American Mineralogist, Volume 71, pages 632–643, 1986

Evolution of the Coast batholith along the Skagway Traverse, Alaska and British Columbia

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Abstract

In an investigation termed the Skagway Traverse, a geologic map was made of an area about 70 km long and 10 to 15 km wide transecting the Coast batholith (Coast Plutonic Complex of most Canadian workers) from Haines to Skagway, Alaska, to Log Cabin and Tutshi Lake, British Columbia. The batholith here consists of (1) Cretaceous or older migmatitic orthogneiss of quartz dioritic and tonalitic compositions and minor metasedimentary rocks; (2) minor, Late Cretaceous or older nonmigmatitic orthogneiss of tonalitic composition; (3) Late Cretaceous (zircon U-Pb age = 72 m.y.) feldspar–porphyritic biotite–hornblende granite—the granite of Log Cabin; (4) Eocene (zircon U-Pb age = 54 m.y.) massive plutons of hornblende-biotite tonalite and granodiorite—the tonalite of Skagway; and (5) Eocene (zircon U-Pb ages are 53 and 48 m.y.) massive plutons of near-minimum-melt biotite leucogranite—the granites of Clifton and Summit Lake.

The orthogneisses and tonalite of Skagway show typical calc-alkaline, Pacific-margin compositions: 59–71% SiO_2, 18.6–15.4% Al_2O_3, 6–3% CaO, 1.5–3.1% K_2O, 830–480 ppm Sr, 65–45 ppm Rb, and chondrite-normalized rare-earth-element (REE) patterns of moderate slope and small negative or no Eu anomaly. The granites of Clifton and Summit Lake have higher SiO_2 (73.9–77.2%), K_2O (4.7–4.2%), and Rb (85–219 ppm), less Al_2O_3 (14.0–12.3%), CaO (1.6–1.1%) and Sr (210–85 ppm), and large negative Eu anomalies and flat slopes for heavy REE. The granite of Log Cabin is transitional between these two types. Initial $^{87}Sr/^{86}Sr$ ratios for most plutonic rock units are 0.7052 to 0.7058; Summit Lake Granite is 0.7049 and 0.7060. They show no systematic variation related to rock type or location.

The orthogneisses and tonalite of Skagway show a rough trend on the normative quartz-plagioclase-orthoclase diagram from near dioritic composition toward granodiorite and granite. These rocks probably originated largely by fractionation of plagioclase, hornblende, and other phases. However, oxygen-isotope ratios indicate either exchange of the magmas with a high $^{18}O/^{16}O$ fluid or minor assimilation of high-$\delta^{18}O$ crustal rocks. The granites of Log Cabin, Clifton, and Summit Lake, however, probably were derived largely by crustal melting of graywacke (flysch) or siliceous to intermediate igneous rocks.

Introduction

The Coast Plutonic Complex, or Coast batholith as we prefer to term it, is the largest continental-margin batholith in the world. It is about 1760 km in length, extending from near lat 49°N at the British Columbia–Washington boundary to well north of lat 61°N in Yukon Territory (Hutchison, 1970; Roddick and Hutchison, 1974; Roddick, 1983). Much of the axial region to the southwestern part of the batholith consists of migmatitic orthogneiss of tonalitic and quartz dioritic composition (IUGS terminology) and of various metasedimentary and metavolcanic rocks—which collectively are termed the Central Gneiss Complex or CGC (Hutchison, 1970, 1982; Roddick and Hutchison, 1974; Barker and Arth, 1984). The CGC is better developed north of lat 53°N than to the south (Roddick, 1983). Extensive tabular to lenticular bodies of quartz diorite and tonalite that are termed the Tonalite Sill or Sill Belt (Brew, 1981) lie along the southwest margin of the northern part of the batholith. Orthogneiss of the CGC ranges in age from Early Cretaceous or possibly Jurassic to early Tertiary, and the Tonalite Sill from latest Cretaceous to Paleocene (Armstrong and Runkle, 1979; Gehrels et al., 1983; Kenah and Hollister, 1983; Woodsworth et al., 1983; Barker and Arth, 1984; Arth, Stern, and Barker, unpub. results).

The Coast batholith differs from many continental-marginal batholiths in that its central and western parts have undergone 10 to perhaps 30 km of uplift (Hollister, 1982; Crawford and Hollister, 1982; Kenah and Hollister, 1983). Thus these parts of the batholith show a much

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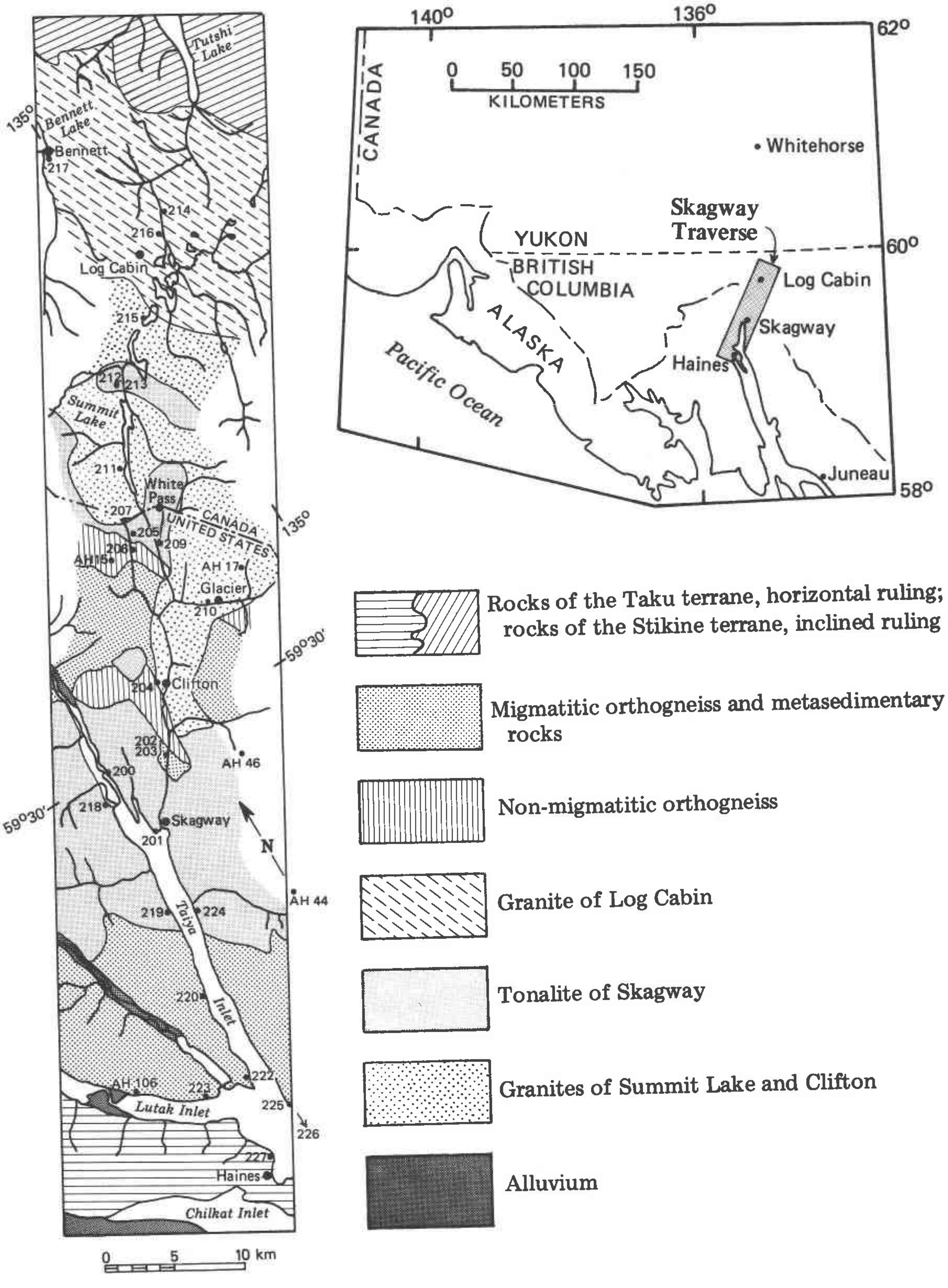


Fig. 1. Reconnaissance geologic map of the Skagway Traverse, showing locations of analyzed samples.

