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THE COAST RANGE BATHOLITH BETWEEN HAINES, ALASKA AND BENNETT LAKE, BRITISH COLUMBIA

Thesis by

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FIGURES

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INTRODUCTION

General Statement

The Coast Range batholith of western Canada and southeastern Alaska, which is a composite of many plutons from a few hundred yards to several miles in cross-sectional width, extends approximately 1,100 miles from the vicinity of Vancouver, British Columbia northwest to Kluane Lake, Yukon Territory. Its width varies from about 40 miles in the north to a maximum of about 120 miles in southern British Columbia. The northern end of the batholith has not been studied previously in detail. The author traversed this portion of the of the batholith from the northeastern contact at Bennett Lake, British Columbia along the tracks of the White Pass and Yukon Route railroad to Skagway, Alaska and from there by boat along Lynn Canal to Haines, Alaska and the southwestern contact of the batholith. The mapping was done on air photos, whose scale is approximately

1:38,000. The traverse was begun on August 4, 1951 and was finished on August 30, 1951. About four weeks were spent studying thin sections in March and April of 1952. The purpose of this report is to present the results of this study.

The author is indebted to Dr. Ian Campbell, who kindly criticized the manuscript, for his advice and suggestions. Mr. Wesley W. Patterson of Skagway was extremely helpful to the author, as was Mr. Kenneth Lamoreaux, also of Skagway, who loaned the author a 12 foot skiff for the Lynn Canal part of the traverse.

Geography

All the area traversed, as shown on pl. 1, lies in the Coast Mountains physiographic subdivision of the Canadian-Alaskan Cordillera (Bostock, 1948, map 922A). Bostock further divides the Coast Mountains into the Boundary Ranges, which lie along the Alaska-B.C. boundary and are separated on the southwest from the main Alaskan coast by the Alsek and Fairweather Ranges, and into the Pacific Ranges, which lie along the coast of southwestern British Columbia.

The Boundary Ranges are approximately 35 to

40 miles wide from the Portland Canal region to their northern terminus at Kusawa Lake, Yukon. They rise 4,000 to 6,000 feet above Lynn Canal and its tributary inlets. Lynn Canal is a typical fiord that extends from Icy Straits (20 miles west of Juneau) 75 miles north to its head near Haines. Three miles northeast of Haines it branches into Taiya Inlet, a mile-wide passage that extends 15 miles north to Skagway; Lutak Inlet, extending 6 miles to the west-northwest; and a small inlet between the two. The Taiya Inlet trough branches just west of Skagway into the Skagway Valley, which extends north-northeast to White Pass; and into the Taiya River Valley, which extends north to Chilkoot Pass.

The White Pass and Yukon Route, a narrow-gauge railroad, passes along the east side of the Skagway Valley from Skagway to White Pass. White Pass, elevation 2,900 feet, and Chilkoot Pass to the northwest, elevation 3,500 feet, are the only passes through the Coast Mountains between Taku Inlet, southeast of Juneau, and the Dezadeash Valley in the Yukon. The White Pass and Yukon Route extends northeast through White Pass, which is a broad, open pass about 10 miles long, to Log

Cabin, B.C. From Log Cabin it goes east and then north to Bennett and along the east shore of Bennett Lake, which for 16 miles lies in a relatively straight, steep-sided valley from 3,000 to 4,000 feet deep. Bennett Lake broadens north of this long, narrow section. The railroad extends north to Carcross, Yukon and to its terminus at Whitehorse, Yukon.

Many glaciers and several small ice fields lie in these mountains and reach their maximum development along the axis of the Ranges.

The climate of the area varies markedly from Haines to Bennett Lake. Haines and Skagway experience relatively mild, humid weather with annual precipitations of approximately 35 and 25 inches per year, respectively, most of it falling as rain during the winter months. The precipitation generally decreases north from Skagway, except for the elevation effect, with Bennett receiving about 15 to 18 inches per year, much of which falls as snow in the winter. Summers are cool and relatively dry north of the axis of the Ranges and winters are severe. Unofficial winter temperatures of -60 F. have been reported from Bennett.

The timber and vegetation of the Alaskan side of the area consist of forests of hemlock, spruce, cedar, and some pine, and of dense brush of willow, alder, devil's club, and other luxuriant growth. On the British Columbian side the forest growth is largely spruce, with some poplar on well-drained slopes. Alder and willow brush grow on slides and burnt-over areas. Timber line lies at about 3,000 feet from Haines to White Pass and gradually ascends to over 4,000 feet at the north end of Bennett Lake.

PREVIOUS WORK

The pre-Permian rocks of the Lower Stikine River area form a complex of slate, schist, gneiss, marble, and other metamorphosed and structurally complex rocks (Kerr, 1948a, pp. 22-24), which Kerr mapped as a single unit. Buddington and Chapin (1929, pl. 1) mapped 20 separate units of pre-Permian sedimentary and volcanic rocks and their metamorphosed equivalents in southeastern Alaska. These rocks are important to the present study only in that they are present in the southwestern half of the batholith as isolated septa and roof pendants. They contain no recognizeable fossils and their lithologic character is not distinctive, so that they are not correlative with any fossiliferous rocks further south.

The Permian rocks of southeastern Alaska are largely cherty limestone beds with some clastic sedimentary rocks and basaltic to felsitic volcanic rocks (Buddington and Chapin, 1929, pp. 122 to 130). Kerr found a section of Permian limestone in the Taku River area that is about 500 feet thick (Kerr, 1948b, p. 23).

