist of quartz veins mineralized with galena and some pyrite and tetrahedrite.

The metallic mineral deposits in the Ingenika group are, with one exception, confined to the limestones or calcareous argillaceous rocks. The largest known deposits are those of the Ferguson group, near Lookout Hill in Ingenika River Valley. There, thick-bedded, relatively pure limestone, locally highly silicified, has been largely altered to siderite and replaced along bedding planes by crystalline galena and sphalerite, with minor pyrite, pyrargyrite, tetrahedrite, chalcopyrite, and marcasite. The best deposits are confined to four bed-like bands, 2 to 8 feet thick, which have been traced for about 450 feet down the dip.

At the Onward property, 1¼ miles south and considerably lower stratigraphically than the Ferguson deposits, small, flat-lying, sheet-like bodies of relatively coarse-grained galena and sphalerite are found lying parallel with thinly bedded, silicified, iron-stained limestone.

Mineral deposits of both the fracture-filling and replacement types are found in closely folded and sheared argillites and impure limestones on the Swannell group of claims. Quartz veins and silicified beds, sporadically mineralized with sphalerite, galena, pyrite, and chalcopyrite, occur at frequent intervals across an exposed width of about 450 feet. The best showings are in quartz veins lying parallel with the bedding.

The large bed of limestone forming the crest of the ridge east of the mouth of Tenakihi Creek contains a vein about 1 foot wide composed almost entirely of fine-grained galena.

The deposits of the Beveley group, a few miles east of the above showing, consist of low-grade, widespread replacement bodies and disseminations of galena and very minor sphalerite, accompanied by much barite, in a highly folded, sheared, dolomitized limestone near a prominent shear or fault zone.

In what is probably the same belt of rocks, about 3 miles east of the east border of the map-area, the Childhood Dream deposits consist of massive to coarse-grained pyrite, accompanied by galena and sphalerite, as irregular replacement bodies and breccia fillings near a steeply dipping fault in blue-grey to rusty, coarsely crystalline limestone.

The Weber group of claims occurs in massive, unaltered Cache Creek limestone south of Osilinka River near Wasi Creek, and contains galena, pyrite, and barite in a strong, northwesterly trending fracture zone.

The Davies group of claims, 3 miles east of the Weber group, includes fissure vein and low-grade irregular replacement deposits of sphalerite, with lesser galena and pyrite, close to faults in relatively massive limestone believed to be part of the lower limestone member of the Cache Creek group.

Metallic mineral deposits that are not of the distinctive lead-silver type are rare in the Tenakihi, Ingenika, or Cache Creek group rocks distant from igneous contacts. One such deposit is on the Burden group of claims, due east of the Ferguson deposit. The Burden showing is in talcose sericitic schists, and consists essentially of a large quartz vein sparsely mineralized with chalcopyrite. Another deposit is found on the east side of Pelly Creek Valley, near the north boundary of the map-area, where a shear zone up to 12 feet wide in brecciated limestone contains much pyrrhotite, with lesser amounts of pyrite, chalcopyrite, and bornite.

Deposits Apparently Related to the Omineca Intrusions

Evidence of mineralization is widespread in the upper parts of the late Palæozoic formations, in the Takla group rocks, and in the Omineca intrusions, and all of it appears to have some genetic connection with these intrusions. Several metallic mineral deposits are found along the eastern margin of the Hogem batholith, and almost all other known deposits are found close to or along the contacts of small intrusive bodies, which, presumably, were emplaced during the main period of intrusion.

A few deposits are found along shear zones in the intrusive bodies themselves. Types of deposits range from disseminated minerals in the pre-batholithic rocks to simple, fissure-filling quartz veins.

The Hogem batholith contains many shear zones mineralized with pyrite and copper sulphides, but most of such deposits carry no appreciable content of the precious metals. One of the largest of these mineralized shear zones occurs at the head of the east fork of Matetlo Creek. There, closely spaced fractures form a permeable, mineralized zone at least 120 feet wide in medium-grained granodiorite. The fractured rock is sparsely but uniformly mineralized with pyrite, chalcopyrite, and bornite. The zone also contains five veins, 2 to 10 inches wide, composed almost entirely of pyrite and chalcopyrite.

Small quartz veins in sheared quartz diorite exposed in the canyon on Haha Creek contain a little free gold.

The complex of sedimentary and volcanic rocks cut by small intrusive bodies along the west border of the map-area between Mesilinka River and Lay Creek contains several heavily pyritized bands up to 1,000 feet wide and several miles long. These bands traverse rocks of several types, but are commonly centred around a diorite dyke or sill. One of the pyritized bands of this type exposed at the Granite Basin workings contains minute amounts of chalcopyrite, tetrahedrite(?), and magnetite, and is reported to carry up to $\frac{1}{3}$ ounce gold a ton across a width of 30 feet.

Quartz veins are numerous in many parts of the area. Those cutting the Hogem batholith are for the most part barren, and appear to be high-temperature veins grading into quartz-feldspar pegmatite dykes. A large carbonatized shear zone on the Elizabeth group north of Osilinka River in the interior of the batholith contains many quartz veins, some of which carry gold and silver. The nearby 'Chief Thomas' vein is 6 to 10 feet wide, at least 300 feet long, and carries chalcopyrite, pyrite, bornite, and a little gold and silver.

Quartz veins are particularly numerous in an area extending northwest from Tutizzi Lake along the west border of the map-area to Lay Creek and continuing into McConnell Creek map-area to the west as far as Goldway Peak and the headwaters of Wrede Creek. The larger veins are, in general, massive white quartz, barren of sulphides or precious metals. Smaller veins, stringer lodes, and silicified shear zones exhibit wide variations of mineral content. The boss-like quartz body exposed on Porphyry Creek contains pyrite, magnetite, and molybdenite; the nearby Croydon group veins and stock-works contain massive pyrite, chalcopyrite, molybdenite, and magnetite, with fair gold content; the veins of the Shell group, whose main showings lie just west of the map-area, contain pyrite and chalcopyrite, with considerable gold and, in places, minor magnetite and erythrite. A little cobalt bloom was also observed coating fractures in small quartz veins in hornblende diorite east of Croydon Creek. Deposits up to 15 feet thick and ⅓ mile long, rich in magnetite, with minor pyrite, pyrrhotite, chalcopyrite, and gold, are exposed along the west edge of the map-area near Croydon Creek. North of Tutizzi Lake, several of the quartz veins contain crystalline galena, commonly accompanied by chalcopyrite or specular hematite. Similar veins cut hornblende diorite and appinite west of Abraham Creek.

The mineral showings on the Vega property occur in intensely faulted and sheared andesites of the Takla group. The andesite contains rounded fragments of feldspar porphyry. Chalcopyrite, pyrite, and bornite are disseminated through the andesite and concentrated along calcite veinlets.

The workings on Thane Creek expose a silicified shear zone about 4 feet wide in amphibolitized andesite near the eastern contact of the Hogem batholith. The zone carries pyrite, chalcopyrite, specularite, and magnetite, and a little gold.

Lenses of pyrite and arsenopyrite up to 50 feet long and 9 feet wide in sheared greenstone near the contact of a sill of granodiorite porphyry are exposed by the Pluto workings. They are reported to carry some gold.

The late Palæozoic rocks outcropping in the Lay Range contain relatively abundant, disseminated, finely crystalline pyrite, which appears for the most part to be the product of general metamorphism rather than hydrothermal mineralization. Stringers and veins of quartz and calcite are numerous, but most of them are small and discontinuous. In these strata, several distinct types of mineralization are represented. All deposits lie near small igneous bodies that appear to be related to the Omineca intrusions. The most widespread type of mineralization is represented on the Jupiter, Polaris, and Stranger showings by highly brecciated quartz-calcite veins or fracture zones associated with much black, lustrous graphite and mineralized with granular pyrite. Some of these veins have been found to be quite rich in gold; most of them, however, are narrow and lensy.

A different type of mineralization is represented on the Jupiter property in fissures that are older than the pyrite-bearing fracture zones. These fissures have been healed by quartz-calcite veins mineralized with sphalerite, galena, tetrahedrite, chalcopyrite, and minor pyrite, and contain, in places, more than 200 ounces of silver a ton. The known veins are for the most part less than a foot wide.

Lens-like replacement bodies of pyrrhotite and pyrite, with some chalcopyrite, occur in the argillite on Polaris Creek near small stocks and dykes of granite and andesite porphyry. These bodies, which are composed almost entirely of sulphides, attain a width of 25 feet and a length of several hundred feet, but none has been found to contain appreciable amounts of the precious metals.

Deposits Younger Than the Post-Paleocene Faults

The carbonatized fault zones cutting the Takla group and late Palæozoic rocks contain a little cinnabar near Tutizika River, on the Vega mineral claims, and near Thane Creek. These fault zones appear to be part of, or related to, major, northwest-trending faults that have displaced all of the rock-units in the map-area. The only cinnabar deposits that have been explored are those on the Vega group of claims.

CHAPTER VII

DESCRIPTION OF PROPERTIES AND PROSPECTS

INGENIKA GROUP (1)[1]

The Ingenika group consists of eight claims, staked in 1947 by Gust Ola of Fort Grahame on the south side of Ingenika River Valley near the extreme west border of the map-area. The writer was unable to find the property, but examined specimens taken by Mr. Ola. The showing apparently consists of several outcrops of drusy quartz veins mineralized with pyrite and minor amounts of galena, sphalerite, and free gold. The surrounding region is underlain by micaceous quartzites and phyllites, but a sample taken by Mr. Ola of the rock in which the veins lie is dark green porphyritic andesite. The veins are reported to be as much as 4 feet wide.

The claims also contain extensive outcrops of limonite-hematite gossan, which appears to be quite pure, without trace of rock material or sulphides. Its origin is at present unknown.

FERGUSON GROUP (2)

References: Geol. Surv., Canada: Alcock, F. J., Lead-zinc Deposits in Canada; Econ. Geol. Ser. No. 8, pp. 238-300; Dolmage, V., Finlay River District, B.C.; Sum. Rept. 1927, pt. A, pp. 37-41 (1928). British Columbia Minister of Mines: Lay, Douglas, Ann. Repts.: 1926, p. 125; 1927, p. 160; 1928, pp. 182-183; 1929, p. 187; 1930, p. 149; 1931, p. 76.

The Ferguson property is 1 mile south of Ingenika River, about 16 miles west of its junction with the Finlay. It lies about 35 miles by water from Fort Grahame. A wagon road, 22 miles long, connects the property with Finlay River a short distance above Fort Grahame. The nearest convenient supply base on a railway is the city of Prince George, 250 miles to the south.

The deposits were staked in 1917 by J. Ferguson of Prince George, who bonded his claims to the Selkirk Mining Syndicate of Victoria, British Columbia, in 1926. In 1927, Ingenika Mines Limited, Vancouver, British Columbia, was formed to promote development of the deposits, and a systematic program of surface stripping, trenching, and underground exploration was undertaken. Results obtained by the lowest underground workings were unfavourable, and operations ceased in 1932.

The showings are on a knoll, known locally as Fergusons Hill, which rises abruptly to an elevation of about 250 feet above the wide terraces on the south bank of Ingenika River. Rock exposures on the valley floor are scarce, and are almost entirely confined to low ridges and knolls near Fergusons Hill. The largest outcrops are on Lookout Hill, a 500-foot knoll 1 mile south of Fergusons Hill.

[1] Numbers, in parentheses, are those of property locations shown on accompanying map. The properties are numbered, and described, in geographic order, roughly from northwest to southeast, rather than in alphabetical sequence of property names, so that the relationship of adjoining or nearby occurrences may be more apparent.

The rock on the Ferguson property is blue-grey to cream-coloured crystalline limestone of the Ingenika group of Lower Cambrian age. In the vicinity of Fergusons Hill the limestones are in part intensely contorted, and in places are converted into a schistose rock containing much sericitic material.

In most parts of the property the bedding strikes about north 80 degrees west and dips northerly at 20 to 40 degrees. The beds outcropping on the west end of the hill have been partly to completely silicified and show all gradations from relatively pure limestone to white quartz rock. Subsequent to silicification, the limestone was attacked by iron carbonate solutions. In the highly silicified, finely bedded rock, siderite was deposited along the bedding planes so that the rock now consists of parallel laminæ of white quartz, $\frac{1}{16}$ inch to 2 inches thick, separated by layers of dense, brown siderite. In the most heavily mineralized parts quartz and siderite are in about equal proportions. In places it is possible, within a distance of 100 feet, to trace the changes along a single bed from blue-grey crystalline limestone to greyish white massive quartz rock, with faint traces of original bedding, to banded, quartz-siderite rock. In the slightly silicified limestone, and to a lesser extent in the highly silicified, massively bedded rock, the siderite is not confined to bedding planes but forms large, irregular masses up to 20 feet in diameter of very coarsely crystalline, nearly pure mineral.

