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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MEMOIR 307

ATLIN MAP-AREA BRITISH COLUMBIA

(104 N)

J. D. Aitken

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ATLIN MAP-AREA
BRITISH COLUMBIA

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Plate I

Oblique air photograph; view southwest from above Zenazie Creek. Note the manner in which each successively smaller tributary of Zenazie Creek bears a hanging relationship to the next larger stream, also the U-shaped valleys heading in cirques. Note also the glacial smoothing of 'cleavers' between cirque-valleys.

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By

J. D. Aitken

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PREFACE

The first geological mapping in the Atlin map-area was done at the turn of the century as a direct result of the interest aroused by the mining boom. Additional geological investigations have been undertaken from time to time, culminating in the work on which this report is based.

The report embodies the result of systematic mapping and the application of modern methods and ideas to the geological problems of the area. Much interesting information is presented and in due course should assist in developments of economic importance.

J. M. HARRISON,

OTTAWA, October, 1958 *Director, Geological Survey of Canada*

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Illustrations

ERRATA TO MEMOIR 307

Page 6, fifth line from bottom for "deposit (2)" read "deposit (1)".
fourth line from bottom for "rafted cobbles (2)" read "rafted cobbles (1)".

Page 11, eleventh line from bottom delete and substitute "The Coast intrusions of the map-area are not known to post-date the Laberge".

Page 12, first column, third line from bottom delete and substitute "Gabbro and diorite (15c) intrude Sloko group; quartz monzonite and granophyre (15a, 15b) are not in contact with it".

Page 13, second column, seventh line from bottom for "(12b)" read "(12d)".

Page 15, ~~fourth para., second line for "Skagway" read "Bennett".~~

Page 25, table, fifth line, for "minor chert limestone" read "minor chert, limestone".

Page 36, third line from bottom, for "Although" read "Because".

Page 45, first line, for "turbid", read "turbidity".
fourteenth line from bottom, for "sharp" read "shard".
seventh line from bottom for "of those units" read "of unit (5)".

Page 47, fourth line under first sub-head, for "Skagway" read "Bennett".

Page 48, second line under first side-head, for "diorite" read "monzonite".

Page 56, third para., second line for "of various colours, with" read ", pleochroic as follows:".

Page 66, second line of text delete sentence "Kerr......related" and substitute "Kerr, however, described intrusions from Taku River area which are so nearly identical in composition, texture, and structural relations with the Surprise Lake and Dawson Peaks intrusions that no reasonable doubt exists that they are related".

ATLIN MAP-AREA
BRITISH COLUMBIA

Chapter I

INTRODUCTION

History

On February 10, 1898, Fritz Miller and Kenneth McLaren reached Atlin Lake from Skagway, Alaska. Following the advice of George Miller, brother of Fritz, who had reached the district about 1896, they found gold on what is now Pine Creek. Returning in the summer of 1898 with six companions they continued their work. On July 3, Miller was appointed Free Miners recorder for the creek, and he and McLaren officially staked their claims on July 25. Despite the attempt of the discoverers to keep the strike secret, news of the find was known in Victoria by August 13. With the rapid spread of the news many miners bound for the Klondike turned to Atlin instead, and before the end of 1898 over 3,000 persons had visited the booming camp. In 1899 the population of the immediate district reached about 5,000 but has since decreased; the 1952 census noted the population of Atlin as 155. For an account of the district's early days the reader's attention is drawn to W. W. Bilsland's (1952)[1] research, from which the foregoing information was drawn.

Previous Geological Work

In 1899, J. C. Gwillim of the Geological Survey of Canada commenced a study of the district, and assisted in 1900 by the topographer W. H. Boyd produced a geological map of an area substantially exceeding that of Atlin map-area (Gwillim, 1901). Gwillim's map and memoir served as valuable guides during the writer's field work. The work of D. D. Cairnes (1913) extends to the west of the map-area, but overlaps it slightly. W. E. Cockfield (1925b) completed a geological traverse from Telegraph Creek to Atlin and visited several of the lode claims near Atlin. The mining activities of the region from year to year and many descriptions of properties are recorded in the annual reports of the Minister of Mines for British Columbia and several other publications of the British Columbia Department of Mines. Unpublished work by J. M. Black was kindly made available to the writer.

[1] Names and dates in parentheses are those of references cited in Bibliography at the end of this report.

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Field Work

In 1951 the writer commenced the geological study of the Atlin map-area, which is bounded by the 59th and 60th parallels north and the 132nd and 134th meridians west (map-area 104N of the National Topographic system). Field work occupied the field seasons of 1951-54, and half of 1955. The field work of 1951 and 1952 served as the basis for the writer's Ph.D. dissertation (Aitken, 1953) at the University of California, Los Angeles.

Field mapping was facilitated by complete air-photo coverage of the area. The topographic base used was the first edition of Sheet 104N, published (1954) by the Surveys and Mapping Branch, Department of Mines and Technical Surveys, at the scale of 1:250,000. Maps at the scale of 1:63,360 for the western part of the area were kindly supplied in preliminary form by the Topographic Division, British Columbia Department of Lands and Forests, and were extremely useful.

Acknowledgments

The writer enjoyed the willing and competent assistance of G. Sears and W. G. Holland in 1951; of G. L. Fletcher, N. Bohonos, and P. Hodgins in 1952; of H. H. Bostock, R. T. Peirce, and C. R. Saunders in 1953; of B. M. Hamil, L. O. Ostensoe, and H. T. Trettin in 1954; and of C. R. Saunders in 1955. Thanks are due also to residents of Atlin for their kindness and cooperation during the writer's stay.

General Character of the Area

Access and Transportation

A well-maintained gravel road connects the town of Atlin with mile 866 of the Alaska Highway, the total distance by road from Whitehorse being 118 miles. At Atlin, a gravelled airstrip and a sheltered bay suitable for use by float-equipped aircraft permit access by air.

Within the map-area, gravel roads give access to the head of Fourth of July Creek, to Ruby, Wright, and Spruce Creeks, and to the abandoned settlement of O'Donnel. About 7 miles of the Alaska Highway cut the northeastern corner of the area.

Atlin and Teslin Lakes, the latter being reached at Teslin, Y.T., on the Alaska Highway, provide access by boat and canoe to a large area. It is possible to work a canoe up Gladys River to Gladys Lake making only one short portage, but this trip is difficult at high water, which generally occurs early in June.

The numerous lakes of the area favour supply by float-equipped aircraft.

In the course of field work, the greater part of the area was reached by pack-train (with aircraft support). The few existing pack-trails were in poor condition in 1952, but the amount of effort expended in reopening old trails and cutting new ones through timbered areas was not excessive. Trail-cutting was minimized by avoiding the major valleys as horse-routes as much as possible, and by choosing routes at or above timber-line. Horse feed is abundant.

Climate and Vegetation

Department of Transport weather records from Atlin townsite indicate that in the average year measurable precipitation occurs on 69 days with a total of 11.11 inches. The average temperature of June, the warmest month, is 51°F, and that of January, the coldest, is 2°. The writer's observations over five summers suggest that the townsite is one of the driest parts of the map-area and many storms that yield heavy rain to the neighbouring mountains miss the town completely. Precipitation is greatest and the vegetation correspondingly dense in the southwestern corner of the area. As it is higher, most of the region is probably cooler than Atlin; summer frosts and snowfalls are certainly more common. The deep valleys in the south may be warmer.

In low-lying areas the forest cover is interrupted by patches of poorly drained ground occupied by muskeg. Where drainage is exceptionally good, as on many fluvioglacial terraces, grassy parkland occurs. A striking characteristic of most valleys above 3,500 feet is a wide, swampy untimbered strip along the valley axis. The timber confined to either flank of such valleys is so close to timber-line as to be of poor quality. Timber suitable for mine support is found in most of the valleys below 3,500 feet, but sawlogs are restricted to the lower parts of the major valleys.

Common trees are white spruce, western white spruce, lodgepole pine, black spruce, alpine fir, balsam poplar, trembling aspen, and several other species of aspen, alder, and willow. Only the first three species listed are used to any important extent for lumber.

Wildlife

Game animals are sufficiently abundant within the map-area to attract non-resident hunters annually. Stone sheep are fairly numerous and widespread, caribou are abundant within the central part of the map-area, and mountain goats in the southern quarter. Moose range over the entire region, but in current years are regarded by local residents to be scarce. Black, brown, and grizzly bears are widespread, the grizzly being the most frequently seen. Wolves and coyotes are not now numerous.

In years of favourable fur prices, many Atlin residents operate winter traplines. Marten and beaver are the important fur-bearing species of recent years, indeed the beaver has become very numerous as the amount of trapping is reduced.

Spruce, blue, and willow (ruffed) grouse are present, and in some years numerous. Two or more species of ptarmigan occur in large numbers.

Lake trout, grayling, and locally pike are found in the Yukon drainage; rainbow and Dolly Varden trout and coho, sockeye, and king salmon are found in the Taku drainage.

Commerce

Mining and prospecting concerns have supplied the chief nourishment to Atlin's economy since the settlement of the town, and the production of placer gold has been and still is by far the most important activity.

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A sawmill at Taku, on Graham Inlet of Tagish Lake, supplies railway ties to the White Pass and Yukon Railway. A second sawmill in Atlin markets the greater part of its lumber in Whitehorse. The provincial government employs some Atlin residents on road maintenance. The fur trade is depressed under present market conditions and many traplines and the fox and mink farms established some years ago are idle.

In earlier days, five farms were operated within a few miles of Atlin, but current agricultural activity is limited to the care of horses and the maintenance of non-commercial vegetable gardens.

The tourist industry was formerly much more actively exploited than it is today. In its setting of outstanding natural beauty and interest the Atlin region could become one of the outstanding northern resort areas, if adequately developed.

A hydro-electric power scheme of large scale is now under study in the area. The completion of this scheme might revolutionize the economy of the region.

Chapter II

PHYSIOGRAPHY

Drainage

Run-off from Atlin map-area reaches the oceans by way of four main rivers. Roughly one third of the area drains into Atlin Lake and thence through Tagish and Marsh Lakes to Yukon River. Another third of the area drains into Teslin Lake and thence by Teslin River to join the Yukon. The third principal drainage system, which also drains roughly one third of the area, is that of Taku River. The principal tributaries of this system are the Nakina, Sloko, and Silver Salmon Rivers. A small area in the southeastern corner of the map-area drains into Inklin River, itself a tributary of the Taku, via Nahlin River.

Abundant evidence demonstrates rapid capture of the Yukon drainage by the Taku system. This is not surprising when the gradients of the trunk rivers are considered; Yukon River reaches the Bering Sea about 1,650 miles from the present divide in Atlin map-area, whereas Taku River reaches the Pacific Ocean after flowing only about 80 miles.

The evidence of rapid capture of the Yukon by the Taku drainage suggests that the entire map-area may formerly have been a part of the Yukon system. A low, wide through-valley in line with the northeastward-flowing upper reaches of the Nakina River shows that the Nakina very probably flowed to Teslin River at an earlier time. The point of postulated capture is marked by a sharp elbow.

Three northwestward-flowing tributaries of the southwestward-flowing part of Nakina River line up with through-valleys to the northwest. Projected northwestward, these tributaries become the headwaters of a hypothetical drainage system of dendritic pattern, flowing towards Atlin Lake via the depression occupied by Pike and lower O'Donnel Rivers. The part of Nakina River valley cutting across the head of the postulated drainage system is of valley-in-valley form, the river canyon, more than 500 feet deep, being cut in the glacially scoured bottom of a higher and much wider valley. Evidence against the possibility that glaciation followed a preglacial river valley along this course is lacking; it is significant, however, that this crosscutting part of Nakina River valley is much narrower than those parts that might be fitted into a scheme of drainage to the northwest. During times of deglaciation, the meltwater from southward-flowing ice in this region must have played an important role in stream piracy.

A small tributary of Silver Salmon River (itself a reversed stream under the above hypothesis) has effected the post-glacial capture of the outlet of Bell Lake, a former tributary of O'Donnel River. The former channel of the beheaded stream can be traced from the elbow of capture to O'Donnel River.

Sloko River valley lacks the valley-in-valley form of Nakina River valley, and is glacially scoured almost to its floor. Its history is not clear. Gold Bottom Creek, a minor tributary, has captured a stream formerly tributary to Pike River.

The through-valley between Tseta Creek and upper Nakina River is an obvious wind gap.

The above considerations show that in preglacial times the Yukon River drainage may have extended to the southern border of the map-area at the 133rd meridian, and even farther south at the 132nd meridian.

Glaciation

Continental Glaciation

Stratigraphic Evidence

With one exception, glacial deposits exposed in cut-banks in Atlin map-area are grey or light grey-buff. Although the grey deposits are complex, commonly involving two distinct tills and/or outwashes, all are equally fresh and evidence for any important difference in age between lowermost and uppermost deposits is lacking. As the uppermost grey deposits support practically unmodified glacial depositional topography, all are assumed to be of Wisconsin age.

The exposures on either side of the hydraulic workings at Discovery on Pine Creek provide the exceptional instance. There, rusty outwash up to 40 feet thick, carrying decomposed boulders of granite and peridotite, is locally overlain by a few feet of compact rusty till of similar composition. The rusty deposits underlie grey Wisconsin till. The alteration of the rusty deposits shows their age to be pre-Wisconsin.

The Wisconsin stratigraphy cannot be correlated with any certainty between cutbanks a mile or so apart. This suggests that much of the observed complexity may reflect only minor fluctuations of an ice-front. Nevertheless, some of the relationships observed indicate significant periods of deglaciation between successive deposits. Resolution of the Wisconsin history of the area awaits detailed study, but the description of a single exposure will serve to illustrate its complexity.

The exposure here considered (*see* Plate II), is the east bank of the lowest hydraulic cut on Otter Creek. The events recorded at the point considered are as follows:

7. Deposition of clay-rich basal till (5), probably a readvance rather than a continuation of 5.
6. Probable retreat.
5. Deposition of washed till (4) by an overriding glacier. (This may be a continuation of 4.)
4. Deposition of glacial-delta foreset beds (3) in another proglacial lake during a glacial readvance.
3. Erosion of deposit (2) after disappearance of the lake.
2. Deposition of silt, sand, and rafted cobbles (2) in a proglacial lake.
1. Deposition of the lowermost outwash gravels (1) by an advancing glacier.

The depth to bedrock beneath the lowest exposed deposit is not known.

The distribution of drift is erratic; though most valleys are drift-floored, some reveal extensive outcrops. On the other hand, thick till is found on some mountains up to an elevation of 5,000 feet. The most remarkable till deposit seen forms the smooth, slightly grooved surface sloping gently northeastward from a line joining Mount Ewing and Black Mountain. This is clearly a deposit of basal till. It is unmarred by any deposit related to glacial retreat and is cut only at wide intervals by modern streams and abandoned meltwater stream-cuts. The deep, tortuous canyon east of Black Mountain, a meltwater-cut now followed by a trickle of water, exposes at least 150 feet of sandy boulder till.

Topographic Evidence

The determinations of ice movement were based mainly on topographic forms, but two boulder trains support the conclusions based on topography. The last glaciation of Atlin map-area can be described in terms of two main ice-streams from sources outside the area and an ice-mass that accumulated within it. Although no peak within the area is known to have escaped glaciation, the influence of major topographic features upon the local direction of ice-movement has been profound.

The main ice-stream flowed northward into the map-area along the Teslin depression (*see* Figure 1). The orientation of glacial grooves and crag-and-tail forms shows that a part of this stream split off from the main mass and turned southwestward toward the Taku trench. The southwestward flow definitely took place during a continental stage of glaciation for its effects can be seen at elevations above 5,500 feet. The rest of the Teslin ice-stream continued northward in the Teslin depression, a part of it again breaking away to flow northwestward through Gladys Lake-Hall Lake valley.

The second ice-stream arose along the axis of the Coast Range, and entered the map-area at the foot of Atlin Lake. A part of this stream flowed northward along Atlin Lake valley, sending a distributary arm northwestward along Shaker Lake-Jones Lake valley. Another part flowed eastward in the Pike River-O'Donnel River depression and found its way southward from there into the Taku Trench. Glacial grooves and a boulder train formed by the latter flow are seen above 5,000 feet elevation.

Boulders derived from the Mount Llangorse batholith are found perched at an elevation of 5,500 feet above the junction of Nakina and Silver Salmon Rivers. This boulder train cannot be attributed to either of the ice-streams originating outside the map-area, but is evidence, rather, of flow from an accumulation of ice on the high central mountain mass. Evidence supporting the postulated radial flow is found in four places. Crag-and-tail topography west of Llangorse Lake indicates southward flow. In O'Donnel River valley northward retreat is proved by meltwater rock-cuts that grade southward. The pattern of outwash streams at Spruce Creek similarly proves southeastward retreat from that vicinity. Each successively smaller tributary of Zenazie Creek hangs markedly above the stream it joins, in striking illustration of a system of glaciers tributary to a trunk glacier

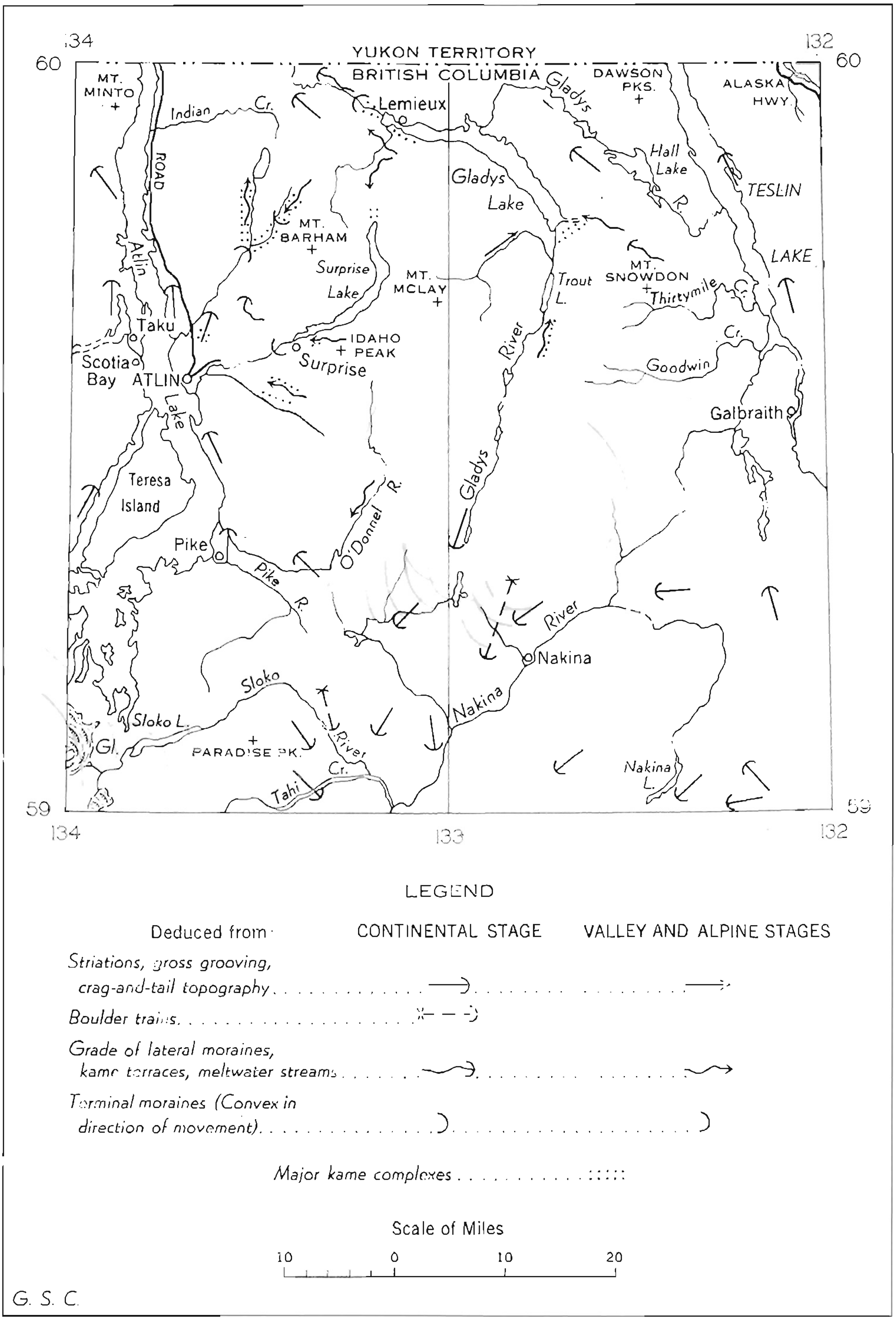

Figure 7. *Major elements of glacial movement in Atlin map-area.*

that followed Zenazie Creek valley in the direction of the modern stream (*see* Frontispiece). Although this as well as some of the evidence above reflects a valley-glacier stage, it is consistent with the radial flow postulated on the basis of the high-level boulder train.

The pattern of the last glacial retreat is well recorded in the northwestern part of the map-area. The most widespread records of the lowering of the ice-surface are in the form of meltwater stream-cuts formed at the glacier margin, which cut almost every mountain spur in the area. Ice-margin stream-cuts are very well developed around the head of Two John Creek and on the northeast spur of Black Mountain. The widespread occurrence of sets of terraces high on the valley flanks gives similar testimony. As these terraces have no counterparts on the opposite side of the valley, they record only local ponding of water against the ice-margin. The high terraces are limited to the vicinity of streams that supplied the detritus forming the terraces.

At low levels grooved topography on bedrock or till, obviously shaped at the base of the moving ice, is commonly unmarred by ice-contact deposits formed during glacial retreat. Furthermore, the outwash deposits that generally occupy the valley axes are not of great volume. These facts support the conclusion that at the close of the last glaciation the englacial debris load was small. In view of this, the materials forming the large, widely spaced esker-kame complexes of the region cannot have been provided solely by the stagnating glacier; an extra-ordinary source of debris is required. In several instances, the excess detritus was outwash from alpine glaciers not continuous with the stagnating valley glacier. Examples of this type are seen on the south side of Fourth of July Creek valley between Crater and Volcanic Creeks, and on the southeast side of the valley of Eva and Trout Lakes. Dependence on such a source of supply perhaps accounts for the common occurrence in Atlin map-area of valleys having kame deposits only on their southern walls.

At the western end of Gladys Lake a different source of detritus may be deduced. There, the till-covered slopes on the south side of the valley are etched with deep cuts carved by meltwater streams originating at the ice-margin. Where several of these cuts debouch into the valley-axis trough west of Fish Lake, the material excavated from the cuts can be contained only in the esker complex present there. Farther east, the lake is flanked on the south by an irregularly pitted, slumped-looking terrace, above which hang the mouths of several melt-water stream-cuts. There the material excavated from the cuts was dumped onto the surface of the much-diminished glacier that remained along the valley axis, the same glacier that apparently built the terminal moraine northwest of Fish Lake. In the latter instance, it appears likely that much of the meltwater came from ice stranded on the valley wall near Davenport Creek. Meltwater stream-cuts are not conspicuous, and the pitted terrace is missing, on the north side of the valley.

Small eskers, little higher than a man, are widespread in the low area east of Nakina Lake. These feeble landforms, in an area admitting no outside source of detritus, give a true picture of the debris load of the waning Wisconsin glaciers.

The earliest static ice-front recorded in the topography of the Atlin map-area occupied upper Fourth of July Creek valley near Volcanic Creek. When ice, pushing into this valley from the Gladys Lake valley trunk stream, had retreated to the point marked by the terminal moraine near Volcanic Creek its meltwater was unable to follow the line of Fourth of July Creek southwestward, for that valley was blocked by ice pushing northeastward from Atlin Lake valley, its position being recorded by a terminal moraine just east of Crater Creek. Meltwater from the two ice-fronts, flowing northward, deposited the wide valley-train that extends to Indian Lake.

The next terminus of the Gladys Lake valley ice-stream is recorded by the eskers and a high, compound terminal moraine in the valley-trough 3 miles northwest of Fish Lake. The terminal moraine at the mouth of Birch Creek and the Spruce Creek esker-kame complex may record the same stage. When the latter were deposited, Pine Creek valley west of Birch Creek was ice-free, but its mouth was blocked by the ice-stream in Atlin Lake valley. Ponding of the meltwater created the terraces above the airstrip, in which delta foreset beds may be recognized, and the overflow followed Thron Gulch, a rock-cut that debouches near the north end of Como Lake. The debris-laden stream through Thron Gulch dumped its load on the ice of the main valley, thus giving rise to the deep deposit of kettle-marked outwash near Como Lake.

At the time of the events just described, a valley-glacier stage had been reached in the vicinity of Atlin, but presumably the southeastern part of the map-area was still deeply ice-covered. Ice-front deposits are scanty in the latter region and the pattern of retreat there has not been deciphered.

Alpine Glaciation

Good evidence is at hand to demonstrate the existence of an epoch of alpine glaciation that pre-dated the last continental glaciation, and to show that Recent alpine glaciers reoccupied ancient cirques. A number of sharp ridges (cleavers) marginal to Recent cirques pass outwards into rounded, glacially scoured ridges (*see* Frontispiece). The rounded ridges are interpreted as the continentally glaciated equivalents of the sharp ridges. Furthermore, the amount of morainal material related to the Recent alpine glaciers is only a minute fraction of the material that was removed to create the cirques.

Much of the cirque excavation must therefore have been accomplished prior to the coming of the last overriding ice-sheet. In other words, over most of the map-area post-Wisconsin alpine glaciation has merely freshened the pre-existing cirques.

Only the granitic masses are highly sculptured by the combined effects of all alpine glaciations, and the few corrie glaciers remaining are mere relics. In the southwestern corner of the map-area, however, where the Coast Mountains are reached, modern glaciers are active and deep cirques are cut in all rock-types.

Chapter III

GENERAL GEOLOGY

The geological record in the map-area begins with the schists and gneisses of the Yukon group, which record the accumulation of thick sedimentary rocks in pre-Permian times. The Sylvester group, metamorphosed sedimentary and volcanic rocks of Mississippian and/or older age found in the northeastern corner of the map-area, may be equivalent to a part of the Yukon group. The Yukon and Sylvester groups were folded and metamorphosed, and the Yukon group was intruded by quartz monzonite before the deposition of the rocks that appear next in the geological record.