Table 1. Modal analyses of samples of Coast batholith, Skagway Traverse (locations of samples shown in Fig. 1)

	Orthogneiss	Granite of Log Cabin				Granites of Clifton and Summit Lake				
	AK-206	AK-214	AK-216	AK-217	AK-204	AK-207	AK-210	AK-211	AK-215	AH-17
Quartz	21	21	22	35	25	40	35	29	32	30
K-Feldspar	6	23	29	34	39	33	30	39	30	44
Plagioclase	57	41	35	28	33	24	29	28	34	24
Biotite	13	12	10	2	1	2	4	3	4	2
Hornblende	2	3	2	TR	--	TR	TR	--	--	--
Opaques	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
Sphene	TR	TR	TR	TR	--	--	--	--	--	--
An Content, Plag.	38	n.d.	30	n.d.	28	26-8	24-10	n.d.	n.d.	24-10

	Tonalite of Skagway									
	AK-200	AK-201	AK-205	AK-209	AK-212	AK-218	AK-219	AK-224	AH-44	AH-46
Quartz	28	28	18	24	19	28	32	26	35	18
K-Feldspar	8	5	1	1	6	6	5	12	15	TR
Plagioclase	49	56	57	55	59	57	52	48	41	51
Biotite	14	9	19	12	13	9	10	11	9	15
Hornblende	1	2.5	5	7	3	TR	1	3	--	14
Opaques	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR
Sphene	--	--	TR	1	TR	--	--	--	--	--
An Content, Plag.	26,46	34	38	56-52	45	50-30	n.d.	35-23	n.d.	39

NOTE: 400-460 counts for most samples; TR=Trace; "--" = not present; n.d. = not determined

deeper level of exposure than, for instance, does the Sierra Nevada batholith.

From Taku River (150 km southeast of Skagway) northward, the northeastern parts of the batholith, in contrast, are more siliceous and potassic and consist largely of granodiorite, granite, and tonalite. These rocks range from Late Cretaceous to Miocene in age, as presented below and as determined by Smith et al. (1979) and Arth, Stern, and Barker (unpub. results) on intrusions of Portland Canal. Plutons of this northeastern part typically are massive and were emplaced at shallow levels.

This investigation, termed the Skagway Traverse, consists of reconnaissance geologic mapping of a strip 10 to 15 km wide across the batholith from Haines to Skagway to the vicinity of Log Cabin (Fig. 1), and petrography, major- and minor-element chemistry, geochronology by the U-Pb method on zircons, and initial ratios of $^{87}Sr/^{86}Sr$ of a suite of representative samples from each major unit. J. G. Smith has provided K-Ar mineral ages determined by standard methods (see Smith and Diggles, 1981) and whose accuracy is ±3%. This paper emphasizes the Tertiary intrusions that dominate the batholith from Skagway to its northeastern margin.

Components of the Batholith

Summary

The Coast batholith from Haines to Tutshi Lake consists of one minor and four major rock units. As shown on Figure 1, these are (1) a Cretaceous(?) complex that consists largely of migmatitic orthogneiss of quartz dioritic and tonalitic compositions, but also includes minor metasedimentary rocks such as biotite gneiss, marble, and quartzite; (2) a minor, Late Cretaceous(?), nonmigmatitic orthogneiss of tonalitic composition, found just southwest of the Canada-Alaska boundary; (3) the 72-m.y.-old granite of Log Cabin, which lies along the northeast margin of the batholith; (4) the 54-m.y.-old tonalite of Skagway, which occurs at Skagway, White Pass, and north of Summit Lake; and (5) the granites of Summit Lake and Clifton, which are similar to each other in petrographic and geochemical character, but which have U-Pb zircon ages of 53 and 48 m.y., respectively, and which form much of the central to northeastern part of the batholith.

Migmatitic orthogneiss

Our traverse shows two major masses of heterogeneous orthogneiss, which occur as rafts or roof pendants in younger intrusives. One is exposed along Lutak Inlet and lower Taiya Inlet (Fig. 1); the other between Skagway and White Pass (Fig. 1). Much of this orthogneiss, especially as exposed in roadcuts along the Klondike Highway about 6–10 km north of Skagway, is markedly migmatitic, showing wavy foliation, light to dark compositional banding, scattered ovoidal masses of dark-colored hornblende-rich rock 0.3–1 m in diameter (as represented by sample AK-203), and pods and small dikes of aplite, pegmatite, and fine-grained trondhjemite. The bulk of this orthogneiss consists of hornblende-biotite quartz diorite and tonalite, which is medium gray, medium to coarse grained, strongly foliated, and streaked with hornblende and biotite (Table 1). The ovoidal bodies in this migmatite, which probably are of basaltic composition, are unique. They probably represent "pillows" of basaltic magma that were injected into the partially molten tonalitic mush and solidified as ovoids (cf. Reid et al., 1983). They later were fractured dilatantly and the fractures filled with locally derived trondhjemitic melt. To our knowledge, this is the only "pillow" migmatite of the circum-Pacific magmatic belt.

The orthogneiss at Lutak Inlet locally shows mortar structure, in which ovoid grains of plagioclase and orthoclase are set in a crushed, partly recrystallized matrix of quartz, biotite, hornblende, and feldspar. The hornblende in some of these grains shows magmatic brown cores and post-magmatic, metamorphic green rims, which indicate that shearing probably occurred at *P-T* conditions of the amphibolite facies.

Two samples of the migmatitic orthogneiss unit were dated, one from Lutak Inlet (AK-223) and one from the east side of Lynn Canal south of the area shown in Figure 1 (AK-226). Sample AK-223, the highly sheared quartz

Table 2. U-Th-Pb age determinations on zircons from samples in the Skagway area (analyses by standard isotope-dilution techniques)

	SAMPLE	AGES in m.y.				CONCENTRATIONS in p.p.m.			ATOMIC RATIOS		
ROCK UNIT	NO.	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{208}Pb/^{232}Th$	PRECISION	Pb	U	Th	$^{208}Pb/^{207}Pb$	$^{207}Pb/^{206}Pb$	$^{204}Pb/^{206}Pb$
Migmatitic orthogneiss	AI-223	68.2	67.3	n.d	2.0	6.77	502.9	n.d	.21009	.12078	.00502
Orthogneiss	AK-206	61.7	66.1	71.0	2.0	15.8	1687.	280.	.07241	.05461	.00026
Granite of Log Cabin	Ak-216	72.4	71.6	57.2	2.0	32.4	2797.	918.	.11554	.05901	.00082
Tonalite of Skagway	AK-212	53.6	54.2	61.8	2.0	10.5	1148.	463.	.18676	.06148	.00094
Granite of Summit Lake	AK-207	53.1	51.4	52.4	2.0	19.1	1941.	840.	.23326	.08367	.00258
Granite of Clifton	AK-208	48.0	47.6	48.1	2.0	19.3	2509.	945.	.13601	.05145	.00033

*at 95% confidence level

diorite mentioned above, gives a $^{206}Pb/^{238}U$ apparent age of 68.2 m.y. and a $^{207}Pb/^{235}U$ apparent age of 67.3 m.y. (Table 2). These essentially concordant results could date an intrusive event that concluded with development of mortar structure in the gneiss, representing protoclastic emplacement. Or they might be registering a thermal event happening long after emplacement, in which the brown, magmatic hornblende grains had their margins converted to green hornblende. AK-226, a relatively homogeneous biotite-hornblende quartz diorite, gave K-Ar apparent ages in hornblende of 59.9 m.y. and on biotite of 43.3 m.y. This rock may be of Tonalite Sill type, the hornblende age being close to the time of intrusion and the biotite age representing uplift in Eocene time, as documented in the Coast batholith east of Ketchikan by Smith et al. (1979).

The migmatitic and sheared orthogneiss shows elemental abundances (Table 3) like those reported from the Coast batholith to the southeast (see, e.g., Barker and Arth, 1984), having SiO_2 from 57 to 69% (not including the fine-grained mafic inclusions) (Fig. 2), Al_2O_3 abundant at 15.9 to 18.6%, Na_2O moderate to high at 2.9 to 4.8%, K_2O low to moderate at 1.7 to 3.0%, Rb low at 45 to 64 ppm, and Sr high at 480 to 775 ppm (Fig. 3). Ba is abundant at 900 to 2800 ppm. REE patterns mostly show rather steep slopes (Fig. 3)—La 30 to 130 and Lu 0.5 to 7 times, chondrites—and Eu anomalies are small or absent. La tends to increase and Lu to decrease as SiO_2 increases. Sample AK-203 is a dark fine-grained inclusion from migmatitic gneiss north of Skagway (Fig. 1). Its composition is much like that of high-Al basalt. The high K_2O content, 1.94%, may be due to infiltration from the enclosing magma when its assemblage plagioclase-hornblende-biotite-quartz was formed.