Replacement of the quartz-siderite rock by pyrite, sphalerite, and galena, with lesser amounts of copper and silver sulphides, has resulted in the formation of distinct mineralized zones, which in general follow the bedding. A little sulphide mineralization is also in evidence along joint planes. The four most prominent mineralized zones have been explored by stripping and underground workings (*See* Figure 13).

The lowest zone, known as No. 1 zone, outcrops only at the west end of the southward-facing cliffs that form the crest of the hill. There a body of coarsely crystalline galena 1 foot to 2 feet thick occurs in a 20-foot band of contorted quartz-siderite rock. Where fractured, this rock contains a little pyrite and sphalerite. It has retained the original bedding structures of the limestone that it has replaced, and appears entirely conformable with the overlying and underlying unmineralized limestone. The galena body lies about 6 feet above the base of the quartz-siderite band, and is overlain by 1 foot to 3 feet of crystalline siderite heavily mineralized with pyrite and, in places, with sphalerite.

Although much deformed in detail, the quartz-siderite rock and the included galena body nevertheless show a uniform, over-all strike of north 70 degrees west, and dip 25 to 40 degrees northeast. The contacts of the mineralized zone are sharp, and in every observed case are parallel with the bedding.

What is believed to be the No. 1 mineralized zone was encountered in crosscuts from No. 4 adit, 80 feet south of the portal (*See* Figure 13). There it appears as discontinuous, lens-shaped bodies of siderite, sphalerite, and galena up to 4 feet thick lying conformably along the same horizon in well-bedded, slightly silicified, blue-grey limestone underlain by sheared sericitic limestone.

The most important mineralized zones explored to date are Nos. 2 and 3. They are well exposed at the west end of the summit of Fergusons Hill, and are explored by Nos. 1, 2, and 4 adits. These zones form two parallel bands, 3 to 10 feet wide, heavily replaced by sulphides, and separated by 1 foot to 8 feet of poorly mineralized rock lying near the middle of a series of beds, with a total stratigraphic thickness of 50 feet, that has been intensely silicified and irregularly replaced by siderite. The base of No. 2 mineralized zone lies about 30 feet stratigraphically above the No. 1 zone.

The series of beds in which Nos. 2 and 3 mineralized zones are found is much contorted, but an over-all uniformity of attitude can be traced, and mineralization seems to have taken place at the same stratigraphic intervals throughout. Wherever observed, the contacts of the sulphide bodies are controlled to a minute degree by the contorted bedding planes of the host rock. As with No. 1 mineralized zone, the most concentrated mineralization has occurred close to the beds that have suffered the most intense silicification, but separated from them by 1 foot to 5 feet of quartz-siderite rock containing a relatively higher proportion of siderite.

The highest mineralized zone, No. 4, lies about 25 feet stratigraphically above the top of No. 3 zone. It outcrops on the summit of the hill, and can be traced down the north slope to the portal of No. 2 adit. The most heavily mineralized body in this zone is from 2 to 8 feet thick. The rocks in which the sulphide body of No. 4 zone is found are highly silicified, but contain relatively less siderite than the host rocks of Nos. 1, 2, and 3 zones.

The mineral composition of all four zones is remarkably uniform. Mineralographic study[1] has indicated the presence of the following minerals, arranged in order of deposition from earliest to latest:

quartz
siderite
arsenopyrite
pyrite
pyrrhotite
magnetite (may be earlier)
sphalerite
chalcopyrite
tetrahedrite (variety freibergite)
galena
pyrargyrite
siderite (and calcite?)

Subsequent, supergene alteration has developed considerable limonite, and minor amounts of marcasite, covellite, and malachite.

Sphalerite and galena together constitute more than 90 per cent of the metallic minerals. Pyrite is locally plentiful in bodies up to 2 feet thick, immediately overlying, and replaced by, galena and sphalerite. The only silver-bearing minerals recognized as such, argentiferous tetrahedrite and pyrargyrite, were found to be much more abundant in pyrite-rich specimens than in specimens consisting chiefly of sphalerite or galena. No silver minerals have been identified in specimens of crystalline galena, although spectrographic analyses of apparently pure galena show a moderate silver content.

[1] The writer is indebted to Mr. E. Lea for assistance in the laboratory investigation of material from this deposit.

Some fracturing has followed sulphide deposition, and carbonate solutions have deposited a second generation of siderite, possibly accompanied by calcite, in the fractures so formed.

The tenor of the ore is remarkably uniform. No attempt was made by the writer to sample the individual zones. The management states (Lay, 1930) that the approximate average assay of more than one hundred samples from Nos. 2, 3, and 4 mineralized zones was: silver, 7 ounces a ton; lead, 15 per cent; and zinc, 7·5 per cent, across a width of 8 feet.

It is evident that mineralization in these deposits was controlled to a large extent by the structure of the folded limestone beds. In general the mineralized beds strike approximately east and dip north at an angle roughly the same as that of the northern slope of Fergusons Hill. The underground workings, consisting of four main adits, Nos. 1, 2, 4, and 5, were driven from the north slope of the hill to probe the continuation of these beds at depth. No. 1 adit, whose portal is close to the lowest outcrop of the No. 3 mineralized zone, exposes almost continuous sulphides for a length of 140 feet. A crosscut from this adit shows Nos. 2 and 3 zones to be heavily mineralized across a combined stratigraphic thickness of about 15 feet.

No. 2 adit, at the same level as No. 1, was driven on the lowest exposure of mineralized zone No. 4. This zone has a slightly flatter dip than the hillside, so that its lower parts have been removed by erosion. An eastward-trending drift from this adit, driven just under, and parallel with, the surface of the hill, shows evidence of almost continuous mineralization throughout its length of 70 feet. A crosscut 60 feet long intersects No. 3 mineralized zone, which at this point is about 3 feet wide and contains abundant galena and sphalerite associated with pyrite and pyrargyrite.

No. 4 adit was driven from 85 feet below the level of Nos. 1 and 2 adits. Drifting east and southwest from the portal has exposed Nos. 2 and 3 mineralized zones, which here cannot be accurately distinguished from one another, for a length of 250 feet. Crosscutting 90 feet south from the portal has penetrated a sphalerite deposit that may represent part of No. 1 mineralized zone. Short drifts have followed this zone for 50 feet, and have disclosed two disconnected mineralized lenses each with a maximum width of about 4 feet and a length of 20 feet.

No. 4 adit is connected with No. 1 adit by a raise 130 feet long. For most of its length this raise lies in No. 2 mineralized zone.

No. 5 adit, 80 feet below No. 4, consists of about 600 feet of main crosscut and 800 feet of exploratory workings therefrom. When visited in 1946 and 1947, the portal was caved and the workings could not be examined. It is understood, however, that although beds were penetrated that were believed to represent continuations of the mineralized zones, no appreciable evidence of mineralization was encountered. The dump from this adit contains a considerable amount of sheared schistose limestone, but no sulphide and relatively little quartz-siderite rock.

The apparently abrupt disappearance of mineralized bodies such as those contained in Nos. 2 and 3 mineralized zones, which, between No. 4 adit and the summit of Fergusons Hill, maintain a fairly uniform composition across a width of as much as 200 feet, a thickness of 8 feet or more, and a length of 450 feet down the dip, is surprising. No definite evidence of faulting below the level of No. 4 adit was obtained, although some movement may be indicated by the occurrence of sheared sericitic or talcose limestone in Nos. 4 and 5 adits and at the surface on the south side of Fergusons Hill at elevations considerably below the outcrop of No. 1 mineralized zone. It is more probable that mineralization was either not effective in the limestone beds to the level of No. 5 adit, or, if effective to that depth, that the mineralized parts have not been penetrated by the No. 5 adit workings.

From the exposures on and around Fergusons Hill, it is evident that the mineralized limestone beds are on the whole much more contorted and drag-folded than the unmineralized limestone. Mineralization is best represented where a few individual beds have been greatly thickened by drag-folding. Such deformed beds are well exposed at the summit of Fergusons Hill and in No. 1 adit along Nos. 2 and 3 mineralized zones, but in No. 4 adit the bedding appears to be much more regular. It may be that only the highly contorted parts of the limestone beds were permeable to mineralizing solutions, and that the contorted structures do not persist to the level of No. 5 adit. Structure-contours plotted on the top of No. 3 mineralized zone show a progressive increase in regularity of the bedding down to the level of No. 4 adit. The known mineralized band in this zone shows a decided northeast rake across the bedding. If the favourable limestone beds and the mineralized band in them are projected to the level of No. 5 adit, the mineralized areas would appear to pass to the east of the main crosscut, about 250 feet from the portal, near the point from which four exploratory workings radiate.

Fergusons Hill as a whole is structurally much more complex than most other known parts of the limestone belt in which it lies. The general structure of the area has not been completely deciphered, but it would appear that Fergusons Hill lies near the nose of a large drag-fold, plunging to the north, on the west limb of a major anticline that has been overturned to the west. Within any one mineralized zone, the individual mineralized bodies are lens-like, being thickest on the crests of small folds and thinning or pinching on the limbs. There is some indication that the whole west end of the hill represents the crest of an anticline whose axial plane passes through the top of the hill near the outcrop of No. 3 mineralized zone. If this is so, it is possible that stratigraphically lower limestone beds may be mineralized in the vicinity of the axis of this anticline.

ONWARD GROUP (3)

References: **Lay, Douglas: Ann. Rept., B.C. Minister of Mines, 1928, p. 184; 1930, p. 151.**

The Onward group lies south of Delkluz Lake, about 1½ miles due south of the Ferguson group. It is owned by Ingenika Mines, Limited, and was explored at the same time as the Ferguson group.

The most important showings on this group are almost at water's edge on the south shore of Delkluz Lake. Here a thickness of about 25 feet of contorted and brecciated limestone of the Ingenika group has been replaced by quartz and siderite over an area at least 60 feet square. Discontinuous lenses, up to 3 feet thick, composed mainly of galena, sphalerite, and pyrite, occur in the upper part of the exposed section. The largest observed lens is nearly flat-lying; is quite heavily mineralized; and occupies an area about 30 feet long and 20 feet wide. Stripping and trenching in the vicinity have failed to expose any significant extension of this deposit, nor has a total of 210 feet of underground workings, directly beneath the mineralized outcrop, revealed any significant indications of lead-zinc mineralization.

Approximately 1,000 feet south of these workings considerable stripping has been done and a shaft sunk to a depth of about 30 feet in brecciated limestone partly replaced by siderite. The shaft encountered a small deposit consisting of relatively coarse-grained, dark brown, resinous sphalerite and finer grained crystalline galena in a creamy, fine-grained groundmass of calcite. This deposit is unique for the vicinity of the Ferguson and Onward properties in that it is found in a breccia that appears to cut across, rather than follow, the bedding of the limestone.

BURDEN GROUP (4)

References: Dolmage, V.: Geol. Surv., Canada, Sum. Rept. 1927, pt. A, p. 35 (1928). Lay, Douglas: Ann. Rept. B.C. Minister of Mines, 1928, p. 185.

The Burden group consists of two claims, the Burden and the Ruth B., staked in September 1927 by E. H. Burden of Prince George. They are on the east bank of Swannell River about 5 miles above its confluence with the Ingenika. The property is about 3½ miles due east of the main workings of the Ferguson group.

The mineral showing on the Burden group consists of several irregular masses of white vein quartz in a highly calcareous talc-sericite schist of the Ingenika group. The quartz is cut by veins and patches of cream-coloured, coarsely crystalline calcite, and contains a few blebs and stringers of pyrite and chalcopyrite.

About 100 feet downstream from the main quartz showing lies a boulder, 2 by 2 by 4 feet, of solid, massive to fine-grained pyrite and chalcopyrite, with blebs of white to bluish quartz and minor covellite and bornite. Undoubtedly much of the work done on this property was undertaken with a view to finding the ledge from which the boulder was derived. It seems probable, however, that the boulder has travelled far, for it is well rounded, and the quartz in it is quite unlike the milky, opaque variety seen in place on the claims.

SWANNELL GROUP (5)

References: Lay, Douglas: Ann. Rept. B.C. Minister of Mines: 1927, p. 189; 1928, p. 180; 1929, pp. 184-430.