The accumulation of the dominantly volcanic rocks around Llewellyn Inlet (4 and 5) either preceded or was contemporaneous with the deposition of the very thick volcanic and marine sedimentary rocks of the Cache Creek group in Pennsylvanian and Permian times. The Atlin ultramafic intrusions are thought to have been emplaced during the volcanic epochs of the Pennsylvanian and Permian.

The next depositional event of which a record remains is the accumulation of a part or all of the rocks grouped as "undifferentiated, mainly volcanic rocks" (A). This took place in the very late Permian or early Triassic after the Cache Creek group had been folded into a northwesterly trend characteristic of every age of folding in the region. Although direct evidence is lacking, it appears probable that the sedimentary and volcanic rocks of the Triassic (?) (unit 10) southwest of Horsefeed Creek, which may be equivalent to a part of the "undifferentiated" volcanic rocks (A), also were deposited unconformably on the folded Cache Creek rocks during the Triassic.

Deposition of the marine sedimentary rocks of the Laberge group during the Jurassic period apparently followed conformably upon that of the rocks of probable Triassic age. The Coast Intrusions of the map-area are not known to post-date the Laberge ~~A surface of mountainous relief had been etched onto the folded Laberge~~ group; however, their emplacement is an event that might be expected to accompany or immediately follow the folding of the Laberge rocks. Tectonic quiet prevailed at the time of emplacement of the Surprise Lake batholith and the Dawson Peaks stock in late Lower or early Upper Cretaceous time. This quiet period post-dates the emplacement of the Coast intrusions and presumably post-dates the folding of the Laberge group.

A surface of mountainous relief had been etched onto the folded Laberge rocks when the dominantly volcanic Sloko group began to accumulate in the late Cretaceous or early Tertiary. The principal north-side-up displacement on the Nahlin fault was complete by this time also. Emplacement of plugs and stocks of granophyre, gabbro, and diorite either accompanied or followed the Sloko vulcanism. The position of the quartz monzonite stocks at Teresa Island and Atlin Mountain with respect to these events is not known.

After the mild warping and small-scale faulting of the Sloko group, the geological record is one of erosion, except for the extrusion and subsequent tilting of some minor masses of basalt during the Tertiary, and further extrusions of basalt in the Pleistocene, after the topography had been sculptured to its modern aspect.

The area was glaciated at least twice, and probably more than twice, during the Pleistocene. These events profoundly affected the topography, and gave rise to widespread and locally thick superficial deposits.

Table of Formations

Era	Period or epoch	Formation	Lithology
Cenozoic	Recent	Map-unit 17, in part	Alluvium, felsenmeer, talus, peat; minor glacial deposits
	Pleistocene	Map-unit 17, in part	Glacial and fluvioglacial deposits
		Map-unit 16b	Olivine basalt, scoria, cinders
	Latest Tertiary and Pleistocene (?)		Rusty gravels
	Tertiary	Map-unit 16a	Olivine basalt, scoria; sandstone and conglomerate locally present at the base
	Tertiary (?)	Map-unit 15	Quartz monzonite; granophyre, gabbro, diorite
Gabbro and diorite (15c) intrude Sloko group; ~~but acidic members~~ quartz monzonite and granophyre (15a, 15b) are not in contact with it			
Mesozoic or Cenozoic	Cretaceous or Tertiary	Sloko group (14)	Bedded lava, dykes and sills of andesite, basalt, albite trachyte, albite rhyolite, and dacite; related tuff and breccia; derived conglomerate and sandstone; minor coaly beds

Table of Formations (Cont'd)

Era	Period or epoch	Formation	Lithology
The Sloko group unconformably overlies Laberge group, but is not in contact with the Cretaceous intrusions			
	Cretaceous	Map-unit 13	Alaskite aplite; quartz monzonite
	Intrusive contact		
	Triassic to Cretaceous	Coast intrusions (12)	Granodiorite and related quartz monzonite, pink granite and monzonite, quartz diorite, diorite and alkali granite
	Granodiorite (12a) and relatives intrude Cache Creek group and map-unit A; quartz diorite (12b) intrudes Cache Creek group, map-unit 10 and Atlin intrusions; other members intrude rocks of Permian or older age; none of Coast intrusions is in contact with Laberge group		
Mesozoic	Jurassic	Laberge group (11)	Massive volcanic greywacke, thin-bedded siltstone, mudstone, and shale; coarse conglomerate; minor concretionary sandy limestone
	Conformable contact (?)		
	Triassic (?)	Map-unit 10	Greywacke, chert, argillite, conglomerate, tuff, slate, greenstone, impure limestone, jasper
	Not in contact; map-unit A may be in part equivalent to map-unit 10		
	Triassic (?) in part	Map-unit A	Andesite, basalt, rhyolite, agglomerate, tuff, breccia; associated diorite and quartz diorite porphyries; in part, derived feldspathic hornblende, biotite, and diopside gneisses (Minto Mountain)

Table of Formations (Concl'd)

Era	Period or epoch	Formation	Lithology
Map-unit A overlies Cache Creek group unconformably, but is not in contact with Atlin intrusions			
Palæozoic	Pennsylvanian and Permian	Atlin intrusions (9)	Peridotite and dunite; serpentinized, carbonatized, and steatitized equivalents; meta-diorite and meta-gabbro
		Intrusive contact	
		Cache Creek group (6, 7, 8)	Chert, argillite, chert conglomerate and breccia; greenstone and volcanic greywacke; fossiliferous limestone and limestone breccia; quartzite, quartz-biotite schist, amphibolite, and marble near major intrusions
	Not in contact. Map-units 4 and 5 may be in part or wholly equivalent to Cache Creek group		
	Pennsylvanian and/or Permian	Map-units 4 and 5	Massive andesite, basalt, and related pyroclastic rocks; conglomerate, sandstone, shale; fossiliferous limestone
	Map-units 4 and 5 in fault contact with Yukon group and pre-Permian quartz monzonite, but bear unconformable relations to both; not in contact with Sylvester group		
	Mississippian and/or earlier	Sylvester group (3)	Greenstone, chlorite schist, greywacke, quartzite, quartz-biotite schist, impure crystalline limestone
Precambrian or Palæozoic	Sylvester group not in contact with pre-Permian quartz monzonite or Yukon group; may be equivalent to a part of Yukon group		
	Pre-Permian	Map-unit 2	Quartz monzonite, commonly porphyritic
		Intrusive contact	
		Yukon group (1)	Hornblende-quartz-feldspar schist and gneiss; quartzite, crystalline limestone

Yukon Group

Metamorphosed sedimentary rocks of unknown age occupy a small area in the southwestern corner of the map-area and are placed in the Yukon group.

As exposed within the map-area and best studied on the mountain lying between the two branches of Sloko River, these rocks consist chiefly of quartz-hornblende-plagioclase gneiss with minor crystalline limestone and mica schist. The prevailing gneiss is dark grey-green and weathers dark green or brown. In the coarser grained varieties, well-oriented hornblende needles up to a half centimetre long are visible to the naked eye. Under the microscope, the rock is seen to consist of porphyroblasts of hornblende in a granular groundmass in which quartz predominates over plagioclase (oligoclase or andesine). Minor constituents are chlorite, epidote, prehnite, magnetite, and sphene. These gneisses are probably derived from greywackes.

The group is highly deformed, and no general trend of gneissosity was distinguished in the small area studied. Porphyritic quartz monzonite intrusive into Yukon group gneisses west of the mouth of Llewellyn Inlet yields cobbles to overlying conglomerate (4) at Llewellyn Inlet. The intrusion and the intruded gneisses therefore underlie the rocks at Llewellyn Inlet unconformably, and are of pre-Permian age. As the intrusion is fairly fresh and non-gneissic, it apparently escaped the metamorphism suffered by the gneisses. On this basis, the metamorphism of the Yukon group is also of pre-Permian date.

The rocks here designated as Yukon group are part of a belt of rocks of similar character that have been so named in the adjacent ~~Skagway~~ Bennett (Christie, 1957) and Whitehorse (Wheeler, 1952) map-areas.

Pre-Permian Quartz Monzonite

A single body of pre-Permian quartz monzonite extends into the map-area at Llewellyn Inlet.

Although not porphyritic everywhere, the quartz monzonite is characterized over much of its extent by large pink phenocrysts of microperthite. White sodic plagioclase exceeds microperthite in amount. The rock contains about 25 per cent of bluish quartz, and 10 per cent of mafic minerals, chiefly green hornblende with subordinate brown biotite. The quartz monzonite is not foliated, but the mafic minerals have been partly altered to chlorite and epidote.

Just off the western border of the map-area, west of the entrance of Llewellyn Inlet, the quartz monzonite is in fault contact with arkose, several hundred feet of which form the lowest observed beds of the rocks of Llewellyn Inlet (4 and 5). The arkose is overlain by a conglomerate carrying abundant cobbles of porphyritic quartz monzonite megascopically identical with that of the intrusive mass.

Sylvester Group

The area between Teslin Lake and the northeastern corner of the map-area is underlain by a group of thick metamorphosed, bedded, predominantly sedimentary rocks. These rocks have been assigned to the Sylvester group by W. H. Poole, (1955, and personal communication), who studied them in Wolf Lake map-area, adjoining to the northeast.

Lithology

Most characteristic of the Sylvester group are banded, light and dark green rocks that are only slightly different in colour on the weathered surface. The bands range from an inch to 12 inches in thickness. Outcrops of these rocks are commonly cut by quartz veins up to 3 feet thick. In thin section, the light green colour is seen to be due to abundant epidote and the dark green to abundant blue-green hornblende, both of crystalloblastic habit. The bulk of the rock is, however, composed of quartz and plagioclase grains of angular, typically clastic outline. Chlorite and biotite occur in traces. The size of opaque grains, chiefly magnetite, varies with the grain of the containing rock. In the coarse-grained bands, fragments of quartzite and fine-grained volcanic rocks are recognizable. Graded bedding is observed in some specimens. The banded green rocks are apparently derived from greywackes containing much volcanic material. The metamorphic grade of the green rocks is that of the albite-epidote-amphibolite facies.

One specimen of greenstone contains the same minerals as the meta-greywackes, but is much richer in mafic minerals. Hornblende-biotite clumps, obviously have replaced phenocrysts of primary hornblende. Rounded bodies of epidote and fine-grained quartz or plagioclase are probably relict amygdules. The proportion of meta-lavas in the group is thought to be small.

A band of calcite-muscovite-chlorite schist (metamorphosed impure limestone) with interbeds of quartzite and greenstone, appears east of Teslin Lake at the British Columbia-Yukon boundary. Stratigraphically above the limestone is a band of green, thin-bedded chlorite schist of unknown thickness.

Sparse outcrops of quartz-muscovite-biotite schist and pink quartz-dumortierite-garnet schist occur along the Alaska Highway in the northeastern corner of the map-area. The latter schist is probably of higher metamorphic grade than the green meta-greywackes near Teslin Lake.

Structure

A stratigraphic section of that part of the Sylvester group exposed in Atlin map-area was not reconstructed. The attitudes of bedding and schistosity indicate that the group has been folded parallel to the regional northwesterly trend.

Age

The Sylvester group is conformably overlain by fossiliferous Mississippian rocks in the Dorsey Range of Wolf Lake map-area (Poole, 1955, map; personal communication, 1954). The age of the group is therefore considered to be Mississippian and/or earlier.

Map-Units 4 and 5

A thick succession of predominantly volcanic rocks occupying much of the area around Llewellyn and Sloko Inlets are here referred to as map-units 4 and 5.

Lithology

The bulk of the map-unit consists of andesitic flows and flow-breccias, chiefly maroon in the lower parts of the section and tending to olive-green in the upper parts. The andesites are consistently porphyritic, plagioclase and less commonly mafic minerals forming phenocrysts. Basalt and olivine basalt are present in subordinate amounts. Pillow lavas are strikingly displayed on the mountain west of the mouth of Llewellyn Inlet. Minor tuff, and sandstone composed of volcanic fragments are interbedded with the lava flows and flow breccias.

Conglomerates, locally thick but apparently not persistent, appear at several places. They are generally coarse and are composed mainly of cobbles of porphyritic volcanic rocks, although cobbles of porphyritic quartz monzonite, identical with that of the intrusive mass flanking the west side of Llewellyn Inlet, are also well represented except in the conglomerate at the foot of Sloko Inlet.

Siltstone and light-coloured feldspathic sandstone form the base of the Llewellyn Inlet section. Fine-grained, crossbedded sandstone and brown shale interrupt the volcanic rocks at the middle of the Sloko Inlet section.

For 8 miles southward from Copper Island, the top of the exposed section is marked by two limestone beds (5). The lower is ferruginous, highly fossiliferous, and overlies lava flows. It appears to be a reef that pinches out completely at one or more points, and reaches its maximum thickness of about 400 feet near the southward disappearance of the limestone outcrops. The upper limestone is grey, locally bears silicified fossils, and is separated from the lower by 200 to 1,700 feet of maroon andesite and greywackes. It also is thickest (about 700 feet) near its point of disappearance southward. Small pods of limestone occur at the middle and near the top of the Sloko Inlet section.

The rocks of these units have been but little metamorphosed. Most of the volcanic rocks are highly saussuritized or carbonatized, but the associated sedimentary rocks are fresh.

Local complexities in the broad structure—an eastward-dipping homocline—allow only a rough section to be given for the Llewellyn Inlet area, where the total thickness is of the order of 7,500 feet.

Top of section	Thickness (feet)
Grey, silicified limestone	50– 700
Andesite, greywacke	200–1,700
Ferruginous limestone and limestone breccia	0– 400
Andesite and basalt flows, pillow lava, breccia, tuff; conglomerate	several thousand
Coarse conglomerate	several hundred
Siltstone, feldspathic sandstone	several hundred
Bottom of section: fault contact with quartz monzonite	

In the vicinity of Sloko Inlet, the structure is a simple homocline and the thickness of the group is about 16,500 feet, as follows:

Top of section	Thickness (feet)
Lava flows and volcanic breccias, chiefly andesitic; minor limestone	2,100
Conglomerate	200
Lava flows and volcanic breccias, chiefly andesitic; minor conglomerate, limestone	6,800
Sandstone, shale	400
Lava flows and volcanic breccias, chiefly andesitic	7,000

Structure

Cobbles of porphyritic quartz monzonite within the conglomerate near the base of the group show that it overlies both quartz monzonite and the Yukon group unconformably. The actual contact is faulted, but it is probable that the fault has followed the unconformity.

At Copper Island, the main trends of these rocks (4 and 5) and of the overlying Laberge group are similar, but the absence of Triassic rocks, contortion of Laberge rocks near the contact, and a strong lineament along the contact establish the presence of a fault. The dip, and hence the sense of movement on the fault are unknown. To the southeast, the contact between the Laberge group and units 4 and 5 is buried by the Sloko group.

Age and Correlation

Fossils collected from the lower, ferruginous limestone bed (GSC Cat. No. 22321) were examined by P. Harker, who reported the presence of large colonial rugose corals, probably *Waagenophyllum* sp. and '*Lithostrotion*' sp. Brachiopod and bryozoan fragments were also noted. Harker suggests that a Permian or Pennsylvanian age is indicated.

The lithological differences between the Cache Creek group and the predominantly volcanic rocks of Llewellyn Inlet (4 and 5) are extreme. If this is a facies change in contemporaneous deposits it is an extreme and very rapid one, for it takes place beneath the 15-mile-wide zone concealed by the Laberge group. On the other hand, the local appearance of maroon tints in the Cache Creek near its southwestern limit may indicate a change to the characteristically maroon-coloured rocks of units 4 and 5. The palæontological evidence does not admit the possibility that these rocks are younger than the Cache Creek; therefore, if the two groups are not equivalent, then units 4 and 5 must be the older.

Cache Creek Group

Marine sedimentary rocks and associated meta-volcanic rocks assigned to the Cache Creek group of Permian and Pennsylvanian age occupy more of the map-area than any other formation. The group is at least 20,000 feet thick.

Lithology

The Cache Creek group has been divided into three lithological rather than stratigraphic map-units, for no consistent means has been found to distinguish between lithologically similar members occurring at different stratigraphic horizons.

Chert

The Cache Creek group is characterized by an abundance of chert. The most common varieties are grey to black, that weather to similar colours, but cream-weathering, greenish varieties are fairly widespread. A red variety (jasper) is found at Sentinel Mountain and Gold Bottom Creek. Lavender and purplish varieties occur but are rare. Chert horizons were not found to be correlatable on the basis of colour; furthermore, in single outcrops, individual chert beds were observed to change colour laterally. Black, grey, and greenish varieties are commonly interbedded, the thickest beds generally being the lightest coloured. Nearly all Cache Creek cherts carry some pyrite, but the sporadic rusty weathering appears to be due less to a high content of pyrite than to intense local fracturing, which favours rapid weathering. Outcrops of chert and argillite are always rust-coloured near contacts with granitic masses.

Bedding in the cherts is mostly of the 'ribbon' variety, individual beds falling for the most part in the range between three quarters of an inch and 2 inches in thickness. Massive outcrops are found, however, and some uniformly ribbon-bedded outcrops are interrupted by pillow-like masses of chert, 4 to 8 inches thick, and 2 to 3 feet long. Instances were noted in which the lateral extensions of two or three ribbon beds were fused into a single bed. In glacially scoured outcrops, the observer is struck by the apparent regularity and persistence of the ribbon bedding (*see* Plate IIIA). However, in the best outcrops the writer was unable to trace individual beds for more than 21 feet. This is not to say that a given bed terminates in such a short distance, but that it merely becomes unrecognizable, chiefly by a change in thickness on crossing very short gaps in exposure. Light-coloured chert beds are internally massive, but the darker, more argillaceous beds display wavy internal bedding lines.

In many outcrops only a bedding joint separates the chert ribbons. More commonly a parting, generally sheared, of light-weathering impure chert intervenes.

Under the microscope, the Cache Creek cherts are seen to consist of very fine-grained quartz sprinkled with chlorite and, in some instances, with white mica or clay. The rare feldspar grains may be of either clastic or authigenic origin, so far as their outlines show, but clastic texture is lacking in the quartz. Spherical spaces about 0.1 to 0.2 mm in diameter, practically free of impurities, are interpreted as fossil radiolaria filled and replaced by quartz. The texture of quartz inside and outside the radiolaria is identical. Radiolaria form an important part of some cherts, and are lacking in others.

The cherts are surprisingly rich in trace-elements, corresponding closely with those of the greenstones (*see* Table I).

Argillite

In the absence of close petrographic control, the term 'argillite' is here used to cover rocks ranging from the more argillaceous cherts through true shales to siltstones. Although distinguishable in a few outcrops, the fabrics of these rocks are generally so blurred by shearing as to frustrate an attempt to separate them in the field. Grey and greenish types occur, but black is the prevailing colour. Most argillite outcrops are black or rusty, but chloritic, black, cherty argillites weather to a green-tinged creamy shade. Under the microscope, the cherty argillites are seen to be very siliceous revealing the chert fabric with no clastic material other than very fine-grained chlorite and white mica. Hand specimens break along fractures smeared with argillaceous matter, giving false emphasis to the argillaceous content. True shales, normally pyritic and graphitic, are unimportant

Table I

Semi-quantitative Spectrographic Analyses of Cache Creek Rocks

	Al	Mg	Fe	Ca	Na	Ti	Sr	Ba	Mn	Zr	V	Cr	Ni	Sc	Cu	Other (F)
Extrusive greenstones (6 samples)	M(6)	M(6)	M(6)	M(6)	M(5) S(1)	S(6)	F(6)	F(6)	T(6)	F(5) T(1)	F(6)	F(6)	F(6)	F(6)	F(6)	Co(1) Zn(2)
Intrusive greenstones (2 samples)	M(2)	M(2)	M(2)	M(2)	M(2)	S(2)	T(2)	F(2)	T(2)	F(2)	F(2)	T(1) F(1)	F(2)	F(2)	F(2)	Co(2) Zn(2)
Greywackes (2 samples)	M(2)	M(1) S(1)	M(2)	M(2)	M(2)	S(2)	F(2)	T(2)	T(2)	F(2)	F(2)	F(2)	F(2)	F(2)	F(2)	Co(2) Sn(2) Pb(1)
Cherts (3 samples)	M(2) S(1)	M(1) S(2)	M(2) S(1)	S(2)	M(1)	S(3)	T(1) F(1)	S(2) F(1)	T(3)	F(3)	F(3)	F(2)	F(3)	F(2)	F(3)	B(2)

Analyst: W. F. White

M- -minor constituent
S—strong trace
T—trace
F—faint trace

Numbers in parentheses show the number of samples with the concentration indicated.

Si is a major constituent of all rocks analysed.

members of the group. Within the metamorphic aureoles of granitic intrusions, they form the only slates of the Cache Creek group in this region. Siltstone has been identified in widely separated outcrops. Its relative importance among the argillites is not known, but is thought to be small.

The argillites are not typically interbedded with cherts, but tend, rather, to form separate members. These are not visibly bedded but are sheared to produce a flaky parting.

The relative resistances of chert and argillite doubtless tend to emphasize chert outcrops; however, in most continuously exposed sections chert is several times as abundant as argillite.

Conglomerate and Breccia

Chert-pebble conglomerate and chert breccia, in isolated beds 50 feet thick or less, occur here and there throughout the group. In all beds encountered chert was the dominant constituent, limestone, and, to a lesser extent, greenstone and argillite fragments playing a minor role. The chert fragments are never well rounded, rather they vary from subangular in the conglomerates to excessively angular in a chert breccia composed of chert flakes. These beds do not persist far laterally; for example a 50-foot bed of distinctive, resistant pebble-conglomerate present south of Nakina Lake is missing 2 miles along strike. The conglomerate and breccia members are not mapped separately, but included with the chert-argillite map-unit.

Volcanic Greywacke

Greywacke of the Cache Creek group does not intergrade with the argillites. It is tough, massive, grey-green to dark green rock, weathering brown, buff, or green, and reveals its clastic texture on the weathered surface. In many exposures, streaks and flakes of black argillite are scattered through the greywacke. The sediment is poorly sorted, the largest fragments, both angular and rounded, reaching a diameter of one centimetre. In thin section, fragments of volcanic rocks are seen to dominate, clastic feldspar taking second place. Among the feldspars, cloudy, well-twinned and well-zoned plagioclase and relatively clear albite occur side by side. A small amount of potash feldspar is found in some specimens. Clastic amphibole, mostly green, and epidote are ubiquitous constituents, and pyroxene is seen in some thin sections. Clastic grains of quartz rarely exceed 10 per cent. Rock fragments observed, other than volcanic types, are, in order of abundance, chert, argillite and granite aplite or granophyre. The interstitial material is chloritic and very fine grained.

The importance of volcanic material is indicated by the name used. The writer earlier (1955) used the term 'tuffaceous greywacke', but, in view of the fact that the heterogeneous volcanic fragments represent eroded volcanic rocks rather than pyroclastic material, the term 'volcanic greywacke' now seems more appropriate.

The results of micrometric analyses of Cache Creek greywackes are presented in Figure 2, where they may be compared with those of Laberge greywackes.

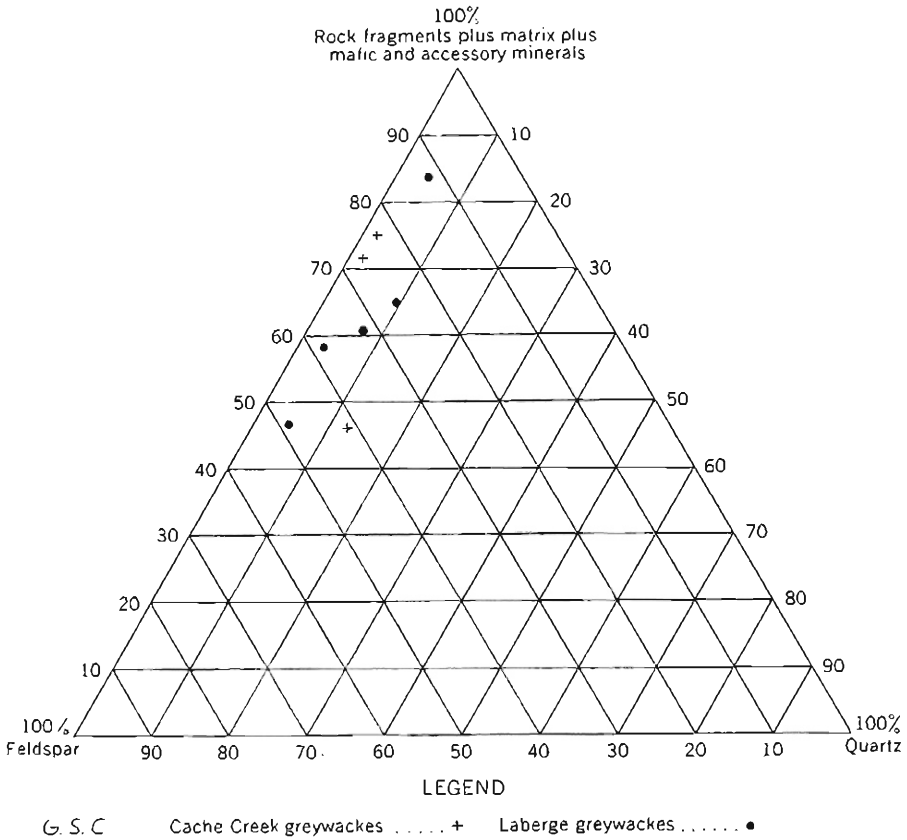

Figure 2. *Compositions (by volume) of greywackes of the Cache Creek and Laberge groups. Determinations by micrometric analysis.*

The volcanic greywackes are easily distinguishable from the chert-argillite rocks, but can be mapped only with difficulty among the greenstones. It has accordingly been convenient and significant to map the volcanic greywackes and greenstones together (7). The components of map-unit 7 at the following localities are volcanic greywacke: west of Laidlaw Lake, north of Mount Barham, head of O'Donnel River drainage, northeast of Eva Lake, southwest shore of Teslin Lake, and northeast of Tseta Creek.

Limestone

Limestone (8) is a widespread constituent of the Cache Creek group and provides the best stratigraphic and structural control of the three lithological subdivisions. A very thick and persistent limestone formation occurs at about the middle of the Cache Creek succession. For ease of discussion, this formation will be referred to as the 'major limestone unit'. All varieties of limestone in the major limestone unit are found also among the thinner, non-persistent beds above and below the unit.