Nonmigmatitic orthogneiss

Nonmigmatitic orthogneiss is exposed along the Klondike Highway south of the International Boundary (Fig. 1), where it lies between migmatitic gneiss and the tonalite of Skagway. This gneiss is well foliated and medium to coarse grained, shows light and dark streaking, and typically is biotite-hornblende tonalite (Table 1). It gives discordant ages by both the U-Th-Pb zircon (Table 2) and K-Ar methods. The $^{206}Pb/^{238}U$ apparent age of 61.7 m.y. could mark either a magmatic or a metamorphic age, but the $^{207}Pb/^{235}U$ and $^{208}Pb/^{232}Th$ ages that are, respectively, 4 and 9 m.y. older indicate a complex thermal history. The 49.4-m.y. biotite and 54.7-m.y. hornblende numbers may represent ages that were reset by the nearby tonalite of Skagway and granites of Clifton and Summit Lake, or they may reflect uplift following emplacement.

The nonmigmatitic orthogneiss (Table 3) has elemental abundances much like the more siliceous samples of migmatitic gneiss. Their very steep REE plots (Fig. 3) are characteristic.

Granite of Log Cabin

The biotite-hornblende granite of Log Cabin extends from about 4 km south of Log Cabin to the margin of the batholith at Tutshi Lake (Fig. 1). This granite is characterized by blocky phenocrysts of potassic feldspar 3–5 cm in length. The matrix is medium to coarse grained, pinkish gray, massive, and homogeneous. Three modal analyses are given in Table 1. Locally this rock is foliated and shows biotitic schlieren. Fine-grained, dark-gray, biotite-rich inclusions of plagioclase–biotite–hornblende–potassic feldspar rock also are sparsely scattered throughout the granite of Log Cabin. These are mostly 5–20 cm in maximum dimension, and tubular to ovoid to irregular in shape; they show ragged margins (but no reaction rims) against the enclosing granite. Aplite and pegmatite dikes a few centimeters thick are found in much of this granite.

The granite of Log Cabin is Cretaceous, giving $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ zircon ages, respectively, of 72.4 and 71.6 m.y. (Table 2) that probably represent the intrusive age. K-Ar ages on hornblende of 66.5 m.y. and on biotite of 63.3 m.y. record either thermal resetting of 5–8 m.y. or uplift well after emplacement.

Three analyses of the granite of Log Cabin show SiO_2 at about 67 and 73% (Fig. 2). The two samples at 67% SiO_2 show higher K_2O, Rb, and heavy REE and lower Sr abundances than do any of the other Skagway Traverse rocks of this SiO_2 composition (Fig. 2). The sample having 73% SiO_2 is very similar in composition to the granites of Clifton and Summit Lake, except that the latter granites have more pronounced negative Eu anomalies.

Table 3. Abundances of major and minor elements of rocks of the Skagway Traverse (total iron reported as FeO; most major elements determined by X-ray fluorescence; Rb, Sr, and Ba also by XRF; H_2O and CO_2 by rapid methods; Cl spectrophotometrically and F with specific-ion electrode; other elements by instrumental neutron activation analysis)

	Migmatitic orthogneiss								Non-migmatitic orthogneiss		Granite of Log Cabin		
Sample:	AK-203	AK-202	AK-223	AK-226	78AH106	AK-220	AK-222	AK-225	AK-206	AH-15	AK-216	AK-214	AK-217
Major and minor element composition in weight percent													
SiO_2	48.20	57.30	60.80	62.40	64.20	65.40	66.20	69.30	64.70	69.70	66.70	67.30	72.70
Al_2O_3	20.20	18.60	16.70	17.70	17.60	16.90	17.30	15.90	17.20	15.60	15.70	15.40	14.80
FeO	9.36	6.32	6.12	5.40	3.24	3.73	2.99	2.56	4.09	2.51	3.41	3.28	1.60
MgO	4.85	3.35	2.73	2.17	1.16	1.32	.71	.89	2.08	.86	1.46	1.42	.59
CaO	7.84	6.33	5.43	5.26	4.39	4.48	3.65	3.31	4.58	2.84	3.04	3.00	1.79
Na_2O	3.20	2.89	3.09	3.37	4.85	3.58	3.27	4.55	3.40	3.58	3.47	3.40	3.25
K_2O	1.94	1.74	2.37	1.85	2.50	1.87	3.05	2.77	2.24	3.19	3.60	3.79	4.42
TiO_2	1.41	1.04	.77	.82	.41	.71	.37	.46	.68	.42	.52	.50	.26
P_2O_5	.34	.23	.13	.18	.09	.11	.02	.06	.13	.03	.07	-	-
MnO	.17	.11	.13	.09	.12	.06	.05	.05	.07	.04	.07	-	.06
SrO	.09	.09	.07	.08	-	.09	.06	.07	.08	0.00	.05	.05	.03
BaO	.20	.19	.11	.18	.10	.22	.31	.20	.22	.42	.15	.17	.12
ZrO_2	.02	.03	.03	.03	-	.03	.03	.02	.03	.02	.03	.03	-
CO_2	.06	.07	.05	.06	.02	.03	.08	.01	.04	.03	.06	.05	.04
Cl	.05	.03	.03	.04	.02	.03	.01	.01	.02	.01	.01	.01	.01
F	.09	.06	.05	.04	.04	.04	.02	.04	.04	.04	.05	.05	.04
H_2O^+	1.30	1.60	1.10	.70	.37	.68	.76	.62	.61	.62	.59	.61	.36
H_2O^-	.19	.02	.09	.08	.13	.06	.07	.11	.11	.13	.18	.08	.19
Subtotal	99.51	100.01	99.79	100.45	99.24	99.34	98.96	100.94	100.32	100.04	99.16	99.13	100.26
Less O	.05	.03	.03	.03	.03	.02	.01	.02	.02	.02	.02	.02	.02
Total	99.46	99.97	99.76	100.42	99.22	99.32	98.95	100.92	100.30	100.02	99.14	99.11	100.24
Trace element contents in parts per million													
Large cations													
Rb	48	45	64	49	50	51	59	59	52	83	124	128	162
Cs	.8	.9	3.8	1.0	1.5	1.4	1.3	1.1	1.3	2.4	2.8	2.8	3.1
Sr	749	762	569	666	-	775	479	595	712	-	384	395	253
Ba	1798	1741	977	1582	880	1988	2815	1805	1936	3730	1359	1559	1069
Rare earth elements													
La	23	27	15	38	9	29.5	50	22	49	61	46	34.5	34.0
Ce	61	49	29	71	17	55	90	47	81	100	77	60	56
Nd	39	27	18	31	10	23	33	19	27	36	28	24	20
Sm	10.0	5.1	3.6	5.5	2.1	4.4	5.5	3.3	4.0	4.6	4.8	4.4	3.4
Eu	1.94	1.38	.90	1.31	.65	1.34	1.38	1.10	1.18	1.15	.95	.98	.60
Gd	6.7	4.6	2.5	4.3	1.9	3.0	4.3	2.5	2.5	.1	1.8	2.0	2.6
Tb	1.14	.73	.46	.52	.33	.37	.45	.22	.34	-	.48	.45	-
Yb	2.30	1.50	1.80	1.10	1.10	.55	.90	.30	.80	.55	1.55	1.50	1.10
Lu	.30	.20	.27	.15	.18	.09	.14	.05	.13	.10	.24	.22	.19
High valence cations													
Zr	160	216	190	194	-	195	248	170	215	175	226	188	
Hf	3.5	4.9	3.1	4.0	3.1	4.5	5.3	3.7	4.7	4.1	4.7	3.7	3.0
Ta	.76	.58	.67	.57	.47	.76	.54	.45	.46	.81	.93	.81	1.54
Th	.90	4.1	4.1	7.1	1.5	6.1	10.9	4.3	9.0	14.8	18.	15.8	24.7
U	-	1.5	3.0	1.3	1.3	1.8	1.8	.8	2.6	2.5	5.2	4.8	9.0
Ferromagnesian elements													
Sc	16.8	11.2	16.3	9.44	6.40	3.64	7.19	2.21	6.51	3.40	6.14	5.53	2.57
Cr	24.4	11.1	27.6	14.0	12.3	7.0	12.0	6.7	9.6	10.5	9.8	8.6	10.1
Co	18.7	11.2	13.2	9.8	5.8	5.2	3.7	3.3	7.2	3.5	5.8	6.6	2.2
Zn	152	102	94	100	59	94	60	75	70	53	52	48	37

Tonalite of Skagway

The extensive tonalite of Skagway underlies more than 200 km² of terrain at Skagway (Fig. 1) and is found also at White Pass and near Summit Lake. This tonalite shows two textural varieties: a predominant one having euhedral, stubby prisms of hornblende 10–15 mm long and books of biotite 5–8 mm in diameter; and a less common one south of Skagway having anhedral hornblende and biotite. Both varieties are medium to light gray, homogeneous except for ubiquitous small inclusions, typically massive but locally foliated, and virtually free of aplite or pegmatite. One sample AK-200 (Table 1) shows two varieties of plagioclase, An_{26} and An_{46}. The inclusions are fine-grained, dark-gray, massive rocks of the assemblage plagioclase-hornblende-biotite-quartz. The tonalite of Skagway ranges from tonalite to granodiorite (Table 1).