The Swannell group of mineral claims is on Swannell River about 10 miles from its mouth, 3 miles by trail south of Delkluz Lake. The deposits have been known for many years, and have been staked at intervals by various residents of the district. They are at present held by Gust Ola of Fort Grahame.

The showings lie on both banks of Swannell River, which at this point flows easterly through a broad, flaring, drift-covered valley containing few rock outcrops. Very little development work has been done on the showing, and exposures are chiefly the result of erosion on the steep banks of the river, which has cut a trench 10 to 40 feet deep and 60 feet wide.

The mineral deposits occur in dark grey to black argillaceous schists and slates, interbedded with thin-bedded, blue-grey, impure limestone of the Ingenika group. The rocks are highly sheared and contorted, and, although they have a general northwest strike and a vertical or steep northeast dip, it is probable that such attitudes are those of parallel limbs of isoclinal folds, and that the strata at this point lie near the trough of a major, northwesterly trending syncline whose northeast limb is overturned to the southwest. Shearing planes are in general parallel with the limbs of the folds, and much graphitic material has formed along them. The rocks contain numerous veins and stringers of white quartz, many of which follow partings between bedding planes and have been shattered by shearing movements and intricately folded. The largest of these veins is about 2 feet wide, but, due to isoclinal folding, as much as 8 feet of white quartz, separated by thin graphitic partings, is exposed in places.

Three distinct types of mineral deposits have been recognized on the claims. Many of the quartz veins are sparsely mineralized with pyrite, and a few carry small streaks of galena and sphalerite. Some fractures in these veins contain malachite and covellite. Metallic sulphides compose no more than 5 per cent of the rock volume of any of the observed veins of this type, and few of the streaks of galena or sphalerite are more than an inch thick. Much of the limited amount of exploratory work done on the claims has been directed toward examining these veins, and one vein, about 20 inches wide, isoclinally folded to a maximum width of about 8 feet, has been shown to have a length of at least 165 feet.

A second, more promising type of deposit is represented by beds of blue-grey, thin-bedded limestone almost completely replaced by quartz, crystalline calcite, sphalerite, galena, and a little pyrite. The original limestone had been contorted into small drag-folds, and these structures have been preserved faithfully during subsequent mineralizing processes, so that original bedding structures can be traced across bodies of nearly solid sulphides. In many specimens the galena is concentrated into distinct bands relatively free from sphalerite, whereas adjacent areas of sphalerite contain little or no galena. Replacement by sulphides is irregular, and inclusions of unaltered limestone are common. The largest deposit of this type is 2 to 4 feet thick, and contains about 40 per cent sulphides. It has been exposed at intervals for a length of 170 feet. A sample of one of the galena-free bands assayed: gold, 0·005 ounce a ton; silver, 0·53 ounce a ton; lead, 1·45 per cent; and zinc, 28·13 per cent. Two selected samples of the best galena-sphalerite ore from different parts of the deposit averaged: gold, 0·02 ounce a ton; silver, 8·14 ounces a ton; copper, 0·05 per cent; lead, 24·64 per cent; and zinc, 27·36 per cent.

The third type of mineral deposit is represented in a single bluff on the north bank of the river. Here, blue-grey limestone, intensely brecciated and silicified, has been mineralized with coarse granular pyrite and varying amounts of fine crystalline galena and sphalerite. The ore minerals occur in several distinct bands parallel with the bedding, which dips vertically or steeply northeast. The westernmost mineralized band, lying adjacent to rusty, sheared argillite, consists of about 10 feet of bedded silicified limestone containing approximately 10 per cent metallic sulphides, chiefly coarse, individual grains of pyrite and fine granular sphalerite and galena in thin seams along bedding planes. A representative sample of this material assayed: silver, 0·95 ounce a ton; copper, 0·01 per cent; lead, 4·45 per cent; and zinc, 4·29 per cent. Farther east is a band 2 to 4 feet thick, of much brecciated limestone almost completely replaced by metallic minerals. Typical samples from this bed consist of approximately 70 per cent coarse granular pyrite, and 10 per cent galena and sphalerite, with minor chalcopyrite, quartz, and iron-bearing carbonate. The pyrite-bearing rock is succeeded to the east by 6 feet of well-bedded, highly contorted, silicified limestone, about 20 per cent of which has been replaced by fine-grained galena and sphalerite. A sample of a sphalerite-rich band in this deposit assayed: silver, 0·80 ounce a ton; copper, 0·10 per cent; lead, 1·69 per cent; and zinc, 18·5 per cent. East of the contorted galena-sphalerite body is a band about 3 feet thick heavily mineralized with coarse pyrite; this band is in turn succeeded by 4 to 8 feet of highly brecciated, silicified limestone containing coarse pyrite, an iron-bearing carbonate, and fine-grained galena, with a little sphalerite. A selected sample of this material assayed: gold, 0·025 ounce a ton; silver, 0·85 ounce a ton; copper, 0·02 per cent; lead, 4·4 per cent; and zinc 0·25 per cent.

Almost all of the significant mineral showings observed on these claims occur in a 200-foot section along the river banks. Several prospect pits have been dug in the drift-covered valley floor at various distances back from the river, but few have reached bedrock and no mineral deposit has been encountered. One pit has disclosed sheared, carbonatized material containing considerable mariposite.

ORION GROUP (6)

The Orion group of mineral claims is located in the valley of Orion Creek, about 2 miles north of its junction with Swannell River Valley. The claims were staked for The Consolidated Mining and Smelting Company of Canada Limited. No significant exploratory work has been done on the deposit.

The showings are in grey and brown, medium- to fine-grained, steeply dipping, well-bedded, micaceous quartzites that are referred with some doubt to the upper parts of the Tenakihi group. The quartzites are cut by a few aplitic dykes up to 3 feet wide, and contain massive white quartz veins parallel with the bedding planes. These quartz veins are cut by smaller veins of smoky grey quartz that in some places contain scattered crystals and irregular bodies up to 4 inches by 1 foot of galena with lesser tetrahedrite. The proportion of sulphides is low in the exposures examined.

'PORPHYRY CREEK' WORKINGS (7)

Reference: Lay, Douglas: Aiken Lake Area, British Columbia; B.C. Department of Mines, Bull. No. 1, p. 14 (1940).

'Porphyry Creek' is the local name for a small northern tributary of Kliyul Creek near the extreme west border of the map-area, about a mile west of Croydon Creek and 10 miles by trail from the west end of Aiken Lake. The claims on this creek were explored by The Consolidated Mining and Smelting Company of Canada Limited. Workings include open-cuts and an adit 10 feet long.

The mineral occurrences consist of narrow veins and disseminated deposits of pyrite, chalcopyrite, and molybdenite, associated with large masses of white quartz in medium-grained, dark green hornblende diorite of the Omineca intrusions. Stripping and natural erosion have uncovered quartz at intervals over an area 200 feet long and 60 feet wide, but because of the large quantity of stream gravels that blanket the deposit, it could not be determined whether the quartz belongs to one large or several smaller bodies. Within the quartz are lensy veins of pyrite and molybdenite up to 4 inches wide, the best exposed of which can be traced for about 20 feet. Stringers of chalcopyrite up to ½ inch wide cut both the quartz and the hornblende diorite, and appear to represent a stage of mineralization distinct from that of the pyrite-molybdenite veins. The average sulphide content of the deposit is very low, and assays for precious metals have not been encouraging.

The stream gravels contain boulders of rusty, porous magnetite, which, when crushed and panned, show a few 'colours' of gold.

MAGNETITE DEPOSITS NEAR 'PORPHYRY CREEK': SHELL GROUP

Reference: Lord, C. S.: McConnell Creek Map-area, Cassiar District, British Columbia; Geol. Surv., Canada, Mem. 251, p. 60 (1948).

Bands of magnetite similar to those that must have supplied the boulders in 'Porphyry Creek', referred to above, are known from at least three places within the watershed of Croydon and 'Porphyry' Creeks. The largest exposed band outcrops mainly on the Shell group of mineral claims, which lies in McConnell Creek map-area just west of the border of Aiken Lake map-area, about 2 miles from the 'Porphyry Creek' workings. The magnetite band outcrops in Takla group volcanic rocks cut by several small intrusive bodies on the mountain slopes above Kliyul Creek, and is spatially distinct from the chalcopyrite-pyrite deposits on the main body of Shell group claims, which have been described elsewhere (Lord, 1948, p. 60). The band is 15 to 20 feet thick, and is exposed in two segments, with a combined length of more than 1,600 feet, separated by a fault gap of 600 feet. Throughout this band the magnetite content appears to be almost everywhere greater than 10 per cent, and a few bodies up to 5 feet thick and 50 feet long are composed almost entirely of granular magnetite. The magnetite is accompanied by relatively small amounts of pyrite, pyrrhotite, and chalcopyrite, with some gold, which is reported to have been found in grains large enough to be seen with the naked eye. Exploration of this deposit by Springer, Sturgeon Gold Mines, Limited, has indicated that the copper mineralization, and most probably the gold mineralization, is later than the fault that offset the rocks containing the magnetite bodies. No magnetite has been found in the fault, and it appears that the magnetite was deposited earlier than the sulphide minerals.

CROYDON GROUP (8)

Reference: Lay, Douglas: Aiken Lake Area, British Columbia; B.C. Department of Mines, Bull. No. 1, pp. 8-19 (1940).

The Croydon group of claims lies about 9 miles by trail from the west end of Aiken Lake on the lower part of Croydon Creek, a tributary of Kliyul Creek. The claims are owned and were explored by The Consolidated Mining and Smelting Company of Canada Limited. Operations ceased when the camp was destroyed by forest fire in 1938. At present, six claims are held in good standing.

The deposits lie in nearly parallel, steeply dipping shear zones in medium-grained hornblende diorite. The shear zones vary in width from a few inches to about 30 feet, and contain lenticular bodies of vein quartz, usually with free walls. The individual quartz bodies are seldom more than 2 feet wide, but an interlacing network of them, separated by thin partings of sheared altered hornblende diorite, in many places occupies the entire width of the shear zone. The sheared hornblende diorite has been largely altered to a soft, green, chloritic material, which in places is probably antigorite serpentine.

The quartz is irregularly mineralized with massive to crystalline pyrite and chalcopyrite. Metallic minerals do not comprise more than about 5 per cent of most of the veins examined, but local concentrations of almost solid sulphides form lenses up to 2 feet wide and 15 feet long. Small amounts of magnetite, molybdenite, gold, and an unidentified soft, silvery mineral accompany the pyrite and chalcopyrite. The ore minerals are confined mainly to the quartz bodies, but in a few places the sheared hornblende diorite is pyritized. Later fractures cutting through the quartz and the ore minerals have been filled with a cream-coloured carbonate mineral, probably calcite.

Exploratory work has been concentrated on four, quartz-filled shear zones that lie within a belt 250 feet wide on the southwest side of Croydon Creek (*See* Figure 14). Each of the shear zones strikes about north 10 degrees east and dips steeply southeast. The two most easterly of these shear zones are actually parts of the same broader shear zone, and are separated by 5 to 20 feet of sheared rock containing small, erratically distributed quartz lenses. The eastern part of this broad zone is known by the owners as 'vein No. 13', and is visibly mineralized for a length of 270 feet. As its northernmost exposure, the 'vein', or quartz-rich part of the shear zone, is 6 feet wide and contains an aggregate width of 4 feet of rusty, fractured, sparsely mineralized quartz. A sample across 5½ feet at this point assayed: gold, 0·03 ounce a ton; silver, 0·13 ounce a ton; and copper 0·01 per cent. Southward from this point 'vein No. 13' pinches and swells, and the vein matter consists of a series of lenticular quartz stringers and veinlets, with an average total width of about 2 feet. In places it is abundantly mineralized. A sample of almost solid, massive to granular pyrite from the dump, very similar to that found at, and believed to be from, the central part of this 'vein' assayed: gold, 0·105 ounce a ton; silver, 0·70 ounce a ton; and copper, 0·32 per cent. At the point farthest south on 'vein No. 13' penetrated by underground workings, the quartz-rich part of the shear zone is more than 10 feet wide. A sample