In the Taku River area east of the Coast Range batholith Kerr reported approximately 9,000 feet of Triassic rocks, slightly more than half of which are volcanic flows, tuff, and agglomerate, and the remainder are intercalated clastic sedimentary rocks (argillite, sandstone, and conglomerate) with an upper limestone formation 200 to 600 feet thick. These rocks are overlain by about 5,000 feet of Lower Jurassic clastic sedimentary rocks and some intercalated volcanics (Kerr, 1948b, pp. 23-31). Unconformably overlying the Lower Jurassic strata is a Jurassic(?) sequence of approximately 2,500 feet of limestone and 13,000 feet of argillite, sandstone, and conglomerate with several thousand feet of intercalated dacitic lava and tuff. This sequence is unconformably (?) overlain by 18,000 feet of Lower Cretaceous clastic sedimentary rocks and dacitic flows and tuffs- the lower half of the section is dominantly volcanic and the upper half is largely clastic sedimentary rock with some limestone. The Mesozoic sediments of the Taku River area appear to thin out very markedly to the southwest (Kerr, 1948b, pp. 30-38).

Eocene conglomerate, sandstone, and volcanic rocks lie in a basin extending from Admiralty Island, 120 miles south of Haines, to the Ketchikan district (Buddington and Chapin, 1929, pp. 260-287). The volcanic rocks vary from basaltic to rhyolitic tuff and some breccia, with the rhyolitic types predominant.

Quaternary olivine basalt flows occur in the Lower Stikine River area (Kerr, 1948a, pp. 39-45). At Miles Canyon, in the Yukon River 4 miles south of Whitehorse, an olivine basalt flow overlies Tertiary river gravels. This flow is believed to be of Quaternary age (Cockfield and Bell, 1929, pp. 33-35).

A. Knopf has described the hornblendite mass that lies immediately north of Haines (Knopf, 1910). This is the only published work on the geology of the Haines-Bennett area. However, the studies of Knopf in the Eagle River-Berners Bay area (Knopf, 1911, 1912), which lies 30 miles south of Haines on the east side of Lynn Canal, and those of Buddington further south in southeastern Alaska (Buddington and Chapin, 1929) give much information on the northern part of the Coast Range batholith and the rocks that it intrudes. The most detailed study of the northern part of the batholith has been made by Kerr in the Lower Stikine River area, B.C. (Kerr, 1948a) and in the Taku River area, B. C. (Kerr, 1948b), the latter area being about 80 miles southeast of Haines. Phemister's work on the southern end of the Coast Range batholith just north of Vancouver, B.C. is of general interest (Phemister, 1945).

In the Lower Stikine River area Kerr reported (1948a, pp. 47-69) that the Coast Range batholith is composed of the nine plutonic units listed below:

Lower Cretaceous (?)	Quartz monzonite Biotite-hornblende andesine-granodiorite Quartz diorite
Jurassic (?)	Hornblende-biotite oligoclase-granodiorite Hornblende-biotite andesine-granodiorite Hornblende oligoclase-granodiorite Hornblende andesine-granodiorite
Triassic (?)	Pulaskite, nordmarkite, nepheline syenite Diorite

COAST RANGE INTRUSIVE ROCKS

The intrusive rocks of the Coast Range batholith in the area traversed are comprised of two major types- quartz diorite and quartz monzonite- and two minor types- hornblendite and granodiorite. Table 1 shows volumetric modes, determined with an integrating stage, of 84 specimens collected at 1 to 8 mile intervals from each of the intrusive masses that comprise the batholith. Sample localities are denoted on pl. 1 by encircled specimen numbers. The individual intrusive bodies of the batholith recognized in this traverse will now be described in a general order of oldest to youngest.

Hornblendite

The hornblendite mass north of Haines was first described by Knopf (1910, p. 145)- "The rock mass exposed along the shore north of Haines is a remarkable occurrence geologically. Specimens collected from the finest textured portions show a rock composed of a coarsely crystalline aggregate of feldspar, hornblende, and pyroxene, throughout which are scattered some visible grains of magnetite. The dark minerals (the hornblende and pyroxene) make up half the bulk of the rock. When examined microscopically the rock is found to consist of an allotriomorphic granular assemblage of plagioclase feldspar (bytownite), hornblende, and augite. Magnetite and apatite are present as accessory minerals in unusually large amounts. From this normal type of rock, which would be termed a gabbro, abrupt variations in texture and mineral composition are

Table 1. Mineral composition of selected samples of intrusive rocks of the Coast Range batholith between Haines, Alaska and Bennett Lake, Yukon. Percentages by volume.

Sample no.	Quartz	Orthoclase	Microcline	Perthite	Plagioclase	Biotite	Hornblende	Augite	Accessory minerals *
2	24	27			27 Ab_{92}	4			1
7	35	23			32 Ab_{70}	5	1		1
[illegible]	31	3		41	22 Ab_{90}	3			1
[illegible]	27				55 Ab_{59}	15	1		1
10	26	17			47 Ab_{38}	8	1		1
21	43	6			44 Ab_{72}	5	1		1
22	19			36	34 Ab_{72}	9			1
24	32	27			34 Ab_{74}	6			1
25	21	16		13	39 Ab_{72}	9	1		1
26	20	4			49 Ab_{62}	16	9		1
27	20	5			54 Ab_{53}	12	7		1
29	32		15	23	26 Ab_{88}	3			1
30	23	4			46 Ab_{52}	19	6		1
31	22	1			53 Ab_{53}	15	7		1
32	34			34	27 Ab_{90}	5			1

					90				
[illegible]	23			40	20 Ab_{85}	3			1
[illegible]	20			[illegible]	26 Ab_{82}	4			1
23	27			35	30 Ab_{84}	7			1
27	22	5			50 Ab_{53}	13	9		1
33	25	1			57 Ab_{53}	12	3		1
39	19			54	25 Ab_{85}	4			1
42	18	2			54 Ab_{53}	11	14		1
44	28		9		49 Ab_{51}	13	2		1
50[2]	19	2			42 Ab_{52}	14	5	5	1
51[3]	15				50 Ab_{62}	10	5		1
53	23				53 Ab_{51}	13	7		1
54	33	7			45 Ab_{33}	14			1
55	8				55 Ab_{57}	28	5	1	2
56	28	1			58 Ab_{58}	11	1		1
59	29	9			51 Ab_{59}	8	3		1
61	27	3			55 Ab_{58}	12	2		1
62	27	11			51 Ab_{59}	9	2		1
64	29	7			58 Ab_{52}	10	1		1
65[4]	15				65 Ab_{48}	13	7		

*Percentages estimated.
[1]Spec. 2 contains 17.5% quartz-chlorite-carbonate veins.
[2]12% of Spec. 50 is fine-grained protoclastic quartz, plagioclase, micropegmatite, orthoclase, and microcline.
[3]20% of Spec. 50 is protoclastic material of the minerals as that in Spec. 50.
[4]Spec. 65 is an inclusion in rock of Spec. 64 type.