The tonalite of Skagway gives concordant $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ zircon ages of 53.6 and 54.2 m.y., respectively (Table 2), that probably represent the time of emplacement. The K-Ar biotite age of 52.4 m.y. suggests that the pluton cooled to about 300°C within 2 m.y. of emplacement.

The tonalite of Skagway shows a large range of SiO_2, without gaps, from 58.6 to 71% (not including the dark inclusion, AK-213, at 53.4%). Its chemical characteristics (Fig. 2, especially) are like those of other contingent-marginal, calc-alkaline intrusions: Al_2O_3 is high, decreasing from 17.8 to 15.3% with increasing SiO_2; K_2O is moderate, increasing from 1.9 to 3.4% with increasing SiO_2; Sr is high at 530–700 ppm, decreasing with SiO_2; Rb is low at 48–55 ppm; and REE plots (Fig. 3) show moderate to steep slopes, La 28–95 times chondrites, Lu 4–7 times chondrites, and typical small, negative Eu anomalies.

Granites of Clifton and Summit Lake

The youngest plutons of the Skagway Traverse, the granites of Clifton and Summit Lake, crosscut or send

Table 3—*Continued*

	Tonalite of Skagway											Granites of Clifton and Summit Lake					
Sample:	AK-2131	78AH46	AK-209	AK-205	AK-212	AL-218	AK-200	AK-201	AK-224	78AH44	AK-219	AK-204	78AG17	AK-215	AK-210	AK-211	AK-207
Major and minor element composition in weight percent																	
SiO_2	53.40	58.60	60.80	61.30	62.80	64.50	67.00	67.50	68.40	70.70	71.00	73.90	74.70	74.80	75.30	76.90	77.20
Al_2O_3	18.60	17.80	17.60	17.50	16.50	17.70	16.30	16.30	15.80	15.80	15.30	13.80	13.90	14.00	13.10	12.60	12.30
FeO	7.86	6.23	5.47	5.42	5.12	3.73	3.64	3.33	3.22	2.36	2.58	1.61	1.36	1.29	1.67	1.36	1.13
MgO	4.46	2.62	2.76	2.77	2.76	1.34	1.62	1.49	1.01	.62	.85	.55	.20 .56	.51	.41	.37	
CaO	7.49	6.03	5.47	5.58	4.97	4.41	3.97	3.97	3.56	2.90	3.23	1.29	1.14	1.60	1.24	1.14	1.15
Na_2O	3.02	2.99	2.74	2.66	3.10	3.53	2.96	3.09	3.40	3.27	3.07	3.20	3.32	2.91	3.96	3.73	3.40
K_2O	1.81	1.93	1.95	1.99	2.33	1.85	2.45	2.15	2.96	3.05	2.80	4.65	4.63	4.53	4.51	4.18	4.34
TiO_2	1.37	.94	.82	.84	.80	.70	.51	.45	.46	.33	.36	.23	.16 .21	.23	.11	.10	
P_2O_5	.33	.16	.15	.17	.16	.13	.22	.21	.07	.01	.02						
MnO	.14	.12	.10	.13	.10	.06	.08	.09	.08	.05	.06	-	.04 -	.05	.05	.04	
SrO	.10	-	.08	.08	.08	.07	.07	.07	.06	-	.07	.02	- .02	.02	.01	.01	
BaO	.16	.19	.18	.18	.20	.22	.20	.15	.23	.28	.23	.13	.10 .09	.11	.14	.12	
ZrO_2	.02	.02	.02	.02	.02	.02	.02	.02	.02	.03	.02	.03	- -	.03	.02	.01	
CO_2	.03	.03	.16	.03	.04	.07	.05	.06	.04	.03	.06	.03	.05 .05	.04	.08	.06	
Cl	.01	.04	.01	.01	.01	.01	.01	.02	.03	.03	.01	.01	.01 .01	.01	.01	.01	
F	.06	.08	.05	.10	.06	.04	.05	.05	.04	.05	.04	.09	.04 .04	.10	.05	.03	
H_2O^+	.79	1.10	.72	.54	.52	.61	.49	.36	.62	.53	.79	.87	.57 .28	.40	.40	.26	
H_2O^-	.15	.16	.15	.11	.12	.15	.11	.20	.12	.11	.02	.10	.10 .12	.06	.07	.15	
Subtotal	99.80	99.04	99.24	99.43	99.70	99.14	99.75	99.51	100.21	100.15	100.51	100.51	100.32	100.52	101.35	101.26	100.69
Less O	.03	.04	.02	.04	.03	.02	.02	.03	.02	.03	.02	.04	.02 .02	.04	.02	.01	
Total	99.77	98.99	99.21	99.39	99.67	99.12	99.73	99.48	100.10	100.12	100.49	100.47	100.30	100.50	101.31	101.24	100.68
Trace element contents in parts per million																	
Large cations																	
Rb	48	55	58	69	58	65	62	57	72	75	65	14535	201	144	132	125	
Cs	1.3	1.2	1.3	1.9	1.2	1.2	1.0	1.7	1.3	1.4	1.0	1.9 2.6	2.41.7	1.5	1.4		
Sr	830	-	638	654	700	620	624	573	531	-	597	153 -	210	139	101	87	
Ba	1469	1670	1649	1616	1802	1935	1784	1350	2061	2520	2075	1164	861	826	1028	1269	1088
Rare earth elements																	
La	21	16	17	19	28	15	31	15	9	26	21	38 34	2546	22	23		
Ce	43	34	34	37	51	30	67	33	19	48	40	77 64	5088	40	42		
Nd	33	20	18	19	24	16	24	17	9.0	21.5	18.5	27 28	2133	15	16		
Sm	6.6	4.9	4.1	5.2	5.0	3.5	4.4	3.8	3.10	4.50	3.55	5.3	6.13.8	6.0	2.8	3.5	
Eu	1.51	1.24	1.11	1.19	1.17	.96	1.08	.96	.95	.99	.99	.55	.52 .56	.56	.34	.31	
Gd	5.1	4.1	3.6	4.1	4.3	3.4	3.9	3.1	3.2	3.5	2.6	5.5 -	2.7 -	1.3	1.6		
Tb	.73	.60	.48	.53	.62	.36	.47	.47	.47	.50	.37	.68	.80 -	.67	.44	.49	
Yb	1.65	1.75	1.50	1.70	1.70	.95	1.10	1.40	1.30	1.05	.95	2.50	2.70	1.45	2.25	2.10	2.15
Lu	.23	.26	.22	.24	.21	.16	.19	.21	.21	.16	.14	.38	.41 .24	.35	.32	.33	
High valence cations																	
Zr	115	140	157	180	169	145	165	155	140	200	132	237 -	-230	122	107		
Hf	2.8	3.4	3.8	3.6	4.0	3.4	3.7	3.6	3.2	4.6	3.4	5.2 5.2	3.45.7	3.2	3.1		
Ta	.73	.74	.65	.73	.79	.58	.77	.85	.63	.97	.70	1.55	1.44	2.36	1.10	.90	.94
Th	2.4	2.4	3.4	4.6	6.6	3.8	7.7	5.3	2.80	8.35	5.45	19.2	28.8	27.8	19.6	12.1	12.6
U	1.3	1.0	1.2	2.1	2.1	1.0	2.8	1.9	-	3.10	-	4.911.1	9.03.3	2.7	2.6		
Ferromagnesian elements																	
Sc	15.8	13.5	12.2	13.8	11.1	3.96	5.76	4.72	6.42	3.27	2.95	2.34	2.44	2.21	2.49	2.44	2.36
Cr	14.8	11.9	13.7	12.7	15.6	5.8	4.8	3.9	9.3	9.1	7.9	3.213.6	7.14.4	6.5	7.8		
Co	16.7	10.8	8.6	8.3	10.1	2.5	3.9	3.3	3.5	2.0	2.3	1.3 .9	1.61.2	.7	.6		
Zn	105	103	95	130	78	76	87	75	145	66	70	37 37	3640	30	35		

