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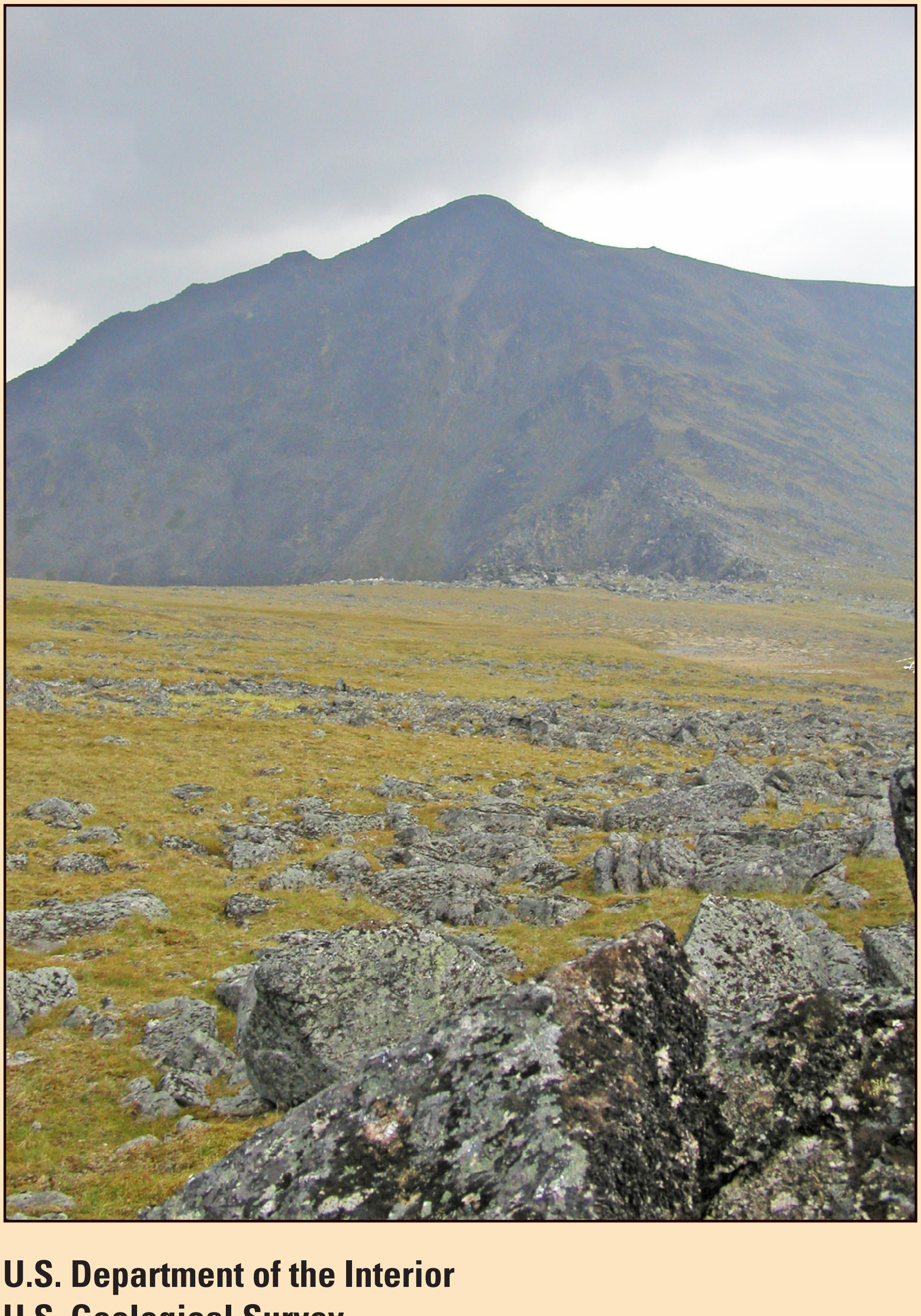

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FRONT COVER

Rubble of tourmaline and quartz replaced granite at the Whitewater occurrence, Taylor Mountains, southwestern Alaska.