Colors are same as on pl. 1.

encountered. In places the cliffs for hundreds of feet are composed solidly of formless hornblende individuals 6 inches long and 3 inches broad. Commonly this hornblende rock contains more or less grayish-green augite admixed with it and is ramified by coarse white feldspathic dikelets or blotched by masses of gabbro. In places it even forms a breccia cemented by such material. Locally the hornblendite contains numerous lumps and particles of magnetite, which can easily be recognized by the characteristic blue tarnish that they assume upon weathered surfaces. At no point along the shore, however, has the segregation of magnetite proceeded far enough to yield a solid body of iron ore, or even a body of ore of commercial grade." This mass has an outcrop belt about 1.2 miles wide. Both its southern and northern contacts are concealed by glacial drift and very thick vegetation, so that its exact relation to the basaltic rocks south of it and the quartz diorite north of it are not known.

A thin section of hornblendite, specimen 47, agreed with Knopf's general description given above, except that only about 5% augite was present. A dikelet (white to pink in hand specimen) in this thin section consisted of about 90% wholly sericitized and kaolinized feldspar (presumably plagioclase), the remainder being mostly clear apatite and a little chlorite that has replaced hornblende. The chloritization is confined to the hornblende in the veins and is assumed to be deuteric. About 95% of the feldspar (all of which is altered) in this rock occurs in the dikelets. The northern part of this mass contains irregular fine-grained dikes of hornblende quartz diorite that contains fresh andesine. These dikes appear to have come from the Lutak Inlet mass described below. The hornblendite appears to have cooled at least to a temperature low enough for the original feldspar and that in the dikelets to be deuterically sericitized and kaolinized before the quartz diorite dikes were intruded.

The abrupt changes in grain size of the hornblendite, from 1/16 inch to about 6 inches in 2 to 3 inches distance, may be due to a differential loss of volatile constituents. The finer-grained portions may have lost their volatiles through sudden cooling and crystallized quickly, and the coarser-grained portions may have retained their volatiles and continued their crystallization through a much less viscous pegmatitic stage.

Hornblendite has been found at various localities along the western edge of the Coast Range batholith. Buddington mentions occurrences of hornblendite at Berners Bay, Etolin Island, Zimovia Straits, Kupreanof Island, Ford's Terror, Tracy Arm, Port Snettisham, Baranof Island, and at Knight Inlet (Buddington and

Chapin, 1929, pp. 194-198). Its remarkable similarity at those localities suggests a common origin, which may have been as an early differentiate of the Coast Range batholith magma.

Quartz Diorite- Lutak Inlet to Taiya River Flats

The quartz diorite that extends from the south side of Lutak Inlet north to the Taiya River Flats is a composite of three separate plutons that are divisible structurally and/or petrographically.

The first of these three plutons (discussing them from south to north), the Lutak Inlet mass, extends approximately 5.2 miles north from its concealed contact with the hornblendite to a point 3.2 miles north of Taiya Point (which is at the entrance of Taiya Inlet).

The well-defined foliation of the Lutak Inlet quartz diorite is generally steeply dipping to the north and has an average trend of about N35W. This pluton contains a total thickness of about 0.4 miles of schist present as septa or relatively tabular roof pendants, which divide the quartz diorite into 8 large sill-like masses. Three of these masses contain up to 10% schist bands that are parallel to the foliation of the quartz diorite and are irregularly spaced, and are from a few millimeters to a few tens of feet wide. At several places these separate bands of biotite and quartz-rich material in the quartz diorite increase in amount toward the septa giving a poorly-defined or gradational contact. The author interprets these dark bands as layers of schist that were partly assimilated after having been invaded by closely-spaced sills of quartz diorite. These were the only gradational contacts found in the traverse across the batholith; all other observed contacts were characteristically sharp. At all but two of the contacts of this quartz diorite with schist the foliation of the quartz diorite pluton is parallel with the schistosity of the schist septa. At the quartz diorite-schist contacts on the north side of Lutak Inlet and also 3.2 miles north of Taiya Point the foliation of the quartz diorite has swung from its regional west-northwest trend to one almost perpendicular to the schistosity of the septa.

The schist septa contain ptygmatically folded quartz lenses that have both up-north and up-south shear senses, implying that a rather thin series of isoclinally folded argillite beds (or rocks of similar chemical composition) has been invaded by the magma along a previously developed cleavage or schistosity. Quartz dioritic aplite and some pegmatite cut the schist as tabular dikes and irregular streaks up to several inches in width. For ½ mile south of the point where spec. 55 was taken (see pl. 1) the quartz diorite contains many narrow, tabular masses of breccia of randomly oriented schist particles in matrices of quartz dioritic aplite and pegmatite. The author interprets these breccias as septa that were brecciated during the last stages of crystallization of the quartz diorite and then were injected by a late stage pegmatitic melt, part of which lost its volatile components and crystallized comparatively quickly as aplite.