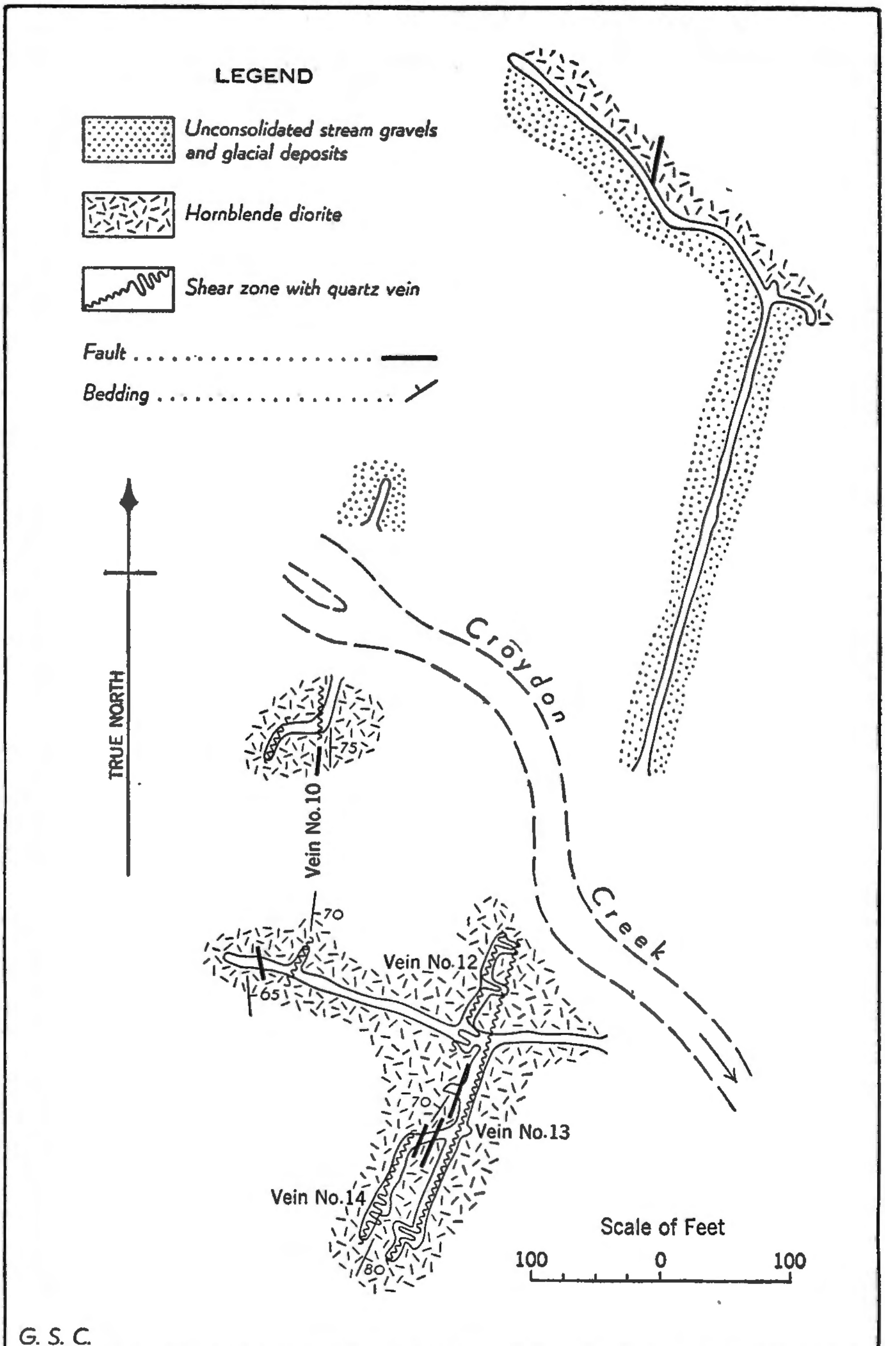


Figure 14. Underground workings on the Croydon group.

across 6½ feet of this, including 4 feet of quartz carrying about 5 per cent sulphides, assayed: gold, 0·005 ounce a ton; silver, 0·055 ounce a ton; and copper, 0·03 per cent.

The western part of the broad shear zone that includes 'vein No. 13' also contains, at the outcrop on the creek and in the northermost underground working southwest of the creek, a network of quartz lenses and veins. This network has been called 'vein No. 12', and has been explored for 80 feet. Throughout this length the 'vein' is about 10 feet wide, consisting in most places of a central quartz vein 4 to 5 feet wide flanked by lenticular subsidiary veins. A sample across 5 feet at the most northerly face of the underground workings on this 'vein' assayed: gold, 0·095 ounce a ton; silver, 0·28 ounce a ton; and copper, 0·88 per cent. A sample from the same place, taken by Douglas Lay of the British Columbia Department of Mines, assayed (Lay, 1940, p. 11): gold, 0·4 ounce a ton; and copper, 0·9 per cent. A sample across 11 feet of the broad shear zone, containing 'vein No. 12' and much of the sheared material between 'vein No. 12' and 'vein No. 13', taken 35 feet south of the above mentioned face, assayed: gold, 0·02 ounce a ton; silver, 0·10 ounce a ton; and copper, 0·04 per cent. A selected sample from broken rock piled in the drift at this point, consisting of about equal amounts of milky quartz and sulphides, assayed: gold, 0·26 ounce a ton; silver, 1·61 ounce a ton; and copper, 5·86 per cent. The aggregate of lens-like quartz bodies with sheared chloritic partings composing 'vein No. 12' pinches abruptly to a width of about 5 inches, 80 feet south of its outcrop on the creek bank. Underground workings farther south along the western side of the broad shear zone have penetrated only sheared pyritized hornblende diorite.

The next important shear to the west, called 'vein No. 14', is known at present from underground workings only. It lies about 35 feet west of the southern part of 'vein No. 13', separated from it by two distinct faults, which have displaced 'vein No. 14' upward and northward with respect to 'vein No. 13'. 'Vein No. 14' is exposed for a total length of 85 feet, and shows a maximum of 3 feet of quartz, though the average width is probably less than 1 foot. A sample across 3 feet of a typical, sparsely mineralized part assayed: gold, 0·005 ounce a ton; silver, 0·045 ounce a ton; and copper, *nil*.

An adit was driven northward on the northeast side of Croydon Creek approximately on the line of strike of these shear zones in an attempt to pick up the northward continuation of the 'veins'. The adit penetrated unconsolidated material for 380 feet before reaching smooth, glaciated bedrock. The edge of the bedrock was followed northwesterly and southeasterly for a total distance of 300 feet, but no appreciably mineralized shear zones were encountered.

The mineralized shear zone known as 'vein No. 10' outcrops as a distinct quartz vein 2 feet wide on the southwest bank of Croydon Creek, 250 feet northwest of the outcrops of 'veins Nos. 12 and 13'. The outcropping vein has been followed southerly in underground workings, and has a maximum width of about 3 feet of heavily mineralized quartz. About 45 feet south of the portal it pinches to a gouge 2 inches wide. A crosscut from the south end of the drift that followed the outcropping vein shows the ground immediately west to be much sheared for a width of 12 feet and to contain many small, mineralized, lens-like quartz veins. A grab sample from one of these veins, consisting of white fractured quartz containing massive pyrite and thin sheets of molybdenite, assayed: gold, 0·06 ounce a ton; silver, 0·35 ounce a ton; and copper, 0·71 per cent. This highly sheared band is separated by 10 feet of pyritized, slightly sheared rock from another, intensely sheared zone to the west containing a heavily mineralized quartz vein with a maximum width of 4 feet. This vein, forming the western side of the 'vein No. 10' shear zone, has been followed southerly by a drift, from the crosscut mentioned above, for 35 feet to where it pinches to a narrow, gouge-filled shear containing no quartz. A sample across 2 feet of this vein assayed: gold, 0·65 ounce a ton; silver, 0·50 ounce a ton; and copper, 1·78 per cent. Some parts of the vein are relatively rich in molybdenite and magnetite. What may be the southwesterly continuation of the 'vein No. 10' shear zone is penetrated by a crosscut extending 140 feet west from the southern end of 'vein No. 12'. A 20-foot drift driven northward from the crosscut along the 'vein No. 10' shear zone exposes a sparsely mineralized quartz vein about 4 inches wide.

Several shear zones, some containing mineralized quartz veins, occur at intervals along the banks of Croydon Creek within 2,000 feet upstream from those explored by underground workings. Some of them apparently contain considerable magnetite, for areas up to 400 feet wide of strong magnetic attraction have been outlined. A limited amount of trenching and stripping has been done on these shears, but due to excessive sloughing little information can now be gained from the workings.

Mineralographic study of samples from the deposits on this property indicates two distinct and perhaps unrelated periods of metallic mineral deposition. The most widespread mineralization is that which resulted in the deposition of the pyrite, chalcopyrite, and an unidentified, soft, silver-coloured mineral that may be a telluride. The chalcopyrite was apparently deposited contemporaneously with and after the pyrite. The molybdenite and magnetite seem to have been formed during a separate period of mineralization; the former is invariably accompanied by magnetite in this deposit. Part of the magnetite is in grains so minute that microscopic flakes of apparently clean molybdenite are affected by a magnet. Owing to the difficulty of polishing masses of soft molybdenite containing grains of hard magnetite, the relations between the molybdenite-magnetite masses and the pyrite-chalcopyrite masses were not satisfactorily observed, but it appears that stringers of molybdenite are interrupted by masses of pyrite in such a way as to suggest that the molybdenite-magnetite mineralization was the earlier of the two processes.

The precious metal content of these deposits is apparently contained mainly within the metallic minerals. Grinding of representative samples to minus 150-mesh, followed by tabling, achieved an almost complete separation of metallic from non-metallic material. Assays[1] of the products from this separation showed almost all the gold to be in the sulphide-magnetite fraction. The gold-copper ratio of the deposit appears to be fairly constant: for each 1 per cent of copper in the ore, 0·10 to 0·30 ounce of gold is carried in the sulphides. Chalcopyrite is probably the main gold carrier. Thus, material from this deposit would require concentration, and relatively higher grade material would be necessary to constitute ore than if the

[1] Run by Mr. Lawrence Adie in the laboratories of the Department of Mining and Metallurgy at the University of British Columbia.

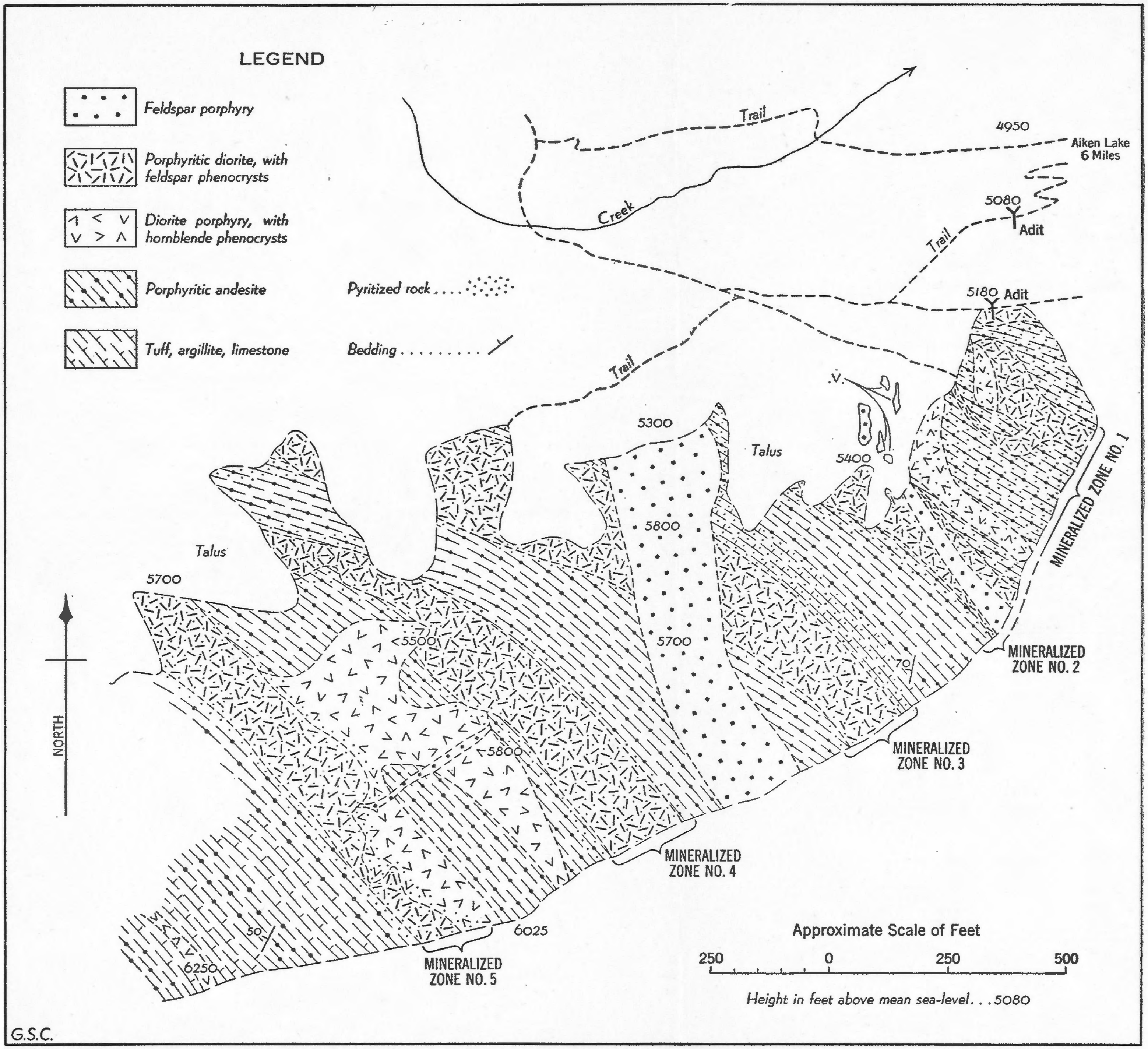


Figure 15. Sketch plan of surface geology on cirque headwall, Granite Basin mineral claim.

gold were entirely free-milling. Some of the gold, however, is apparently free, as evinced by a few, irregularly high assays. In this connection, the presence of free, relatively coarse gold in the magnetite on the Shell group of claims, and in the boulders on Porphyry Creek, mentioned above, is of interest. It may be that the free gold is associated with the magnetite-molybdenite mineralization.