marginal dikes into the other intrusions or orthogneisses and are similar in petrographic and chemical type. Because a sample of the Summit Lake body gave a nearly concordant U-Pb zircon age of 53 m.y. and a sample of the Clifton body gave 48 m.y. (Table 2), we know that the youngest intrusion was emplaced in two discrete pulses. The two age types, however, are similar in outcrop; because we could not locate their mutual contact, they are shown in Figure 1 by the same pattern. These granites are pink to buff, leucocratic, massive, fine (Clifton body) to medium grained (Summit Lake body), homogeneous, free of inclusions, and cut by sparse veinlets and pods of aplite and pegmatite. Miarolitic cavities occur near Clifton; they probably indicate shallow emplacement. The color index is less than 5, and biotite is the major ferromagnesian phase (Table 1).

The granite of Summit Lake gave almost concordant zircon ages for the three U-Th-Pb decay systems of 53.1, 51.4, and 52.4 m.y. (Table 2). These agree with a 52-m.y. K-Ar age on biotite. The pluton was thus emplaced and cooled rapidly at this time, consistent with its shallow emplacement. The zircon ages of the granite of Clifton are concordant at 48.0, 47.6, and 48.1 m.y.

These granites are chemically different from the several tonalitic gneisses and intrusions: their SiO_2 ranges from 73.9 to 77.2%; K_2O is high at 4.2–4.6%; Sr is relatively low at 87–210 ppm; Rb is rather high at 125–200 ppm; and REE plots are characterized by prominent negative anomalies and very gentle slopes of the heavy REE. REE and Hf contents are, however, about 50% higher in Clifton than in Summit Lake (Table 3, Fig. 3).

Intrusion versus uplift

The Coast batholith at the Skagway Traverse areally is approximately one-half Cretaceous (or perhaps older) and one-half Eocene in age. Orthogneiss at the western margin apparently was emplaced in a compressive stress regime and, considering its secondary blue-green hornblende and other metamorphic minerals of amphibolite facies, was uplifted at least 10–12 km. Much of this uplift probably occurred before shallow intrusion of the Clifton pluton. In the Prince Rupert area and in nearby Alaska, near Ketchikan, pronounced uplift of the older rocks of the Coast batholith and of rocks to the west has been demonstrated by discordance of K-Ar ages on biotites and hornblendes by Smith et al. (1979). Uplift of the Ecstall

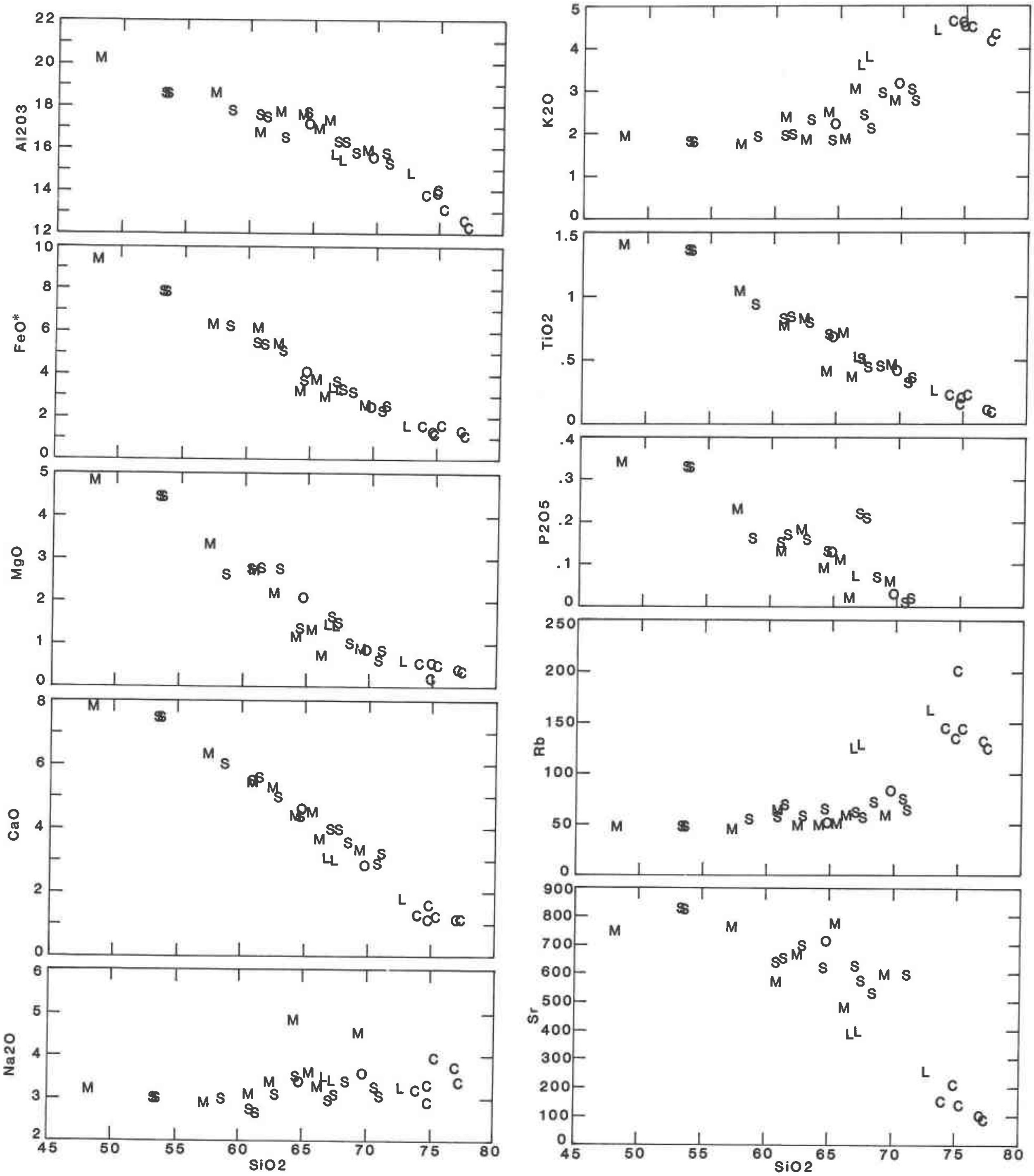


Fig. 2. Silica-variation diagrams of major elements (weight percent) and Rb and Sr (parts per million). Symbols are M, migmatitic orthogneiss; O, nonmigmatitic orthogneiss; L, granite of Log Cabin; S, tonalite of Skagway; I, basic inclusion in tonalite of Skagway; and C, granites of Clifton and Summit Lake.

pluton has been demonstrated by Harrison et al. (1979) by several methods of radioactive age determination. Modeling based on pressures and temperatures of assemblages of the western part of the Central Gneiss Complex by Crawford and Hollister (1982), Hollister (1982), and Kenah and Hollister (1983), taken in conjunction with the radiometric ages, suggests uplift from about 35-km to 5-km depth in the interval 62–58 m.y. ago. In contrast, the large eastern Eocene plutons of the Skagway Traverse were emplaced when the western part was being uplifted. Also,