The limestones are most commonly grey to black, and weather light grey to white. Some very fine-grained, dense material is buff-grey. Buff-weathering, buff-coloured, apparently dolomitized limestone is of sporadic occurrence, in several instances relatable to intense fracturing but in one instance following a bed of limestone breccia. Cache Creek limestone is fetid wherever found.

The limestone is generally massive, but bedding appears here and there. Most bedding is manifested only by warped joints seen in distant views. In the vicinity of Nakina River canyon, however, distinct bedding between lighter and darker layers outlines the structure. Near the same place is a unique occurrence of interbedded limestone and chert within the major limestone unit.

The limestones were not analysed; nevertheless, their composition may be surmised. Terrigenous clastic material is lacking. The dark coloration and the black coating seen on sectioned fossils are carbonaceous. Where thermally metamorphosed, the limestones normally carry only rare needles of tremolite, to indicate a small content of magnesia and silica. East of Hurricane Creek and immediately east of Atlin Road at the Yukon boundary, the occurrence of brucite-serpentine marble betrays a much higher magnesia content.

The limestones are separable, where fossiliferous, into two varieties based on the contained organisms. The foraminiferal variety is coquina-like, and commonly displays breccia structure. Fusulinid tests form the bulk of the rock, accompanied by a few crinoid columnals. The coralline variety carries a lower proportion of animal remains dominated by solitary and compound corals, in some instances accompanied by brachiopods and crinoid remains. The compound corals in some outcrops form cabbage-sized 'heads', suggesting that they grew where found.

A final noteworthy characteristic of the limestones is the abundance of breccia. This is most strikingly displayed by the major limestone unit. Breccia structure is widespread and apparently for the most part randomly distributed. A bed of buff-weathering limestone breccia was, however, observed at about the middle of the major limestone unit at four widely separated places from the vicinity of Shaker Lake to that of Dry Lake, and presumably represents a single stratigraphic horizon. Rounding, crude sorting, and heterogeneity of the fragments show this to be a sedimentary, rather than a tectonic breccia. The maximum thickness noted, estimated at about 500 feet, occurs north of the junction of Nakina and Silver Salmon Rivers. The major limestone unit northeast of Hall Lake is in part a breccia of blocks of foraminiferal limestone exceeding a foot in diameter cemented by foraminiferal limestone. Although less strikingly displayed, breccia is common in lesser limestones of the group.

Greenstone

Greenstones (7) of the Cache Creek group include altered lavas, pyroclastic rocks, and intrusions. Sedimentary rocks composed mainly of volcanic materials are included in the same lithological map-unit.

The nature of the meta-lavas is not easily discernible in the field. Many are tough, very fine-grained, streaked and veined light to dark green rocks that permit the recognition of none of the constituent minerals in the hand specimens. In others, coarser and less altered, feldspars, mafic constituents, and the texture of the rock may be recognized. The intrusive greenstones are recognizable in some outcrops by their relatively coarse grain, but as a general rule the grain becomes very fine when traced laterally, so that the contact with extrusive rocks cannot be mapped.

Primary structures are scarce in the greenstones. Except where interbeds of sedimentary rocks are found, the greenstones are not visibly bedded, although the strongest set of joints in many places indicates the bedding plane. Amygdaloidal structure is fairly common. Pillow structure was not positively identified in outcrops, but boulders of Cache Creek meta-lavas in the McKee Creek workings display obvious pillows, emphasized by partings of red sediment.

Microscopic study reveals much about the original nature of the meta-lavas because the primary texture of many of them is preserved by secondary minerals. The original flow rocks were predominantly basalts and andesites. The former are recognized by their tendency to ophitic texture, relicts of primary plagioclase more basic than An_{50}, and a content of relict pyroxene or green amphibole pseudomorphous after pyroxene (uralite) approaching or exceeding 50 per cent. Serpentine after olivine was observed in one specimen of meta-basalt. Meta-andesites are recognized by relicts of plagioclase more acid, and a mafic content lower, than those of the meta-basalts. Their texture is commonly porphyritic with a pilotaxitic groundmass showing flow structure, but variolitic types also occur. Primary brown hornblende was observed in three specimens. The pyroxene of both meta-basalt and meta-andesite is augitic, rather than pigeonitic. The rare dacites have a quartz content, exclusive of that in amygdules, of up to 10 per cent.

The meta-diorites and meta-gabbros are mineralogically like the basalt and andesite to which they correspond, but relict plagioclase is very rare in them. The predominant meta-diorites are of hypautomorphic granular texture. Ophitic and diabasic tendencies appear in the meta-gabbros.

Fragmental greenstones include tuff and breccia. Conglomerate composed of rounded greenstone pebbles is not separately mapped. The fragmental nature of these rocks can be recognized in the field by inspection of the weathered surface, which is buff to rusty brown, or less often grey or grey-green. The coarser grained fragmental greenstones are more or less confined to the thick volcanic accumulations; their finer grained relatives, the volcanic greywackes, are distinguished by a higher proportion of non-volcanic and pure mineral fragments and are not confined to thick sections of volcanic rocks. Nevertheless, the failure of volcanic greywackes to appear in the Hall Lake-Gladys Lake section suggests that they too bear a spatial relationship to the volcanic piles.

In many outcrops, Cache Creek greenstones are interbedded with chert, argillite, and fossiliferous limestone. Pods of massive chert are completely enveloped by meta-lavas in many exposures. Where the interbedding of volcanic and sedimentary rocks is on a scale too fine to permit their separation, the outcrops have been mapped as 6 or 7 according to which lithology appeared dominant. This may have resulted in some of the contacts being drawn across the plane of stratification.

Structure

Composite Stratigraphic Section

The structural uncertainties involved in the mapping of the Cache Creek group, particularly the questions of resolving the upper side of beds and assessing the effectiveness of minor structures in increasing the apparent thickness of map-units, prohibit the presentation of stratigraphic sections in detail. In fact, the sections offered here are based upon a solution of the structure that may not be correct.

The major limestone unit is the only widespread horizon marker. The writer earlier (1953, p. 17) suggested that this limestone might be about 8,000 feet thick near Wilson Creek. Although no new evidence has been gained, the above figure now seems too large, but the unit may be regarded as several thousand feet thick in the region between southern Atlin Lake and Nakina Lake. Palæontological evidence (fossil collection Nos. 1-4, Table III, p. 31) supports the assumption that the limestone band through the Hall Lake region corresponds with the major limestone unit of the southwestern part of the map-area.

At Sentinel Mountain, the section underlying the major limestone unit is roughly as follows:

	Thickness (feet)
Top—base of major limestone unit	
Ribbon chert, argillite, greywacke	3,000
Limestone (lenticular)	100 locally
Ribbon chert, argillite	1,000
Greenstone, mostly pyroclastic; minor chert limestone	3,000
Reddish ribbon chert and argillite; minor limestone; pebble-conglomerate at top	3,600
Greenstone, mostly massive meta-lavas with pods of chert	2,100
Variegated ribbon chert, minor crinoidal limestone and meta-pyroclastic greenstone	1,800
Thick massive greenstone	thickness unknown

This greenstone-rich succession crosses Atlin Lake, then is buckled back upon itself to trend northeastward to Mount Barham, where it is separated from the stratigraphically overlying major limestone unit by the Fourth of July batholith. To the southeast, the greenstones of Chikoida Mountain apparently represent the same zone, but are separated from those of Sentinel Mountain by a wide, greenstone-free gap. No greenstone appears below the major limestone unit in the vicinity of Hurricane Creek. The greenstone-free parts of the group that appear to be stratigraphic equivalents of the greenstone accumulations are characterized by many non-persistent limestone members.

The sequence of beds below the base of the Sentinel Mountain section is not known. A large area centred on the head of Gladys River is occupied by monotonous cherts and argillites, unbroken by other members. The stratigraphic position of the volcanic greywackes of Mount Farnsworth and vicinity is unknown; they possibly are equivalent to the Sentinel Mountain greenstones.

The section above the major limestone unit southwest of Silver Salmon River exposes the highest recognizable beds of the Cache Creek group in the map-area. In this vicinity, the apparent thickness of each unit varies greatly along the strike.

The variation in thickness may in part be real, but it is largely due to thickening of the chert-argillite members by intense crumpling along the trough of the mapped syncline. The total thickness of this section is on the order of 12,000 feet.

Top of exposures	Thickness (feet)
Greenstone	thickness unknown
Ribbon chert	at least several hundred
Fusulinid-bearing, slightly silicified limestone	200-500
Chert and argillite	several hundred to 2,000
Massive greenstone	several thousand
Chert and argillite	several thousand
Base of section: top of major limestone unit	

A well-exposed homoclinal section, about 6 miles south of Nakina Lake, apparently corresponds to the lower part of the foregoing section.

Top of section: contact with peridotite mass	Thickness (feet)
Massive greenstone, with minor interbeds of chert and maroon tuff near the base	4,500
Limestone (persistent member)	75
Chert and argillite, with pebble-conglomerate (non-persistent) near base, greenstone intercalations increasing towards top	4,300
Bottom of section: major limestone unit	

In the Hall Lake region, the sections above and below the major limestone unit are entirely different from those described above. Minor limestone members are barely represented, and greenstone is of very limited thickness and lateral extent. For instance, greenstone occurs southwest of Hall Lake, but is only 100 feet thick and is not mappable. The entire section is dominated by ribbon chert.

Traced northwestward along strike, the Hall Lake succession gives way to one in which siltstone, sandstone, and greywacke are well represented (Mulligan, 1955, map); these clastic beds are scarcely present south of the 60th parallel.

Internal Structural Relations

The writer earlier (1953, pp. 13, 14) postulated an unconformity at the base of the major limestone. Mapping over a much larger area than was then considered has failed to support this postulate, and the evidence, reconsidered, appears to admit a fault for the relationships earlier believed to indicate an unconformity.

The breccias and pebble-conglomerates found here and there throughout the section are conformable with the enclosing beds and are not persistent. Apparently they do not represent important breaks in sedimentation.

Resolution of the structure of the Cache Creek group is hampered by the paucity of horizon markers and the complete absence of reliable indicators of the upper side of beds. Furthermore, bedding-cleavage relationships and minor folds in the thin-bedded members are so erratic in attitude as to be useless in deciphering the larger structures. Nevertheless, it has been possible to arrive at a structural interpretation, based on the assumption that certain obvious folds are not completely inverted, which is consistent with all directly mappable folds of the map-area and is therefore probably valid. The stratigraphic sections presented earlier are drawn up in the sequence demanded by this structural interpretation.

The fold structures discussed here are those found in the Cache Creek group in the northeastern and southeastern parts of the map-area, where extensive areas devoid of major intrusions are found. Elsewhere, the structure is strongly affected by granitic intrusions, the effects of which will be dealt with later.

The ubiquity of nearly parallel northwesterly strikes and very steep dips and the rarity of attitudes counter to the fold trends in the thin-bedded members (6) of the group show that, in these incompetent members, folding is isoclinal or nearly so. The isoclinal folding of the incompetent members is subordinate to the close, but non-isoclinal folding of the massive greenstones. The limestones are apparently isoclinally folded in a few exposures in which bedding is displayed. The great apparent thickness of some of the limestone zones suggests that isoclinal folding may be widespread, but not visible because of the massiveness of the limestone.

All folds of the Cache Creek group plotted on the map are in a sense secondary. The nature of the fundamental fold, involving the whole group, is deduced as follows. The structural interpretation demands that the major limestone unit face south at Nakina River. Thus a traverse southwesterly from Silver Salmon River crosses successively higher members of the group, a circumstance consistent with the existence of a mappable syncline at Mount O'Keefe. Though independent evidence is lacking, the major limestone unit in the Hall Lake area must (ignoring secondary folds) face northeast to be consistent with the foregoing, and must be locally overturned. The fundamental fold is therefore an anticlinorium which occupies the greater part of the map-area.

External Structural Relations

Within the map-area, the Cache Creek group is nowhere in contact with the Yukon group, or with map-units 4 and 5, which may or may not be stratigraphic equivalents.

The Teslin Lake lineament probably follows a fault that separates Cache Creek and Sylvester group rocks; however, unless the postulated fault juxtaposes rocks once separated by a distance of some miles, the difference in metamorphic grade between the schistose Sylvester group rocks of albite-epidote amphibolite facies and the non-schistose Cache Creek group rocks of greenschist facies demonstrates an unconformity.

All of map-unit A appears to overlie the Cache Creek group unconformably. That near Graham Inlet dips gently westward over highly deformed Cache Creek rocks, and the isolated patches at Atlin Mountain, Mount Minto and Dawson Peaks occupy topographic eminences above folded Cache Creek rocks.

The Cache Creek group is shown on the map in contact with the Laberge group only at Atlin and Birch Mountains. At neither place has the exact contact been observed, or its nature determined. One possibility is that the fault that forms the northeastern limit of the Laberge group everywhere southwest of Atlin Lake may persist as far northwest as Atlin Mountain.

Metamorphism

Outside the metamorphic haloes of the major intrusions, which are discussed later in sections dealing with the intrusions, chert, argillite, and limestone are not visibly metamorphosed except where sheared. The sheared rocks are to some extent recrystallized. Specimens of volcanic greywacke collected away from the areas of thick piles of greenstone reveal mild alteration when examined in thin section. Fragments of zoned and well-twinned pyrogenetic plagioclase are clouded with white mica; tufts and individual needles of actinolite are scattered through the rock; and clinozoisite and chlorite replace both the fine interstitial sediment and some of the volcanic-rock fragments. This weak regional metamorphism is of the muscovite-chlorite subfacies of the greenschist facies (Turner and Verhoogen, 1951, p. 471).

Within the thick volcanic piles, meta-lavas affected only by the weak metamorphism described above occur side by side with others in which alteration to secondary minerals is complete. All too commonly the highly altered rocks are a formless mixture of pale green amphibole, albite, chlorite, epidote or clinozoisite. Minor amounts of quartz are present, and the rocks are dotted with magnetite, leucoxene, and apatite. Nearly all the pyroclastic rocks have suffered this sort of alteration. On the other hand, the pseudomorphous replacement of plagioclase by clear albite, and of pyroxene by green fibrous amphibole (uralite) have produced a facsimile in secondary minerals of many of the original lavas. Such rocks as carry albitized plagioclase are spilites. They retain their original texture and carry no secondary lime-rich phase such as epidote, to account for the lime removed from the original plagioclase. A chemical analysis of a spilite from the McKee Creek road 4 miles south of Atlin is given in Table II. Although the plagioclase of this fine-grained, variolitic rock is completely altered to clear albite (An_5), the rock is not soda-rich.

Much of the meta-lava, including masses closely associated with spilites, has suffered saussuritization. This alteration replaces plagioclase with a mixture of albite, epidote (or clinozoisite) and minor chlorite and/or pale amphibole (actinolite). In the saussuritized rocks, the primary texture is not well preserved.

In the volcanic piles, these alterations, all of them hydrothermal, vary in degree and type from outcrop to outcrop, and on the scale of this investigation, no pattern of distribution is discernible. Either plagioclase or the mafic mineral may be more extensively replaced in a given specimen.

Except within the metamorphic haloes of the granitic intrusions or in immediate contact with ultramafic bodies none of the Cache Creek greenstones is schistose.

Table II

Chemical Analyses of Spilite and Meta-diorite

Constituent	Specimen (1)	Specimen (2)
SiO_2	50.10	50.70
Al_2O_3	13.48	14.03
Fe_2O_3	9.86	7.33
FeO	3 62	4.06
CaO	9.83	11.28
MgO	6.33	7.37
Na_2O	2.60	2.57
K_2O	0.39	0.22
H_2O+	2.89	1.11
H_2O-	0.16	0.23
TiO_2	0.95	1.05
P_2O_5	0.06	0.04
MnO	0.16	0.07
CO_2	nil	nil
S	0.41	0.16

Analyst: R. J. C. Fabry
(1) Spilite of the Cache Creek group. McKee Road, 4 miles south of Atlin.
(2) Meta-diorite from a body enclosed in serpentinite. North bank of Pine Creek at Discovery.

Origin

Origin of the Greenstones

The association of marine sedimentary rocks with the greenstones demonstrates that much of the Cache Creek vulcanism was submarine. Furthermore, the association of much fragmental volcanic rock with the lavas and the implication that the volcanic greywackes are largely derived from Cache Creek greenstones yet are more or less contemporaneous with them, suggest that the volcanic rocks formed topographic eminences. Such eminences would be volcanic islands in the Cache Creek sea.

The irregularly distributed hydrothermal alteration of the volcanic rocks of the thick piles has been described above. The abundance of transported fragments of secondary minerals (albite, uralite, epidote), typical of the hydrothermally altered lavas, in the volcanic greywackes of the group indicates that hydrothermal alteration (as distinct from regional low-grade metamorphism) was more or less contemporaneous with vulcanism.

Origin of the Sedimentary Rocks

The outstanding characteristic of the sedimentary rocks of the group is the paucity of clastic material that could not have been derived from within the map-area. The only components of the volcanic greywackes that are not obviously relatable to the contemporaneous vulcanism are the rare fragments of potash feldspar and fine-grained granitic material. The close association of the cherts with greenstones, a phenomenon widely noted, and the parallelism between the trace-element contents of the two rock-types also point to vulcanism as the source for the vast amounts of silica deposited, although the origin in detail of the cherts is obscure (Armstrong, 1949, pp. 37-39 and others). The limestones of the group are notably free of clastic impurities. The only important rocks that cannot have had their source in volcanic processes are the argillites.

Age and Correlation

The rocks considered here are assigned with confidence to the Cache Creek group on the basis of Armstrong's (1949, p. 50) redefinition: " . . . the Cache Creek group may be defined as a very thick assemblege, 20,000 feet or more 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." Gwillim (1901, pp. 16, 18) noted the resemblance to the Cache Creek group.

Most collections of satisfactorily preserved and stratigraphically significant fossils from the Cache Creek group of Atlin map-area (*see* Table III), and the adjoining Bennett map-area (R. L. Christie, M. L. Thompson, personal communications, 1953), have been dated as Permian, and dominantly as Upper Permian. Two localities, however, yield fossils of earlier dates. Thompson (personal communication, 1954) collected fusulinids from three outcrops of the major limestone unit along the Atlin highway between 5.2 and 5.8 miles south of the Carcross Road. These collections were dated by him as Upper Pennsylvanian or Lower Permian, Upper Permian, and Middle Pennsylvanian, in that order. The presence of *Triticites* in collection No. 6, from Mount Farnsworth, demonstrates an Upper Pennsylvanian or Lower Permian age.

Armstrong (1949, pp. 50, 51) thoroughly reviewed the probable correlatives of the Cache Creek group. It is necessary only to point out in addition that the Teslin formation (Watson and Mathews, 1944, map) southeast of Teslin Lake is physically continuous with the major limestone unit of the Cache Creek of Atlin map-area, and that the term 'Braeburn limestone', having been applied to both Triassic and Permian limestones, is no longer used.

Table III

Significant Fossil Collections from Upper Palæozoic Rocks

Map No.	GSC Catalogue No.	Locality	Forms Identified	Age	Studied By
1	19642	West of Wilson Creek	*Parafusulina* n. sp. *Dunbarula* aff. *D. cascadensis* Thompson, Wheeler and Danner	Guadalupian (Upper Permian)	M.L.T.
2	21816	North of O'Donnel	*Parafusulina*	Guadalupian	M.L.T.
3	21817	Katina Creek	*Schwagerina* ? sp. *Neoschwagerina* sp.	Guadalupian	M.L.T.
4	20282	Hall Lake	*Schwagerina* *Neoschwagerina* *Yang chienia* n. sp.	Guadalupian, upper ?	M.L.T.
5	22321 & 20284	Sloko Inlet	*Waagenophyllum* ? sp. "*Lithostrotion*" sp.	Permian or Pennsylvanian	P.H.
6	24931	Mt. Farnsworth	*Triticites* sp.	Upper Pennsylvanian or Lower Permian	P.H., R.T.
7	24933	Silver Salmon River	*Yabeina* sp.	Late Permian	P.H., R.T.
8	21814	Wilson Creek	*Athyris* ? sp. *Composita* ? sp., cf. *Productus uralicus* Tschern.	Lower Permian ?	P.H.
9	23951	Disella Lake	*Heritschia* sp. ?	Permo-Carboniferous	P.H.
10	24932	Mt. O'Keefe	*Schwagerina* sp.	Permian	P.H., R.T.

P.H. = Peter Harker; M.L.T. = M. L. Thompson; R.T. = R. Thorsteinsson

Atlin Intrusions

The ultramafic and minor basic bodies to which the term Atlin intrusions was originally applied (Aitken, 1953, p. 21) are small bodies closely associated with greenstones of the Cache Creek group, for which a Pennsylvanian and Permian age appears likely. The long ultramafic body that extends from Mount O'Keefe southeastward beyond the limits of the map-area, differs structurally from the 'type' intrusions, and may be unrelated. Its assignment to the Atlin intrusions is provisional.

Distribution

Atlin intrusions follow the greenstone belt from Sentinel Mountain to Mount Barham, via Atlin Mountain. Ultramafic rocks appear also in association with the greenstones of Chikoida Mountain, which are probably stratigraphic equivalents of the Sentinel Mountain greenstones. Small ultramafic bodies are found in the greenstone belt between Sloko and Silver Salmon Rivers, and in the continuation of the same belt around Nakina Lake, where the bodies are too small to be shown on the map. Ultramafic rocks are again associated at Marble Dome with greenstones whose stratigraphic relationships are unknown.

The enormous northwesterly trending body of ultramafic rocks northeast of Sloko River, the Mount O'Keefe body, has been traced by the writer to Nahlin River, in Tulsequah map-area. It is distinctly different in scale and structure from the smaller intrusions discussed in the foregoing, and merits separate description.

Lithology

Ultramafic Rocks

Fresh ultramafic rocks of the Atlin intrusions normally range in composition from dunite, recognized in the field by its smooth, khaki-coloured weathered surface, to peridotites containing up to 40 per cent pyroxene, recognized by their darker, reddish brown weathering and by the resistant pyroxene crystals which stand out in relief on the weathered surface.

In the bulk of the rocks, olivine contains more than 90 per cent of the forsterite molecule. The normal pyroxene is enstatite, accompanied by traces of clinopyroxene in the more pyroxene-rich rocks. A small body of peridotite occurring within the main body near Mount O'Keefe is unusual in that it contains traces of altered plagioclase, 50 per cent diopside, 10 per cent enstatite, and olivine containing only 85 per cent of the forsterite molecule. Diopside-rich peridotite, very coarse grained, occurs locally at the contacts of the main body.

A chrome spinel, chromite or picotite, occurs in traces in all specimens, but was not observed in amounts greater than those appropriate to an accessory mineral.

Within the map-area, the Atlin intrusions nowhere display the banding typical of stratified intrusions. At Monarch Mountain, widely spaced planes enriched in pyroxene occur, and a few loose blocks derived from the Mount O'Keefe ultramafic body were observed to carry parallel pyroxene-rich planes. Farther southeast, however, in the Tulsequah map-area, the extension of this body is distinctly banded.

At Chikoida Mountain and at several points within the main body, irregular lenses of very coarse-grained pyroxenite, a few feet in greater dimension, occur in normal peridotite.

Some of the Atlin intrusions are completely serpentinized; all are partly serpentinized and no specimen studied contained less than 10 per cent by volume of serpentine. The ubiquity of serpentinization to the extent of 10 to 25 per cent (accompanied in many specimens by a little talc, fringing pyroxene) is such as to suggest that the development of secondary minerals to this amount is a deuteric or 'autometamorphic' alteration, not dependent upon a source of water outside the intrusion.

Basic Rocks

The basic rocks associated with the Atlin intrusions are indistinguishable from the intrusive representatives of the Cache Creek greenstones, and have suffered the same alteration (*see* Table I). In the course of mapping, basic masses associated with ultramafic rocks were shown as Cache Creek greenstone if of mappable size, and if not, were lumped with the Atlin intrusions.

Several dykes of albitite and one sheet-like mass of albite granite, none of mappable extent, were found cutting ultramafic rocks.

Structure

Bodies Spatially Related to Cache Creek Greenstones

Internal Structural Relations

The highly serpentinized rocks are nearly all highly sheared. The less-altered ultramafic rocks bear little megascopic evidence of shearing or brecciation, but are seen in thin section to be composed of warped and crushed grains.

The basic bodies associated with the Atlin intrusions are characteristically rounded, ranging from a few feet to several hundred feet in greatest dimensions. They have been crushed and 'mashed' on both a microscopic and megascopic scale. They are normally enclosed by ultramafic rocks, but the inverse relationship also occurs in some bafflingly complex exposures (*see* Figure 3). The basic bodies display the form of dykes in a few exposures; one definite dyke cutting the largest ultramafic body on Atlin Mountain gives way laterally to a string of ellipsoidal 'beads' of the same material. All the basic bodies display a fine-grained, chloritized reaction-selvedge against the ultramafic rocks, effectively concealing a chilled selvedge should one exist. A general tendency has been noted for basic bodies to be most numerous in serpentinized zones, but some large areas of both serpentinized and fresh ultramafic rocks lack basic bodies.