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Reconnaissance Study of the Taylor Mountains Pluton, Southwestern Alaska

By Travis L. Hudson, Marti L. Miller, Edward P. Klimasauskas, and Paul W. Layer

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Reconnaissance Study of the Taylor Mountains Pluton, Southwestern Alaska

By Travis L. Hudson[1], Marti L. Miller[2], Edward P. Klimasauskas[2], and Paul W. Layer[3]

Abstract

The Taylor Mountains pluton is a Late Cretaceous to early Tertiary (median age 65±2 Ma) epizonal, composite biotite granite stock located about 235 km (145 mi) northeast of Dillingham in southwestern Alaska. This 30 km^2 (12 mi^2) pluton has sharp and discordant contacts with hornfels that developed in Upper Cretaceous clastic sedimentary rocks of the Kuskokwim Group. The three intrusive phases in the Taylor Mountains pluton, in order of emplacement, are (1) porphyritic granite containing large K-feldspar phenocrysts in a coarse-grained groundmass, (2) porphyritic granite containing large K-feldspar and smaller, but still coarse, plagioclase, quartz, and biotite phenocrysts in a fine-grained groundmass, and (3) fine-grained, leucocratic, equigranular granite. The porphyritic granites have different emplacement histories, but similar compositions; averages are 69.43 percent SiO_2, 1.62 percent CaO, 5.23 percent FeO+MgO, 3.11 percent Na_2O, and 4.50 percent K_2O. The fine-grained, equigranular granite is distinctly felsic compared to porphyritic granite; it averages 75.3 percent SiO_2, 0.49 percent CaO, 1.52 percent FeO+MgO, 3.31 percent Na_2O, and 4.87 percent K_2O. Many trace elements including Ni, Cr, Sc, V, Ba, Sr, Zr, Y, Nb, La, Ce, Th, and Nd are strongly depleted in fine-grained equigranular granite. Trace elements are not highly enriched in any of the granites. Known hydrothermal alteration is limited to one tourmaline-quartz replacement zone in porphyritic granite. Mineral deposits in the Taylor Mountains area are primarily placer gold (plus wolframite, cassiterite, and cinnabar); sources for these likely include scattered veins in hornfels peripheral to the Taylor Mountain pluton. The granite magmas that formed the Taylor Mountains pluton are thought to represent melted continental crust that possibly formed in response to high heat flow in the waning stage of Late Cretaceous subduction beneath interior Alaska.

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Introduction

This study reports field relations, petrology, major- and trace-element data, and one new Ar-Ar age for the granite pluton in the Taylor Mountains, southwestern Alaska. This pluton is part of a regionally extensive suite of Late Cretaceous and early Tertiary igneous rocks widely developed in Alaska (Moll-Stalcup and others, 1994; Bundtzen and Miller, 1997). Reifenstuhl and others (1985) compiled field observations and reported some major-element data and K-Ar ages for the Taylor Mountain pluton.

The Taylor Mountains are a 200 km^2 (77 mi^2) isolated glaciated upland in the northwestern Taylor Mountains D-4 quadrangle, about 235 km (145 mi) northeast of Dillingham (fig. 1) in southwestern Alaska. Valley glaciers flowed outward from the central uplands during the Last Glacial Maximum. The northerly flowing glaciers cut longer and deeper valleys and coalesced along the north flanks of the mountains. The mountains reach an elevation of 1,091 m (3,581 ft). Maximum vertical relief is about 700 m (2,300 ft), and outcrops are scattered along the rubble-mantled ridges left between the glacial valleys.

Figure 1. Map showing the location of the Taylor Mountains and the Taylor Mountains 1:250,000-scale quadrangle, southwestern Alaska.

The Taylor Mountains are an area of resistant hornfels intruded by a 30 km^2 (12 mi^2) granite pluton. The hornfels is developed in clastic sedimentary rocks of the regionally extensive Upper Cretaceous Kuskokwim Group (Cady and others, 1955; Decker and others, 1994; Miller and others, 2006). Cordierite bearing spotted hornfels is found locally near the contact; the hornfels aureole extends for several kilometers and gradually decreases in grade away from the contact.