The Lutak Inlet pluton is composed of mottled gray and black coarse-grained biotite quartz diorite. In both outcrop and hand specimen it shows a well-defined foliation in which the biotite and hornblende grains tend to wrap around the larger plagioclase and quartz grains. Five thin sections (spec. 50, 51, 53, 54, and 55) of this quartz diorite showed from 10 to 33% of biotite, hornblende, and fine-grained plagioclase, quartz, and some potash feldspar that occurs interstitially between larger partly granulated plagioclase and quartz grains. This pluton was probably stressed just before or after it was completely crystallized, giving this protoclastic or cataclastic texture (referred to hereafter in this report as an autoclastic texture). The quartz diorite is allotriomorphic granular, with about half the biotite as chunky crystals and half of it as flakes that may have been sheared to their present shape from original chunky grains.

An average of volumetric modes of the 5 specimens listed above show the quartz diorite to consist of the following: 21% quartz, 4% orthoclase, 53% andesine (Ab_{33}), 16% biotite, 4% hornblende, 1% augite, and 1% accessories (magnetite, ilmenite, apatite, sphene, and zircon).

The next separable quartz diorite pluton, the Kalatu Ridge mass, is partitioned from the one to the south that has an autoclastic texture by a septum of schist. This pluton is exposed from 3.2 to 6.5 miles north of Taiya Point. It is bounded on the north by a 125 foot thick septum of schist. The foliation of the Kalatu Ridge mass is parallel to the schistosity of the septum that bounds it on the south but is markedly discordant to the septum on the north.

A 0.35 mile wide mass of schist, 4.8 miles north of Taiya Point, occurs in this pluton. This schist is cut by many quartz dioritic aplite dikes that form up to one-half of the rock exposed. These dikes generally strike east-west to northeast-southwest and dip gently north, as shown in figure 2. Many of them are gently undulating but of rather constant thickness. Similar dikes are found in the quartz diorite just north of this schist-aplite mass. These dikes may be aplitic fillings of marginal fissures, slightly folded after injection of aplite, associated with the Taiya River Flats pluton that is discussed below.

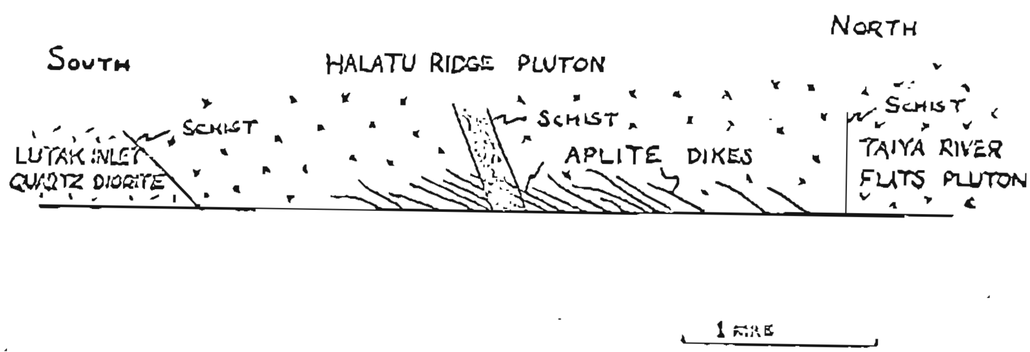

Figure 2. Showing aplite-filled marginal fissures in the Halatu Ridge pluton and included schist.

The Kalatu Ridge mass is represented in table 1 by spec. 53 and 58. This rock is different from the quartz diorite south of it in that its texture is hypidiomorphic subequigranular without any mashing or recrystallization. Compositionally this quartz diorite is similar to the Lutak Inlet quartz diorite except that it has 6% less biotite, 6% more quartz, no augite, and allanite is an accessory. The differences may be within the sampling error, as both plutons contain schlieren and dark bands much richer in femic minerals.

The third pluton, the Taiya River Flats mass, found between Lutak Inlet and the Taiya River Flats extends from a schist septum 6.5 miles north of Taiya Point to beyond the Taiya River Flats, north of which it is not exposed.

This pluton is foliated for about 4 miles from its southern contact, grading north to a massive rock that is free of septa or other rock of country rock derivation. Inclusions are rather scarce in this pluton (as contrasted to the Kalatu Ridge and Lutak Inlet plutons) and they are small (less than 6 inches long), well-rounded, and diversely oriented. A thin section, spec. 65, of an inclusion in the unfoliated northern part of this pluton shows approximately 15% quartz, 65% zoned plagioclase (averaging sodic labradorite), 13% biotite, and 7% hornblende. All inclusions seen have a well-foliated fine-grained fabric.

Three thin sections of the Taiya River Flats pluton (spec. 61, 62, and 64) show normally zoned plagioclase that varies from calcic labradorite to sodic andesine. This is the only pluton in the batholith in which markedly zoned plagioclase was observed. The texture of this rock is hypidiomorphic inequigranular in which subhedral to euhedral plagioclase and chunky biotite subhedra contain interstitial quartz and orthoclase. Three modes give an average of 28% quartz, 7% orthoclase, 53% plagioclase (averaging about Ab_{56}), 10% biotite, 1% hornblende, and 1% accessory minerals (apatite, magnetite, ilmenite, sphene, and zircon). The rock type, therefore, is a granodiorite closely allied to quartz diorite.

The evidence bearing on the relative ages of the Lutak Inlet, Halutu Ridge, and Taiya River Flats plutons may be summarized as follows: the Lutak Inlet mass is autoclastic in texture, whereas the other two are not; aplite-filled marginal fissures appear to extend southward from the Taiya River Flats pluton and cut the Kalatu Ridge mass. Hence the Lutak Inlet mass appears to be the oldest because the stresses that caused its autoclasis would probably have similarly affected a pluton just north of it (the Kalatu Ridge mass), but the pluton that lies just north of it is not autoclastic in texture; so the Kalatu Ridge mass was probably not present when the Lutak Inlet mass was intruded. The schist septum between these two plutons was probably too thin to have cushioned the Kalatu Ridge pluton from the stresses that partly granulated the Lutak Inlet mass, if one assumes that the Kalatu Ridge mass is the older. The Taiya River Flats pluton appears to be younger than the Kalatu Ridge pluton immediately south of it because marginal fissures could only have extended out of the Taiya River Flats pluton into an older rock mass. If these three reasons are valid the three plutons were successively intruded from south to north, or the Lutak Inlet mass is the oldest, the Kalatu Ridge mass is intermediate in age, and the Taiya River Flats mass is the youngest.