The silver is, apparently, associated with the sulphides, and in most samples is 10 to 20 times as abundant as gold. The high gold assays, supposedly indicative of free gold in the quartz or with the magnetite, are not accompanied by correspondingly high silver assays. The mineral in which the silver occurs is not known.

GRANITE BASIN GROUP (9)

Reference: Lay, Douglas: Aiken Lake Area, British Columbia; B. C. Department of Mines, Bull. No. 1, pp. 15-18 (1940).

The Granite Basin group of claims, owned by The Consolidated Mining and Smelting Company of Canada Limited, covers the south wall of a northeasterly facing cirque draining into Lay Creek, 6 miles by trail from the east end of Aiken Lake. The showings consist of broad, pyritized bands in Takla group andesite and intercalated sedimentary rocks invaded by small bodies of Omineca intrusions.

The predominant rock in the immediate vicinity of the main workings is a moderately dark, grey-green, porphyritic andesite, with small black hornblende and scattered grey feldspar phenocrysts. A few beds of tuff, argillite, and impure limestone are intercalated with the andesite. This rock is cut by a grey to greenish grey 'diorite porphyry', with hornblende phenocrysts up to $\frac{1}{8}$ inch long in a fine-grained matrix. The porphyry closely resembles the andesite, and in places is difficult to distinguish from it. Contacts between the two rocks are in places sharp and definitely intrusive; in other places they appear to be gradational.

Both the andesite and the 'diorite porphyry' are intruded by a medium to light grey or buff-coloured, medium-grained to sugary, 'porphyritic diorite' with abundant feldspar phenocrysts and a few hornblende phenocrysts in a light grey, medium-grained matrix. Although individual bodies of this rock were never traced for more than 300 feet or so, the nature of their contacts and outcrop positions would indicate that they may be irregular sill-like bodies, 50 to 150 feet thick, in the andesites and bedded tuffs.

The andesite, the 'diorite porphyry', and the 'porphyritic diorite' are all cut by well-defined dykes 10 to 100 feet wide of light grey feldspar porphyry.

The andesite and the 'diorite porphyry' are generally sparsely mineralized with fine-grained pyrite, but may be well mineralized where they are in contact with the 'porphyritic diorite', which is everywhere heavily, though somewhat irregularly, pyritized.

Four pyritized bands are exposed within a horizontal distance of about 2,000 feet, between elevations of 5,150 and 6,000 feet, on the east end of the precipitous south wall of the cirque (*See* Figure 15). They appear to consist mainly of sill-like bodies of 'porphyritic diorite' trending about parallel with the bedding of the tuffs and argillites, which are well exposed farther west on the cirque wall, where they strike northeast and dip 40 to 60 degrees northwest. The most easterly of these bands is split by an unmineralized porphyry dyke about 60 feet wide, producing, at the crest of the ridge, five pyritized bands, which the owners have numbered 1 to 5 consecutively from east to west. The pyritized bands do not have definite margins, and are not uniformly mineralized. Some heavily pyritized areas, as evidenced by dark, rusty weathering patches on the cirque wall, are as much as 200 feet wide and 400 feet long.

Exploration, consisting of trenches, open-cuts, and two adits totalling 379 feet of underground workings, has been confined largely to the most easterly pyritized band. Most of the workings are in a rusty weathering, intensely fractured, friable rock containing much fine-grained, disseminated pyrite. Minute grains of chalcopyrite, and what appear to be bornite and tetrahedrite, were noted in one specimen, but copper mineralization has nowhere been sufficient to yield a conspicuous copper stain.

It is impossible to assign definite widths to the pyritized bands. Workings crossing the easternmost band are from 10 to 90 feet in length. Mr. E. Bronlund of The Consolidated Mining and Smelting Company of Canada Limited reported that encouraging assays had in places been obtained across widths of as much as 45 feet, and that the highest part of the zone carried up to $\frac{1}{3}$ ounce gold a ton across 30 feet. A sample taken by Douglas Lay of the British Columbia Department of Mines across 40 feet in the upper underground working assayed: gold, 0·2 ounce a ton.

HALQUINN AND RED DYKE GROUPS (10, 11)

The Halquinn and Red Dyke groups were staked in the summer of 1947 by independent prospectors on the 'Granite Basin' mineral zone, immediately south of and adjoining the Granite Basin claims. No exploratory work has been done on them to date.

JUPITER GROUP (12)

Reference: Lay, Douglas: Aiken Lake, British Columbia; B. C. Department of Mines, Bull. No. 1, 1940, pp. 18-22.

The Jupiter property is on the northeast side of Lay Creek, 4 miles by trail from the east end of Aiken Lake. It was staked for, and explored by, The Consolidated Mining and Smelting Company of Canada Limited. No work has been done on the property since 1937.

The wide, flat-bottomed valley of Lay Creek is underlain by andesitic flows with intercalated tuffs, argillites, and impure limestones. In its upper reaches the valley follows a longitudinal fault that brings structurally discordant members into contact; but from the vicinity of the Jupiter property to the junction of Lay Creek with Mesilinka River, the rocks are structurally conformable across the entire width of the valley and the fault appears to become an irregular shear zone 300 or more feet wide. Along this fault and shear zone, Lay Creek has incised a narrow gorge 9 miles long and as much as 400 feet deep. The fault and shear zone are provisionally placed at the contact between known Takla group rocks on the west and underlying rocks of pre-Takla age on the east. The Jupiter mineral deposits are exposed near the bottom of the gorge at the junction of Lay Creek with a small tributary stream locally known as Berry Creek. The rocks in the gorge have been considerably altered: the andesites and tuffs to smooth, shiny, chloritic and serpentinized rocks, and much of the argillite to soft, flaky, graphitic material. A small body of blocky, less friable, porphyritic rock of andesitic or dioritic composition, exposed near the portal of the 'main adit' and encountered in some of the underground workings, may be intrusive.

Two distinct types of mineral deposits are recognized on the property. One is represented by a brecciated fault zone, striking north and dipping steeply west, cemented by white quartz and cream-coloured calcite, which contains much graphitic material and is sparingly mineralized with pyrite. This fault zone has been called 'vein No. 2' by the owners. The other type of mineral deposit is represented by well-defined fissure veins striking northeast and northwest, consisting of quartz and calcite heavily mineralized with sphalerite, tetrahedrite, galena, and minor chalcopyrite, covellite, and pyrrhotite. The two largest of these veins, which strike northeast and lie to the west and east of the 'vein No. 2' fault zone, have been named vein No. 1 and vein No. 3 respectively.

Exploratory work has consisted of hydraulic stripping the steep slopes of Berry Creek gulch, and of driving two adits, one on each side of the creek. The surface workings are now completely sloughed, but it is understood that the mineral deposits were well exposed within an area of 250 by 140 feet.

The 'main adit' is driven into the west bank of Berry Creek about 50 feet above the level of Lay Creek. It consists of a drift, 795 feet long, on the mineralized, brecciated fault zone (vein No. 2) and a total of 813 feet of branch workings that explored subsidiary fault zones and the fissure veins (*See* Figure 16). Vein matter in the fault zone followed by the drift is very lensy. Pyrite is the sole metallic mineral noted, and occurs in part very sparingly disseminated through quartz, in part somewhat more abundantly disseminated through the brecciated altered wall-rocks, but for the most part as thin stringers and seams with calcite forming a matrix to the fault-zone breccia. The fault zone contains much graphitic material; lens-like bodies up to 4 feet wide, consisting almost entirely of soft, impalpable, carbonaceous matter, were noted. The best mineralized section observed was about 100 feet long and in most places less than 2 feet wide. Samples from this fault zone, taken by the owners, are reported (Lay, p. 21) to have yielded 0·31 ounce to 7·18 ounces of gold a ton across widths of 2 to 12 inches. A grab sample taken by the writer in 1946 assayed: gold, 0·135 ounce a ton; silver, 4·75 ounces a ton; copper, 0·08 per cent; and zinc, 0·60 per cent. Microscopic examination of specimens from this deposit has shown no gold; it may be that the pyrite itself is auriferous.

The sphalerite-tetrahedrite-galena deposits, represented by vein No. 1, vein No. 3, and several smaller veins, have a maximum observed width of 1 foot. Vein No. 1 has been followed by a drift for 105 feet, and vein No. 3, on the opposite side of the 'vein No. 2' fault zone, for 60 feet. The very close similarity in width, attitude, and mineralogy of veins No. 1 and

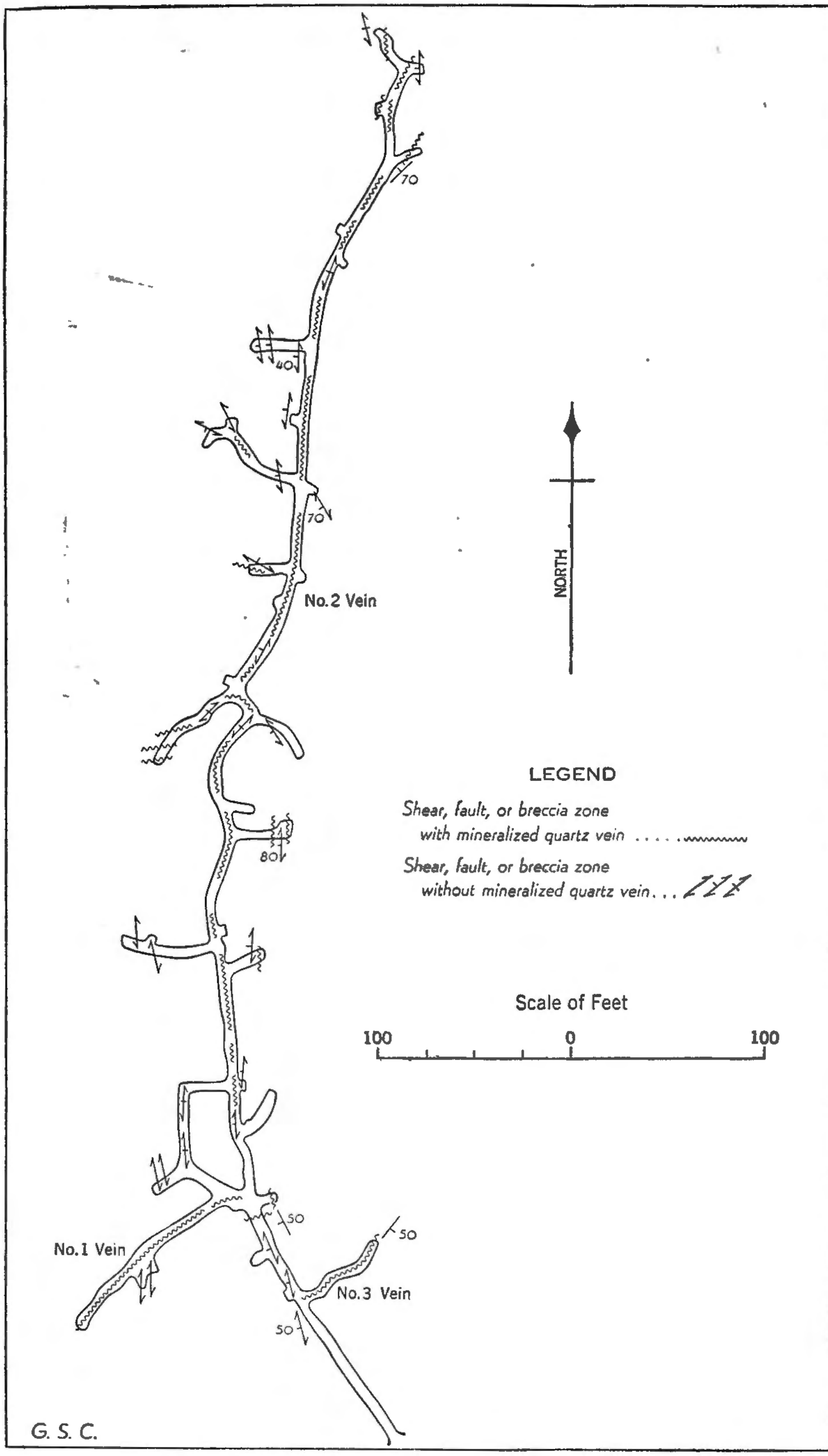


Figure 16. Plan of main adit, Jupiter mineral claims, showing veins and faults.