External Structural Relations

Most of the ultramafic bodies studied are in a broad way concordant, in that their long axes lie parallel to the strike of the enclosing rocks, but the contacts

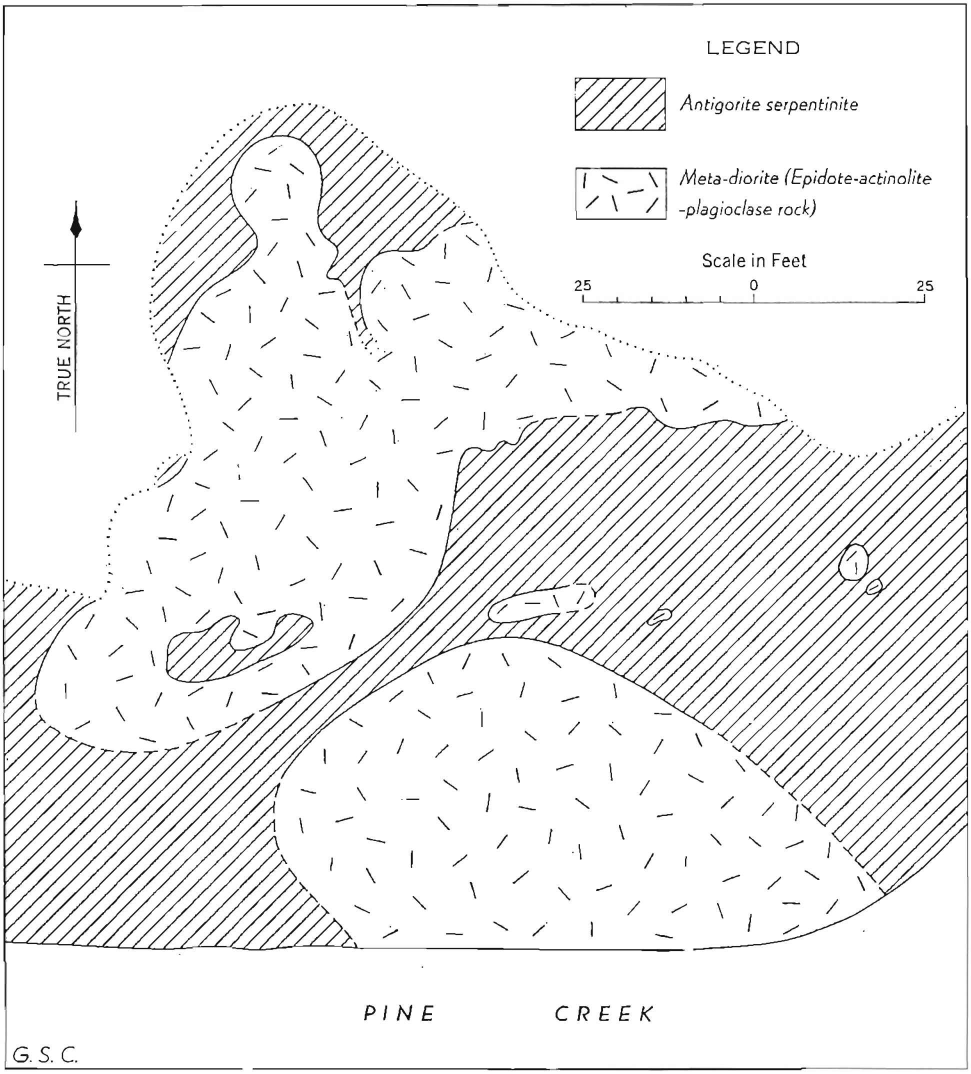

Figure 3. Relations of antigorite serpentinite and meta-diorite on Pine Creek.

are discordant in detail. These contacts are simple, lacking apophyses, and are invariably sheared and serpentinized. Some highly sheared serpentinite bodies lie along faults.

In no instance studied is the metamorphic grade of rocks in contact with any of the 'type' Atlin intrusions abnormal for the area in which the contact occurs.

The Atlin intrusions are cut by several of the Coast intrusions. Furthermore, just south of Safety Cove a brecciated mass of carbonatized serpentinite is cut by undisturbed and unaltered, amygdaloidal green porphyry dykes. That these dykes belong to the volcanic rocks that unconformably overlie the Cache Creek group nearby is probable but not provable, owing to limited knowledge of the petrology of the volcanic rocks.

Mount O'Keefe Ultramafic Body

Internal Structural Relations

As stated above, compositional banding was not observed in place in Atlin map-area, but was observed in a few loose blocks near Mount O'Keefe. About long. 132°50′ and 3 miles south of lat. 59°, however, the continuation of the ultramafic body is banded to a variable but locally striking degree. In most banded exposures, the principal banding is displayed by parallel pyroxene- or olivine-rich bands which strike more or less parallel to the trend of the body and dip in either sense. This banding is crossed by pyroxene-rich bands and by irregular sack-like bodies of dunite.

Within the map-area, the basic bodies in the Mount O'Keefe ultramafic body are small and non-persistent like those of the other Atlin intrusions. Most of them occupy serpentinized zones in the peridotite, particularly the serpentinized zones along the contacts. In an undisturbed part of the body in Tulsequah map-area, however, the basic rocks form regular, persistent dykes, and display chilled selvedges against the enclosing peridotite.

The reason for the northwestward change of the Mount O'Keefe body from a largely fresh, banded intrusion to a largely serpentinized, sheared, non-banded one, is found in the structural disturbance of its northwestern part. The body is first severely disturbed in the vicinity of the stock south of Focus Mountain, and from there northwestward becomes increasingly more sheared and altered, finally fraying out in 'horsetail' fashion in the vicinity of Gold Bottom Creek to lose its identity as a single body.

External Structural Relations

Although they appear concordant over stretches of several miles, the contacts of the Mount O'Keefe ultramafic body truncate thousands of feet of Cache Creek strata on the north, and thousands of feet of Mesozoic strata (Laberge group in Atlin map-area) on the south.

The southern contact of the body is the Nahlin fault which, although it strikes parallel to the regional trend, cuts strongly across the bedding of the Mesozoic rocks in some exposures, and southeast beyond the 59th parallel brings rocks apparently older than the Laberge group against the intrusion. The rocks south of the fault are unmetamorphosed. The fault is followed as far as it has been mapped by a zone of carbonatized serpentinite (quartz-carbonate rock) up to several hundred feet wide.

The northern contact of the ultramafic body likewise truncates the structure of the Cache Creek group from Nakina River southeastward, and is faulted over much of its length. In several places, however, low-grade metamorphic rocks

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abnormal for the region occur near the contact, suggesting that at these points the contact is intrusive. The metamorphic rocks are quartz-chlorite schists and banded meta-greenstones characterized by much secondary amphibole, chlorite, epidote, and notable amounts of prehnite.

The mass of unmetamorphosed strata (10) at the summits just south of the 59th parallel appears to be a fault 'horse' in the structure controlling the main ultramafic body. The stock south of Focus Mountain has intruded and locally metamorphosed the ultramafic body.

Metamorphism

Serpentinization

Intense serpentinization is characteristic only of the ultramafic rocks in the vicinity of contacts or faults. The association between the basic bodies and serpentinization has been pointed out.

Provided that they have not been excessively sheared, the serpentinized rocks preserve the texture of the original rocks in serpentine pseudomorphs, so that the original proportions of olivine and pyroxene can still be determined by microscopic examination of thin sections.

Carbonatization

Carbonatization is an alteration apparently limited to the vicinity of faults in serpentinized zones. The bodies of carbonatized serpentinite form bright, orange-weathering outcrops which can be seen for miles. The outcrops are riddled with veinlets of quartz liberated during the conversion of serpentine to a magnesian carbonate. The massive buff carbonate is for the most part ankerite rather than magnesite, and the white, coarsely crystalline carbonate in several veins examined is dolomite. Magnesite containing less than 5 per cent of impurities does, however, occur as dense, pure-white material in veins in some exposures, particularly those of the carbonatized contact zone of the main ultramafic body northeast of Sloko River.

Dynamothermal Metamorphism

The normal serpentine minerals (chrysotile in part) are stable to a metamorphic grade a little higher than that at which biotite appears in the associated greenstones and sedimentary rocks. On being subject to metamorphism of higher grade, all trace of the original texture is destroyed as the original serpentinite is recrystallized to a reticulate mass of antigorite serpentine blades. Antigorite persists very close to the contacts of granitic masses, but suffers progressive replacement by talc and tremolite.

The possibility exists that some olivine and enstatite in the ultramafic rocks of the high-grade metamorphic zones are metamorphic minerals, that is, that they are regenerated. Although serpentinization, the only process that has brought about the destruction of pyrogenetic minerals on a large scale, is unrelated to the granitic intrusions, it is virtually certain that *some* olivine and enstatite of the high-grade zones are relict pyrogenetic minerals. The sole basis for identifying regenerated olivine and enstatite is textural evidence; this unfortunately is ambiguous, and the question has not been resolved.

In the course of dynamothermal metamorphism, exchange of material across greenstone-ultramafic contacts has resulted in the development of talc and tremolite in the ultramafic rocks by introduction of silica and lime, and the chloritization of the greenstones by introduction of magnesia. These effects are limited to narrow reaction-zones at the contacts.

The metamorphism of the ultramafic rocks has possible economic significance in that all cross-fibre asbestos veinlets observed occur in ultramafic rocks of a metamorphic grade at which the serpentinite is recrystallized but talc and tremolite have not appeared in quantity. A similar relationship appears to be significant in the origin of the asbestos deposit at Cassiar, British Columbia (H. Gabrielse, personal communication, 1956). With a little practice, the fine mat of antigorite blades in the recrystallized serpentinites can be recognized in the hand specimen.

Origin

Emplacement of the Ultramafic Bodies

The fact that the margins of every ultramafic body studied are sheared offers the possibility that all contacts observed juxtapose rocks that were widely separated at the time when the Atlin intrusions were originally emplaced. Under this hypothesis, all bodies would be 'cold intrusions' emplaced in the solid state by tectonic forces. Highly serpentinized and thoroughly sheared bodies, particularly those occupying recognizable faults, are accepted as having been emplaced as solid serpentinite. Many bodies, however, are intensely serpentinized only at their margins, and although the component grains are warped and crushed, they are not much affected by the through-going shear surfaces that characterize the 'cold intrusions'. The crushing observed apparently took place while the component grains were free to move with respect to one another.

With few exceptions, the country rocks are not thermally metamorphosed at contacts with the Atlin intrusions, and at the several points on the contacts of the Mount O'Keefe body where there is metamorphism this is of low grade, certainly well below the amphibolite facies. There is thus no evidence of the ultramafic bodies having been emplaced at or above the very high minimum temperature at which a hydrous ultramafic magma can exist (Bowen and Tuttle, 1949, pp. 452, 453, 455). The evidence at the contacts and the ubiquitous crushing of the olivine and pyroxene grains are consistent with emplacement in the form of largely crystalline, weakly coherent masses (crystal mush), according to Bowen's long-standing hypothesis.

The banded part of the Mount O'Keefe body may require a magmatic interpretation, although some of the banding is clearly secondary and all may be secondary. The diallage-rich selvedges that occur at some points are interpreted as resulting from accessions of lime and silica from the wall-rocks during emplacement. This complex and well-exposed intrusion merits future detailed study.

Emplacement of the Basic Bodies

The rounding and isolation of many of the basic bodies in peridotite, and the failure to find near them a breccia of basic rock fragments in an ultramafic matrix were earlier (1953, p. 115) considered strong evidence that the basic bodies were not dykes disrupted subsequent to their consolidation. It was then proposed that the basic material was in a largely crystalline but non-coherent state when movement of the enclosing mass disrupted it into the rounded bodies observed.

The discovery of clean-cut dykes of identical material in a part of the main ultramafic body renders the above hypothesis very doubtful. It now seems likely that the basic bodies are fragments of disrupted dykes, plastically deformed into ellipsoidal shape by movement of the enclosing peridotite.

Serpentinization

Intense serpentinization is limited to the vicinity of contacts and faults, obvious paths of access for serpentinizing fluids. The ultramafic rocks are mostly in contact with hydrothermally altered (albitized and saussuritized) volcanic rocks, whose alteration has been related to contemporaneous volcanic processes. The serpentinization of the ultramafic rocks is regarded as another manifestation of Permian hydrothermal activity in the volcanic piles.

Carbonatization

Carbonatization is limited to the vicinity of faults in serpentinized zones. Its occurrence bears no visible relationship to metamorphic zones or other bodies of rock. The evidence of the dykes cutting quartz-carbonate rock south of Safety Cove suggests that some of the carbonatization is of pre-Jurassic age, but the carbonatized zone following the Nahlin fault is clearly of Jurassic or younger age.

Age

'Type' Atlin Intrusions

The spatial relationship between the 'type' Atlin intrusions and the Cache Creek greenstones strongly suggests a genetic relationship between the two groups of igneous rocks. The basic rocks enclosed in the ultramafic masses have suffered the same type of alteration as the extrusive greenstones, and it is reasonable to suppose that both were affected by the same agency. It has already been shown (p. 28) that the hydrothermal alteration of the volcanic rocks was contemporaneous with vulcanism. On theoretical grounds, therefore, the emplacement of the Atlin intrusions was probably contemporaneous with the Cache Creek vulcanism. If future investigation can prove conclusively that the dykes cutting ultramafic rocks south of Safety Cove belong to the overlying volcanic rocks, the age of the 'type' Atlin intrusions will be demonstrably pre-Jurassic. A Pennsylvanian and Permian age is concluded.

Mount O'Keefe Ultramafic Body

The basic bodies enclosed by the Mount O'Keefe ultramafic body also have suffered alteration similar to that of the nearby Cache Creek greenstones, and by this argument, the intrusion is of Pennsylvanian or Permian age and properly belongs to the Atlin intrusions.

On the other hand, the emplacement of this body appears to have been controlled by the Nahlin fault, which, except for the intervention of the ultramafic mass, juxtaposes Permian and Jurassic rocks. If control of emplacement by the fault is accepted, the body can be no older than Upper Jurassic. It is possible, however, that the southern contact of the intrusion localized the fault, a hypothesis enhanced by the lack of metamorphism of the Laberge group at the contact.

The evidence being inconclusive, the main ultramafic body is provisionally assigned to the Atlin intrusions, and a Pennsylvanian or Permian age is assumed.

Undifferentiated, Mainly Volcanic Rocks of Mesozoic Age

Widely separated areas of unfossiliferous, mainly volcanic rocks have been mapped as map-unit A. Aside from the fact that all or nearly all must be of Mesozoic age, it has not been possible to establish their relationship to one another.

Rocks at Graham Inlet

Table Mountain in the angle of Graham Inlet is a pile of dominantly volcanic rocks dipping gently westward. Purplish and greenish andesites, characterized by phenocrysts of brown altered plagioclase, are prominent as vesicular and amygdaloidal lavas, breccias, and agglomerates. Varicoloured basalt, dacite, trachyte, and rhyolite also occur, the more felsic of these as tuffs. Only the bedded tuffs reveal the attitude of the rocks in outcrop; the bedding of the massive volcanic rocks is seen only in distant views under suitable lighting conditions. The Table Mountain section is at least 2,500 feet thick. Minor porphyritic intrusions on Table Mountain are of a composition similar to that of the lavas, and are apparently related to them.

The islands in Scotia Bay and a part of the peninsula to the north are composed of volcanic rocks, mainly porphyritic, very like those at Table Mountain. Coarse conglomerate composed of cobbles of purple and green porphyritic andesites is very widespread in the islands. These beds dip gently westward, like those at Table Mountain.

Rocks at Atlin Mountain

Atlin Mountain is partly capped by porphyritic lavas and fragmental, mainly andesitic, volcanic rocks, similar to those at Table Mountain but more subdued in colour. These rocks have been slightly recrystallized by the effects of the stock on Atlin Mountain which intrudes them. Their structure is unknown, but they do not appear to have been much deformed.

Rocks at Dawson Peaks

The volcanic rocks at Dawson Peaks are remarkably similar, both in appearance and situation (perched on top of an intrusive stock) to those at Atlin Mountain. The porphyritic andesites in the vicinity of the intrusive contact display the same subdued, greyish coloration as the Atlin Mountain rocks and are recrystallized to various degrees. Farther from the contact, however, many of the lavas are greenish and purplish in colour, and partly glassy. Black basalt, reddish maroon albite trachyte, and minor grey-green weathering, black tuff or argillite are also found at Dawson Peaks.

Rocks at Mount Minto

Mount Minto consists largely of porphyritic, greenish and purplish andesites very similar to those at Atlin Mountain and Dawson Peaks. Light-coloured rhyolite is of minor importance. Small porphyritic intrusions, mostly quartz diorites, are associated with the Mount Minto volcanic rocks. They have suffered the same metamorphism and are thought to be related.

The volcanic rocks high on Mount Minto appear in the field to be fresh, but microscopic study reveals much crystalloblastic biotite and green amphibole. At the foot of Mount Minto on its west and south sides, are quartz-plagioclase-biotite-hornblende schists and gneisses. These may be traced through intermediate stages to recognizable volcanic rocks. Furthermore, augen in the gneisses consist of strained and broken crystals of plagioclase as basic as labradorite—obviously relict phenocrysts of the original lavas. In general, the highly metamorphosed rocks are lighter coloured than their parents, but some outcrops of intermediate grade are dark green. The spatial relationships and the orientation of the foliation, transverse to the trend of the regional folding, demonstrate that the metamorphism was caused by the Fourth of July Creek batholith.

Outcrops of altered volcanic rocks on both sides of Atlin Lake as far south as Logger Bay are very similar to those of Mount Minto. Metamorphosed porphyritic intrusive rocks are particularly prominent. Many outcrops are sheared but none is truly schistose.

Structural Relations and Age

Although no firm basis exists for correlating the several isolated areas of map-unit A, all except the Atlin Mountain rocks are shown by their structural relationships to be of Mesozoic age and there is no evidence to demonstrate any difference in age between separate masses.

With the exception of the shoreline outcrops on Atlin Lake, all areas of map-unit A occupy topographic eminences above closely folded rocks of the Cache Creek group; hence, must overlie them unconformably. The Graham Inlet mass of volcanic rocks apparently dips westward beneath the Laberge group (the contact is not exposed) and is, therefore, probably of Triassic age. All masses of map-unit A, with the exception of the Atlin Mountain mass, are intruded by Mesozoic granitic rocks. The Atlin Mountain mass is intruded by quartz monzonite of uncertain, probably early Tertiary, age. As it occupies a similar position in the stratigraphic column, map-unit A may be in part equivalent to the rocks of map-unit 10.

Map-Unit 10

A group of distinctive sedimentary and volcanic rocks (10) form the summits of mountains southwest of Horsefeed Creek on both sides of the 59th parallel. A small area of lithologically similar rocks southwest of Pike River is also assigned to this unit.

The brief study of the group was concentrated in the Hardluck Peaks just south of the map-area where the exposed thickness appears to be at least 8,000 feet. No fossils were found, but a Triassic age appears probable.

Lithology

Fragmental rocks of map-unit 10 are characteristically ill-sorted, and range from greywacke to conglomerate. The matrix of the coarser conglomerates is greywacke and has the same bluish or greenish grey colour and reddish brown weathering as the normal greywackes. The greywackes carry angular and rounded phenoclasts up to one centimetre in diameter. Thin beds of white chert-pebble conglomerate appear at wide intervals. The recognizable fragments of the clastic rocks are mainly of siliceous rocks of types common to map-unit 10. Fragments of silty and sandy limestone also appear to have their source within the unit. Volcanic pebbles are scarce and no fragment of Cache Creek-type greenstone was found. Pebbles of fine-grained granite are rare.

Fine-grained clastic rocks of the group include grey-green weathering, unsheared black argillite and cherty argillite, rusty-weathering black slate, and greenish and maroon tuffs.

Limestone occurs in two habits. One member about 50 feet thick involves both grey-weathering and buff-weathering (dolomitic?) limestone, internally bedded and in part carrying an admixture of reddish silt. Discontinuous black chert beds an inch to 3 inches thick occur in the limestone. Elsewhere, dominantly clastic parts of the section carry at intervals 1-foot beds of silty limestone which weathers to a terra-cotta shade.

Greenstone masses of the group form two of the highest summits just south of the map boundary. These are massive green rocks, much veined by quartz and epidote, that weather to rusty red and purplish surfaces. The greenstones lack lateral persistence and the possibility of their being intrusive rocks must be recognized.

Structure

Internal Structural Relations

No criterion of stratigraphic tops was found in place, despite careful search, and the section is described on the assumption that the beds are upright. Most of the beds are very well exposed, and apparently not repeated.

	Thickness (feet)
Top of section: intrusive contact with quartz diorite	
Greywacke, pebble-conglomerate	2,600
Chert, slate, jasper	1,200
Greenstone (may be intrusive)	1,200
Greywacke, conglomerate, chert, cherty tuff, silty limestone	1,500
Chert, argillite, tuff	1,000

Northeast of the quartz diorite body at Hardluck Peaks, the beds of the group strike more or less parallel to the regional trend, but east of the intrusive body and immediately south of the map-area, where the bulk of them are, they strike uniformly N35° to 45°E (perpendicular to the regional trend) and dip vertically or steeply northwestward. Several obvious faults of unknown length and displacement were noted, but no folds or repetition of beds were observed.

External Structural Relations

The principal mass of map-unit 10 is completely surrounded by intrusive rocks: by quartz diorite on the west, and by the O'Keefe ultramafic body on the north, east, and south. The quartz diorite makes a locally crosscutting but broadly concordant contact with rocks of the group, which are metamorphosed near the contact. The only probable explanation for the abnormal attitude of the beds is that they have been pushed aside by the quartz diorite intrusion.

All contacts with the ultramafic body are sheared, and the bedded rocks are not metamorphosed by them. Proof is therefore lacking that these are intrusive contacts in a magmatic sense. Several highly sheared serpentinite masses too small to be shown on the map are found within the area occupied by the principal mass of the map-unit 10. In every instance, these lie along faults. The situation suggests that the mass of bedded rocks is a fault 'horse' in the great Nahlin fault, surrounded by tectonically introduced ultramafic rocks.

The rocks southwest of Pike River assigned to map-unit 10 (contorted, purple and grey, white-weathering cherts, sandy, buff to grey limestone, and finely bedded siltstone) strike N60°W and dip more or less vertically. There is no evidence of unconformity where the first rocks of Laberge character appear, but exposures are poor.

In Tulsequah map-area, in the vicinity of Yeth Creek, the writer found an assemblage of rocks including chert, sandy limestone, and greenstone, and provisionally grouped them with the rocks of map-unit 10, on the basis of lithological similarity. These rocks are conformably overlain by the Laberge group.

Age

The conformable superposition of rocks of the Laberge group over rocks of map-unit 10 suggests a Triassic age for the latter.

Laberge Group

Marine Jurassic sedimentary rocks of the Laberge group occupy a northwesterly trending, graben-like belt about 15 miles wide, in the southwestern part of the map-area. The group is dominated by massive volcanic greywacke, but siltstone, mudstone, shale, conglomerate, and sandy limestone are also present. Partial sections 10,000 feet thick have been observed, but these involved neither the lowest nor the highest beds of the group, and the total thickness may be much greater.

Lithology

Greywacke

The Laberge group is typified by massive volcanic greywackes. These range in colour from grey through grey-green to dark olive-brown, and many beds are mottled. The greywackes are poorly sorted in general, but many of the thinner beds display distinct grading from coarse sandstone at the base to silt or shale at the top. Greywacke beds more than 2 feet thick commonly are coarse grained, and carry many flakes of shale, pebbles up to 2 inches in diameter and a few slabs of shale up to 3 feet in length. Such beds have not been observed to display graded bedding.

Spherical concretions up to 6 inches in diameter, in which carbonate has replaced the fine-grained matrix, are exceedingly common in the massive greywackes.

The gross compositions of five Laberge greywackes, as determined by micrometric analysis, are plotted in Figure 2. The diagram shows the paucity of quartz in these rocks. Rock fragments in Laberge greywackes are over 90 per cent volcanic types, mostly andesitic. The only other widespread rock-type is chert. Clastic feldspar is dominantly plagioclase, mostly very fresh, potash feldspar being present only in traces. The most common of mafic mineral fragments is deep green hornblende, which is also a common constituent of the volcanic fragments. Epidote is widespread, and most thin sections reveal some pyroxene. Sphene and apatite are common accessory minerals. The matrix of Laberge greywackes is a very fine-grained paste containing much chlorite. A little carbonate commonly replaces some of the matrix and often some of the plagioclase as well.

Angular grains characterize the greywackes, and many grains of plagioclase and hornblende were seen which still show the original crystal outlines. A few well-rounded grains of quartz and feldspar are normally present.

Siltstone, Mudstone, and Shale

Most of the siltstone and mudstone are poorly sorted rocks gradational into the finer greywackes and differing from them only in grain size. Many of the mudstone beds are distinctly graded, beds about 2 inches thick grading from buff siltstone at the base through the dominant mudstone to black shale at the top. Convoluted bedding is ubiquitous. Thin-bedded mudstones form members some tens of feet thick that interrupt the sections dominated by massive greywacke. True shale is generally limited to the tops of the graded mudstone beds, and to beds at most a few feet thick between massive greywacke beds. However, occasional members consisting of several hundred feet of black shale do occur.

Thin-bedded, black, buff-weathering siltstone bearing worm-like Carbonaceous markings is exposed south of Pillman Creek and also high in the Section Mountain section. It is much better sorted than is typical of the Laberge group.

Conglomerate, Pebbly Mudstone, and Pebbly Greywacke

True conglomerates are rare in the Laberge group of Atlin map-area, but pebbly mudstone and pebbly greywacke are fairly widespread.

A conglomerate at about the middle of the exposed section at Section Mountain is about 60 feet thick and carries boulders up to 3 feet across. One exposed on the shore line 1½ miles south of Janus Point is 60 feet or more thick, and carries cobbles up to 5 inches in diameter and slabs of concretionary sandy limestone up to 7 inches in length. The southern tributaries of Pillman Creek expose at least two major conglomerates, one of which is more than 25 feet thick and carries 8-inch cobbles, and several 1- and 2-foot conglomeratic beds. Whether the two first-mentioned conglomerates represent the same horizon and correspond to one of the Pillman Creek conglomerates is not known.

The conglomerates are composed mostly of pebbles of porphyritic volcanic rocks. Next in importance are limestone fragments, and among these, slabs of buff-weathering, sandy limestone with worm-like markings (clearly derived from the Laberge group) are prominent. Pebbles of other sediments typical of the group are common. Granitic pebbles do not exceed 10 per cent, but can be seen in most outcrops. The matrix of the conglomerates is greywacke.

The terms pebbly mudstone and pebbly greywacke are applied to mudstone and greywacke beds that carry up to 25 per cent (characteristically only a few per cent) of pebbles. The two types intergrade, but the first-named is the more widespread. These rocks occur in massive beds 5 to 20 feet thick. The pebbles are of types similar to those found in the true conglomerates, but rarely exceed 3 inches in diameter.

Concretionary Limestone

Beds of sandy, buff-weathering limestone are commonly associated with the thinner bedded members of the Laberge group, and in extensive, evenly bedded exposures commonly occur at regular stratigraphic intervals of a few tens of feet. The beds rarely exceed 6 inches in thickness. Many of the sandy limestone beds display convoluted bedding identical in form to that of the enclosing siltstones or graded mudstones. Many also display worm-like markings on surfaces perpendicular to the bedding. These markings are highly distinctive, but of unknown origin.