Quartz Diorite- Skagway to Mile 4

The Skagway pluton, of foliated quartz diorite, extends (normal to the foliation) from south of Skagway to 4 miles northeast of Skagway (along the White Pass and Yukon Route tracks). A smaller pluton of the same rock, the Mile 4 mass (which may once have been continuous with the Skagway pluton), 0.7 miles wide across the foliation, occurs one-half mile north of the Skagway mass. These two masses are separated by a mass of younger granite, which appears to be a potassic variant of a much larger quartz monzonite body to the north (that is discussed below). A curved railroad cut intersects in three places the contact of the Skagway quartz diorite mass with the younger granite north of it. All three exposures of this contact show that the granite has irregularly transected the foliation of the Skagway mass. Angular, diversely oriented blocks of quartz diorite were found in the granite. At these exposures the contact appeared to be about vertical.

The northern and southern contacts of the Mile 4 quartz diorite mass are essentially planar with the foliations of the granite to the south and the quartz monzonite to the north parallel to the contacts and to the foliation of the Mile 4 quartz diorite. Thus the northern contact of the granite pluton that separates the Mile 4 and Skagway masses is accordant and foliated and its southern contact is discordant and no foliation has developed. The granite may first have been selectively and forcefully intruded along a foliation surface in the quartz diorite, and then later stoping, presumably guided by joints, modified the southern contact of the granite (with the Skagway mass).

Both the Skagway and Mile 4 masses contain some schlieren and dark flow bands that have been symmetrically folded so as to have horizontal axial planes and steeply dipping trends parallel with the foliation of the adjacent quartz diorite that has not been so folded, as shown in figure 3.

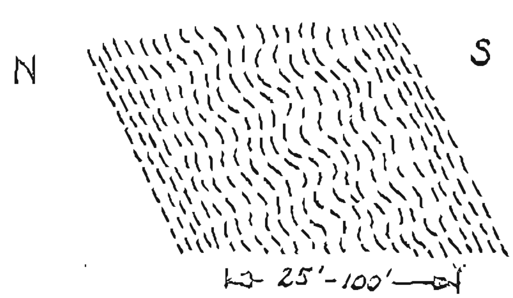

Figure 3. Showing folding (schematically) of foliation and schlieren in the Skagway and Mile 4 masses.

The author believes that the viscous, partly crystallized magma (with flow-banding and foliation already developed) was subjected to stress parallel to the foliation, that the magma chamber expanded in a direction normal to the foliation, and that the change of dimensions of the pluton took place by the folding of the foliation and the flow-banding (or schlieren). This folding appears to have taken place before the rock was completely crystalline because no clasis is evident in thin section.

The Skagway quartz diorite contains a total section of about 650 feet of schist, quartzite (often showing gently plunging boudins), and marble. The schistosity and bedding of the metamorphic rocks are generally parallel or subparallel to the foliation of the quartz diorite, but local truncations of the schistosity and bedding by the foliation of the igneous rock imply some stoping. The Mile 4 mass is devoid of schist and other metasedimentary rocks. The foliation of the quartz diorite in both masses is steeply dipping with a trend of about N30W.

Both the Skagway and the Mile 4 masses are variable in composition with alternating bands of medium gray quartz diorite several feet to several tens of feet thick and darker bands much richer in biotite and hornblende a few inches to several feet thick. Three modes of the lighter, more common type (spec. 37, 38, and 42) show an average of 22% quartz, 3% orthoclase, 53% andesine (Ab_{55}), 12% biotite, 9% hornblende, and 1% accessory minerals (apatite, magnetite, ilmenite, sphene, and zircon). This quartz diorite is generally similar to those of the Lutak Inlet-Taiya River section, except for its higher hornblende content.

Quartz Diorite- White Pass and Mile 26

The White Pass and Mile 26 quartz diorite bodies, found on the south side of White Pass and at Mile 26, respectively, on the railroad tracks (Mile 0 is at Skagway; White Pass Summit is Mile 20), are similar to each other in structure and petrography, and they may have been parts of the same pluton before the intrusion of the quartz monzonite that now separates them.

Three of the four contacts of the White Pass and Mile 26 masses with the younger quartz monzonite are exposed along the line of traverse. At these three contacts the foliation of the quartz monzonite is parallel to the foliation of the quartz diorite . The quartz diorite is all well-foliated or lineated. The foliation of the White Pass mass trends E-W and dips from 0 to 37 degrees north. A lineation plunging 75 degrees in a NE direction was found. The foliation of the Mile 28 mass trends about N30W and dips 65 to 77 degrees south. Inequidimensional inclusions of biotite and hornblende-rich rock (meta-andesite), up to about 1 foot in size, are generally parallel to the foliation; at the locality where spec. 27 was collected the inclusions were tabular in shape and were flat-lying in quartz diorite whose foliation dips 65 degrees. These inclusions may have been sinking through the magma after its foliation was developed and before it became too viscous or crystalline to allow flowage of an inclusion in it. No schist was found in these two masses.

Four thin sections of the White Pass and Mile 28 bodies (spec. 28, 27, 30, and 31) show it to be hypidiomorphic inequigranular with coarse subhedra and euhedra of plagioclase and hornblende, chunky subhedra of biotite, and anhedra of quartz set in a fine-grained matrix of these minerals and orthoclase. An average of modes of these four sections gives 21% quartz, 4% orthoclase, 50 % andesine (with slight oscillatory zoning and averaging Ab_{55}), 16% biotite, 8% hornblende, and 1% accessory minerals.