The Kuskokwim Group was deposited mainly as turbidites in a basin underlain by a variety of older basement terranes (Decker and others, 1994). The nearest such basement rock lies about 25 km (16 mi) to the northeast of the Taylor Mountains in an area where the Kuskokwim Group appears to depositionally overlie platform facies sedimentary rocks of the Neoproterozoic to Jurassic Farewell terrane and to have been involved in thrusting that imbricated the Farewell rocks (Miller and others, 2006). In the area of Figure 1, the non-hornfels Kuskokwim Group south of Taylor Creek is a thick section of mudstone, siltstone, and fine- to medium-grained lithic sandstone, moderately deformed into broad, open folds.

Taylor Mountains Pluton

The Taylor Mountains pluton is a 5 by 6.5 km (3 by 4 mi) granite stock, slightly elongate in a northwest-southeast direction (fig. 2). The contacts with surrounding hornfels are sharp, discordant, and appear to be steep to moderately steep, dipping away from the pluton; however, the northwestern contact, near benchmark “Spike” (northwest corner, fig. 2), dips shallowly north, just below the ridgeline, for about 3 km (2 mi). A small roof pendant

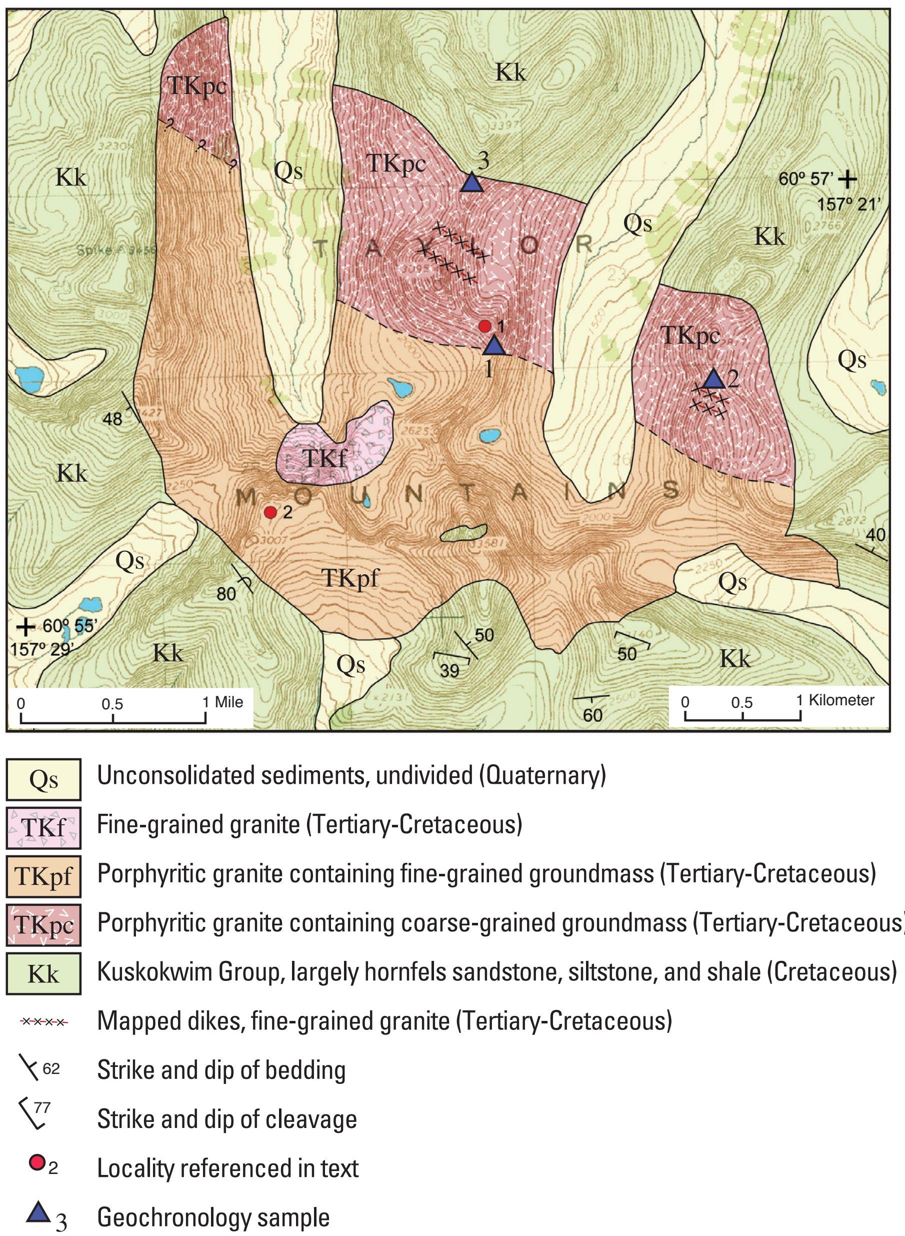

Figure 2. Geologic map of the Taylor Mountains pluton, southwestern Alaska.

of hornfels (unit Kk) is present on the north side of elevation 3,581, the highest peak in the Taylor Mountains (fig. 2).

The composite Taylor Mountains pluton contains three intrusive phases (fig. 2). The earliest phase is porphyritic biotite granite containing large K-feldspar phenocrysts scattered through a medium- to coarse-grained groundmass. This phase lies on the north-northeast side and makes up approximately 40 percent of the exposed pluton (fig. 2). Most of the remainder of the pluton is porphyritic biotite granite containing large K-feldspar phenocrysts in a fine-grained groundmass. The latest intrusive phase is a small body of fine-grained, equigranular biotite-muscovite granite in the pluton's interior (fig. 2).