No. 3 suggest that they were originally parts of the same vein, dislocated by movement along the 'vein No. 2' fault zone. The walls of the fissure veins are free, indicating some post-mineral movement.

Typically, veins No. 1 and No. 3 consist of interbanded light brown sphalerite, dark brown sphalerite, and quartz. Cream-coloured calcite and white to dull grey massive quartz fill abundant fractures in the sphalerite, and contain minute grains of chalcopyrite. Tetrahedrite and galena occur as irregular patches in the sphalerite, mainly in the darker variety, and as layers up to 1 inch wide in the sphalerite and along contacts of quartz and sphalerite bands. Some covellite was also observed along these contacts.

Microscopic examination of specimens from veins No. 1 and No. 3 shows the sphalerite to have been fractured, healed by quartz and calcite, and then irregularly replaced by argentiferous tetrahedrite. Later, both the sphalerite and the tetrahedrite, but principally the latter, were replaced by galena. A still later period of fracturing was followed by deposition of a second generation of calcite and a little chalcopyrite. Pyrrhotite was identified as irregular masses in the quartz and in the tetrahedrite near quartz. Its age relative to the other sulphides is unknown.

Microchemical analysis of the galena showed no evidence of silver. The tetrahedrite, however, is the strongly argentiferous variety, freibergite.

Grab samples of veins No. 1 and No. 3 were taken by Douglas Lay in 1939 and by the writer in 1946. They assayed as follows:

Vein	Gold, oz./ton	Silver, oz./ton	Copper, per cent	Lead, per cent	Zinc, per cent
No. 1—					
1939 sample	0·02	76·3	0·6	0·4	8·8
1946 sample	0·01	91·3	1·01	8·70	30·15
No. 3—					
1939 sample	0·02	152·0	1·2	7·5	11·7
1946 sample	0·025	153·78	1·76	3·15	22·16

On the east bank of Berry Creek, an adit 160 feet long has been driven in badly fractured, sheared ground along a brecciated quartz-calcite vein with a maximum width, at the portal, of about 2 feet. The vein is sparingly mineralized with sphalerite, pyrite, galena, and tetrahedrite. As seen in the back of the adit, the vein is lensy and discontinuous, and within 100 feet pinches into small, pod-like bodies of crushed quartz. Except near the portal, little evidence of mineralization was noted.

POLARIS GROUP (**13**)

Reference: Lay, Douglas: Aiken Lake Area, North-central British Columbia; B.C. Department of Mines, Bull. No. 1, 1940, pp. 22-24.

The Polaris group, staked and explored by The Consolidated Mining and Smelting Company of Canada Limited, consists of eight claims on Polaris Creek, about a mile above its junction with Lay Creek. The property is reached by a trail, 2½ miles long, from the Jupiter workings.

A short distance upstream from the property, Polaris Creek enters a rocky gorge that increases in depth to about 300 feet at its junction with Lay Creek. The gorge exposes a complex assemblage of slaty argillite, impure limestone, tuffs, and andesitic flows cut by many small dykes and stocks of acidic to intermediate composition.

Near a small stock of quartz-biotite porphyry, calcareous and cherty, black, slaty argillites are cut by a network of small quartz and quartz-calcite veins. The veins in places are well mineralized with disseminated, banded or blebby pyrite, arsenopyrite, and pyrrhotite, with, very minor chalcopyrite. The network of veins has an observed width of as much as 3 feet; the individual veins, commonly symmetrically banded, reach a maximum width of 4 inches, but are mostly less than 2 inches wide. Remarkably high gold assays are reported to have been obtained from samples across narrow widths of some of these veins, but it is understood that the average gold content across mineable widths did not approach commercial grade.

Also exposed in the Polaris Creek gorge are several lens-like replacement bodies of pyrrhotite, with minor pyrite and chalcopyrite. The largest of these is about 30 feet wide, and is exposed on both sides of the canyon wall for a vertical distance of at least 100 feet. None of these bodies has shown a significant precious metal content.

HOPE GROUP (14)

The Hope group, staked in 1944 by O. Schmidt of Fort St. James, lies at an elevation of about 6,800 feet in a col on the crest of the ridge 2½ miles northeast of Blackpine Lake. The claims cover a fracture zone 12 to 25 feet wide and several hundred feet long in uniformly banded quartz-mica-feldspar gneiss, quartzite, and quartz-feldspar-actinolite amphibolite. Most of the fracture zone consists of fragments up to 2 feet in diameter of gneiss and bluish grey, massive quartzite partly to completely replaced by pyrrhotite, pyrite, and arsenopyrite, with very minor chalcopyrite, together with others of solid crystalline sulphides, in a matrix of massive to crystalline pyrrhotite, massive hematite, and earthy, friable limonite. Mineralization appears to be due both to replacement and fracture filling.

In other parts of the deposit bands of crystalline sulphide minerals have formed along the foliation planes of the quartz-mica-feldspar schist, giving the exposures a veined appearance.

Assays of samples from this deposit have indicated only traces of gold and silver.

STRANGER GROUP (15)

The Stranger group, staked in 1929 by H. Ravenal of Fort Grahame, is on Tutizika River about 5½ miles above its confluence with the Mesilinka. Evidence of mineralization consists of a network of narrow, quartz and quartz-calcite veins, sparsely mineralized with pyrite, in a slaty, black, somewhat sheared argillite, which is in part calcareous. The largest single vein noted was about 4 inches wide, but at one place an aggregate width of 2 feet of vein matter was distributed within a width of 10 feet of rock.

Nothing is known of the precious metal content of the veins, but in view of the fact that almost no exploratory work was done and the lease on the claims was allowed to lapse, it is assumed that assay returns were disappointing.

LEAD-COPPER SHOWING NEAR TUTIZZI LAKE

The ridge immediately north of the west end of Tutizzi Lake exposes many quartz veins containing lead and copper minerals. One of the best mineralized of these is exposed in an iron-stained zone about 30 feet wide in medium-grained diorite cutting coarse-grained hornblendite and pyroxenite. It consists of about 3 feet of brecciated, rusty quartz, which in turn contains a more compact quartz vein with a maximum width of 15 inches, heavily mineralized with galena and chalcopyrite. Assays of two grab samples of this material averaged: gold, 0·0075 ounce a ton; silver, 5·05 ounces a ton; copper, 1·44 per cent; and lead, 50·38 per cent. This vein is exposed for a length of about 30 feet.

Quartz veins are numerous in the surrounding area, some attaining a width of 3 feet and a length of several hundred feet. All contain some galena or chalcopyrite, but in general the quantity of sulphides is small, and all the veins sampled gave low gold and silver assays.

CHIEF THOMAS SHOWING (16)

The Chief Thomas showing consists of a single quartz vein in slightly gneissic quartz diorite, exposed on the south side of a peak east of the headwaters of Etschitka Creek at an elevation of 7,500 feet. The vein is 6 to 10 feet wide, at least 350 feet long, and stands vertically. Sulphide minerals are distributed at intervals across the vein, but are most concentrated and continuous along the west side of the vein, where 1 foot of quartz and 18 inches of the adjacent rock are heavily impregnated with malachite and contain many blebs and patches of bornite, chalcopyrite, and pyrite. The largest solid sulphide mass observed was 2 by 8 inches in surface area. Part of the quartz is badly fractured and 'vuggy', and contains much dark red to specular hematite. Limonite boxworks are well developed in places.

Only the western contact of the vein is exposed. Here the wall-rock has been converted, for a width of about a foot, to a fine, compact material composed largely of malachite, flanked by 1 foot to 3 feet of malachite-stained quartz diorite.

The vein has not been systematically sampled. Two grab samples, free from the larger sulphide blebs, assayed: gold, trace to 0·015 ounce a ton; silver, trace to 0·27 ounce a ton; and about 1 per cent copper.

ELIZABETH GROUP (17)

The Elizabeth group, staked in the autumn of 1946 for The Consolidated Mining and Smelting Company of Canada Limited, covers a shear zone in granodiorite and quartz diorite near the head of the east branch of Etschitka Creek. The zone contains numerous quartz and quartz-carbonate veins, in two intersecting sets, one of which is reported to have provided fairly consistent, but low, assays in gold and silver. No exploratory work was done on the deposit in 1947 or 1948.

MATETLO COPPER SHOWING (18)

The Matetlo copper showing is exposed in the precipitous wall of the cirque at the head of the east branch of Matetlo Creek. It consists of a series of fractures and veins carrying iron and copper minerals in granodiorite. The fractures are abundant across a width of 120 feet, striking north 50 degrees west and dipping 85 degrees northeast. Within this zone at least five veins, 6 to 10 inches wide, consist, typically, of coarse-grained crystalline pyrite at the centre, flanked by mixed chalcopyrite and pyrite, which, in turn, merge into a quartz-epidote border zone containing disseminated malachite and azurite. A grab sample of nearly solid pyrite-chalcopyrite ore assayed: gold, 0·01 ounce a ton; silver, 1·31 ounces a ton; and copper, 18·93 per cent.

The granodiorite between the veins is much fractured; the fractures are filled with thin seams of malachite and azurite, and small grains of sulphide, thought to be in part chalcopyrite, are disseminated through the freshly broken rock. A grab sample of this material assayed: gold, trace; silver, 0·03 ounce a ton; and copper, 2·02 per cent.

PLUTO GROUP[1] (19)

Reference: Lay, Douglas: Aiken Lake Area, North-central British Columbia; B.C. Department of Mines, Bull. No. 1, 1940, pp. 26-28.

The Pluto property consists of four claims on Pluto Creek, a small tributary of Thane Creek. It is 11 miles by pack-trail from Uslika Lake. The property, held by The Consolidated Mining and Smelting Company of Canada Limited, has been prospected by stripping the surface hydraulically.

Most of the mineral showings are in greenstone of the Takla group within 50 feet of their contact with porphyritic diorite, but a few of minor consequence are in the diorite. Both the greenstones and the diorite are here intensely sheared, in a north-northwesterly direction, roughly parallel with the contact. Most of the shear planes dip from 60 to 75 degrees to the southwest. They are probably part of a major shear or fault zone that follows Pluto Creek.

The mineral showings comprise lenses of mixed pyrite, arsenopyrite, and minor chalcopyrite along the shear planes. Lenses of the following maximum surface dimensions have been uncovered: 3 by 53 feet; 9 by 30 feet; 25 by 12 feet; 3 by 37 feet; 10 by 50 feet; and 3 by 30 feet. Gold assays up to 0·4 ounce a ton have been reported. Most of the gold is associated with arsenopyrite.

THANE GROUP (20)

Reference: Lay, Douglas: Aiken Lake Area, North-central British Columbia; B.C. Department of Mines, Bull. No. 1, 1940, pp. 28-29.

The Thane group, consisting of four claims held by The Consolidated Mining and Smelting Company of Canada, Limited, is on Thane Creek about 7 miles above its mouth. It may be reached by a pack-trail, about 12 miles long, which leaves the Germansen Landing-Aiken Lake winter road at Thane Creek crossing, ½ mile north of Uslika Lake.

[1]Reported on by J. E. Armstrong, Geological Survey of Canada.

The property straddles the contact of the large granodiorite batholith to the west with Takla group volcanic formations. Many of the andesites along the contact have been altered to green, chloritic and amphibolitic schists, which strike north 70 degrees west and dip 70 degrees northeast. Both shearing and faulting are pronounced in this direction.