Quartz Diorite- Lake Lindeman

The quartz diorite mass at Lake Lindeman is exposed for about one-half mile along the railroad tracks. This rock, represented by spec. 18, is a hypidiomorphic inequigranular quartz diorite very similar to that in the Mile 26 and White Pass masses. This quartz diorite, however, contains plagioclase phenocrysts up to 12 mm. long, and the plagioclase is slightly zoned but not oscillatorily.

At its most northerly contact the foliation of the Lake Lindeman quartz diorite is parallel to the foliation and inclusions of the younger quartz monzonite. At the other exposed contact the quartz monzonite cross-cuts the foliation of the quartz diorite.

Quartz Diorite Correlations

Buddington states that quartz diorite forms the western part of the main batholith, and his descriptions correspond closely to those given above (Buddington and Chapin, 1929, pp. 207-214). Knopf's description of the quartz diorite of the Eagle River area corresponds to that of the auto-clastically-textured Lutak Inlet quartz diorite pluton (Knopf, 1912, pp. 23-24). Kerr correlated the quartz diorites of the Lower Stikine River area, which generally correspond with those described in this paper, with those described by Buddington (Kerr, 1948a, pp. 59-61). If these correlations are correct the quartz diorites in the Haines-Lake Lindeman area were emplaced as the seventh major unit of the Coast Range batholith.

<u>Granodiorite- Dyea-Skagway Road</u>

The mountain between Skagway and the mouth of the Taiya River is underlain by the Dyea-Skagway Road granodiorite pluton. This granodiorite is quantitatively similar to the Lutak Inlet-Taiya River Flats quartz diorites (except for its microcline content), but it is separable from those quartz diorites in that it is lighter colored, coarser-grained, rather homogeneous (except for two zones of inclusions), and is foliated or hornblende-lineated. One of the zones of inclusions, about 50 feet wide, at least one-half mile long, and lying vertically at N70W, contains from 25 to 50% fine to medium-grained, dark, irregularly shaped and oriented fragments of biotite-hornblende quartz diorite. The other zone of inclusions is similar, but its extent is not known. The shape and orientation of the first zone suggests that it was formed either by brecciation of a septum in situ or that blocks were stoped off a now-eroded away tabular roof pendant or septum and that these blocks were stopped in their downward flow by an increase in viscosity of the slowly crystallizing magma. The subangular to rounded shapes of these inclusions suggests rounding of originally angular fragments by assimilation.

A volumetric mode of the Dyea-Skagway Road granodiorite, spec. 44, shows 23% quartz, 9% microcline, 49% slightly zoned calcic andesine (Ab_{51}), 13% biotite, 2% hornblende, and 1% accessory minerals.

The relative age of this granodiorite is not known, as its contacts appear to lie beneath the Taiya River Flats and the Skagway River. However, in outcrop and thin section it generally corresponds to Kerr's description of the biotite granodiorite found in the Lower Stikine River area (Kerr, 1948a, pp. 61-63), which is younger than the quartz diorite found there and is younger than the quartz monzonite associated with it. Thus a tentative correlation may be made which would place this rock as intermediate in age between the quartz diorites described above and the quartz monzonite described below.

Quartz Monzonite- Mile 4 to Bennett Lake

Quartz monzonite forms most of the eastern half of the Coast Range batholith. As shown on pl. 1 it extends from Mile 4 on the White Pass and Yukon Route tracks (4 miles northeast of Skagway) to the northeastern contact of the batholith at Bennett Lake. As stated above, four masses of older quartz diorite were found to divide the quartz monzonite into 5 parts along the line of traverse. It is not known whether these parts have underground or surface connections, or whether they are separate plutons. Two quartz monzonite masses were found on the east shore of Bennett Lake north ofthe main batholith contact. A small mass, one mile north of the main batholith contact, was found exposed for one-half mile along the lake shore. A second and larger pluton extends for four miles along the lake shore at the Yukon-B.C. boundary.

The main contact of the batholith, of quartz monzonite with the country rock to the northeast, at Bennett Lake is sharp, approximately vertical, and is almost parallel to the north-south axial planes of isoclinal folds of quartzite, conglomerate, phyllite, and chlorite schist. The actual contact is covered by slide debris. Spec. 15, of quartz monzonite, was collected about 100 feet southwest of the contact; it has no apparent foliation or lineation. A thin section of quartzite, spec. 14, taken about 100 feet northeast of the contact, shows about 20% quartz, 5% orthoclase, and 5% oligoclase from ½ to 2 mm. in size set in a much finer-grained, partly sericitized quartzite matrix. The coarser-grained material and the sericite may have been introduced by emanations from the adjacent crystallizing magma, but this could not be proved.

If the feldspar of the quartz monzonite that intrudes this quartzite contains 10% kaolin and sericite, the feldspar contains about 1% water (assuming that the kaolin and sericite contain about 10% water) and the rock will contain about 2/3% water. About 1/2 % water could also be retained by the quartz monzonite in pore spaces, which are slightly enlarged during the differential shrinkage of the rock upon cooling through the deuteric temperature range. Hence the quartz monzonite may contain, after solidification and cooling, up to 1 1/3% original water. If then, this magma had a low original (or magmatic) water content little or none of it may have been forced into the wall rocks during or just after solidification, and the wall rocks would show very slight or no hydrothermal alteration.

The stratified rocks north of the main batholith are represented on pl. 1 by a single color, as it was not possible in this survey to map separate units.

Foliation and schlieren are poorly developed or not present in the quartz monzonite. Most of this rock is massive, but the few schlieren, phenocryst lineations, and foliated parts found have been plotted on pl. 1. The quartz monzonite has developed a fair foliation at 5 of its observed contacts, but the remainder of the schlieren and folia appear to be randomly oriented with respect to each other and to the boundaries of these plutons.