The pluton's internal contacts all appear to be sharp and intrusive, although they were not directly observed in outcrop. The porphyritic granite containing a coarse-grained groundmass is interpreted as the oldest phase because it is cut by dikes (fig. 2) that have textures similar to the other two phases. These dikes are primarily fine-grained granite that is texturally and chemically similar to the fine-grained granite phase (fig. 2). One dike of porphyritic granite containing a fine-grained groundmass was observed to cut porphyritic granite containing a coarse-grained groundmass (locality 1, fig. 2). The fine-grained granite is interpreted as the youngest phase because of its location within the pluton and its fine-grained equigranular texture.

Porphyritic Granite Containing Coarse-Grained Groundmass

Large, white, euhedral K-feldspar phenocrysts—commonly 6 cm (2.5 in) long, but ranging in length from 3 to 12 cm (1 to 5 in)—make up 10 to 15 percent of this biotite granite (fig. 3). The phenocrysts are scattered through a medium- to coarse-grained hypidiomorphic equigranular groundmass of biotite, quartz, plagioclase, and anhedral K-feldspar. The K-feldspar phenocrysts are weakly to moderately aligned in some places. Aplitic segregations and rare tourmaline clots are locally present.

Figure 3. Photograph of a hand specimen of porphyritic granite containing coarse-grained groundmass, Taylor Mountains, southwestern Alaska.

The K-feldspar phenocrysts are perthitic and have inclusions of plagioclase, quartz, and biotite. Biotite, which constitutes 5 to 10 percent of this granite, is as much as 0.5 cm (0.2 in) across, dark red brown, and scattered through the groundmass as discrete intergranular grains. Plagioclase is subhedral and not zoned. Zircon is the accessory mineral in this phase; it occurs as subhedral to euhedral intergranular grains and as small inclusions in biotite. Zircon in biotite lacks well-developed pleochroic halos. Minor muscovite incompletely replaces biotite and some plagioclase in places, and it also forms a few intergranular grains associated with small, opaque grains that may represent completely replaced biotite.

Granitic dikes locally intrude this phase (fig. 2). These dikes are primarily fine-grained equigranular granite (for example, sample AH-21, table 1) measuring as much as several meters (tens of feet) wide. A thicker (6 m, 20 ft) dike (locality 1, fig. 2) is porphyritic granite containing a fine-grained groundmass. Small tourmaline-bearing quartz veins are associated with some fine-grained granite dikes. Xenoliths, other than hazy, biotite-rich patches, were not observed in the dikes.