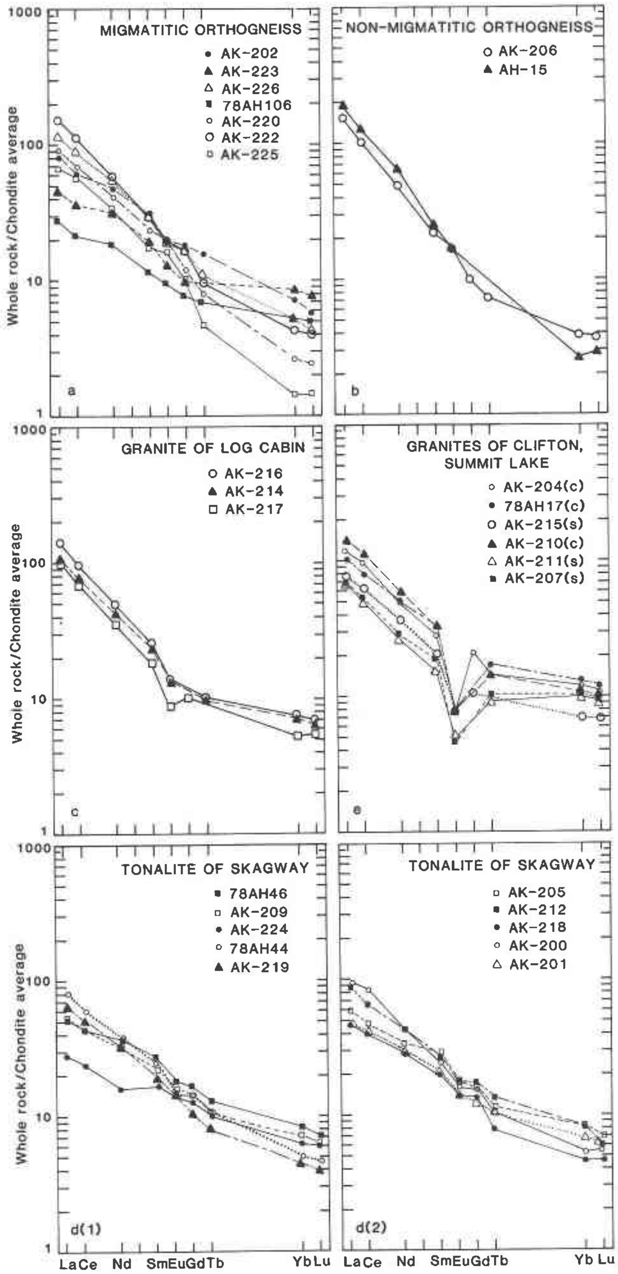


Fig. 3. Chondrite-normalized plots of rare-earth elements.

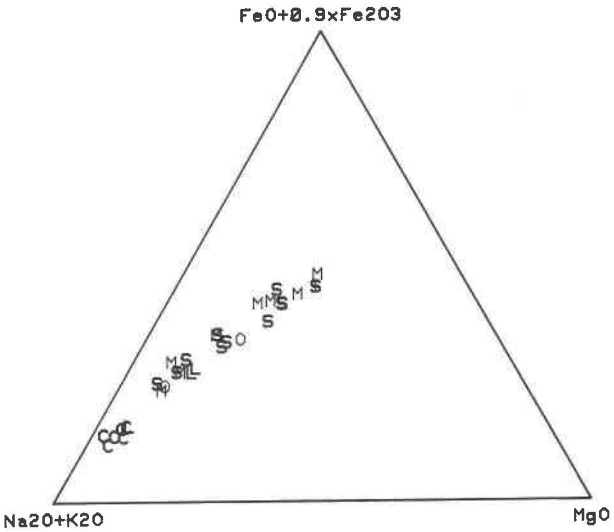


Fig. 4. Alk-F-M plot (weight percent) of Na_2O + K_2O, FeO* (FeO + 0.9 Fe_2O_3), and MgO. Symbols as in Fig. 2.

the Late Cretaceous granite of Log Cabin apparently was emplaced at moderate or shallow depth; its wallrocks of the Stikine terrane are basaltic and andesitic volcanic rocks, graywacke, and argillite of greenschist or lower metamorphic facies (Christie, 1957).

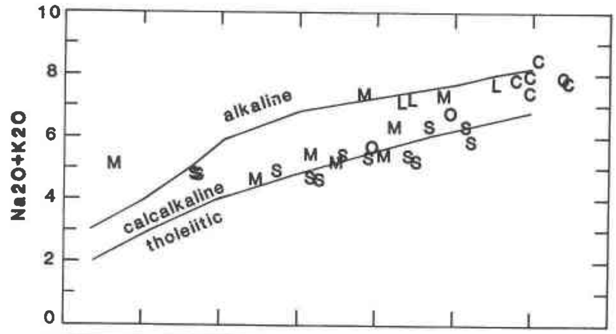
Calc-alkaline Character of the Batholith

In spite of their differences in abundances of various major and minor elements, all analyzed samples of the Skagway Traverse show a calc-alkaline trend on an Alk-F-M diagram (Fig. 4). On a Kuno plot of total alkalis against SiO_2 (Fig. 5) most samples lie in the calc-alkaline field, the exceptions being one sample of the granite of Clifton plotting as alkaline and six of the tonalite of Skagway plotting as tholeiitic. On Miyashiro's plot of FeO*/MgO (FeO* = FeO + 0.9Fe_2O_3) versus SiO_2 (Fig. 6), however, more than half of the points lie in the calc-alkaline field and the remainder in the tholeiitic field. Some samples of migmatitic gneiss and tonalite of Skagway show mild iron enrichment. On Peacock's index, the alkali-lime index is ca. 64, so the suite would be classed as calcic. Our opinion is that the Alk-F-M plot gives the most reliable indication of calc-alkaline or tholeiitic nature of a rock suite.

Sr-isotope ratios

Initial $^{87}Sr/^{86}Sr$ ratios of nine samples from the major plutons and nonmigmatitic orthogneiss are listed in Table 4. Collectively they range from 0.7048 to 0.7060. However, all of this range is encompassed by two samples of Summit Lake Granite. The other two granites, of Clifton and Log Cabin, have ratios of 0.7052. Four samples of tonalite to granodiorite of Skagway and nonmigmatitic orthogneiss fall in a close grouping from 0.7054 to 0.7058. One quartz diorite inclusion in Skagway Tonalite has a ratio of 0.7056 and is not isotopically distinguished from the enclosing rock.

The initial Sr-isotope values of these batholithic rocks are greater than those of oceanic tholeiite, or ca. 0.704. They also are less than those of pre-Mesozoic continental rocks, which by late Mesozoic time mostly exceeded 0.710. They do lie in the range of calc-alkaline orogenic andesitic suites, which is about 0.703 to 0.708 (Hedge, 1975). The accreted rocks composing the crust both to the northeast and southwest of the Coast batholith consist largely of oceanic igneous rocks (island arcs, rift, and intraplate basalts, and minor intrusive rocks), and immature sedimentary rocks. The Sr-isotope ratios of most of these rocks initially ranged from about 0.703 to the value for sea water



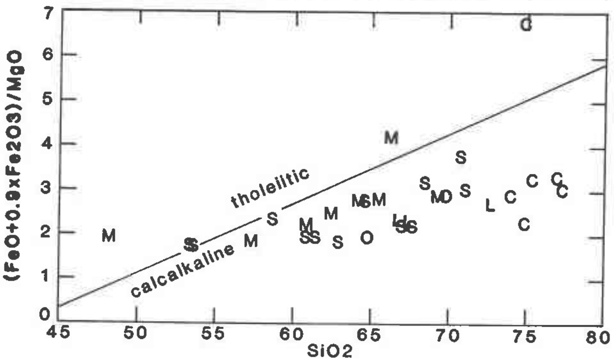


Fig. 5 (upper). Plot (weight percent) of total alkalis versus SiO_2. Symbols as in Fig. 2.

Fig. 6 (lower). Plot of FeO*/MgO versus SiO_2. Symbols as in Fig. 2.

(ca. 0.707–0.708). Their Rb/Sr ratios are not high, so their Late Cretaceous–early Tertiary values of $^{87}Sr/^{86}Sr$ probably were in the range 0.703–0.709. Because the ratios of primary igneous rocks and their wallrocks overlap, Sr isotopes cannot be used as an indicator of assimilation or mixing.