Spec. 23, from the quartz monzonite mass just north of Summit Lake in White Pass, was collected several feet from a contact with quartz diorite. It is a massive quartz latite porphyry, composed of about half medium-grained phenocrysts of euhedral microperthite and beta-quartz and about half groundmass. A magma composed of only 50% or fewer crystals would probably not develope a foliation during flowage because the crystals could move during flowage or changes of shape of the magma without interfering with each other (and thereby retaining a massive structure). If the large quartz monzonite bodies in the batholith were only one-half crystalline at the time of their emplacement they probably would not have developed foliation.

Volumetric modes of 14 specimens of the quartz monzonite (and closely related rock types), spec. 2, 7, 15, 19, 21, 22, 24, 25, 29, 32, 33, 34, 36, and 39, show 10 quartz monzonites, 1 granodiorite, 1 granite, and 2 types on the quartz monzonite-granite division line (potash feldspar/ plagioclase ratio is 2). These variations are probably within the sampling error as all the specimens are coarse-grained, 4 to 6 mm., and all of the quartz monzonite north of the Mile 26 quartz diorite mass is very coarsely porphyritic with pink microperthite and often plagioclase phenocrysts up to about 50 mm. long. The average of the 14 modes gives 29% quartz, 10% orthoclase, 23% microperthite, 1% microcline, 31% oligoclase (Ab_{81}), 5% biotite, and 1% accessory minerals (apatite, magnetite, ilmenite, sphene, and zircon). Four of these thin sections contain about 1% hornblende.

Quartz Monzonite Correlations

The quartz monzonite found from Bennett Lake to Mile 4 corresponds very closely to that found in the eastern part of the Coast Range batholith in the Taku River area (Kerr, 1948b, pp. 46-48). Kerr found the quartz monzonite in that area to be pink colored, uniform in composition, coarse-grained, commonly porphyritic, rather clean of inclusions, and affecting the wall rocks only slightly- all of which applies to the quartz monzonite described above. In the Lower Stikine River area Kerr mapped a mass of quartz monzonite 270 square miles in area that appeared to be a single pluton (Kerr, 1948a, p. 63). Kerr stated that quartz monzonite masses also extend (from the Stikine River) to the northwest at least as far as the Taku River, 125 miles away, and "throughout maintain the same composition and similar shapes" (1948a, p. 63).

DIKE ROCKS

Aplite Dikes

A number of aplite dikes, as shown on pl. 1, cut the Coast Range intrusives and the pre-intrusive rocks. Three of these were examined in thin section and found to correspond fairly closely to the associated normal plutonic rocks. A few small pegmatite dikes, up to about 2 feet thick, were found associated with aplites. The grain size of the quartz and feldspar in these pegmatites was seldom larger than an inch. The general scarcity of aplite and pegmatite, especially in the quartz diorite, implies low hyperfusible contents in the magmas that formed the various plutons.

Rhyolite Dikes

Rhyolite dikes were found in the granodiorite and quartz diorite north and northeast of Skagway. They contain phenocrysts averaging about 1 mm. in size of orthoclase and quartz, the latter of which appears to be beta-quartz as it does not show prism faces. The orthoclase occurs as twinned (law not recognizable) graphic intergrowths with quartz. The orthoclase-plagioclase ratio could not be determined on account of the extreme fine grain of the groundmass, but the plagioclase content appears to be low so that these rocks are here classed as rhyolite porphyries.

Basic Dikes

Twenty-four basalt and andesite dikes or groups of dikes were found from the west side of Taiya Inlet west of Skagway to Bennett Lake in the Yukon. Two thin sections examined showed one dike to be basalt porphyry with labradorite and augite phenocrysts. The other dike is a hornblende andesine whose feldspar is a sodic andesine. The dikes west of Skagway on Taiya Inlet are vesicular. If they were injected before Pliocene time they would probably have had heads of at least 5,000 feet, as there appears to have been an upland surface of approximately that age that now shows only as a generally accordant summit level in this part of the Coast Mountains. Hence the author is of the opinion that they were emplaced in Quaternary time, when the present valley system was moderately well developed and the dikes would have had much lower heads of basic magma above them during crystallization, thus facilitating vesiculation.

CONCLUSIONS

The quartz diorite and granodiorite plutons appear to have been injected into a closely folded complex of pre-Jurassic rocks. The partial granulation of the Lutak Inlet quartz diorite pluton, was assumed above to have been caused by stresses from below (and of the same origin as the stresses that initially caused the emplacement of that pluton); however, this clasis may have been caused by horizontally-directed stresses in a late stage of the folding of the country rock. If the latter happened the Lutak Inlet pluton is the only synkinematic pluton observed in this traverse. The quartz diorites and granodiorite plutons appear to have been intruded parallel to the schistosity and bedding of the isoclinally folded wall rock. Subsequent stoping (of unknown butpresumably small magnitude) has somewhat modified the wall rock-pluton surfaces. The large quartz monzonite plutons were probably intruded to a shallower level than the quartz diorite and granodiorite plutons, or the quartz monzonite plutons have not been eroded down as far as the older plutons. However, both series of plutons are now at the same level, and the older series definitely indicates a level of intrusion deeper than that of the younger series; hence the the older quartz diorite and granodiorite plutons must have been eroded at least several thousand feet and possibly several miles before the emplacement of the younger quartz monzonite.

The approximately 15,000 foot total sequence of Mesozoic andesitic and dacitic volcanic rocks in the Taku River area (Kerr, 1948b, pp. 30-38) implies that some of the Coast Range batholith plutons made their way entirely to the surface.

The author believes that all of the plutonic bodies that form the Coast Range batholith from Haines, Alaska to Bennett Lake, British Columbia have been formed as a result of emplacement and crystallization of magma. The reasons for this, as exhibited in one or more of the plutons, may be summarized as follows:

1. Sharp contacts (with few exceptions) of plutons with wall rocks, septa, and roof

pendants.