Porphyritic Granite Containing Fine-Grained Groundmass

K-feldspar phenocrysts in this phase of the Taylor Mountains pluton are similar to those in the porphyritic granite containing coarse-grained groundmass. The K-feldspar phenocrysts are large, white, and euhedral; they are commonly 6 to 8 cm (2.4 to 3 in) long, but locally exceed 9 cm (3.5 in). However, these phenocrysts are slightly less abundant than those in the other porphyritic phase (5 to 10 percent), and they are not generally aligned. The large K-feldspar phenocrysts, accompanied by phenocrysts of much smaller, but still coarse plagioclase, quartz, and biotite (to 0.5 cm across) are scattered through a fine-grained, hypidiomorphic, equigranular groundmass (fig. 4). Small biotite-rich clots and scarce, thin tourmaline-bearing quartz veins are locally present. The jointing in this phase appears to be more closely spaced than that in the coarse-grained-groundmass porphyritic granite.

The K-feldspar phenocrysts are perthitic and include some plagioclase, quartz, and biotite. The biotite is dark red brown and occurs as both coarser, subhedral grains and as smaller, somewhat shreddy grains in the groundmass. The coarser plagioclase grains display some growth bands along their outer margins, but are not strongly zoned. The K-feldspar in the groundmass is mostly anhedral. Zircon occurs as inclusions in biotite (without strong pleochroic halos) and as intergranular, subhedral to euhedral grains. Anhedral and intergranular sphene is present in trace amounts. Muscovite irregularly replaces biotite and clouds parts of some plagioclase crystals.

Table 1. Major-oxide and trace-element data for samples of the Taylor Mountains pluton, southwestern Alaska.

[Analyzed at the GeoAnalytical Laboratory, Washington State University, Pullman. Trace-element contents of V, Cr, Ni, Cu, Zn, Ga, and Zr determined by wavelength-dispersive X-ray-fluorescence analysis and of other elements by inductively coupled plasma mass-spectrometric analysis. LOI, weight loss on ignition]

Granite unit	Porphyritic, coarse-grained groundmass			Porphyritic, fine-grained groundmass			Fine-grained (AH-21 is a dike)			
Sample No.	**AH-19**	**AH-22**	**AH-31**	**AH-24**	**AH-25A**	**AH-33**	**AH-25B**	**AH-32**	**AH-36**	**AH-21**
Unnormalized major elements (weight, in percent)										
SiO_2	68.22	68.35	69.36	66.98	68.06	67.89	73.61	74.76	73.07	73.72
TiO_2	0.629	0.543	0.617	0.735	0.685	0.675	0.094	0.070	0.229	0.179
Al_2O_3	14.95	14.82	14.36	15.14	14.59	14.78	13.90	13.46	14.20	13.69
FeO*	4.04	3.52	3.90	4.30	4.10	4.11	0.92	0.74	1.71	1.57
MnO	0.080	0.096	0.086	0.097	0.088	0.095	0.038	0.033	0.063	0.063
MgO	1.07	0.94	1.05	1.26	1.26	1.23	0.17	0.15	0.41	0.32
CaO	1.57	1.42	1.55	1.91	1.58	1.51	0.39	0.34	0.63	0.57
Na_2O	3.10	3.11	3.19	3.08	2.86	3.01	3.51	3.20	3.26	3.00
K_2O	4.51	4.66	4.01	4.39	4.48	4.42	4.47	4.79	4.93	4.90
P_2O_5	0.302	0.305	0.271	0.349	0.304	0.297	0.261	0.243	0.280	0.226
Sum	98.47	97.76	98.40	98.25	98.01	98.03	97.36	97.78	98.79	98.24
LOI (%)	0.73	0.79	0.72	0.77	0.75	0.97	0.59	0.34	0.81	0.82
Normalized major elements (weight, in percent)										
SiO_2	69.28	69.91	70.49	68.18	69.44	69.25	75.60	76.46	73.97	75.05
TiO_2	0.639	0.555	0.627	0.748	0.699	0.688	0.097	0.072	0.232	0.182
Al_2O_3	15.19	15.15	14.60	15.41	14.89	15.08	14.28	13.77	14.37	13.93
FeO*	4.10	3.60	3.96	4.38	4.18	4.20	0.95	0.75	1.73	1.60
MnO	0.081	0.098	0.088	0.099	0.090	0.097	0.039	0.034	0.064	0.064
MgO	1.08	0.96	1.07	1.28	1.29	1.26	0.17	0.15	0.42	0.32
CaO	1.59	1.46	1.58	1.94	1.61	1.54	0.40	0.35	0.64	0.58
Na_2O	3.14	3.18	3.24	3.13	2.92	3.07	3.60	3.27	3.30	3.05
K_2O	4.58	4.77	4.07	4.47	4.57	4.51	4.59	4.90	4.99	4.99
P_2O_5	0.307	0.312	0.275	0.356	0.310	0.303	0.268	0.249	0.284	0.230
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Trace elements (in parts per million)										
Ni	19	23	19	17	22	24	9	6	10	8
Cr	29	26	28	31	37	36	5	4	10	9
Sc	9	8	9	9	10	9	4	4	6	4
V	63	54	60	71	76	71	5	2	24	16
Ba	692	837	565	861	752	720	58	31	222	107
Rb	215	206	207	189	193	192	322	265	280	253
Sr	157	163	157	202	166	156	14	9	50	34
Zr	257	226	238	226	207	223	37	32	77	68
Y	23	22	19	22	22	26	8	7	12	13
Nb	26.1	23.2	25.7	23.8	22.5	23.6	11.1	5.1	16.7	12.8
Ga	25	22	23	24	21	22	21	19	20	19
Cu	3	29	4	11	15	19	9	1	2	0
Zn	103	103	93	103	93	96	53	30	50	50
Pb	18	19	16	19	18	19	13	15	17	17
La	37	34	36	35	31	36	5	3	12	11
Ce	77	65	66	70	64	69	9	7	28	25
Th	11	10	11	11	10	10	2	1	3	3
Nd	34	29	28	31	29	32	3	4	11	11
U	5	7	4	4	4	4	6	5	3	4
Cs	28	22	28	16	19	14	58	14	38	33
As	6	15	16	4	20	13	16	2	20	11