Abundant evidence shows that the limestone beds are of concretionary origin. In places a single bed, generally of siltstone, changes abruptly to silty or sandy limestone, the bedding lines crossing uninterrupted from one facies to the other. In other instances a continuous bed of sandy limestone gives way laterally to a string of tabular limy concretions that are exactly the same thickness and occupy the precise stratigraphic position of the continuous bed. In some instances fragments of limestone appear to have localized the concretions or beds. An obvious kinship exists between the spherical limy concretions of the massive greywackes, the sandy limestones of the thin-bedded zones, and the carbonate veinlets seen in most exposures of the group.

Primary Features and Origin

Features diagnostic of deposition in shallow water are missing from the Laberge group. The graded bedding, phenoclasts, convoluted bedding, and flow casts at the base of graded beds, all typical of Laberge beds, are a combination of features characteristic of rocks deposited by turbid currents. Indications of accumulation on an appreciable slope are seen in two outcrops in which recumbent folds involving a foot or so of thin beds are sandwiched between undisturbed beds. This effect is attributable to slumping of unconsolidated sediments.

Only one of the Laberge conglomerates bears discordant relations to the underlying beds; it transects several feet of thin-bedded mudstones in an exposure on the south fork of Pillman Creek. More remarkable is the fact that the other conglomerates studied, as well as the pebbly mudstones and greywackes, bear perfectly conformable relations to underlying fine-grained beds. One must conclude that the conglomerates in general are not current-deposited and do not reflect a shallowing of water in the area of deposition. Probably the coarse conglomerate beds arrived where they are now found as submarine landslides or mudflows. Their unsorted greywacke matrix is consistent with this view. Although the single instance of a discordant conglomerate may reflect a disconformity, the discordance may equally well have been formed by the snout of a submarine slide carrying cobbles and boulders that tore up unconsolidated sediments.

Two aspects of the Laberge sediments merit discussion. These are the presence in Laberge conglomerates of fragments of sedimentary rocks and lithified fossils belonging to the Laberge group, and the preponderance of volcanic rock fragments.

The occurrence of a Laberge conglomerate that transects the underlying beds offers a complete solution to the means by which Laberge sedimentary rocks and fossils were freed to become parts of Laberge conglomerates, if the base of the conglomerate represents a true disconformity. The rounding of many of the Laberge fragments implies that they were lithified when transported, and such lithification implies some depth of burial. That a submarine slide of coarse material is capable of eroding to sufficient depth is doubtful. What is more probable is that differential subsidence between the axis and the margins of the trough of deposition exposed earlier sediments at the margins of the trough to erosion while deposition proceeded uninterrupted nearer the axis of the trough.

Although volcanic fragments are by far the most important component of Laberge sediments, their heterogeneity and the lack of sharp outlines typical of glass fragments among the fines demonstrate that the Laberge sediments are of greywacke affinities and are not pyroclastic rocks. The primary structures offer similar evidence. The volcanic content of the greywackes, therefore, reflects a source terrain dominated by fresh volcanic rocks. The rocks of map-unit 4 are a possible source, but their alteration is on the average more severe than is characteristic of volcanic fragments of the Laberge group. Furthermore, fragments of the distinctive ferruginous limestone of those units were not observed in Laberge rocks. Of the pre-Jurassic rocks studied, parts of the volcanic rocks of map-unit A correspond most closely with the fragments found in the Laberge group.

Primary structures of Laberge sediments were not studied with an eye to determining the direction of transportation, but a detailed study of this kind would probably yield worth-while results.

Structure

Internal Structural Relations

Neither the base nor the highest beds of the Laberge group have been recognized. Furthermore, the lack of horizon markers prevents the summation of partial sections, measured in different areas, to achieve a figure for the thickness even of the part of the group that is exposed. Only a minimum thickness as revealed in partial sections can be presented.

The axis of a major anticline trending northwest coincides with the line of Section Creek. The northeastern limb of this anticline on Section Mountain exposes at least 10,000 feet of strata, as follows:

Top of section	Feet
Greywacke; subordinate mudstone and shale; minor pebbly mudstone; highest beds mostly thin-bedded siltstone and shale	4,700 at least
Cobble and boulder conglomerate	60
Mostly thick-bedded greywacke; subordinate mudstone and shale members, increasing in amount upward	5,300

A section of Laberge beds at least 10,000 feet thick is exposed in canyon walls east of Paradise Peak, but has been observed only from a distance. The section appears to consist of alternating greywacke and mudstone-shale members.

The Laberge group is deformed into open folds along northwesterly trending axes. The fold axes mapped were determined solely on the basis of direct observation of opposed dips, for in no instance was it possible to establish stratigraphic equivalence of beds on the opposite limbs of a fold. The folds are asymmetrical, southwest dips being characteristically steeper than northeast dips. No thrust fault was mapped but a fault of unknown extent, exposed on the south fork of Pillman Creek, displays thrusting towards the southwest, a direction consistent with the asymmetry of the folding.

External Structural Relations

The base of the group has not been observed, as from Pike Bay southeastward, the northeastern contact of the group is the Nahlin fault. The deflection of the contact on crossing the deep valleys of Gold Bottom Creek and Nakina River suggests, but does not prove, a steep northeast dip for the fault. If so, it is of reverse type.

At Simpson Creek, the fault brings Sloko group rocks on the north into contact with Laberge group rocks on the south. This movement is of opposite sense to that suggested above, but the throw indicated is 1,000 feet at most. If the principal movement on the fault is northeast-side-up, minor reversal of movement in post-Sloko time is implied.

Field work by the writer in Tulsequah map-area during the season of 1955 showed that the fault continues at least to Nahlin River. At Yeth Creek local overturning of beds on the southwest side supports the view that the fault is of reverse type.

The nature of the Laberge-Cache Creek contact is not revealed at Teresa Island or Atlin Mountain, but as pointed out earlier (p. 28), it may be a continuation of the fault discussed above. Evidence for a fault contact between the Laberge group and the rocks of map-units 4 and 5 at Copper Island is given on page 18. The Laberge group is overlain unconformably by the Sloko group.

Age and Correlation

The rocks mapped as Laberge group are physically continuous with the Laberge group ('Laberge Series') of the type area (Cairnes, 1910, p. 30; Bostock and Lees, 1938, pp. 13-15) in Laberge map-area, Yukon, through the intervening Whitehorse (Wheeler, 1952) and Skagway (Christie, 1957) map-areas. This is not to say that the entire sequence of the type area is exposed in Atlin map-area. Armstrong (1949, pp. 59-62) lists the possible correlatives of the Laberge group in the course of his discussion of the Takla group.

In the Laberge map-area, fossils collected were mostly or entirely taken from the lower member of the group, and indicated a Lower Jurassic age. In the Whitehorse map-area, both Lower and Middle Jurassic fossils were found, the latter occurring in the highest beds exposed (J.O. Wheeler, personal communication, 1955). Two collections of ammonites from the neighbouring Skagway map-area (GSC Cat. Nos. 17601, 17602) are of Lower Jurassic (Lower, Middle and Upper Lias)[1] age, but do not include fossils from the highest beds. A limy concretion found as a transported cobble in the conglomerate south of Janus Point (GSC Cat. No. 19639) yielded an ammonite, *Arnioceras*[1], characteristic of the Sinemurian stage of the Lower Lias and also present in the Laberge group of the type area. Shales 40 feet below the conglomerate yielded a belemnoid[1] of probable Lower Jurassic age. The stratigraphic position of these occurrences is not known.

Coast Intrusions

The use of the term Coast intrusions (12) for certain granitic bodies of Atlin map-area implies conformity with long established practice (Lord, 1947, p. 243) rather than a correlation on the basis of age or composition with any individual body or bodies so named elsewhere. On the preliminary map (Aitken, 1955) it was expedient to designate nearly all granitic rocks as Coast intrusions, but the alaskite of Surprise Lake (13a), the quartz monzonite of Dawson Peaks (13b) and the quartz monzonite of Teresa Island and Atlin Mountain (15a) have since been separated from the others on the basis of their younger age and distinctly different character.

Fourth of July Creek Batholith

Distribution

A zoned intrusion—the Fourth of July Creek batholith—composed mainly of granodiorite (12a) and quartz monzonite (12b) occupies an area of more than 300 square miles in the northwestern corner of the map-area. The peak and northern flank of Mount Snowdon are composed of granodiorite (12a), and

[1] Identifications by Hans Frebold, Geological Survey of Canada.

related monzonite appears in limited outcrop north of Marble Dome. The pink granite (12c) believed to be related to the above rocks occurs mostly in the southwestern part of the batholith.

Lithology

Granodiorite

The granodiorite (12a) is readily recognized in thin sections but not always identifiable in the field. It can generally be distinguished from the quartz diorite (12b) by its darker colour and weathering and lower quartz content, but many of the 'undifferentiated' plutonic rocks are not separable from it in the field.

The nearly anhedral plagioclase of the granodiorite normally has ragged boundaries. Most of it appears to be about An_{40} and is not prominently zoned, but many grains are rimmed by plagioclase as sodic as An_{20}.

The mafic-mineral content varies from 20 to 35 per cent, the amount of hornblende plus the pyroxene cores of hornblende grains exceeding biotite in almost all specimens studied. Hornblende is ragged, and in many instances poikilitic. Colour-mottling or zoning is common, but the characteristic pleochroism is: X, faint yellow; Y, olive-green; Z, green. The cores of most hornblende are colourless clinopyroxene but some of the green variety surrounds a hornblende core that is brownish on Y and Z. Brown biotite occurs in part as a replacement of hornblende.

Potash feldspar, mostly non-perthitic and lacking visible microcline-type twinning, makes up less than one third of the total feldspar. It occurs in small interstitial patches that share a common orientation over areas several times the length of the average plagioclase grain. Ragged remnants of plagioclase with a common orientation surrounded by potash feldspar prove widespread replacement of plagioclase by potash feldspar.

Quartz, making up 10 or 15 per cent of the granodiorite, forms fairly large equant grains, but the extremities of these display interstitial and replacement relationships very like those shown by potash feldspar.

Apatite prisms, some with smoky cores, are prominent among the accessories. Sphene is well represented. A few small zircons and opaque grains are present.

Inclusions, particularly masses of amphibolite, are numerous in some granodiorite exposures.

Quartz Monzonite

The quartz monzonite (12b) is a granitic rock that intergrades with the granodiorite (12a), but is unmistakable where ideally developed.

The lighter coloured representatives of the quartz monzonite are recognized in the field by abundant smoky quartz, small hornblende euhedra, and crystals of brown sphene that catch the eye in every specimen. Some outcrops are even more distinctive, the potash feldspar appearing as pink phenocrysts. The quartz monzonites that approach the granodiorite (12a) in composition are darker in colour and weathering. Inclusions of amphibolitic and dioritic material are locally numerous, but lacking over wide areas, and in general are not so common as in the granodiorite.

The quartz monzonite (12b) is medium to coarse grained and commonly inequigranular. The texture seen in thin section is typified by the presence of grains of weakly perthitic potash feldspar that display 'growth lines', manifested by zones unusually rich in perthitically intergrown sodic plagioclase (*see* Plate IV). The growth lines correspond to the typical outlines of potash feldspar euhedra, but not to the boundaries of the grain that bears them, which are very irregular, in part with apophyses into the interstices of surrounding grains and in part with ragged replacement contacts against plagioclase. The growth lines are important in demonstrating that although some of the potash feldspar undoubtedly originated by replacement, much of it did not. The growth lines are not inherited from the composition-zoning of replaced plagioclase, for in many instances a single growth line surrounds two or more plagioclase grains of different orientation. Furthermore, the growth lines are deflected upon encountering a Carlsbad twin-plane in potash feldspar. Finally, small plagioclase crystals engulfed by potash feldspar were observed in many instances to lie parallel to growth lines related to different, non-parallel, possible crystal faces of the potash feldspar grain. This suggests that the growth lines approximate what were once the physical boundaries of a growing crystal. Small, interstitial, non-perthitic grains of potash feldspar also occur, bringing the total content to more than one third of the feldspar in the rock.

Plagioclase is well formed and strongly zoned. The average composition appears to be basic oligoclase. A little myrmekite is found at some contacts with potash feldspar.

Quartz, making up 10 to 25 per cent of the quartz monzonite, normally occurs in large simple grains, but also forms clumps of small round grains in some specimens.

Mafic minerals constitute 7 to 20 per cent of the quartz monzonite. In practically every specimen, colourless clinopyroxene is present, at least in traces, at the cores of hornblende grains, and the ratio of pyroxene to the total content of mafic minerals is probably as high as in the granodiorite. Hornblende tends to euhedral outlines, and in pleochroism resembles the green hornblende of the granodiorite. Biotite comprises about half of the total content of mafic minerals and is like that of the granodiorite.

The accessory mineral suite, dominated by large euhedra of sphene, is distinctive. In almost all specimens, some of the small apatite prisms have smoky cores, pleochroic from brown to dark grey. A few zircons are present associated, like apatite, with mafic minerals. Apatite and tourmaline are rare. Opaque accessories are of minor importance.

Micrometric and chemical data pertaining to both the granodiorite (12a) and the quartz monzonite (12b) are plotted together on Figures 5, 6, 10 and 11.

Pink Granite

The pink granite (12c), porphyritic in some outcrops and aplitic in others, outcrops at many points in the western part of the Fourth of July Creek batholith, particularly along Atlin Lake.

The granite is characterized by growth lines in potash feldspar similar to those seen in the quartz monzonite (12b) and by an abundance, not usual in so felsic a rock, of crystals of sphene which are easily visible in hand specimens. The mafic mineral, altered to destruction in many specimens, is green hornblende. Molybdenite occurs in the habit of an accessory mineral in the pink granite north of Burnt Creek.

The data obtained by micrometric analyses of several specimens of pink granite show a wider scatter than is normal for members of the granodiorite-quartz monzonite series. Recalculated for plotting on Figure 5, the data straddle the line at which potash feldspar equals one third of total feldspar. The quartz content ranges from 12 to 27 per cent. These analyses actually have not been plotted on Figure 5, in order not to mask the significance of the other data. Figure 6, however, shows that the pink granites continue the other trends of the granodiorite-quartz monzonite series.

Many specimens of pink granite, appearing fresh in hand specimen, are seen in thin section to be riddled with micro-faults followed by veinlets of quartz or carbonate and are too altered to encourage detailed study.

Where contact relationships are exposed, pink granite is seen to cut the granodiorite (12a) and the quartz monzonite (12b). It is cut in many outcrops by lamprophyre dykes associated with the Fourth of July Creek batholith.

The spatial association of the pink granite with the Fourth of July Creek batholith, the distinctive growth lines of its potash feldspar, reminiscent of those of the quartz monzonite, its richness in euhedral sphene, and the fact that most of the variation trends of the granodiorite-quartz monzonite series are continued by the pink granite, are considered sufficient evidence for relating the pink granite to that series. The fact that the lamprophyre dykes related to the main batholith cut the pink granite apparently links the age of the two.

Monzonite

North of Marble Dome a few outcrops of monzonite appear in a topographic notch, flanked on the one side by greenstone and on the other by coarsely crystalline limestone. The mineralogical composition of the monzonite is unique, with 2 per cent quartz, 28 per cent microcline, 42 per cent plagioclase, and 26 per cent hornblende, but its fabric, the pleochroism of its hornblende, and its unusually high content of sphene are strongly reminiscent of the granodiorite-quartz monzonite series.

Other Related Rocks

In the western part of the Fourth of July Creek batholith lie many outcrops of quartz monzonite, granodiorite, and quartz diorite that possess some of the characteristics of the series discussed but are not typical. Many of the outcrops are inhomogeneous and appear to be hybrid, and many of the specimens reveal crystalloblastic textures in thin section.

Lamprophyre Dykes

Most parts of the Fourth of July Creek batholith are cut by dykes of dark green lamprophyre characterized by easily visible needles of pyroxene and/or amphibole. These dykes have not received the petrographic study they merit. Specimens studied are variable in the proportions of constituent minerals but similar in the common fabric of well-formed crystals and a tendency to display phenocrysts of the mafic minerals. Plagioclase is altered in most specimens. Either pyroxene or amphibole (brown or green) may predominate to the exclusion of the other. Biotite is present in every specimen studied.

The lamprophyre dykes display chilled boundaries against the granitic rocks, and textural zoning with the coarsest grain in the middle, showing that the host rocks were cool when the dykes were emplaced. However, the fact that few dykes reach beyond the margin of the batholith (none was observed more than a few hundred yards beyond the margin), strongly suggests some kind of genetic relationship. The lamprophyre dykes are cut by the Surprise Lake batholith.

Structure

Internal Structural Relations

If minor complexities are ignored, the Fourth of July Creek batholith displays an asymmetrical zoned structure with a core of quartz monzonite and a shell of granodiorite up to 6 miles wide. North of Atlin and at Mount Ewing, however, quartz monzonite reaches the margin of the batholith. The pink granite is found mostly in the southwestern part, but also occurs in small bodies of unknown shape and as dykelets in other parts.

Where the transition from granodiorite to quartz monzonite has been studied, it is gradational, but pink granite has been observed only in intrusive contact with other rocks of the batholith.

Flow structure, manifested by aligned hornblende crystals and parallel elongate inclusions, is seen in many outcrops of the granodiorite (12a). A trachytoid arrangement of feldspars is seen in many hand specimens of the quartz monzonite (12b), and in some thin sections of the granodiorite. On the west flank of Mount Hitchcock a schlieren-like structure is present in granodiorite. Determinations of the attitudes of these structures are too few to permit any generalization other than the prevalence of very steep dips.

The flow structures are primary. They occur in igneous rocks intrusive into non-schistose country rocks and hence cannot be the product of regional metamorphism. Crushing of the component grains is a rare feature, except in the fractured zone along Atlin Lake, and is lacking in many well-lineated rocks. Finally, hornblende lineation and elongate inclusions lie parallel wherever observed in the same outcrop. The parallelism is to be expected if the flow structure is primary, and the result of chance if it is secondary.

Fracturing and alteration are widespread in the granitic outcrops along Atlin Lake, suggesting that the northern part of the lake lies along an important zone of faulting.

External Structural Relations

The exact contact of the Fourth of July Creek batholith has been observed at only one place, the western nose of Mount Munro, where quartz monzonite is in contact with amphibolite phyllonite (metamorphosed mylonite). There, the

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contact is sharp but irregular, and no modification of the phyllonite is visible. A few blocks of phyllonite are surrounded by quartz monzonite at the contact, but, with the exception of one about 100 feet wide, none lies more than a few feet from the contact. A few small pegmatitic and aplitic dykes that cut the country rock are clearly fissure-fillings. The schistosity of the phyllonite is parallel with the general trend of the contact.

At Deep Bay, a part of the contact zone is exposed. The outcrops are inhomogeneous, which suggests either that the contact zone is contaminated or that the wall-rocks have been granitized. Some of the specimens collected display crystalloblastic textures.

Elsewhere, the exact contact is hidden, but where observed, bedding in the country rock near the contact strikes parallel to the contact and dips steeply. Two localities at which the bedding follows abrupt changes in the trend of the contact are: (a) where the Atlin road crosses the southern contact, and (b) on the Yukon boundary, northeast of Black Mountain. A most significant phenomenon is the manner in which the Sentinel Mountain-Mount Barham belt of greenstones splits away from the overlying limestone where it encounters the Fourth of July Creek batholith.

The granodiorite (12a) is intruded by alaskite (13a) at the head of Boulder Creek and at Mount Snowdon.

Metamorphism Related to the Fourth of July Creek Batholith

Where chert and argillite adjoin the Fourth of July Creek batholith, they are generally converted to quartz-biotite-muscovite schist. Plagioclase and potash feldspar are present, interstitial to quartz in these schists. Garnet is locally present in small amount. An outcrop on the west shore of Atlin Lake at the Yukon boundary reveals contorted and partly granitized meta-chert of the contact zone.

Where greenstone approaches the batholith, it is metamorphosed to a fine-grained, dark green amphibolite phyllonite (hornfels at the exact contact) composed chiefly of green hornblende, andesine, and quartz. The amphibolite loses its schistosity within 2 miles of the contact. Farther away, the composition of the plagioclase becomes less calcic until the albite of the normal greenstone is found unchanged. In the vicinity of Pine Creek, biotite believed to owe its formation to the effects of the batholith is found in greenstone up to 6 miles from the contact (*see* Figure 4).[1]

A xenolith of brucite-serpentine marble about 100 feet wide lies in the granodiorite a few hundred feet above the Atlin road, a mile south of the Yukon boundary. At the contact, diopside skarn appears over a width of several feet. Inclusions of similar material are widespread in the granodiorite west of the lake for a mile or so south of the boundary.

[1] The writer in 1953 attributed the metamorphism at Pine Creek to the alaskite batholith on Surprise Lake, which was then considered to include the southern part of the Fourth of July Creek batholith. When the two batholiths were recognized as separate entities, the eastward crowding of the metamorphic isograds could be explained on the basis of the different metamorphic effects of the two batholiths.

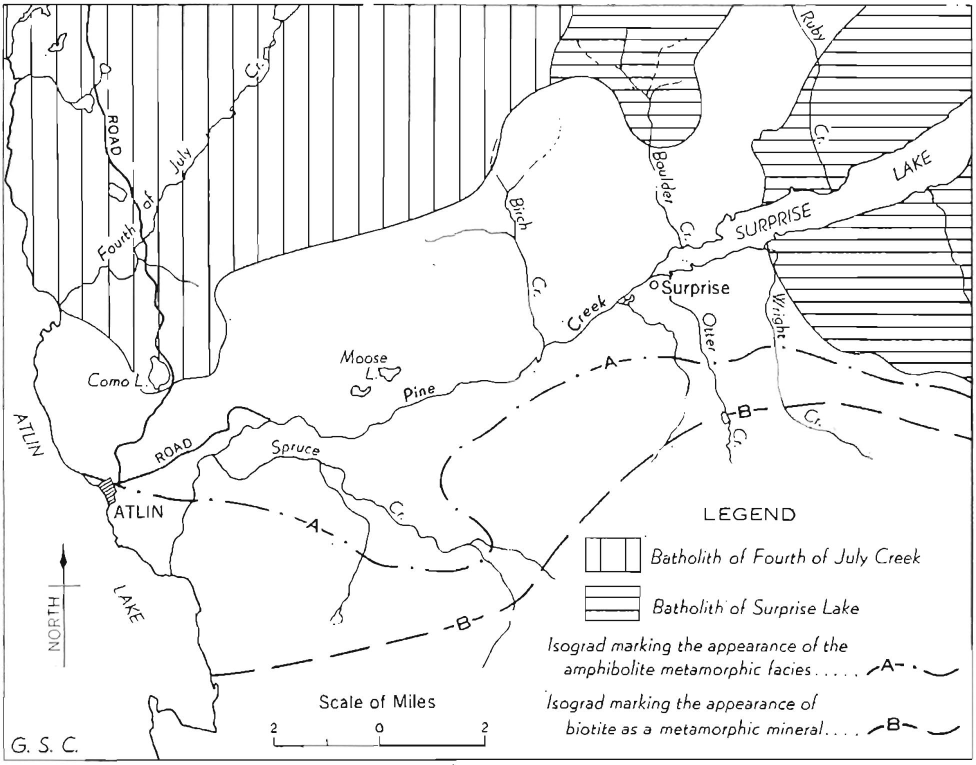

Figure 4. Distribution of metamorphic facies in the vicinity of Pine Creek.

Metamorphism by the Fourth of July Creek batholith of the volcanic rocks of Mount Minto, described on page 40, is unlike the metamorphism of the Cache Creek greenstones. The difference probably reflects not a difference in the conditions of metamorphism but the difference between the behaviour of fresh volcanic rocks (Mount Minto) and hydrothermally altered volcanic rocks (greenstones) under conditions of dynamothermal metamorphism.

Manner of Emplacement

It is not denied that some country rock has disappeared to make room for the Fourth of July Creek batholith. However, the country rocks in the main have *not* disappeared, but have been moved aside to accommodate the batholith. Only the intrusion itself can have provided the radially acting force responsible for this movement. This argument proves the batholith to be derived from a magma. That it was fairly fluid when emplaced is shown by the widespread primary flow structures and the testimony of the 'growth lines' in potash feldspar, which show that each crystal achieved a large part of its growth before encountering interference from surrounding crystals.