2. Finer-grained porphyritic variations of phaneritic bodies at several contacts.

3. Foliation at contacts grading into massive rock.

4. Discordance at three localities between foliation in plutons and schistosity of septa.

5. Subangular to rounded, randomly oriented fragments or clots forming breccia zones in granodiorite.

6. Symmetrical folding of flow-layering and foliation, with trends parallel and axial planes perpendicular to the non-folded foliation of the remainder of the pluton.

7. Angular discordance between tabular inclusions and foliation.

8. Uniformity in structure and petrographic nature of individual plutons for distances up to 16 miles.

9. Associated dikes of aplite and some pegmatite.

10. Aplite dikes extending from a younger into an older pluton as marginal fissures.

11. A general sequence of intrusion from ultrabasic to acidic plutons.

15. Associated andesitic and dacitic volcanic rocks.

In this work the author has partly used ideas and methods set forth by Balk in <u>Structural Behavior of Igneous Rocks</u>. In a survey of this sort, of course, only the grossest granotectonic features were mapped. The word <u>inclusion</u> in the pages above is equivalent to the word <u>clot</u> as used in Balk's book.

REFERENCES

1. Bostock, H.S., 1948, *Physiography of the Canadian Cordillera, with Special Reference to the Area North of the Fifty-Fifth Parallel*, Geol. Surv. of Canada, Memoir 247.

2. Buddington, A.F., and Chapin, T., 1929, *Geology and Mineral Deposits of Southeastern Alaska*, U.S.G.S. Bull. 800.

3. Cockfield, W.E., and Bell, A.H., 1926, *Whitehorse District, Yukon*, Geol. Surv. of Canada, Memoir 150.

4. Kerr, F.A., 1948a, *Lower Stikine and Western Iskut River Areas, British Columbia*, Geol. Surv. of Canada, Memoir 246.

5. Kerr, F.A., 1948b, *Taku River Map Area, British Columbia*, Geol. Surv. of Canada, Memoir 248.

6. Knopf, A., 1910, *The Occurrence of Iron Ore near Haines*, U.S.G.S. Bull. 442, pp. 144-146.

7. Knopf, A., 1911, *The Berners Bay Region, Alaska*, U.S.G.S. Bull. 446.

8. Knopf, A., 1912, *The Eagle River Region, Southeastern Alaska*, U.S.G.S. Bull. 502.

9. Phemister, T.C., 1945, *The Coast Range Batholith near Vancouver, British Columbia*, Quart. Jour. Geol. Soc. London, Vol. 51, pp. 37-88.

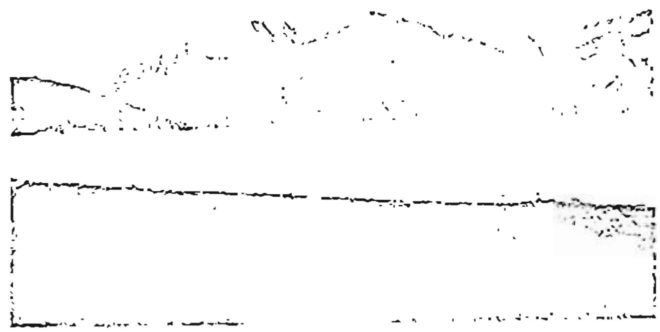

Figure 4. View northeast across Lynn Canal from 2 miles northeast of Haines. Taiya Point in left background.

Figure 5. Sea cliffs on west side of Taiya Inlet 6½ miles north of Taiya Point.

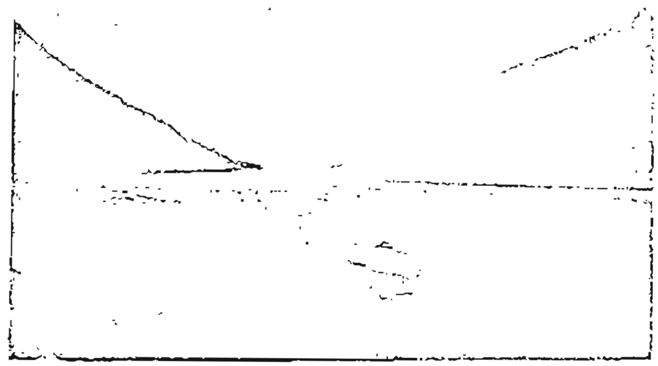

Figure 6. View south of Taiya Inlet from Taiya River Flats.

Figure 7. View north of White Pass from just north of Summit Lake.

Figure 8. View north of Bennett Lake from just north of Bennett.

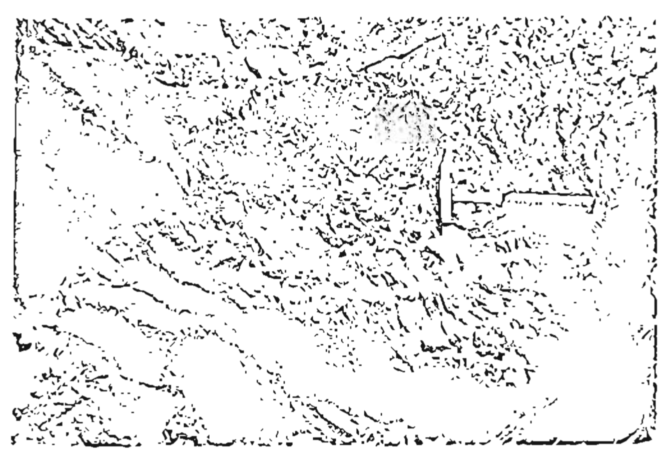

Figure 9. Hornblendite, 3/4 mile northeast of Haines, showing abrupt variations in texture.

Figure 10. Schist, in a septum in the Lutak Inlet quartz diorite north of Taiya Point.

Figure 11. Inclusions in the Dyea-Skagway Road granodiorite. Part of a large tabular zone of inclusions.

Figure 12. Contact of the younger Bennett quartz monzonite on the right that transects the flow-layering of the Lindeman quartz diorite on the left. Near railroad tracks east of Lake Lindeman.