The principal deposit is a silicified shear zone about 4 feet wide mineralized with a little pyrite, chalcopyrite, magnetite, and specularite. Low assays in gold have been reported.

VEGA GROUP[1] (21)

Reference: Lay, Douglas: Aiken Lake Area, North-central British Columbia; B.C. Department of Mines, Bull. No. 1, 1940, pp. 25-28.

The Vega group of ten claims is situated on Vega Creek about 6 miles above its mouth. It may be reached by a pack-trail about 7 miles long, which leaves the Germansen Landing-Aiken Lake winter road at Thane Creek crossing ½ mile north of Uslika Lake.

Six claims were staked about 1928, for The Consolidated Mining and Smelting Company of Canada Limited, and during the 10-year period ending in 1938 they were explored by surface stripping and by an adit level from Vega Creek comprising at least 500 feet of underground work. At that time the gold and copper content of the showings were of chief interest.

A little cinnabar was found on the property in 1942, and as a result four more claims were staked and much trenching done in search of mercury ore. The property has been idle since 1944.

The claims on which the showings occur are mainly underlain by northwesterly trending, steeply dipping, dark green, andesitic flows, breccias, and tuffs of the Takla group. The andesite exposed in the adit contains numerous pebbles and boulders of feldspar porphyry up to several feet in diameter. Minor interbeds of argillite and conglomerate were observed in several trenches, and Lower Jurassic fossils were collected from the argillite.

A major shear or fault zone striking north 15 degrees west and dipping 65 degrees southwest crosses the property several hundred feet west of the adit. This zone has been traced for several miles southeast of Vega Creek. It is characterized by intense shearing and alteration of the andesites to ankeritic carbonates across a width of about 200 feet.

An examination of the underground workings indicated three directions of faulting and shearing, striking about north 15 degrees east, north 65 degrees east, and north 75 degrees west respectively, with the fault planes spaced at intervals of about 20 feet. Many of these faults are marked by a few inches to 18 inches of gouge.

The main gold-copper showings, as exposed in the underground workings, consist of chalcopyrite, pyrite, and minor bornite, either disseminated through the andesite or concentrated along calcite stringers that lie along fractures. No sulphides were seen along the faults, which are apparently post-mineral. Epidote is common throughout the mineral showings. The best body of ore is reported to be about 10 feet wide and at least 25 feet long, and to average 0·25 ounce of gold a ton and 1·5 per cent copper.

[1] Reported on by J. E. Armstrong, Geological Survey of Canada.

About half a mile south of Vega Creek, cinnabar has been found in the carbonatized rocks that lie along the major fault zone previously described as crossing the property. The cinnabar occurs as minute stringers along small fractures and as individual specks. Two zones, one 15 feet wide and the other 40 feet wide, are reported to assay ½ pound of mercury a ton.

RUBY GROUP (22)

The Ruby group of mineral claims lies on both sides of Jim May Creek about 4 miles from its mouth. A tractor road about 5 miles long connects the property with the Aiken Lake winter road near mile 50, at the Tenakihi Creek crossing. The group was staked in 1944 for The Consolidated Mining and Smelting Company of Canada Limited. Exploratory work carried out in 1945 and 1946 has consisted of surface stripping by hydraulicking and bulldozing methods.

The deposits lie in highly contorted quartzites and quartz-mica schists, in part garnetiferous, of the Tenakihi group, within one of the 'trains' of anomalous structures (*See* page 41) that pass obliquely across the major anticline of Tenakihi group rocks in the vicinity. Several tabular and irregular bodies of white vein quartz up to 15 feet wide are exposed on and near the property. These are cut by sill-like bodies of buff-coloured granophyre and feldspar porphyry, and a stock of feldspar porphyry outcrops ½ mile south of the property. The mineral showings occur in a series of brecciated fault or shear zones, along which there has been repeated movement and deposition of quartz and sulphide minerals. Although the granophyre intrusive bodies were not observed to have been cut by any of the mineralized shear zones, they are affected by similar, unmineralized shears, and are thus probably older than the mineralized quartz veins.

The most persistent fault and shear zones strike north 35 to 40 degrees east and dip about 55 degrees southeast. The latest movement has been mainly directly down the dip, with the southeast side dropped relative to the northwest side. The fracture zones exposed by exploratory work are all extremely irregular, and branching, curving, 'horsetail' structures are common (*See* Figure 17). The most prominent subsidiary breaks trend north 25 degrees west and dip about 60 degrees northeast, and north 75 degrees east, dip 50 degrees southeast. It is apparent that the main, north 40 degrees east-striking zones, which cut indiscriminately through the schists, quartzites, and large barren quartz veins, were first developed, and cemented with vein quartz accompanied by a little pyrite to form a breccia zone up to 10 feet wide. This was refractured, and a complex sequence of shattering, quartz vein formation and sulphide deposition, and silicification of the surrounding rock ensued. During this period, stock-works of quartz veins and stringers along the 'main break', and numerous branching veins and irregular bodies of erratically mineralized quartz were formed. Several of the veins are vuggy. Finally, the 'main break' and a few of the subsidiary fractures suffered shearing movement unaccompanied by vein formation, and contain relatively uniform, persistent shear zones up to 1 foot wide, filled with a graphitic-appearing gouge consisting in part of finely comminuted sulphides.

The best mineralized zone is exposed in open-cut No. 5 for a length of 464 feet. It varies from two clean fissures less than 1 foot wide to a shattered zone, 60 feet across, containing more than 40 feet of vein quartz (*See* Figure 17). Most of the quartz is in veins and stringers less than 6 inches wide, commonly forming a closely interwoven network intersecting the larger, irregular bodies. Several barren, highly contorted bodies in the quartzites and schists may be much older, and unconnected with the mineralization sequence.

The aggregate content of metallic minerals in these deposits is small. The minerals recognizable in hand specimens include pyrite, sphalerite, galena, tetrahedrite, ruby silver, arsenopyrite, and, very sparingly, molybdenite and chalcopyrite. Pyrite is by far the most abundant sulphide mineral, and is found all along the main shear zones and in most of the subsidiary veins. Sphalerite, galena, tetrahedrite, and arsenopyrite are confined chiefly to the stock-works of smaller veins or to the borders of larger quartz masses, and in places occur as veins of apparently pure sulphide material up to 1 inch wide in otherwise unmineralized quartz. They are found to a lesser extent as stringers of sulphide in the quartz-healed quartzite breccia. Ruby silver (pyrargyrite) is found in the vuggy quartz veins, usually accompanied by tetrahedrite and sphalerite, and also as specks and blebs along thin fractures in the quartzite.

Mineralographic investigation[1] has shown the following metallic minerals to be present in this deposit, arranged in their apparent order of deposition from earliest to latest:

pyrite (may be considerably earlier)
molybdenite
sphalerite
pyrite
chalcopyrite
galena
tetrahedrite
arsenopyrite
pyrargyrite
polybasite
native silver

Assays are reported to have shown a good silver and fair gold content across relatively large widths in parts of this deposit.

LEAD SHOWING IN TENAKIHI CREEK VALLEY

Near the south end of the ridge east of the confluence of Tenakihi Creek and Osilinka River, an irregular, pod-shaped vein of solid, crystalline galena replaces slightly banded, dense, flat-lying limestone. The galena is exposed for only 3½ feet, and the maximum observed width was 1 foot. It shows a slight banding of coarse- and fine-grained material parallel with the banding of the limestone that it has replaced. The exposure, however, lies in a rusty, badly weathered area of limestone, and the talus on the west side of the ridge contains abundant blocks of nearly pure galena, some of the larger of which approximate the size of a 1-foot cube.

[1] The writer is indebted to Mr. W. H. Dow for much of the information resulting from laboratory investigations of specimens from this property.

Assays of samples from the outcrop and talus from this deposit show a very uniform lead and silver content, averaging silver, 45·96 ounces a ton, and lead, 83·53 per cent.

BEVELEY GROUP (23)

References: Bennett, J. H.: Ann. Rept., B.C., Minister of Mines: 1950, p. A101; 1951, p. A118.

The Beveley group is situated on a limestone ridge on the north side of the valley of Osilinka River about 3 miles east of its junction with Tenakihi Creek. The property is about 13 miles by trail from the north end of Uslika Lake. The original eight claims were staked in October 1946 for The Consolidated Mining and Smelting Company of Canada Limited, and exploratory work, consisting initially of trenching and stripping, commenced in 1947. In 1950 the deposit was mapped in detail by the owners, and a program of diamond drilling was begun the following year. The accompanying description is based mainly on a visit to the relatively undeveloped property in 1947.

The limestone formation in the vicinity of the showings appears to have been folded into a major anticline striking slightly east of north, plunging northerly at 30 to 40 degrees, and overturned to the west. This fold is truncated to the southwest by a major, steeply dipping fault. The mineral showings are on the limbs and crests of minor folds, and appear to be related to fracture cleavage.

Within the mineralized area, the limestone has been extensively altered to a grey, crystalline, largely structureless rock, which the owners state is mainly ferrodolomite and dolomite. The altered limestone has been replaced by lead and minor zinc sulphides, and by coarsely crystalline to fine-grained, bony appearing barite. Over an area of 1,500 by 2,500 feet or more, most of the exposed rocks contain a little galena, and several large bands of ferrodolomite are quite heavily mineralized (*See* Figure 18). About half the galena occurs in individual grains that are alined in closely spaced stringers, rarely more than ⅛ inch thick and 6 inches long, which appear to follow the bedding. Much of the rest of the galena occurs as fine-grained patches or blebs that also appear to follow the bedding. Many of the mineralized bands have a crescentic or hook-shaped outline. The sphalerite is in scattered, dark brown grains, and was observed only near the patches or blebs of galena.

Secondary lead minerals, principally lead carbonate, were noted in some of the exposures. The barite formed later than the sulphides, and veins the galena in places. It is most noticeable near several of the small faults and shears that terminate some of the galena-rich bodies, and is relatively less conspicuous in the most heavily mineralized areas.

WEBER GROUP (24)

Reference: Lay, Douglas; Report of the Minister of Mines of British Columbia, 1930, p. A153.

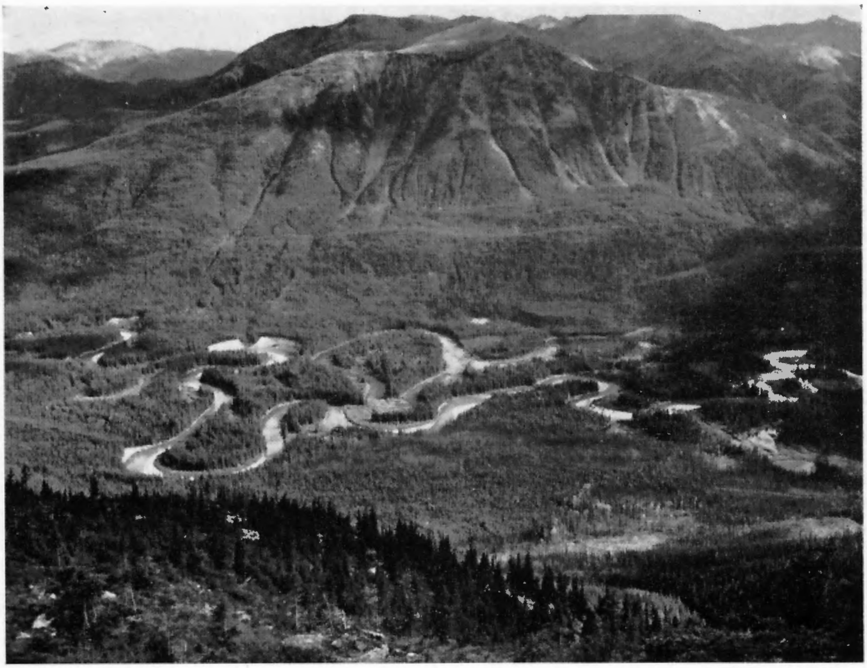
The Weber group, first staked in 1929 by F. Weber of Fort Grahame, and restaked at intervals since, is on the east side of Wasi Creek about 1½ miles south of its junction with Osilinka River. The mineral deposit on this property consists of a pyrite-galena-sphalerite-barite replacement body in limestone along the northeast side of an open fracture that strikes north 30 degrees west and dips 80 degrees northeast. The fracture appears to be related to a fault zone exposed in a creek canyon 1 mile southeast of the mineral deposit. This fault, if projected to the northwest, is approximately in line with the major fault zone near the Beveley mineral deposits.