The variation in the measurable properties and partial chemical analyses of the granodiorite-quartz monzonite series forms a trend consistent with the hypothesis that the granodiorite is the earlier and the quartz monzonite the later

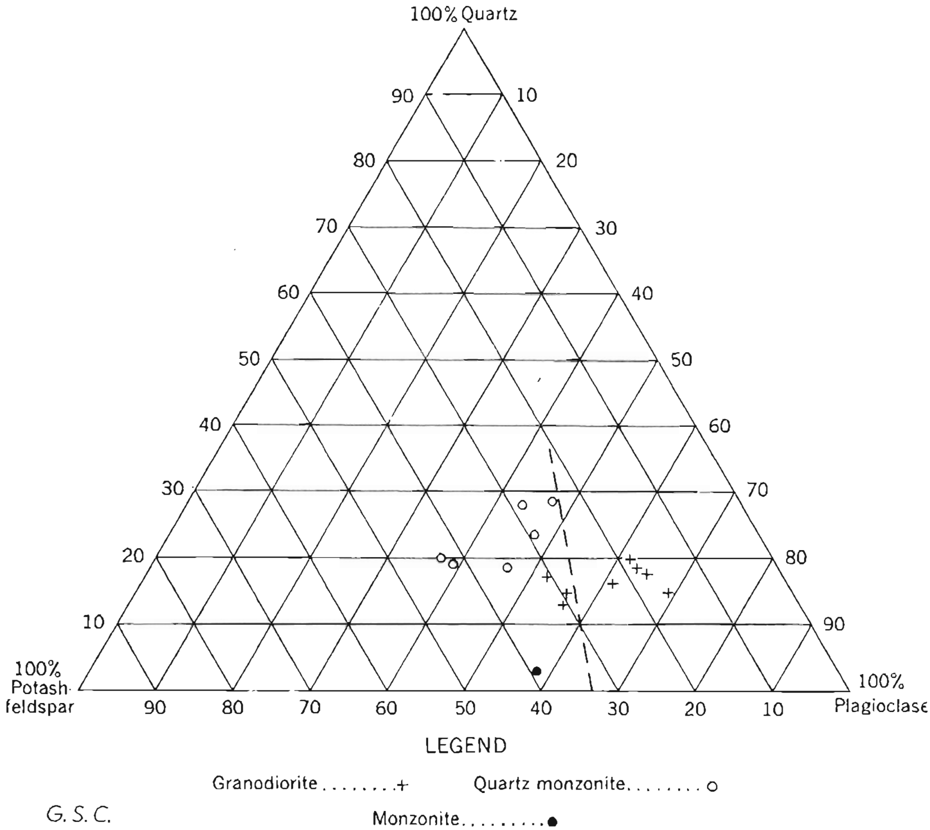

Figure 5. *Proportions (by volume) of quartz, potash feldspar and plagioclase in granodiorite (12a), quartz monzonite (12b), and related monzonite. Determinations by micrometric analysis.*

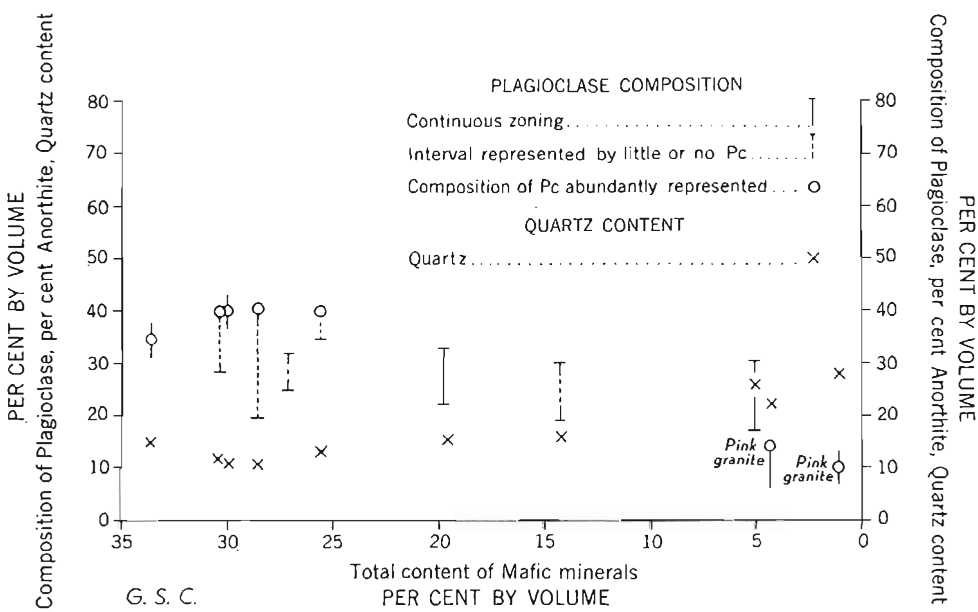

Figure 6. *Variation of plagioclase composition and quartz content with decreasing mafic-mineral content in the granodiorite (12a), quartz monzonite (12b), pink granite (12c).*

crystallized product of a differentiating magma. The occurrence of the postulated early crystallized rock as a shell more or less surrounding a relatively siliceous and potassic core is consistent with the concept of crystallization from the walls inward, with consequent enrichment of the core in late-crystallizing components. Contamination by assimilation of greenstone may have played a part in the basification of the shell of the batholith, as described by Reesor (1958, pp. 92-95) and Compton (1955, pp. 34-37) for other zoned intrusions, but cannot be confirmed by evidence in this instance. That contamination did not bring about all the observed variation is clear, for near Atlin quartz monzonite reaches the contact with greenstone and at Black Mountain granodiorite is in contact with siliceous rocks.

The pink granite appears to continue the variation trend established for the granodiorite-quartz monzonite series, except that enrichment in potash feldspar gives way to enrichment in sodic plagioclase as the dominant trend with decreasing mafic mineral content. The scatter in any plot showing mineral content is, however, wider for the pink granites than for the granodiorites and quartz monzonites, possibly reflecting complex and partly non-magmatic events late in the history of the batholith.

The monzonite north of Marble Dome is apparently the product of desilication of a member of the granodiorite-quartz monzonite series by reaction with the nearby limestone.

That some relationship exists between the Fourth of July Creek batholith and its myriad lamprophyre dykes seems clear, but what that relationship is the writer is unable to say.

Quartz Diorite

The quartz diorite (12d) comprises the equidimensional Mount McMaster stock, the Mount Llangorse batholith, the Chikoida Mountain stocks and the Nakina River stock.

Lithology

The quartz diorite (12d) forms light-coloured outcrops. The rock is almost white where fresh except for the more mafic members, but pink where the feldspar has been sericitized. Glassy quartz is a prominent constituent. Well-formed biotite and hornblende crystals are easily visible. In some hand specimens cleavage planes of a single potash feldspar crystal can be seen surrounding several other grains. The quartz diorite is everywhere equigranular and medium or coarse grained. Locally, near contacts, a distinct gneissic structure is displayed. A parallel alignment of hornblende and/or plagioclase crystals was noted here and there. Mafic inclusions are generally present, but only abundant at the contact of the Nakina River stock, where an orbicular contact phase occurs.

Plagioclase occurs in strongly and irregularly zoned subhedral grains. The cores of the grains are normally sodic labradorite, and the rims calcic oligoclase. The average plagioclase is estimated to be calcic andesine. Characteristic of this quartz diorite is widespread, irregular replacement of plagioclase at the centre of the crystal by more sodic plagioclase continuous with one of the outer zones. A little myrmekite is present in most specimens.

Quartz occurs in large grains and clumps of grains and also interstitially, Non-perthitic potash feldspar, constituting up to one fifth of the feldspar content, occurs characteristically in interstitial masses, optically continuous over wide areas. Replacement of plagioclase by potash feldspar is a minor, localized phenomenon.

Hornblende is generally dominant over biotite in those quartz diorites carrying more than 25 per cent mafic minerals; in the others, biotite dominates. Hornblende is normally found in well-formed crystals of various colours, with X, yellow, Y and Z, deep green or olive-green, or else olive-brown. In colour-zoned crystals, the rim is of the green variety. Biotite is less well formed, and is brown, reddish brown, or olive-brown in colour. It occurs in part as a replacement of hornblende. Biotite is partly altered to bright green chlorite and golden epidote.

The sparse assemblage of accessory minerals consists of ragged grains of sphene, euhedra of apatite, and very small equant grains of magnetite.

The results of micrometric and partial chemical analyses of the quartz diorite (12d) are summarized in Figures 7, 8, 10 and 11. The data demonstrate a direct correspondence between the quartz and potash feldspar contents of the rocks and the albite content of the associated plagioclase; these parameters bear an inverse relationship to the mafic-mineral content and the ratio of hornblende to biotite.

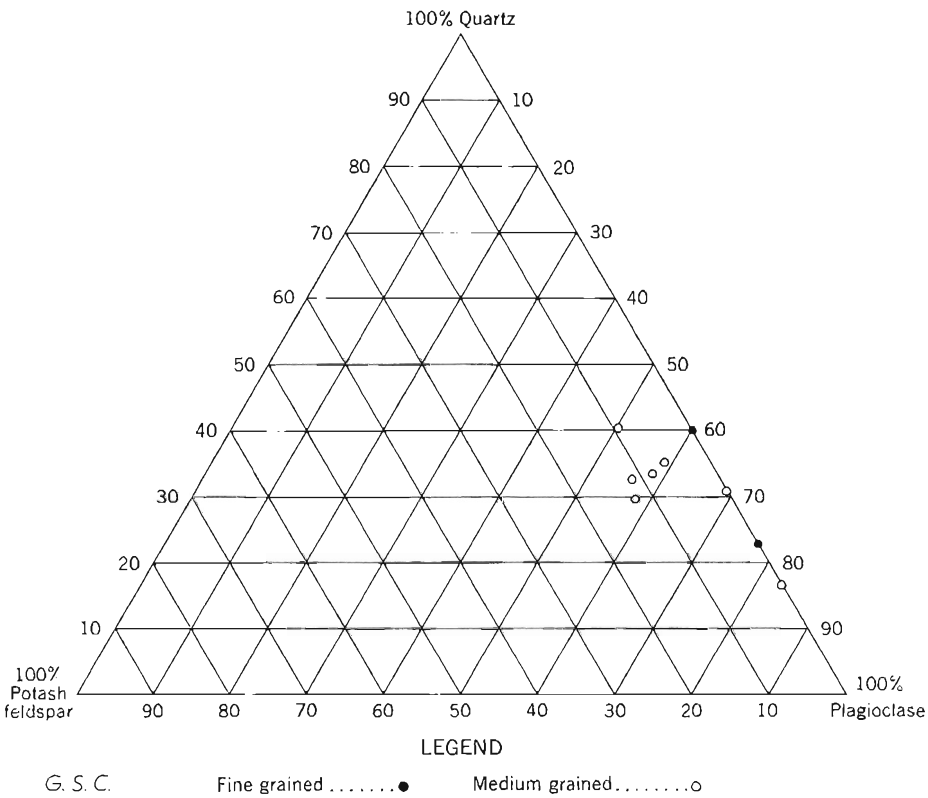

Figure 7. Proportions (by volume) of quartz, potash feldspar and plagioclase in the quartz diorite (12d).

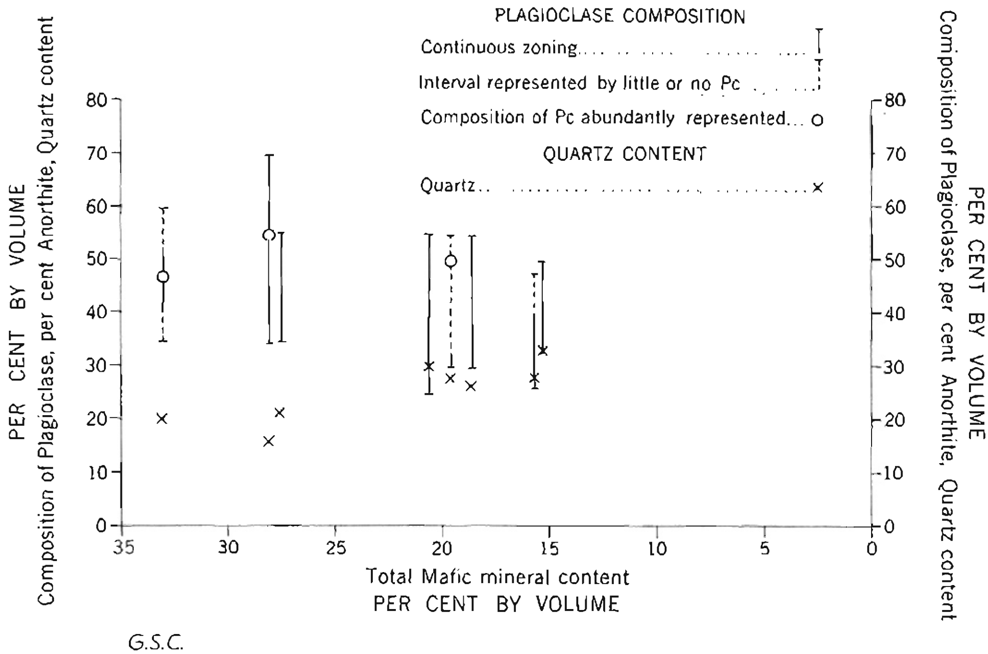

Figure 8. *Variation of plagioclase composition and quartz content with decreasing mafic-mineral content in the quartz diorite (12d).*

Structural Relations

The Mount McMaster stock is equidimensional, crudely circular in plan, and the attitudes and schistosity of the country rocks are tangent to the intrusive contact wherever observed. A gneissic border phase in the quartz diorite is widely developed.

Around the Chikoida Mountain stock the attitudes of the country rocks are also parallel with the intrusive contact wherever observed, although exposures are lacking on the northeast flank of the stock. On the southeast flank, individual thin beds of quartzite (metamorphosed chert) form the contact over tens of feet, but a mass of limestone forming an embayment in the stock shows that some crosscutting must have taken place. A gneissic border phase of the quartz diorite is locally present.

Nakina River Stock

The Nakina River stock is the only body of the quartz diorite (12d) that is elongated parallel with the regional structural trend. It is intrusive into, and almost completely displaces, the main ultramafic body (6) at Nakina River. The anomalous trend of the Triassic (?) beds (10) on its eastern contact has been pointed out previously. The trend of a sliver of Cache Creek sedimentary beds swings through nearly 90 degrees in following a bend in the contact south of Focus Mountain. On the other hand, distinctly crosscutting relations were observed at one point on the contact south of 59th parallel. Where the southern contact crosses Nakina River, a zone 500 feet wide of primary flow structure is oriented parallel with the contact. This structure has been followed by later shearing.

Mount Llangorse Batholith

A great area of the quartz diorite (12d) extends from near Paddy Lake to Hayes Peak east of Hurricane Creek, and appears to be continuous with the widespread outcrops of quartz diorite extending farther east and southeast. All of these exposures are regarded as reflecting a single subjacent batholithic intrusion. Quartz diorite typical of the core of the batholith closely approaches the contact in at least two places, but in general, the batholith displays an inward increase in grain size, quartz content, and potash feldspar content, and an inward decrease in mafic-mineral content. Country-rock bedding and schistosity are everywhere parallel to the contact, so that for 20 miles along the northwestern contact, the attitudes of the Cache Creek beds are roughly perpendicular to the regional trend. East of Hurricane Creek, a single folded limestone bed about 150 feet thick marks the contact of the batholith, wherever exposed, over a distance of 4 miles. A gneissic phase of the quartz diorite, its foliation parallel to the contact, has been observed locally in the contact zone. As is true of all bodies of this type of quartz diorite (12d), apophyses are very rare.

The small circular plug east of Hurricane Creek, possibly a cupola of the batholith, consists of fine-grained, fairly basic quartz diorite. The attitudes of the country rock on its north, east, and south sides swing through 180 degrees to follow the contact. The contact on the west is not well exposed.

Other Areas of Quartz Diorite

The outcrops in the vicinity of Swift River are typical of the quartz diorite (12d), and are so mapped. Outcrops of quartz diorite found at several places within the Fourth of July Creek batholith near its western contact may or may not be related to this quartz diorite as it has not been feasible in the course of this work to define their limits against the surrounding rocks of the batholith.

Effects Related to Contacts

The quartz diorite (12d) is commonly, but not everywhere, finer grained and relatively basic near contacts. Gneissic structure is found locally in the contact zone. The quartz diorite is desilicated to diorite where it is in contact with limestone east of Hurricane Creek.

The metamorphic haloes surrounding intrusions of the quartz diorite (12d) vary in width but are everywhere narrow in comparison with that of the Fourth of July Creek batholith. Megascopic evidence of metamorphism, for instance, disappears 4,000 feet from the steeply dipping contact northwest of Mount Llangorse. The well-exposed contacts are mostly against chert and argillite of the Cache Creek group. These are modified at the contact to quartz-biotite schist, with about 10 per cent feldspar (plagioclase and microcline), rare garnet, and traces of tourmaline. Greenstones near the Chikoida Mountain and Nakina River stocks show that the amphibolite facies of metamorphism is reached. Several contacts with limestone have been studied, but the only skarn found was a layer of garnet, less than a centimetre thick in direct contact with quartz diorite at Chikoida Mountain. East of Hurricane Creek, brucite-serpentine marble with traces of relict periclase and olivine is found at two points in limestone near the contact.

Manner of Emplacement

The profound influence of the bodies of quartz diorite (12d) upon the structure of the surrounding rocks demonstrates that these bodies have displaced rather than replaced the country rocks. The existence of locally crosscutting contacts shows that some of the country rock has been engulfed, but no feature of the quartz diorite yields a clue as to what has happened to this material. Because of the incomplete knowledge of Cache Creek stratigraphy, it has not been possible to estimate even semi-quantitatively, as Compton (1955, pp. 24, 25) did, how much room has been created by the disappearance of country rock. However, pushing-aside has obviously been the dominant process.

The metamorphic haloes demonstrate that the quartz diorite was hot relative to its surroundings when emplaced, and microscopic study reveals that it was fluid enough to allow only local deformation of the contained crystals. The textural evidence is consistent with the view that the bulk of the minerals crystallized from a magma. Potash feldspar and quartz appear in many specimens merely to have filled the spaces left when, say, 80 per cent of the magma had crystallized to plagioclase, mafic minerals, and quartz. The complex, but small-scale replacement effects noted are interpreted as late-magmatic and deuteric effects.

The micrometric data reveal that the quartz, potash feldspar, and albite content increase as the mafic-mineral content decreases. The chemical data display a parallel increase in potash and decrease in lime. The trend of decreasing mafic-mineral content is in general the trend inward from the intrusive contact. The data are consistent with the classic concept of enrichment of the remaining magma in late-crystallizing constituents during crystallization from the walls of the magma chamber inward.

Diorite

Some of the rocks mapped as diorite (12e) appear to be quartz-poor relatives of the quartz diorite (12d). Others are of unknown relations and varied character and do not merit individual description.

Alkali Granite

A distinctive porphyritic alkali granite (12f) appears in a belt of outcrops of unknown structural relations northeast of Jennings River.

The rock is characterized in outcrops by large red phenocrysts of microperthite in a medium-grained groundmass of white sodic plagioclase and dark green mafic minerals.

Under the microscope, the dominance of potash feldspar over albite or sodic oligoclase is seen. Quartz in interstitial position makes up 10 to 20 per cent of the rock. The mafic minerals, totalling not more than 10 per cent, are bright green soda pyroxene and blue-green soda amphibole.

Age of the Coast Intrusions

The Fourth of July Creek batholith must be of Mesozoic age because it intrudes rocks unconformably overlying strata of late Permian age, and is intruded by the alaskite (13a) of Cretaceous age. Related bodies are assumed to be of the same age as the batholith.

A common age is assumed for the bodies of quartz diorite (12d). Of these bodies, two affect only Cache Creek rocks, one, the Chikoida Mountain stock, also affects the Atlin intrusions, and only one, the Nakina River stock, south of Focus Mountain intrudes rocks that are probably Mesozoic in age. Its emplacement appears to have been controlled in part by the Nahlin fault, which displaces Jurassic rocks. The minimum age of the quartz diorite (12d) bodies is even less definable than its maximum age, but the intrusions are completely unroofed, suggesting that they are older than the Surprise Lake and Dawson Peaks bodies, which are still partly roofed. The similarity of the structural relations of the Fourth of July Creek batholith and of the quartz diorite intrusions (12d) suggests that they may be broadly of the same age.

Little or nothing is known of the structural relations or the age of the diorite, alkali granite, and 'undifferentiated bodies'.

Alaskite (13a) and Quartz Monzonite (13b)

The alaskite (13a) forms a single batholith which is considered to extend east from Surprise Lake to include the mass of alaskite east of Trout Lake. The quartz monzonite (13b), an obviously related rock-type, forms the Dawson Peaks stock and a small intrusive plug nearby.

Lithology

Alaskite

The alaskite (13a) forms light brown crumbly outcrops from which fresh specimens are not easily gained. It is recognized in the field by its inequigranular, highly variable texture (from fine to very coarse grained, and in places, porphyritic), abundant smoky quartz, low mafic-mineral content, and lack of colour-contrast between the two feldspars. Streaks and clots of simple pegmatite, a few inches long at most, are widespread and some outcrops contain small drusy cavities.

In thin sections, the potash feldspar is seen to be highly perthitic and commonly microcline-twinned. Plagioclase in some specimens is zoned from An_{20} to An_{05}; in all others the determinable plagioclase is of a composition between those limits, but its average composition is almost impossible to compute. Myrmekite is present in traces. The only mafic mineral, brown biotite fringed

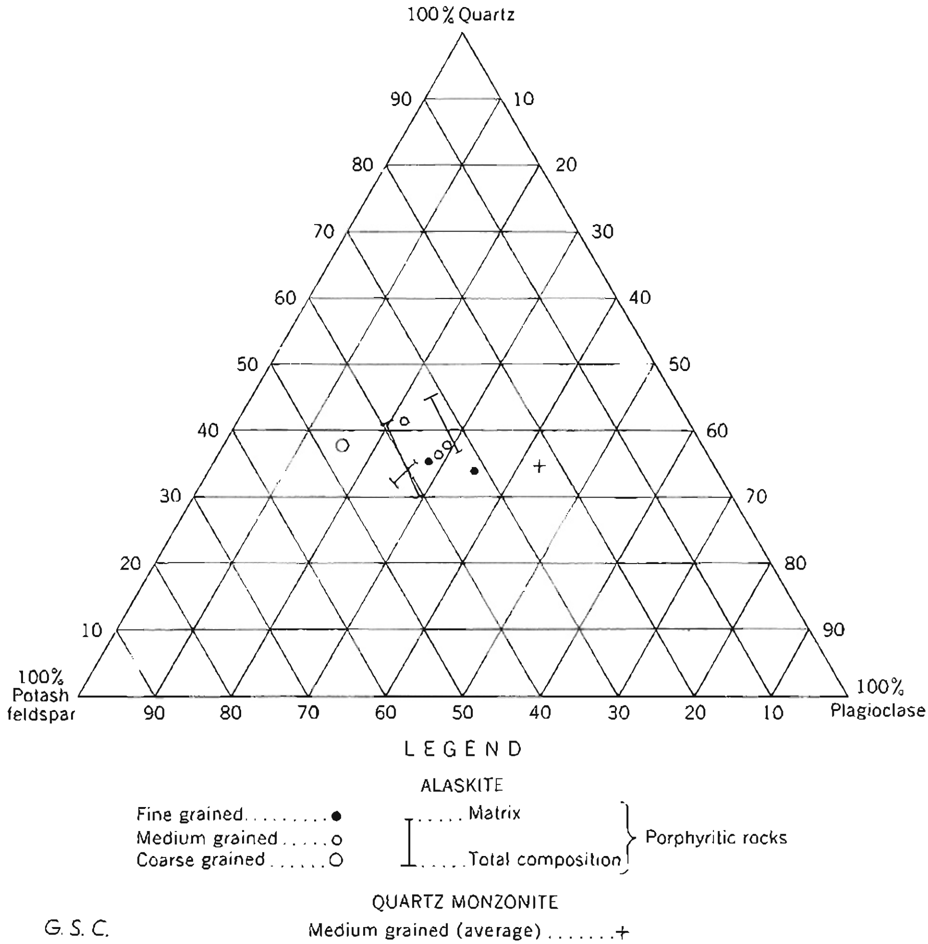

Figure 9. *Proportions (by volume) of quartz, potash feldspar and plagioclase in the alaskite (13a) and the quartz monzonite (13b).*

with green, comprises 1 to 5 per cent of the rock. Traces of muscovite are present in most specimens. Fluorite and apatite are widespread in traces. Topaz and allanite are very rare. Arsenopyrite appears in the habit of a normal accessory mineral in one specimen. The results of micrometric and partial chemical analyses of several alaskite specimens are presented in Figures 9, 10 and 11.

A wide variety of textures are seen. The simplest textures occur in the coarse-grained and nearly equigranular rocks, in which quartz forms large grains of simple outline. In these, grains of potash feldspar contain many shapeless or blocky patches of sodic plagioclase of common orientation. This relationship does not prove replacement of plagioclase by potash feldspar, for a series of specimens can be assembled to show every gradation between potash feldspar with well-defined plagioclase inclusions and normal microperthite. The series appears to demonstrate annealing of the filaments of sodic plagioclase in the normal microperthite. Other relationships, however, demonstrate replacement on a small scale of plagioclase by potash feldspar.

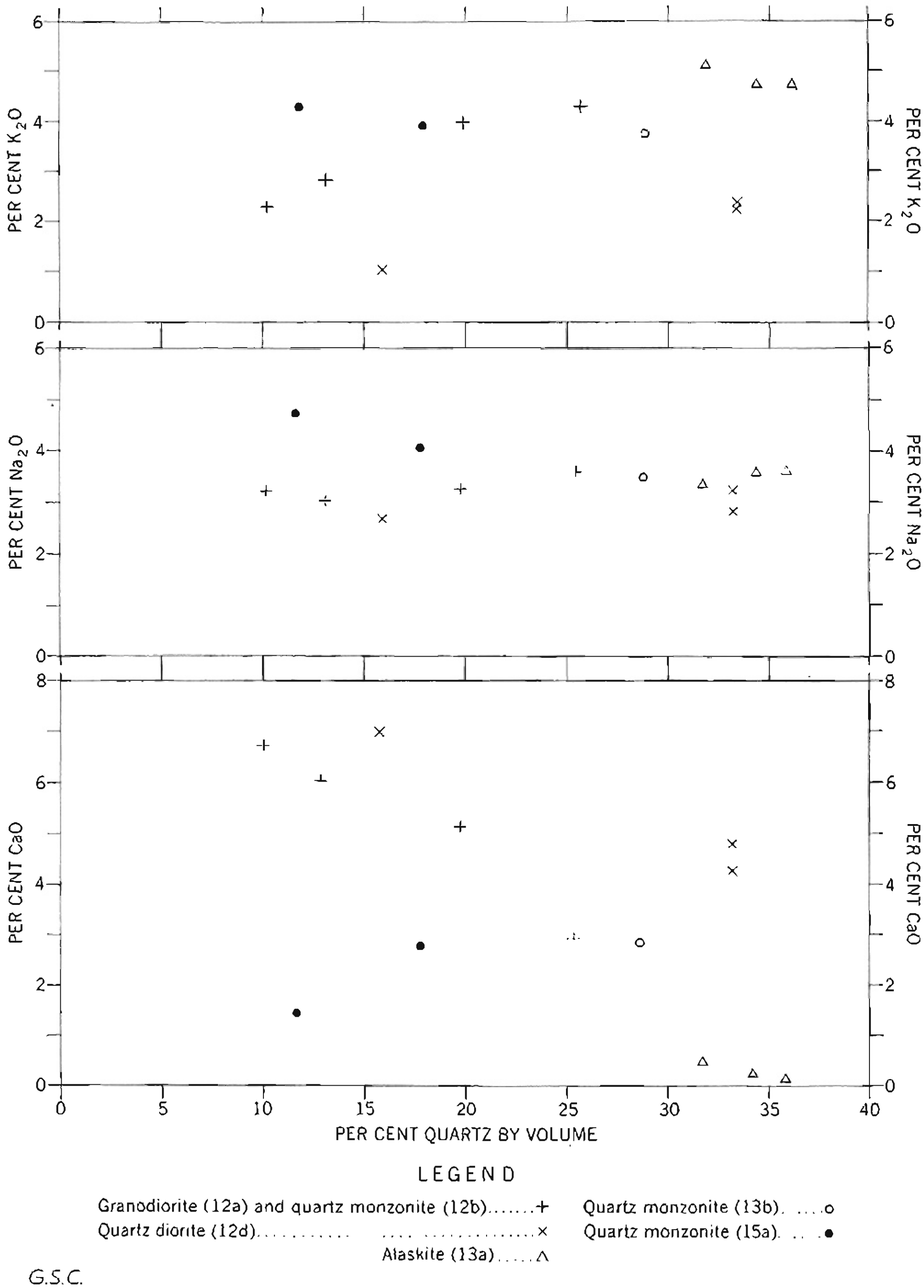

Figure 10. K_2O, Na_2O, and CaO contents of granitic rocks of Atlin map-area, plotted against quartz content. Chemical data by R. A. Rogers, analyst. Quartz content by micrometric analysis.