Light stable isotopes

Magaritz and Taylor (1976) presented $^{18}O/^{16}O$ and D/H isotopic analyses of samples collected by one of us (Barker, 1952). They concluded that (1) low δD values and anomalous spreads between $\delta^{18}O$ of quartz and $\delta^{18}O$ of feldspar indicate that meteoric water or fluid circulated through virtually all of the intrusive rocks between Haines and Lake Bennett to depths of at least several kilometers after crystallization of these rocks; (2) the largely low values of δD (less than ca. −80‰ and as low as −166‰) and the near-pristine values of $\delta^{18}O$ of feldspar (only two samples are <7‰) indicate water/rock ratios of exchange with the fluid of about 0.3–1.4 (weight ratio); quartz generally was unaffected, feldspars only slightly or not affected, but biotite and hornblende had their D/H ratios reset in most samples; and (3) anomalously high values of $\delta^{18}O$ of quartz of 10.1–11.5‰ of orthogneiss and tonalite of Skagway resulted either from interaction between magma and a fluid generated from metasedimentary or weathered volcanic rocks of high $^{18}O/^{16}O$ ratios or of actual assimilation of such rocks by magma. However, whole-rock values of

Table 4. Sr-isotope data for granitoid plutons of the Skagway area, coast batholith, Alaska

Sample number	Rb in[1] ppm	Sr in[1] ppm	Rb/Sr	$^{86}Sr/^{86}Sr$[2] measured	age[3] in m.y.	$^{87}Sr/^{86}Sr$ initial	95%[4] confidence level
Non-migmatitic orthogneiss							
AK-206	52	712	0.073	0.70565	> 62	<0.70546	0.00020
Granite of Log Cabin							
AK-214	128	395	0.324	0.70615	72	0.70519	0.00021
Tonalite of Skagway							
AK-205	69	654	0.106	0.70605	54	0.70582	0.00020
AK-201	57	573	0.100	0.70599	54	0.70577	0.00015
AK-212	58	700	0.083	0.70561	54	0.70543	0.00015
AK-213I	48	830	0.058	0.70571	[54]	0.70558	0.00015
Granite of Clifton							
AK-210	144	139	1.04	0.70725	48	0.70521	0.00026
Granite of Summit Lake							
AK-211	132	101	1.41	0.70770	53	0.70485	0.00030
AK-215	201	210	0.957	0.70812	53	0.70603	0.00022

1. Rb and Sr analyses by X-ray fluorescence spectroscopy.
2. Measured $^{87}Sr/^{86}Sr$ ratios were normalized to an $^{86}Sr/^{87}Sr$ ratio of 0.11940. The uncertainty in the $^{87}Sr/^{86}Sr$ ratio is 0.00010 at the 68% confidence level. Fourteen analyses of NBS SRM 987 gave a mean value of 0.71016 ± 0.00003 (1 sigma).
3. Ages determined by U-Th-Pb method (Table 2).
4. Uncertainty includes that for concentration measurements, isotopic ratio measurement, and reported age.

$\delta^{18}O$ (which should be 1–3‰ less than the $\delta^{18}O$ values of quartz) are in the range 7.5–10‰ and thus lie below the limiting value of ca. 10‰ for melts derived from pelitic rocks (O'Neil et al., 1977).

This disturbance of magmatic D/H ratios and quartz-feldspar partitioning of O isotopes, however, is not reflected in a detectable effect on either elemental abundances or $^{87}Sr/^{86}Sr$ ratios, or in visible alteration of magmatic minerals. The possibility of deep circulation of meteoric fluids needs further study.

Coast batholith and diorite-tonalite-granite (DTG) suites

Our chemical data may be considered in terms of the character and origin of continental-margin batholiths. The predominant rock suite in this type of batholith includes (in IUGS terminology) diorite, quartz diorite, tonalite, quartz monzodiorite, granodiorite, and granite. The term "diorite-tonalite-granite (DTG) suite" may be applied. The DTG suite of the Skagway Traverse ranges from about 50% SiO_2 to more than 75%, deeply eroded rocks of the western Coast batholith showing the lowest values and shallow plutons such as the leucogranites north of Skagway showing the higher ones. The suite typically is calc-alkaline to calcic, and K_2O shows moderate values of 2.5–4.3%.

The DTG suite is well characterized in the plot of normative quartz (Qz), plagioclase (Ab + An), and orthoclase (Or). In such a diagram (Fig. 7), Bateman et al. (1963) showed trends of five typical Pacific-margin DTG batholiths. The orthogneisses and the tonalite of Skagway, though of different ages, plot among several of the DTG trends. The curved, strongly contrasting trend of the gabbro-diorite-tonalite-trondhjemite suite of southwestern Finland (Arth et al., 1978) also is shown. This trend—

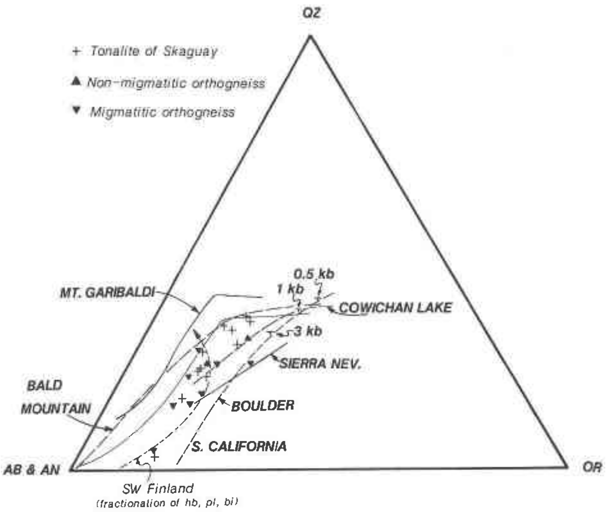


Fig. 7. Plot (weight percent) of normative quartz (Qz), plagioclase (Ab + An), and orthoclase (Or), showing trends of six suites from Bateman et al. (1963); experimental minimum-melting compositions from Tuttle and Bowen (1958) at 0.5-, 1-, and 3-kbar P_{H_2O}; and hornblende (hb)-plagioclase(pl)-biotite(bi) fractionation trend of the gabbro-trondhjemite suite of southwestern Finland (Arth et al., 1978).

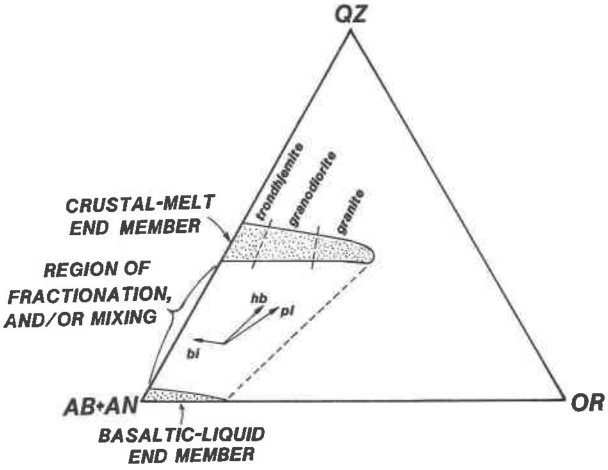


Fig. 8. Normative (weight percent) Qz–(Ab + An)–Or plot, showing end members of mantle and crustal origin, and directions (shown by arrows) that the composition of the liquid will change if biotite (bi), hornblende (hb), or plagioclase (pl) are removed.

quantitatively modeled by closed-system fractionation of hornblende, plagioclase, and biotite—differs from all known circum-Pacific margin trends.

We accept, with other workers (for references, see Barker, 1981), the premise that continental-margin batholiths are initiated by flux of high-Al_2O_3 or more primitive basaltic liquid from the mantle into the lower or intermediate crust. This liquid undergoes fractional crystallization and may partially or wholly melt or react with its enclosing crustal rocks. In Figure 8, this basaltic liquid plots near the Ab + An corner. Trends of the composition of the liquid in this diagram are controlled by two direct variables (not considering changes in total pressure, a_{H_2O}, and other variables): the compositions and fractions of (1) crystalline residuum settling out of the liquid and (2) partial melts of wallrocks added to the liquid. Mixtures of basaltic and crustal end members theoretically may lie anywhere within the bounding line shown on the diagram. One would expect plagioclase, clinopyroxene, and minor olivine or orthopyroxene to be the major phases from typical high-Al_2O_3 basaltic liquid. Removal of olivine or pyroxenes will not affect liquid compositions in a regular way, because these minerals (except aluminous clinopyroxene) do not contain the components Ab, An, or Or. However, liquid compositions will change, as shown by the arrows, if hornblende, plagioclase, or biotite are removed. REE patterns give restraints on minerals in the residuum. In the absence of hornblende, small or no Eu anomalies suggest that little or no plagioclase was removed from the fractionating liquid (assuming that Eu^{2+} did not oxidize to Eu^{3+}). In magmas having SiO_2 percentages in the high 60s to 70s, hornblende's partition coefficient for Eu is relatively lower than those for Sm and Gd (Arth and Barker, 1976). Hence its removal tends to give a positive Eu anomaly. Thus, the coprecipitation of plagioclase and hornblende can produce a derivative liquid having either a small Eu anomaly or none. Closed-system fractionation by removal of these two phases and biotite, however, would produce a DTG trend from gabbro to tonalite, as in the Proterozoic suite of Finland. Suites terminating at granite obviously did not have biotite as a precipitating phase.