The deposit has been traced at intervals for a length of 150 feet, and is confined to a width of about 15 feet. Within it the sulphides occur as disseminated blebs and patches in coarse-grained limestone. They are roughly in the proportion 60 per cent galena and sphalerite to 40 per cent pyrite.

A sample taken by D. Lay of the British Columbia Department of Mines across 17 feet of this material assayed: gold, 0·02 ounce a ton; silver, 1·0 ounce a ton; lead, 1·6 per cent; and zinc, 3·6 per cent.

A grab sample taken by the writer from one of the heavily mineralized bands assayed: gold, trace; silver, 2·00 ounces a ton; lead, 10·24 per cent; barite ($BaSO_4$), 4·06 per cent.

PLATE II



A. Osilinka River Valley below mouth of Tenakihi Creek, looking southeast, showing meanders and bars on outwash-filled valley floor, and glacio-fluvial terraces on valley slopes. (Pages 7, 22.)

B. View south from altitude 7,590 feet over Omineca Mountains in vicinity of Kliyul Creek, showing the complexity of topography, dominated by small cirques and short hanging valleys, and the general accordance of summit levels. One of the rare remnants of an earlier (immediate post-Glacial) erosion surface forms a narrow strip along the crest of the ridge in the foreground. The mountains are composed of Takla group rocks, cut by many bodies of the Omineca intrusions. (Pages 13, 15, 23.)

PLATE III

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A. Looking west along the crest of Wrede Range, showing smooth, rolling ridge crests, probably representing the land surface left by the Cordilleran Ice-sheet, and over-steepened ridge flanks developed by later valley glacier erosion. (Page 15.)

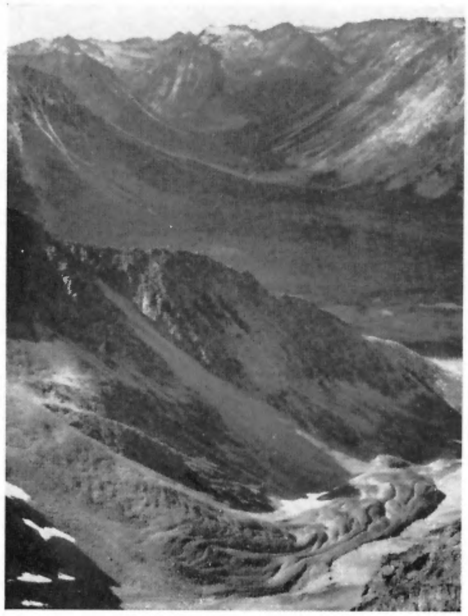
B. Kame terraces on the southwest flank of Mesilinka River Valley about 10 miles below Aiken Lake. Note that the terraces persist from the main valley into tributary valleys, whose deep filling of glacial drift has been notched by post-Glacial stream erosion. (Pages 16, 22.)

A. Southwest side of Kliyul Creek Valley, about 9 miles west of Aiken Lake, showing three distinct levels of cirque formation. The floors of these cirques are at altitudes of about 5,600, 6,300, and 7,100 feet, respectively. (Page 16.)

B. Small dying glaciers, lying below the present regional snow line, due west of the forks of Osilinka River, as seen on August 10, 1945. (Page 17.)

A. Furrows carved by surface runoff in glacial drift along north side of Ingenika River Valley at Ingenika Crag. Boulder clay and stratified silt and sand coat the valley walls up to 1,500 feet above river level. (Pages 22, 23.)

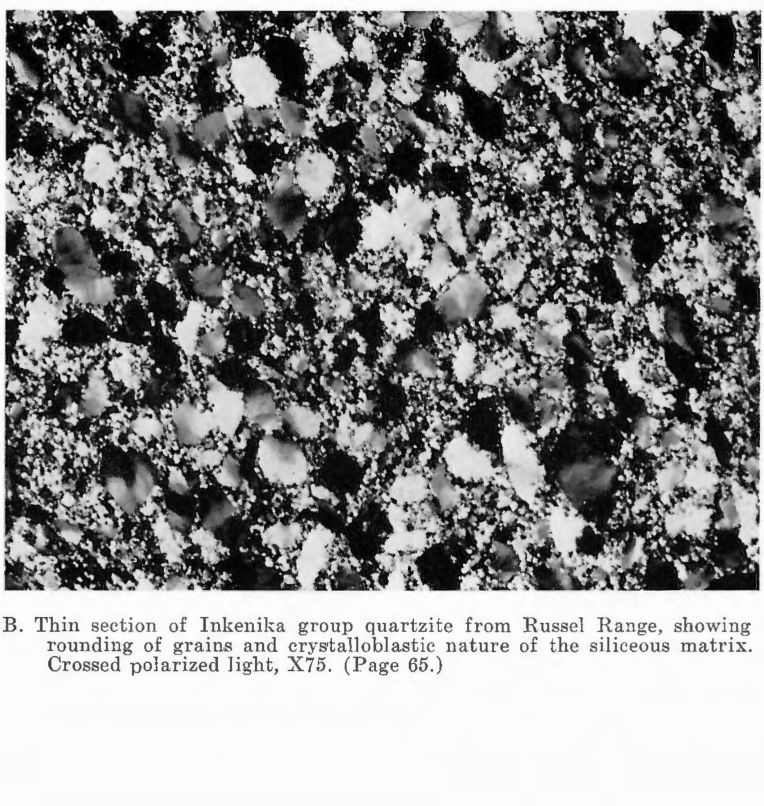
B. Felsenmeer slope in the Lay Range. This slope has an angle of about 22 degrees, and is sliding as a unit, with relatively little differential motion of the individual fragments. (Page 23.)



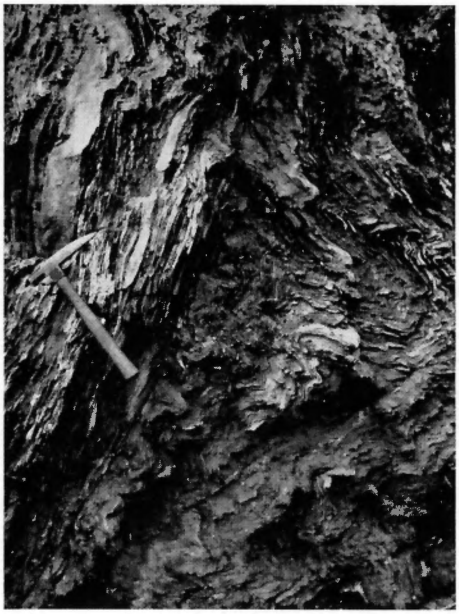
A. Well-developed rock glacier on the west side of Hornway Creek Valley. The rock glacier begins high on the cliffs to the left. descends 800 feet to the valley floor, and flows along it for 1,000 feet. The rock is gneissic diorite. Klakring Creek Valley in background. (Pages 24, 25.)

B. Bedding in Tenakihi group gneissic quartzite and quartz-mica- feldspar gneiss, at the head of Jim May Creek. Gneissosity is parallel with bedding, even at small unconformities as, for example, at the point of the pick. (Page 50.)

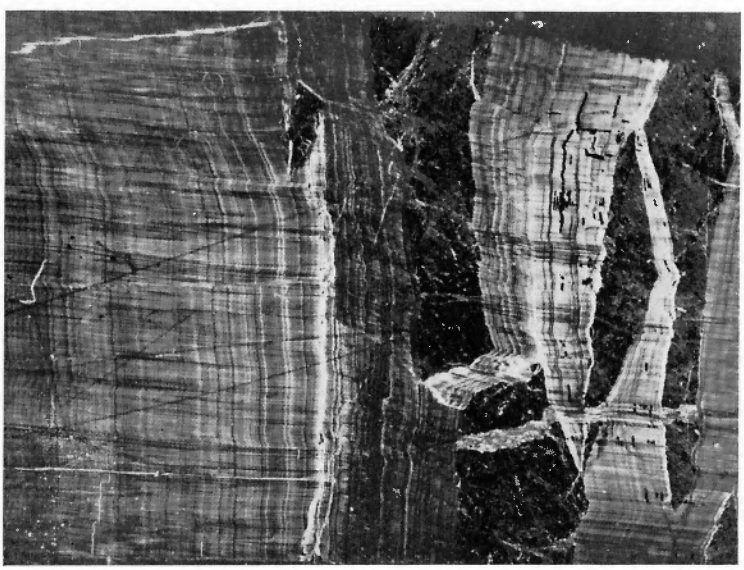
A. Banded Ingenika group limestone east of Mount Lay. Cream-coloured beds with bright purple partings. (Page 60.)



B. Thin section of Inkenika group quartzite from Russel Range, showing rounding of grains and crystalloblastic nature of the siliceous matrix. Crossed polarized light, X75. (Page 65.)

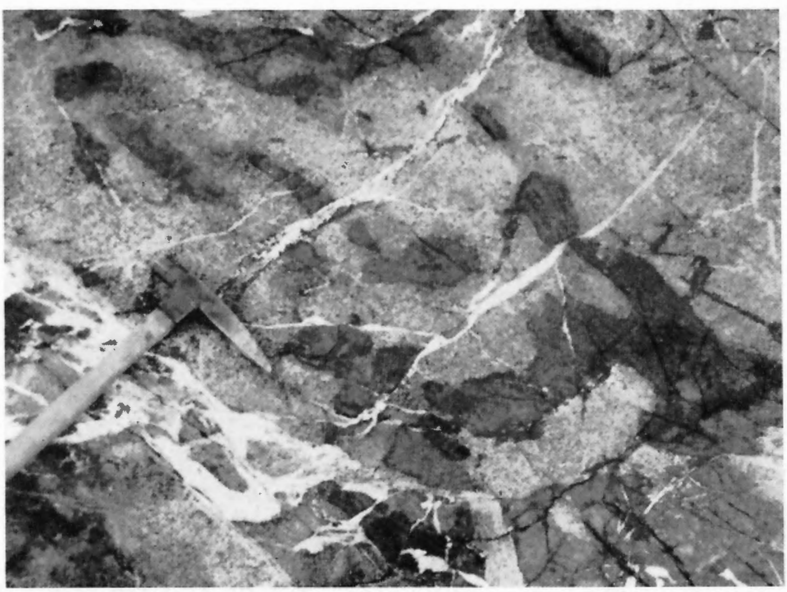


A. Detail of fault plane in sheared argillite (foot-wall) and tuff (hanging-wall) on north bank of Tutizika River about 5 miles above its mouth. Believed to be part of a compound fault forming the contact between Takla group and late Palæozoic rocks. (Pages 116, 198.)



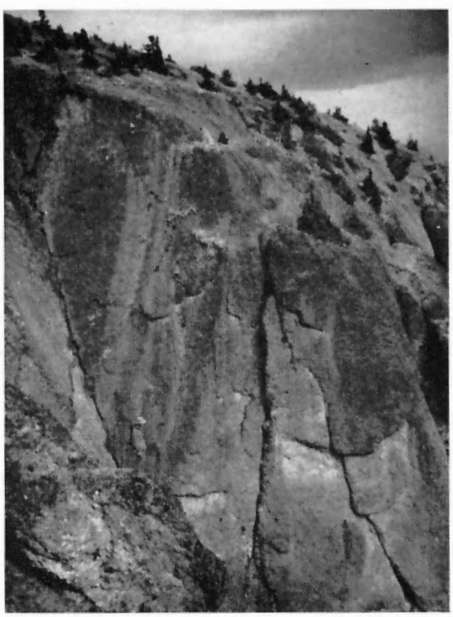
B. Thin section of fibrous chrysotile serpentine in vein cutting serpentinized peridotite largely altered to serpophite. The fibres of chrysotile are perpendicular to the apparent lamination of the vein. Crossed polarized light X25. (Pages 132, 142.)

A. Banded dyke in 'starred' appinite, west of headwaters of Abraham Creek. The banded part of the dyke is about 3 feet wide, with coarse 'starred' appinite to left, and finer, more feldspathic appinite to right. (Pages 168, 170.)



B. Partly assimilated inclusions of green, coarse-grained, 'uralite' hornblendite in grey hornblende diorite, west of the north fork of Abraham Creek. The whole mass is cut by younger feldspathic material. (Page 171.)

A. Quartz diorite near the headwaters of Abraham Creek, intruded by a dyke of fine-grained dark grey diorite, and cut by stringers and dykes of pegmatite and aplite, whose smooth curves suggest plastic deformation of the whole mass after the youngest dykes were emplaced. (Page 185.)



B. Typical exposure of Uslika formation on Conglomerate Mountain, 4 miles southeast of Uslika Lake, showing characteristic uniform, coarse texture, lack of bedding, and widely spaced joints. (Page 188.)

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