The fine-grained alaskites and those that are porphyritic with fine-grained groundmass are texturally complex. In many of these, both potash feldspar and plagioclase are intimately intergrown with quartz in a completely xenomorphic relationship (*see* Plate IV B). This texture, if interpreted as a replacement phenomenon, would lead to the absurd conclusion that each of the three principal components has to some extent replaced the other two. A more acceptable conclusion is that the texture is that of a three-component eutectic intergrowth.

Quartz Monzonite

Quartz monzonite (13b) displays a fabric like that of the medium-grained, equigranular alaskite, but the Dawson Peaks stock lacks the textural variety of the Surprise Lake batholith. It has less potash feldspar, contains more basic, strongly zoned plagioclase (cores of andesine, rims of albite, average composition about middle oligoclase), and more mafic minerals, including green hornblende. Micrometric and chemical data are presented in Figures 9, 10 and 11 where they may be compared with the data concerning the alaskite.

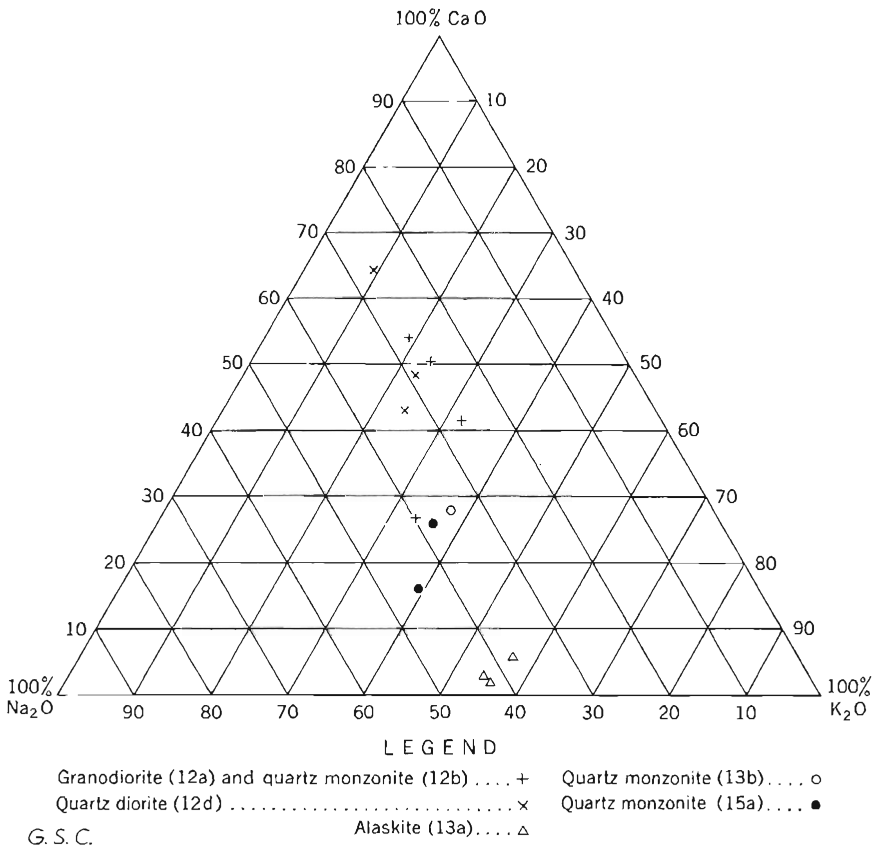

Figure 11. Proportions of K_2O, Na_2O, and CaO in granitic rocks of Atlin map-area. R. A. Rogers, analyst.

Structure

The body of quartz monzonite at Dawson Peaks is steep-sided at the lower levels of exposure. A projection of the inward-curving upper parts of the contact suggests that the roof was dome-like. Shore outcrops along Teslin Lake, at the southern contact of the stock, reveal the quartz monzonite in indistinct contact with partly granitized quartzite and quartz-biotite schist of the Cache Creek group. High on the mountain, however, the quartz monzonite is chilled where in sharp contact with the volcanic rocks. Elongate crystals of quartz and plagioclase in contact with the highly metamorphosed wall-rocks are mostly oriented perpendicular to the contact, a further demonstration that crystallization started at the walls and proceeded inward. Small veins and dykelets of aplitic and pegmatitic material are abundant in the immediate vicinity of the contact, but do not extend far beyond it.

The contacts of the Surprise Lake batholith also dip steeply outward everywhere except in the vicinity of Ruby Creek, where parts of the roof remain, and in detail the contact relations are exactly like those at Dawson Peaks. An intrusion-breccia of angular, clearly displaced fragments of greenstone in a fine-grained alaskite matrix is locally present at the contact but, as at Dawson Peaks, inclusions are extremely rare more than a few feet from the contact. A unique phenomenon is seen at Mount Leonard, where a 100-foot-thick, vertically oriented slab of granodiorite lies a short distance within the alaskite. Dykes of alaskite reach up to a quarter-mile from steep contacts, but are few. At some places, however, as at the head of Consolation Creek, a thin remnant of the roof of the batholith is riddled with porphyritic dykes. The alaskite displays a confusing variety of textural types, here in sharp contact with one another, there in gradational contact. Finer-grained varieties generally cut coarser-grained ones, but there are many exceptions.

Generally the batholith cuts across the structures of the country rock but along the southern contact from Surprise Lake to Eva Lake, structural trends abnormal for the region are parallel with the contact.

The youngest rocks affected by the quartz monzonite are the undated volcanic rocks at Dawson Peaks. The Surprise Lake batholith intrudes the granodiorite (12b) at Mount Snowdon and at Boulder Creek.

The band of Cache Creek rocks through Trout Lake is a graben let down into the batholith along faults marked by two prominent lineaments. One of the lineaments is in part impressed upon the batholith and the alaskite is slightly sheared near the faults, showing that movement on the faults post-dates consolidation of the batholith. The configuration of the contact in the Snowdon Range appears to have been affected by the eastern of the two faults, which therefore may have existed prior to intrusion.

Contact Metamorphism

Schistose rocks are found at several points along the contacts of the Surprise Lake batholith and the Dawson Peaks stock, but normally the contact-metamorphosed rocks are hornfels. Greenstones at the contact are metamorphosed to the grade of amphibolite hornfels. Some slates near the contact carry clusters of sericite, which probably record the prior existence of porphyroblasts of either cordierite or andalusite. At Consolation Creek, green diopside skarn is developed where pure limestone comes into contact with the alaskite (13a). The galena-chalcopyrite deposit there is of contact-metamorphic origin. At Ruby Creek, diopside skarn and diopside-garnet-magnetite skarn are developed in limestone close to the contact of the batholith.

In general, the contact-metamorphic effects of the batholith and the Dawson Peaks stock are not visible more than half a mile from the contact.

Manner of Emplacement

The presence of a chilled margin against the wall-rocks is believed to prove that the Surprise Lake batholith and the Dawson Peaks stock are intrusive bodies of magmatic origin.

The hypothesis of forcible emplacement is rejected as neither the Surprise Lake batholith (13a) nor the Dawson Peaks stock (13b) displays the overall structural relations that support that hypothesis in the case of the quartz monzonite (12b) and quartz diorite (12d). The only hypothesis that occurs to the writer for the concordant southern contact is that the alaskite batholith intruded and destroyed an earlier forcefully emplaced intrusion, of which the granodiorite inclusion on Mount Snowdon is a remnant, inheriting its concordant relations.

No megascopic evidence of assimilation is visible, and the consistency of the micrometric data supports the view that the intrusive rocks have not suffered contamination.

The limitation of xenoliths to practically unmodified blocks of country rock in the immediate vicinity of contacts demonstrates that piecemeal stoping was not an important process in providing room for the intrusions.

One hypothesis of emplacement remains to be considered, not on its own virtues so much as by default of other hypotheses. This is, that the roof rocks foundered into the magma in large blocks that sank below the level of observation without effecting significant contamination of the magma. The weak positive evidence in favour of this hypothesis is (a) the apparent steep-sided, dome-roofed form of the Dawson Peaks stock, which is the ideal form of intrusions filling the space left by the foundering of a roof-block detached by fractures of ring-dyke type (Billings, 1942, p. 286); and (b) the very large stoped block at Mount Leonard. The Dawson Peaks stock might conceivably fill the space left by the subsidence of a single huge block, but this can hardly be imagined in the case of the Surprise Lake batholith. The abundance of contacts between alaskites of different textures within the batholith suggest that the batholith grew through a complex series of events that, according to the writer's hypothesis, involved the foundering of roof-blocks that consisted in part of solidified alaskite into the subjacent alaskite magma.

Age

The bodies of alaskite (13a) and quartz monzonite (13b) are assumed to be of the same age on the basis of their compositional, textural, and structural kinship. In Atlin map-area they can be dated, on the basis of field evidence only, as younger than the volcanic rocks at Dawson Peaks and the Fourth of July Creek batholith. Kerr, however, described intrusions from Taku River area with the intrusions at Surprise Lake and Dawson Peaks, which are so nearly identical in composition, texture, and structural relations that no reasonable doubt exists that they are related. Kerr (1948, pp. 46-48) traced a belt of such intrusions to Taku River map-area from Stikine River map-area, where the intrusions are dated as of late Lower or early Upper Cretaceous age.

Sloko Group

The name Sloko group is proposed for a thick group of predominantly volcanic rocks in the southwest corner of the map-area. The name is taken from Sloko Lake, where a well-exposed section at least 3,700 feet thick has been studied. Thinner, but petrologically identical rocks in the vicinity of Mount McCallum have been assigned with confidence to the Sloko group. A 500-foot section of flat-lying, mainly felsic lavas, with minor sandstone and conglomerate, west of Atlin Mountain, is also assigned to this group.

Lithology

Andesite and subordinate basalt dominate the Sloko group. These rocks when fresh are mauve, brown, dark grey, black, or greeenish black. All weather to a brown shade. Most are porphyritic, phenocrysts of plagioclase and less commonly pyroxene being distingishable in the hand specimen. Amygdules of calcite, chlorite, quartz, opal, chalcedony, or combinations of these, are very common, and in some flows reach a diameter of 6 inches. Flow-structure and flow-breccias are widespread. All the lavas are well jointed, generally with joints parallel and perpendicular to the bedding, but well-developed columnar jointing is rare.

Under the microscope, most of the andesites and basalts are seen to be crystallized, and a groundmass composed chiefly of glass is rare. Plagioclase phenocrysts are almost invariably present, though by alteration to carbonate their composition can rarely be determined. A felted mass of minute plagioclase crystals makes up the bulk of the groundmass in nearly all instances. Phenocrysts and groundmass crystals of fresh pyroxene are much less common than those of plagioclase, and in several specimens, including some bearing bytownite plagioclase, there is no evidence of crystallized mafic minerals. Pyroxene commonly is partly or completely altered to chlorite or carbonate plus iron oxide; many of the abundant opaque grains of the groundmass may thus be secondary.

Dacite, lighter coloured than the andesites and basalts and carrying about 10 per cent quartz, is a minor component of the Sloko group. One olivine basalt has been recognized.

The felsic members of the Sloko group are albite trachytes, and to a lesser extent, albite rhyolites. These are mostly dirty looking, cream-coloured or faintly greenish rocks with rust-coloured spots, though one thick, partly glassy flow is mauve-brown, like an andesite. Albite in dull-white crystals is usually the only mineral recognizable in hand specimen. The albite trachytes and rhyolites occur as tuffs, breccias, and flow-breccias. Nearly all outcrops are rotten, and display a rough, flaky fracture.

Under the microscope, the plagioclase, where identifiable, is albite. Much of the plagioclase, however, is carbonatized, sericitized, or clouded with other secondary minerals. Quartz in the sparsely distributed albite rhyolites is in large sieve-like grains. In some of these rocks, rectangular casts of 'limonite' record the former existence of a mafic mineral, but in others, there is no trace of a mafic mineral. Glass is an important constituent of many of the felsic rocks.

Successive lava flows of the Sloko group are separated at many places by layers of rotten clastic rocks from a few inches to 10 feet thick. The material ranges in coarseness from sand to cobbles, and is entirely volcanic, being derived from the breakdown of the underlying lavas. Similar material in local patches appears to have filled gulleys eroded between eruptions in the lava flows. Thicker intervals of sandstone and conglomerate also occur. These are well bedded and, with the exception of those at the base of the group, are also composed of volcanic materials of local derivation. Seams of coal less than half an inch thick are found interbedded with sandstone south of Sloko Lake, and poorly preserved plant fossils occur here and there. The sedimentary beds are very limited laterally.

Structure

Internal Structural Relations

The succession of the Sloko group changes rapidly from place to place. The only section measured that approaches the maximum thickness of the group is the well-exposed one south of the east end of Sloko Lake, which is here designated as the type section:

	Thickness (feet)
Thick-bedded, green-black columnar basalt (highest beds exposed)	200
Dark grey, coarsely columnar andesite (single flow)	220
Light green tuff	20
Dense grey andesite	80
Sandstone, volcanic-cobble conglomerate	40
Mauve and dark green andesite and basalt flows with large and abundant amygdules; interbeds of derived sediment; minor thin sills	900
Mostly mauve andesite and basalt flows, minor greenish dacite	600
Sandstone and volcanic-pebble-and-boulder conglomerate, traces of coal	300
Not exposed	300
Massive, dark grey and black, chiefly andesite flows; basalt and olivine basalt	700
Pale greenish, rusty-specked, albite trachyte flow-breccia; conglomerate	250
Coarse, purple-and-green andesite breccia	thickness not known
Total, in excess of	3,700

Although the general character of the group is more or less persistent, sections observed elsewhere are distinctly different in detail. No important sedimentary bands were seen south of the west end of Sloko Lake. On the north side of Sloko Lake directly opposite the type section felsites are much more prominent in the upper part of the section. At the south end of Atlin Lake, several hundred feet of sandstone and conglomerate bearing cobbles and boulders of Yukon group metamorphic rocks and Laberge group sedimentary rocks form the base of the section. The comparatively thin section exposed west of Atlin Mountain commences with siltstone, sandstone, and conglomerate, and is chiefly composed of felsites.

At both Sloko Range and Mount McCallum, the highest exposed beds are the same unmistakable albite trachyte flow-breccia with mauve-brown glassy groundmass overlying cream-coloured albite trachyte. These beds are flat lying, and occur at similar elevations, but the section at Sloko Range is more than twice as thick as that at Mount McCallum. This shows that variations of thickness within the Sloko group are chiefly the result of the accumulation of the Sloko group in an area of mountainous relief. The relief of the pre-Sloko surface is again seen south of western Sloko Lake, where the bedding of the Sloko group terminates against two steep-sided buttresses of volcanic rocks of map-unit 4 (*see* Plate IIIB).

Within the group, one unit commonly truncates another and evidence of high initial dips is abundant. Areas of horizontal bedding are widespread, but dips up to 40 degrees were seen. No structural trend was detected; apparently any horizon may form 'humps and hollows'.

External Structural Relations

At the south end of Atlin Lake, gently dipping Sloko conglomerates and felsites overlie steeply dipping Laberge beds. The exact contact has not been observed, but the presence of boulders of Laberge greywacke and mudstone in the conglomerates proves the unconformity.

The horizontal Sloko beds west of Atlin Mountain overlie Laberge beds dipping at 60 degrees, in classic demonstration of an unconformity.

Many dykes, feeders of the overlying lavas of the Sloko group, cut the Laberge beds at Pillman Creek and west of Atlin Mountain.

Age

No identifiable fossils have been recovered from the Sloko group. The stock at Paradise Peak, which cuts the group, is not dated and, by analogy with similar bodies in northern British Columbia and southern Yukon, may be as young as early Tertiary. Kerr (1948, p. 38) observed the Sloko group from a distance, and considered it to be Upper Cretaceous, by analogy with gently deformed Upper Cretaceous rocks overlying intensely deformed Jura-Cretaceous rocks in the Stikine River region. The Sloko group is here regarded as Cretaceous or early Tertiary in age.

Tertiary (?) Intrusions (15)

Various small intrusive stocks and plugs occurring within the map-area cannot, because of the limited extent and uncertain age of post-Jurassic rocks, be accurately dated, nor is there proof that any one is of the same age as any other. These intrusions are provisionally assigned to the Tertiary on the basis of their similarity to dated Tertiary intrusions in northern British Columbia and southern Yukon.

Quartz Monzonite (15a)

Quartz monzonite stocks (15a) form the two largest Tertiary (?) intrusions in the map-area, one at Atlin Mountain and one on Teresa Island. These bodies are extremely variable in texture, some parts being as fine grained as felsite and others medium grained. Two fabric characteristics are however constant in all specimens. These are, the presence of grains of different sizes, commonly expressed in truly porphyritic texture, and the presence of much micropegmatite. Plagioclase mantled by potash feldspar is observed in many specimens.

The presence of phenocrysts and finely intergrown interstitial material prohibits accurate micrometric analyses. The data obtained however indicate that potash feldspar and plagioclase are about equal in amount and that the quartz content ranges from 10 to 25 per cent. The content of mafic minerals ranges from 5 to 12 per cent. Green hornblende and both brown and green biotite are present in most specimens. A few specimens carry clinopyroxene.

The two stocks have effected feeble contact metamorphism of the nearby country rocks. The stock at Atlin Mountain is still partly roofed, and a few large stoped blocks are visible in the quartz monzonite just below the roof contact.

Granophyre (15b)

Plugs of light-coloured, very fine-grained rock, characterized by a few phenocrysts of quartz and feldspar and an intergrown groundmass of quartz and sodic plagioclase (granophyre), are found in the southwest corner of the map-area, and near Mount O'Keefe. The three separate small plugs at the latter locality are shown as a single body.

The sodic character of these bodies suggests that they are related to the felsic volcanic members of the Sloko group.

Gabbro and Diorite (15c)

The gabbro stock at Pillman Creek and the diorite stocks at Simpson Creek and Paradise Peak have much in common, differing mainly in the anorthite content of the contained plagioclase. Most of the specimens studied carry some interstitial micropegmatite. The mafic-mineral content is less than 20 per cent in all three bodies. Pale green hornblende and both green and brown biotite occur, in part, as replacements of clinopyroxene.

The gabbro and diorite stocks are surrounded by zones of hornfels a few hundred feet wide.

The composition and spatial distribution of the gabbro and diorite stocks suggest that they may be related to the basic volcanic members of the Sloko group.

Olivine Basalt

Superficial olivine basalt of at least two ages has been recognized. The older basalt (16a) occurs in four small patches, three south of Mount Llangorse, and one west of Line Lake. The mass of columnar basalt 2½ miles south of the summit cairn on Mount Llangorse is about 200 feet thick, and overlies a boulder conglomerate about 75 feet thick. The conglomerate contains some basalt pebbles, but is chiefly composed of boulders of the underlying quartz diorite. Both basalt and conglomerate dip 30°N. This occurrence and the basalt west of Line Lake, which dips 20°NE, establish Tertiary faulting in the region. A Tertiary age for these basalts is shown by the fact that the present topography truncates their bedding.

The younger basalts (16b) occur as a volcanic conelet and a related lava flow at the head of Volcanic Creek, another conelet at the head of Cracker Creek, and a series of columnar flows more than 100 feet thick that form the walls of Ruby Creek gorge and are probably related to the Cracker Creek conelet. The Ruby Creek flows overlie gold-bearing gravels and are overlain by grey glacial till. The volcanic conelets, though dotted with glacial erratics, sit in the bottoms of glacially modified valleys, and are too perfect in form to have withstood the erosion of the entire Pleistocene epoch. By this reasoning, the conelets are of late Pleistocene age.

The stratified mass west of Ruby Creek is regarded as the battered remains of a stratovolcano and is probably older than the columnar lava flows in the valley. The unconsolidated basalt rubble which covers much of the floor of Ruby Creek valley is the product of a landslide from the stratified mass on the ridge.

Unconsolidated Deposits

The oldest of the unconsolidated deposits are certain of the rusty, decomposed, pre-Wisconsin gravels lying on deeply weathered bedrock, which are exposed in some of the placer workings. These deposits are discussed at length in the next chapter, in the section on placer deposits.

Pre-Wisconsin glacial deposits were recognized only in the hydraulic workings at Discovery. There rusty, partly decomposed outwash is locally overlain by thin till, similarly decomposed. The rusty deposits are overlain by normal grey deposits of the last glaciation.

The topographic manifestations of deposits of the last (Wisconsin) continental glaciation are discussed on pages 6-10; their chief significance is that they conceal bedrock over wide areas.

Deposits related to Recent alpine glaciation are of very minor extent.

Recent alluvium is of little importance compared with the valley-fills and terraces of Pleistocene outwash. The largest deposits are those still forming from the outwash of the Llewellyn and neighbouring glaciers. There, in Llewellyn Inlet, on the west side of Atlin Lake just northwest of Sloko Inlet, and in Sloko Lake valley, trains of gravels, sand, and silt almost bare of vegetation cover the valley floors and are building rapidly into the lakes. Also to be classed as alluvium are the tailings of the placer mining operations, particularly in Spruce and Pine Creek valleys where they extend for several miles.

Talus and coarse felsenmeer cover a large percentage of the areas above timber-line. Peat is accumulating today in the muskegs of the poorly drained valleys.

Chapter IV

MINERAL DEPOSITS

Metalliferous Deposits

Lode Deposits

Silver-Lead

References: Ann. Repts., B.C. Minister of Mines, 1921-34, 1951-52, especially 1922, pp. N 89-91. Geol. Surv., Canada, Sum. Rept., 1952, pp. 15A-24A.

The occurrence of silver-lead minerals at Crater Creek, a small tributary of Fourth of July Creek, was known as early as 1901. In 1921 work started in earnest on the Ruffner and Big Canyon groups of claims and continued until 1930, at which time Atlin-Ruffner Mines, Ltd., was formed. The company acquired the Ruffner group and developed it for 3 years, then allowed the property to fall idle. Work started again in 1951. In 1952, the company acquired the adjoining Vulcan and Big Canyon groups, and the Hurrah, Blacksmith, and Saddle Nos. 1 and 2 claims. After 4,000 feet of exploratory drilling had been done to investigate the continuation of vein zones into the newly acquired ground, the property once more fell idle.

The workings were not open at the time of the writer's visits. According to the literature cited above, the deposits are remarkable for the persistency with which fracture and ore zones are confined to lamprophyre dykes in the prevailing Fourth of July quartz monzonite. The dykes and shear zones strike N30° to 50°E and dip steeply northwest. At the Big Canyon group a fault zone, in part mineralized, was traced for a distance of 3,000 feet. Throughout that length the fault zone was confined to a dyke not more than 15 feet thick. At the Ruffner group a vein, which is probably continuous for upwards of 5,000 feet, apparently is confined to a dyke not more than 30 feet thick. The shear zones in the dykes are intermittently filled and replaced with quartz, calcite, and ankerite carrying galena, arsenopyrite, sphalerite, and minor pyrite and chalcopyrite. Ore occurs in irregular bands and lenses, widths of 6 feet being common.

Shipments of ore have yielded smelter returns as follows:

Year	Source	Amount (tons)	Au oz/ton	Ag oz/ton	Pb per cent	Zn per cent	Remarks
1922	No. 4 vein	3	ca. 0.1	81	31	...	Sorted
1925	No. 2 vein	10	1.1	200	6.2	3	Sorted
1951	?	44	0.16	121	4.1	0.65	Sorted?

The oxidation of the orebodies near the surface (a feature emphasized by Clothier and minimized by Cockfield) suggests that the sulphides yielding the above values may have been secondarily enriched. The answer to this problem can be gained only by detailed study when the workings are open.

Copper-Lead-Zinc

A typical contact-metamorphic base-metal deposit lies in silicated limestone at the contact of the alaskite batholith at the head of Consolation Creek. A few pits on the deposit yield green skarn and some solid sulphides consisting of galena, chalcopyrite, and sphalerite. The results of drilling carried out in 1954 by Selco Exploration Ltd. are unknown.

This occurrence and that of a copper-stained magnetite skarn in limestone at the alaskite contact between Ruby and Cracker Creeks draw attention to other limestone bodies striking towards the contact of the Surprise Lake batholith (13a), none of which is exposed at the contact. Silicated limestone was not seen at the contacts between limestone and Coast intrusions.

Tungsten

The occurrence of placer wolframite pointed to the existence of a wolframite deposit in the drainage basin of Boulder Creek. In 1942, Consolidated Mining and Smelting Co. carried out prospecting and test-pitting on a showing of wolframite in quartz between the middle and west forks of Boulder Creek.

In 1950 Black Diamond Tungsten Ltd., a company formed by Transcontinental Resources Ltd., acquired 50 claims and fractions at the head of Boulder Creek. Stripping revealed five mineralized zones. During the winter of 1951-52, a road was completed to No. 5 zone, at an elevation of 6,000 feet, and an adit was driven 400 feet along the vein.

The vein explored is persistent and 2 to 4 feet wide, but mineralization is patchy, successive samples at the same point yielding grossly different assays. The vein matter is essentially quartz and wolframite with rare specks of sulphides. The alaskite near the vein is sericitized and carries reddened feldspar.

In 1952 the company sampled and diamond-drilled zones Nos. 5, 6, and 6A. The neighbouring Emil group of claims was acquired and explored by trenching and test-pitting. The quartz vein exposed in the pits on that property is on strike with the No. 5 zone, but lies in greenstone beyond the contact of the alaskite and carries arsenopyrite together with fine-grained wolframite. The Black Diamond operation fell idle in the autumn of 1952.