Crustal melts, as represented in Figure 8, will be of several major types: trondhjemitic to leucogranodioritic melt, derived from amphibolite or other basaltic protolith, will extend from the Qz–(Ab + An) sideline into the diagram (Barker et al., 1976); and granitic melt, derived from graywacke, siliceous igneous rocks, or other protolith, will plot near the experimentally determined, low-pressure, H_2O-saturated minima of the Qz-Ab-Or-H_2O system (Tuttle and Bowen, 1958). Granodiorite melt may result from mixing of crustally derived trondhjemitic and granitic melt or from a high fraction of melting of a volcanic graywacke protolith. The average pelite-derived, or S-type, partial melt (White and Chappell, 1983) is relatively low in normative Ab but high in An (Qz, 39%; Or, 25%, Ab + An, 36%), so will plot just to the left of the experimental 1-kbar minimum (Fig. 8).

In the Skagway Traverse, the two medium-K, high-Sr gneiss units and the tonalite of Skagway constitute DTG suites (Fig. 7). They probably are fractionates of high-Al basalt (Barker and Arth, 1984), but minor assimilation of crustal rocks could have been involved.

Points on Figure 7 for the tonalite of Skagway define a rough trend that extends to granodioritic compositions. The two textural varieties show a minor difference: the fine-grained variety (AK-219, AK-224, and 78AH44) shows about 0.5% more K_2O, slightly less Al_2O_3 and more Ba than the typical, coarser-grained, hornblende-biotite-

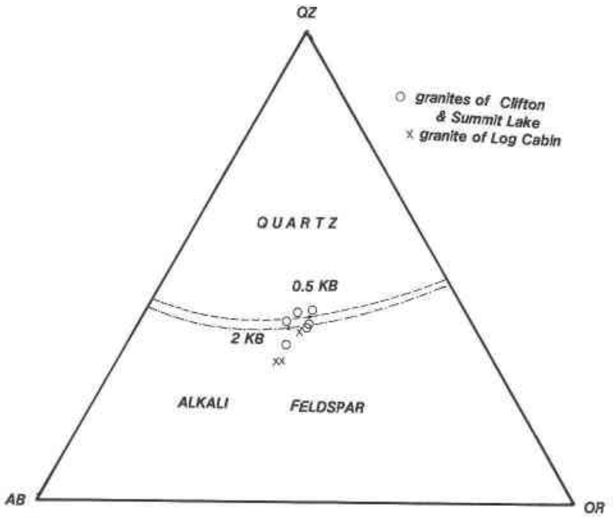


Fig. 9. Plot (weight percent) of normative quartz (Qz), albite (Ab), and orthoclase (Or), showing points for granites of the Skagway Traverse and the low-pressure water-saturated minima of Tuttle and Bowen (1958).

porphyritic variety (Table 3). The fine-grained variety also shows differences in REEs: AK-219 and AK-224 show essentially no Eu anomaly, whereas other samples show moderate negative anomalies; and sample AK-224 shows anomalously low light REEs. The $\delta^{18}O$ values of quartz of the fine-grained variant are 1–2.5‰ greater, at 11.4–11.5‰, than those of the more typical variety, which range from 8.9–10.4‰ (Magaritz and Taylor, 1976). This tonalite shows consistent initial $^{87}Sr/^{86}Sr$ ratios at 0.7054 to 0.7058 and *may* have originated largely by closed-system fractionation. If so, REE abundances must generally be buffered, because they show no systematic changes with SiO_2; plagioclase was involved in the residuum as indicated by the persistent negative Eu anomalies; and the moderate range of $\delta^{18}O$ values of quartz (and presumably whole-rock values as well) must be a result either of a small proportion of contaminating high-$\delta^{18}O$ crustal rock or of interaction of some parts of the magma chambers with a high-$\delta^{18}O$ fluid. Generation mechanisms of the fine-grained variety, however, must explain its higher $\delta^{18}O$ values, K_2O, and Ba and its lower Al_2O_3. Moderate assimilation of a crustal melt of perhaps 4% K_2O, low Al_2O_3, and $\delta^{18}O$ values of 13–16‰—a melt of the type derived from graywacke or pelite—by typical magma of the tonalite of Skagway *could* produce such a tonalite.

The granite of Log Cabin is not a DTG-type rock. It plots near the low-pressure, H_2O-saturated minimum of the experimental Qz-Ab-Or-H_2O system (Tuttle and Bowen, 1958). Our data are not sufficiently extensive to allow us to distinguish between origin by feldspar-dominated fractionation of less siliceous magma or by melting of crustal rocks. The large size of this body and the lack of less siliceous rocks favor the latter. The initial $^{87}Sr/^{86}Sr$ ratio of 0.7052 of sample AK-214 of this granite is sufficiently low to necessitate either a short-lived protolith (i.e., of late Paleozoic or Mesozoic age) or, less likely, an older protolith of low $^{87}Sr/^{86}Sr$ initial ratio and a low Rb/Sr ratio.

The granites of Summit Lake (53 m.y. old) and Clifton (48 m.y. old) are leucocratic, contain 74–77% SiO_2 (Table 3), and plot near the low-pressure, H_2O-saturated "granite" minimum (Fig. 9). Could such a suite originate as the fractionated DTG end member of the slightly older (54 m.y.) tonalite of Skagway, or did it form by melting of crustal rocks—the heat source being the subjacent chamber of generation of the tonalite of Skagway? The data show initial $^{87}Sr/^{86}Sr$ ratios of 0.7048 and 0.7060 for Summit Lake samples and 0.7052 for a Clifton sample (Table 4); $\delta^{18}O$ values of quartz of 9.8‰ for the Summit Lake and 7.9 to 8.7‰ for the Clifton type (Magaritz and Taylor, 1976); and patterns of steep light REEs, gentle (Clifton) to flat (Summit Lake) slopes of heavy REEs, pronounced negative Eu anomalies, and a crude inverse correlation of REE abundance with SiO_2 content. The minimum-melt composition and the mild variation in $^{87}Sr/^{86}Sr$ initial ratios *may* indicate that these granites originated by partial melting. The gentle to flat slopes of heavy REEs imply source material free of garnet, and the Eu anomalies imply feldspar in the residuum. These magmas show sufficient differences from the nearby granite of Log Cabin (e.g., large differences in Yb) to indicate a different protolith.

Tectonics and Magmatism

The Coast batholith was generated when the Farallon and Kula plates were being subducted from Cretaceous to Eocene time (see, e.g., Byrne, 1979; Engebretson and Cox, 1984). Assuming a direct relationship between subduction and generation of the Coast batholith as a magmatic arc, the youngest plutons, at 48 m.y., mark the approximate end of subduction and a change to transverse motion of oceanic plates relative to North America. Monger et al. (1982) saw the Coast batholith as a welt separating their Terrane I on the east from their Terrane II on the west. These authors concluded that the batholith was generated in response to collision between these terranes, forming as a magmatic arc in response to subduction of oceanic crust. We partly agree and further suggest that (1) the Coast batholith is an Andean-type magmatic arc or continental-margin batholith; (2) the only two necessary conditions for generating such a magmatic arc are (a) a subducting slab of oceanic crust and lithosphere and (b) continental (in this case accreted) crust situated above that slab, extending from the continental interior oceanward to where the upper surface of the subducting slab is about 90 km below the surface (see, Gill, 1981); (3) generation of a continental-margin batholith and accretion of terranes via an oceanic plate may commence independently but that (4) the course of development of a magmatic arc (especially shifts in the locus of magmatism) may be affected by accretion: addition of new crust to the trench-margin system may cause roll-back of the hinge of the subducting plate, which in turn may affect the position of dehydration reactions within the slab. Thus the position of the Coast batholith between the inboard and outboard groups of terranes of Monger et al. (1982) may be fortuitous.

Acknowledgments

We thank Travis Hudson for his help in field mapping, preparing the geologic map, and other aspects of this study. We thank Robert Ayuso and Steve Nelson for reviews of the manuscript.

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Manuscript received March 29, 1985
Manuscript accepted November 25, 1985