Small showings of wolframite are scattered throughout the alaskite, particularly near the contact zone in the Boulder Creek-Ruby Creek area. Wolframite is, however, not restricted to the contact zone for a little was found on Mount Weir near the heart of the alaskite batholith. The tungsten minerals are associated with comb quartz in sericitized alaskite. Weathering of the associated arsenopyrite forms a greenish yellow stain over the mineralized alaskite. Some of these stained outcrops contain the secondary uranium mineral, zeunerite[1].

[1] Zeunerite fluoresces under ultraviolet light, but prospectors should be warned that the weathered feldspar of ordinary alaskite also displays a greenish fluorescence.

Alaskite float found at the head of Ruby Creek carried molybdenite in a quartz veinlet similar to the wolframite-bearing veinlets.

Gold

References: Ann. Repts., B.C. Minister of Mines, 1918, pp. K95, 96; 1933, pp. A77, 78.

Small, low-grade gold deposits occur in the vicinity of Pine Creek. Several of these, for instance the Imperial and Lakeview occurrences, are quartz veins sparsely mineralized with sulphides and carrying small amounts of free-milling gold. Gwillim (1901, p. 45) reported that a mill-run of several weeks on vein material from the Paris Exhibition (later the Imperial group?) on Mount Munro yielded a little over $10 in gold a ton (gold at about $20 an ounce).

Several other deposits, for instance those on the Yellow Jacket and Anaconda properties, are in quartz-carbonate rock (carbonatized serpentinite). Both the quartz veinlets and the carbonate matrix carry small amounts in gold.

The well-defined quartz veins generally lie in carbonatized wall-rocks, and display the crustification and comb structure typical of the quartz veinlets in carbonatized serpentinite, suggesting that the two types of deposits may be genetically related. On the other hand, the Pine Creek area is the only extensive area of dynamothermally metamorphosed greenstones in the map-area, which may account for the localization of gold-bearing quartz veins there. In any event, both types of gold occurrences display the structural features of deposits formed at no great depth.

Though economically unpromising, the lode gold deposits of the region are interesting as the probable source of the gold placers.

Copper

Copper minerals occur in the volcanic rocks (4) at three places in the southwestern corner of the map-area. The occurrences are: a prospect on Copper Island (not visited by the writer), a thin stringer of solid chalcocite followed by a short adit on the east shore of Llewellyn Inlet, and a copper-stained, pyritized zone on the creek entering the north end of Llewellyn Inlet from the west.

Nickel

Disseminated pyrrhotite-pentlandite is scattered through an extensive greenstone mass on the west flank of Mount Barham.

Uranium

An outcrop of radioactive, jasperized skarn, probably a volcanic rock altered by the surrounding pink granite, occurs on the isthmus between Graham Inlet and Atlin Lake, south of Deep Bay. Its discovery in 1953 by William Husselbee set off a staking rush that blanketed the west shore of Atlin Lake. Assays of 0.014 per cent U_3O_8, 0.16 per cent ThO_2 and 0.07 per cent U_3O_8, 0.17 per cent ThO_2 have been reported.

The occurrence of the uranium mineral zeunerite has been mentioned in the paragraphs dealing with tungsten occurrences.

Placer Deposits

References: Ann. Rept., B.C. Minister of Mines, 1936, pp. B39-56.
Geol. Surv., Canada, Ann. Rept. 1899, vol. 12, pp. 32B-44B.

Gold

Since the first claims were staked in 1898 the only mineral produced in important amounts from the Atlin camp has been placer gold. Gold produced up to 1946 was worth about $15 million and that produced in the period 1946-53 is estimated to be worth well over $1 million. All creeks that have yielded gold in important quantity were being worked by 1900.

Pine Creek

Worked ground on Pine Creek is confined to a section 9,000 feet long and 500 to 1,125 feet wide adjacent to Discovery, along the post-glacial course of Pine Creek. The termination downstream of the pay channel is apparently due to glacial scour. Mining upstream apparently ceased when the bedrock level became substantially lower than the bed of the modern Pine Creek and the difficulties of removing deep overburden and disposing of tailings apparently prohibited hydraulic mining. The last pits were apparently still in pay gravel and Mandy (1936, p. B45) gave good evidence that the pay channel was angling under the north bank at the head of the workings. Old prospect shafts are numerous on the north side of the creek upstream to Birch Creek, and the ground has been drilled once or more with undisclosed results.

Pay gravel has been reported from Gold Run, a small swampy creek south of Pine Creek above Discovery. The remains of a number of shafts may be seen along Gold Run, but there is no evidence of a large amount of gravel having been removed from any of these. An attempt started in 1904 to operate a dredge on Gold Run was unsuccessful.

Spruce Creek

The pay channel on Spruce Creek has been continuously worked for a distance of 17,000 feet, the widths being as much as 1,200 feet in the lower part narrowing to about 375 feet in the upper part. The narrower channel near the upstream limit of worked ground has yielded some of the richest ground in the region, 14,241 cubic yards extracted from Dream lease in 1950 averaging $22.02 per cubic yard.

The Spruce Creek pay channel coincides in elevation with the modern (or pre-mining) stream channel at the Tax lease. Traced downstream the old channel rises relative to the creek level, then is cut off at a steep bank where the old channel is 22 feet above the modern channel. The hanging termination of the preglacial channel coincides with the debouchment of Spruce Creek into Pine Creek valley, and is doubtless due to glacial erosion.

Upstream from Tax lease the old channel becomes progressively more deeply buried beneath grey glacial drift, until, at the junction of Spruce and Dominion Creeks, bedrock is 218 feet below creek level. From the shaft on Dream lease at this point, the pay channel has been followed upstream for nearly a mile on a 3 per cent grade. There, however, the channel filled with 'red dirt' gives way to a channel filled with 'grey wash' on less deeply weathered bedrock having a gradient of 1 per cent. The so-called grey wash carries many decomposed, rounded pebbles and is strongly iron- and manganese-stained, but does not contain as much clay as the red dirt. The average gold content of the grey wash is much below that of the red dirt but rich spots do occur, particularly above and on the downstream side of bedrock humps. In the autumn of 1956 the working-face was still in grey wash about 800 feet upstream from its first appearance. If the grey wash channel continues to coincide with the line of the red dirt channel upstream, there appears to be little probability that more red dirt will be found. Projection of the grades of the older and younger channels indicates that red dirt will have been preserved only if the younger channel deviates from the older. If this is so, the older channel will occur at a higher level than the channel occupied by grey wash, and will not be easy to find.

The writer can find no record of the bedrock trough having been reached at any point on Spruce Creek above the present working face on the Dream lease, though one drill-hole is said to have gone to 295 feet. Gold has been produced from shallow bench diggings near the junction of Rose and Spruce Creeks. Dredging was attempted at 'Blue Canyon' on upper Spruce Creek, but the valley-fill was of course much too deep to allow success.

The red dirt of Spruce Creek is so full of clay that a certain amount of gold incorporated in mudballs is lost to the tailings in the first sluicing. This gold is recoverable after the tailings have weathered for a year or two. Lower Spruce Creek has been reworked at a profit in recent years by a partnership using a diesel shovel to move gravel to the sluice-boxes and a dragline to stack tailings. By this means 70,000 yards of material sluiced in 1951 (tailings and patches of virgin ground left behind by the small operators who worked most of Spruce Creek) yielded an average of about 0.034 ounce of gold per yard. This operation will eventually be brought to a halt by the increasing depth of the pay channel below the modern creek.

$1.19/yd. + past tailings.

McKee Creek

McKee Creek has been worked by hydraulic methods more or less continuously since the early days. In the past few years, work has been mainly confined to the north bank, where the pay gravel lies beneath deep glacial deposits. The pay gravel at McKee Creek strongly resembles the Spruce Creek grey wash and, like the latter, carries coarse gold well above the weathered bedrock surface.

Birch Creek

Birch Creek, noted for large nuggets, has been worked for a distance of 2½ miles above its debouchment into Pine Creek valley. In recent years work on the creek had decreased and finally stopped. Shortage of water was a persistent difficulty and may have been the main reason for the cessation of work.

Ruby Creek

Ruby Creek differs from other creeks in that the pay channel is cut in granitic bedrock and is narrow compared with the channels of creeks with greenstone or ultramafic bedrock. The auriferous gravels are capped by a series of columnar-jointed olivine basalt lava flows which are more than 140 feet thick at the Columbia Development Ltd. shaft opposite the low pass to Cracker Creek. The creek has been idle since 1946.

Otter Creek

Hydraulic mining has been carried on along the line of the modern Otter Creek, both in its lower reaches and in the westerly flowing upper section. The middle part of the creek has not been mined but has been drilled over a period of years. One drill-hole below the wingdam is said to have encountered 'rim' at a depth of 120 feet, showing that the valley-fill is as deep as surface appearances would suggest.

The ancient channel of Otter Creek, underground and east of the modern channel, was worked at a profit through inclined shafts. Three pay levels were worked: one on bedrock, one 30 feet above, and one 60 feet above (N. Forbes, personal communication). The two higher pay levels lie on 'false bedrock', apparently glacial till. The pay gravel on 'false bedrock' was thin but of good grade.

Otter Creek has been idle, except for drilling, since 1942.

Wright Creek

Wright Creek has been worked only along its westerly flowing upper part, where the last hydraulicking operation ended in 1942. The reach between the elbow of the creek and the lower canyon has been drilled in recent years, apparently with encouraging results, for at the time of writing, a shaft expected to meet bedrock at a depth of 135 feet was being sunk immediately below the elbow of the creek.

O'Donnel River and Tributaries

O'Donnel River, like its neighbour Wilson Creek, has never been an important producer of placer gold, but has yielded enough to maintain prospecting interest for many years. Most of the activity has been in the immediate vicinity of the settlement of O'Donnel where hydraulicking and drifting on bedrock have been carried on. High-grade though apparently local concentrations of gold have been reported from a westward-sloping weathered bedrock bench beneath the west bank. None of the drifts is known to have reached the lowest part of the bench.

Several attempts have been made to sink to bedrock in the river-bottom at O'Donnel, but all were apparently defeated by the inflow of water.

Nearly every tributary of O'Donnel River has yielded some gold, in several instances from shallow diggings, but none has been worked at a profit.

The O'Donnel River system, and with it Wilson and Rapid Roy Creeks, have three things in common: they lack important areas of metamorphosed greenstone within their drainage basins; they carry enough gold, including coarse gold, to have encouraged intensive prospecting; they have never been worked at a profit.

Gold-Tungsten

Boulder Creek

Boulder Creek was worked more or less continually in the years 1899-1953. Worked ground is continuous for about 2¼ miles along the creek. Until recent years the wolframite in the pay gravel was considered a nuisance, as it rapidly filled the riffles and necessitated frequent clean-ups; only the gold was saved. Apparently no attempt was made to market the placer wolframite until 1950. Shipments made then assayed 46.88 and 49.01 per cent WO_3, and 7.42 and 10.75 per cent tin.

The lower part of Boulder Creek flows on serpentinite and amphibolite. Upstream from the alaskite contact the amount of both gold and tungsten gradually dwindled to a non-economic level.

Age and Origin of the Placer Deposits

Gwillim (1901, p. 32) referred to the rusty, decomposed gold-bearing gravels of the district as "pre-glacial gravels". Although he did not say so specifically, it is clear that he used the term pre-glacial as meaning Tertiary. Subsequent writers also have stated or implied that the gold accumulations on bedrock are of pre-Quaternary age. This idea, probably imported from the Cariboo goldfields in the earliest days of the camp, merits careful inspection because of the absence of fossil remains to prove the age of the deposits.

The arguments stated or implied in defense of the alleged pre-Quaternary age of the deposits on bedrock are:

(a) The gold-bearing gravels in most of the workings are immediately overlain by fresh glacial drift.

(b) The auriferous gravels are cemented and somewhat decomposed and lie on weathered bedrock.

(c) A long period of time (by implication a period longer than an interglacial interval) is assumed to be required for the accumulation of rich placer deposits.

The first observation raises more questions than it answers. Cutbanks revealing deposits related to more than one glacial advance are common (p. 6), but none of the buried deposits has been weathered to even such a feeble extent as the deposits at the present surface and all are therefore probably of Wisconsin age. The Atlin area probably suffered multiple glaciation during the Pleistocene epoch, but what has happened to the deposits of the pre-Wisconsin glaciation? The only traces are the rusty outwash and till at Discovery. All other traces of the glaciation recorded at Discovery and all traces of other glaciations that presumably occurred have vanished. Their disappearance should not be surprising. It is one thing for a complete sequence of glacial deposits to be preserved on the Great Plains, whence come so many of our concepts of Pleistocene events, and quite another for a similar sequence to be preserved in a mountainous region, where interglacial erosion must have been much more rapid. The freshness and thickness of the Wisconsin deposits today are no arguments against the stripping of earlier glacial deposits, for according to all estimates the interglacial intervals were several times as long as post-Wisconsin time (*see* Flint, 1947, pp. 400, 401). Support for the argument presented here is found in Bostock's (1936, pp. 48, 49) description of the Nansen Creek district of Carmacks map-area. He says: "The area shows all the features of an unglaciated country except for certain terraces of sand and certain drainage features", but reports the presence of boulder clay of undoubtedly glacial origin beneath some of the placer deposits. The boulder clay lies beyond the limit of the 'last glaciation' as mapped by Bostock and is the sole diagnostic evidence of an earlier glaciation. If it is granted that older glacial deposits have been stripped from the region, it is unreasonable to assume that erosion stopped in each instance precisely when the auriferous gravels had been laid bare.

The argument relating to the deeply weathered character of the pay gravels is weakened by the considerations outlined above, and invalidated by the existence at Discovery of glacial deposits whose degree of decomposition is comparable to that of much of the rusty gold-bearing gravels.

The length of time involved in the accumulation of placer gold in economic amounts is not easily assessed. Nevertheless, the two upper paystreaks at Otter Creek clearly were concentrated during non-glacial intervals which, according to the writer's interpretation, were merely interruptions of the Wisconsin glaciation.

In summary, although the possibility that some of the placers on bedrock are of Tertiary age is not denied, it appears probable that most of the deposits of the Atlin camp date from pre-Wisconsin interglacial events.

Source of the Gold

Gold-bearing quartz veins are known to occur in the vicinity of the placer accumulations but the probable gold content of the known lode deposits is small compared with what has been recovered from the placer deposits. In regard to the possible existence of undiscovered rich lodes, it is significant that many acres of bedrock in the most favourable area have been stripped in the course of placer mining without a single promising vein being discovered.

Gold-bearing veins displaying the structural features characteristic of the veins in the vicinity of Pine Creek commonly become too low-grade for profitable exploitation at no great depth, although they may be very rich near the surface. It appears likely, therefore, that the known lodes of the area and perhaps some of the multitude of barren quartz veins are the roots of lodes, now completely eroded, that may have been the source of the placer gold.

Non-Metallic Deposits

Asbestos

Claims have been staked for asbestos in three areas: Monarch Mountain, Chikoida Mountain, and 2 miles southwest of Focus Mountain. The three occurrences display a distinct community of geological setting; all occur in ultramafic rocks within the haloes of dynamothermal metamorphism surrounding granitic intrusions. In contrast, no trace of cross-fibre veinlets was observed in any part of the great ultramafic mass near Mount O'Keefe. The search for asbestos may, then, be limited to the metamorphic zones in which serpentinites are recrystallized but lack large amounts of talc and tremolite.

Magnesite

The high-grade magnesite observed is very fine-grained, pure-white material occurring as veins up to 4 feet wide in outcrops of carbonatized serpentinite. Coarse-grained white carbonate is dolomite in the examples studied. High-grade magnesite occurs widely in the carbonatized zone along the southern contact of the Nahlin ultramafic body.

Brucite

Some limestone members of the Cache Creek group are sufficiently magnesian to give rise to brucite marble upon being thermally metamorphosed at granitic contacts. Brucite marble was observed a few hundred feet above the Atlin road just south of the Yukon boundary, and also 4 miles east of Hurricane Creek.

Hydromagnesite

Reference: B.C. Dept. Mines, Bull. 4, pp. 115-119, 1940.

Superficial deposits of hydromagnesite occur immediately east of Atlin townsite. The four deposits exceeding an acre in area have an average thickness of 2½ to 3 feet and contain an estimated 118,000 tons of white hydromagnesite. About 83 per cent of the total tonnage carries between 41 and 42 per cent MgO, and about 3 per cent combined CaO, Al_2O_3, Fe_2O_3, and SiO_2, the remainder being of lower grade.

The gently mounded form and sharp limits of the hydromagnesite deposits indicate that they either are of very recent origin or are forming today. Cold mineral springs in the vicinity of the deposits and shallow wells at the townsite yield carbonated water which precipitates hydromagnesite upon standing. There can be little doubt that the mineral springs are the source of the hydromagnesite deposits.

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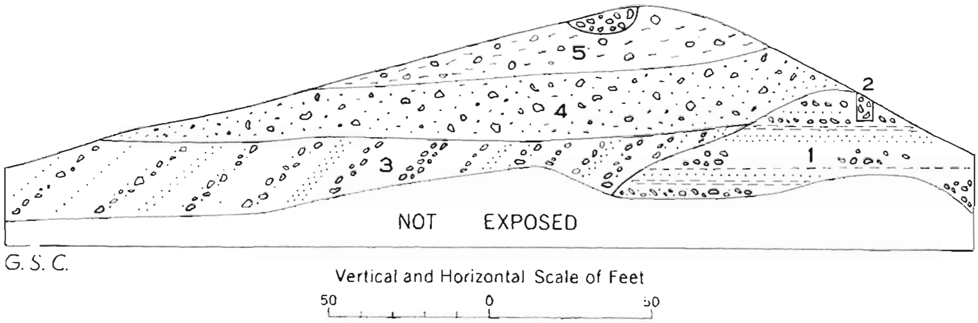

A. Sketch of the lowest cutbank on the east side of Otter Creek (see p. 6).
Explanation: (1) Bedded lake sands and silts with rafted cobbles. Outwash gravels at base.
(2) Coarse gravel filling vertical-walled cut-in (1).
(3) Delta foreset beds of gravel and sand.
(4) Weakly stratified, washed grey till.
(5) Buff, clay-rich till.

Plate II

B. Photograph of part of the bank illustrated in (A). Shows bedded lake sands and silts with rafted cobbles (1), overlain by steeply inclined delta foreset beds (3), and above them weakly stratified till (4).

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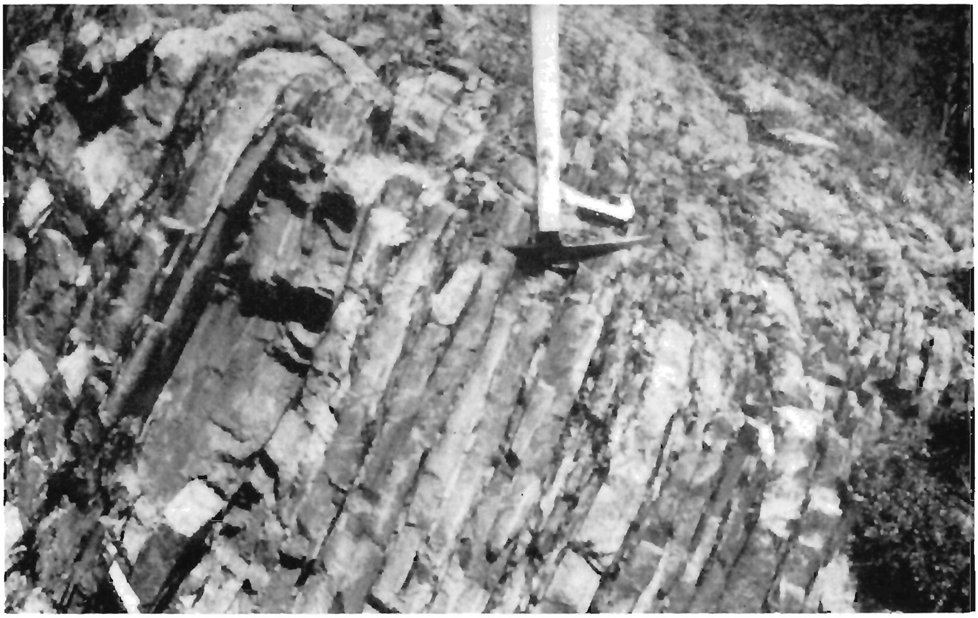

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A. Ribbon bedding in Cache Creek cherts near Hall Lake.

Plate III

B. Sloko River and Sloko Lake, view looking northeast. The braided outwash-gravel flats of the head of Sloko River lead to the silty water of Sloko Lake in the left middle distance. The distinctly bedded volcanic rocks of the Sloko group, in the middle distance, are interrupted by a 'buried mountain' of volcanic rocks of Llewellyn Inlet, the dark massive buttress near the centre of the picture. Paradise Peak, right of centre, is supported by a diorite stock. Note the trimline left by Recent retreat of the glacier in the foreground.

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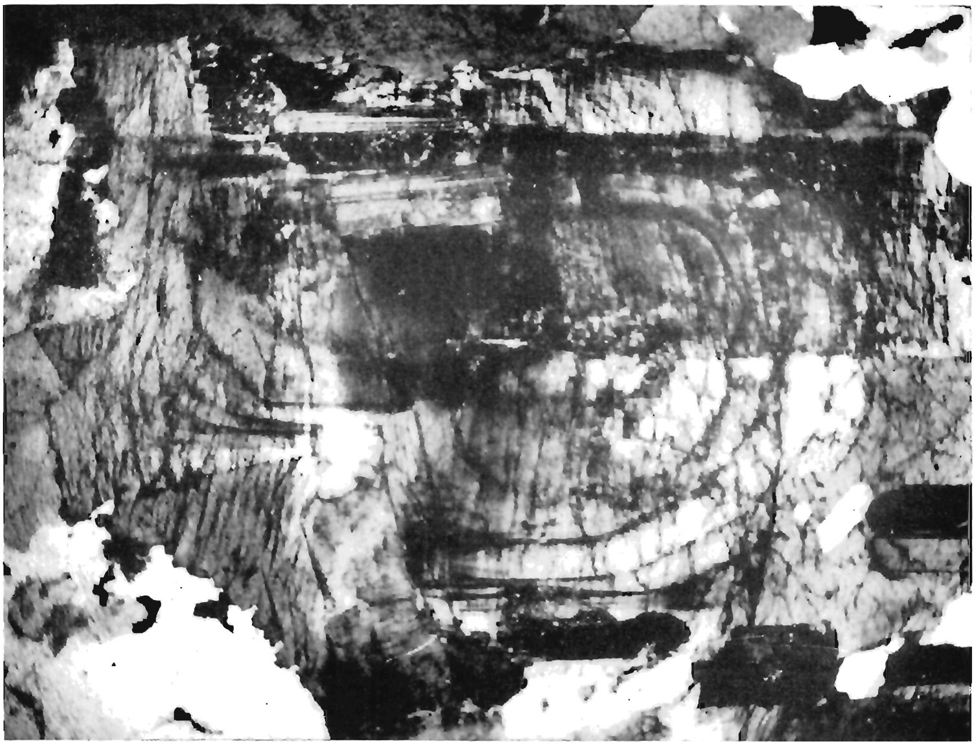

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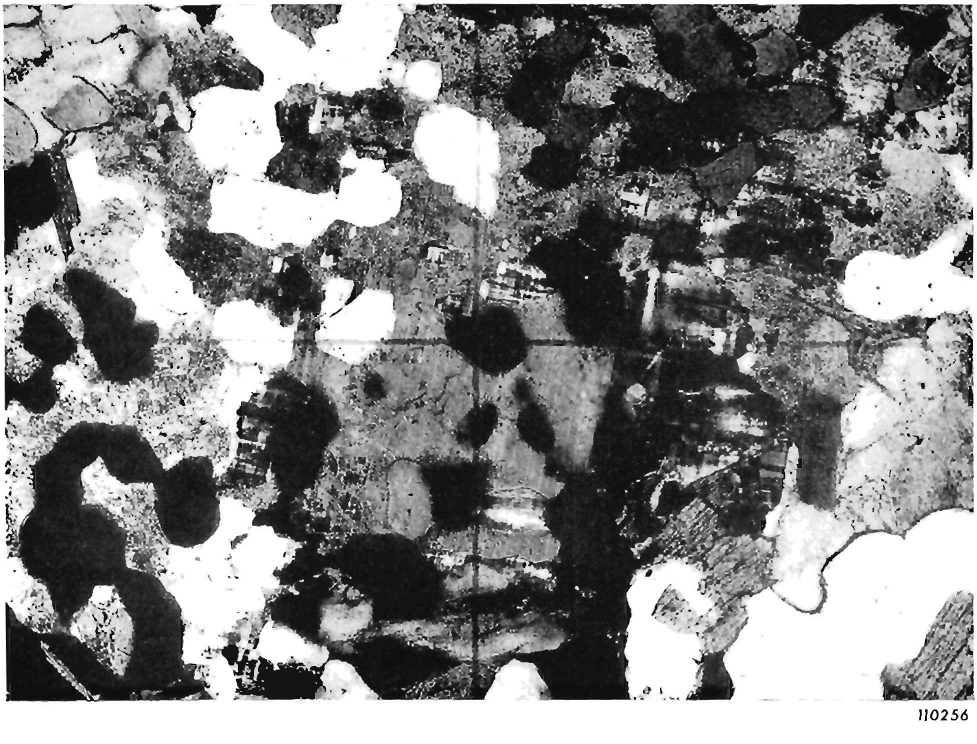
A. Potash feldspar grain from quartz monzonite of Fourth of July Creek, showing 'growth lines'. The right-hand part of the crystal is bisected by a Carlsbad twin-plane. Note the angle in several of the growth lines where they cross the twin-plane. The small inclusions of twinned plagioclase are of various orientations, and several of them lie tangent to the growth lines. Magnification 16X; crossed nicols.

Plate IV

B. Intergrowth of quartz, potash feldspar, and plagioclase in Surprise alaskite. The irregular rounded areas of low relief are amoeboid grains of quartz. Note their common optical orientation over wide areas. Note that individual amoeboid grains of quartz are intergrown with both potash feldspar (grid twinning) and plagioclase (faint albite twinning, as at centre of photo). Small grains with high relief and strong cleavage are biotite. Magnification 50X; crossed nicols.



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