Fine-Grained Granite

Fine-grained, hypidiomorphic, equigranular granite (fig. 5), in places verging on medium-grained and seriate, makes up a small (0.6 km^2; 0.24 mi^2), slightly elongate body within the porphyritic granite containing fine-grained groundmass (fig. 2). The fine-grained granite has 1 to 2 percent biotite, minor, disseminated tourmaline, and some feldspar that weathers light rosy red. Hydrothermal alteration that significantly modifies original textures and mineralogy is not developed in this phase.

The subhedral to shreddy biotite is yellowish brown, but it is largely replaced by muscovite. Muscovite, as much as 1 or 2 percent, also forms intergranular grains. Small, opaque grains commonly accompany muscovite. Plagioclase is subhedral and unzoned. A few grains of zircon are included in biotite. Traces of tourmaline occur as anhedral to euhedral interstitial and intergranular grains.

Chemistry

Major- and trace-element data for three samples of porphyritic granite containing coarse-grained groundmass, three samples of porphyritic granite containing fined-grained groundmass, and four samples of fine-grained granite (including a dike, sample AH-21) are listed in table 1. The least felsic sample (AH-24, 68.18 percent SiO_2, normalized) is from the fine-grained-groundmass porphyritic granite unit. Sample AH-24 was collected from the central part of the pluton, near the contact with coarse-grained-groundmass porphyritic granite; a small, biotite-rich clot was observed in outcrop here, and this sample contains slightly more biotite than the others. The major-oxide composition of the porphyritic-granite samples is generally similar (fig. 6); SiO_2 ranges from 68.18 to 70.49 percent (averages 69.43 percent), CaO ranges from 1.46 to 1.94 percent (averages 1.62 percent),

Figure 4. Photographs showing (*A*) a field exposure of the porphyritic granite containing fine-grained groundmass and (*B*) a hand specimen of same rock, Taylor Mountains, southwestern Alaska.

FeO+MgO ranges from 4.56 to 5.66 percent (averages 5.23 percent), Na_2O ranges from 2.92 to 3.24 percent (averages 3.11 percent), and K_2O ranges from 4.07 to 4.77 percent (averages 4.50 percent). The major-oxide data reported by Reifenstuhl and others (1985) for three samples from the Taylor Mountains pluton are similar to that for the porphyritic-granite samples reported here.

The fine-grained granite is distinctly more felsic than the porphyritic granites (table 1; fig. 6). SiO_2 ranges from 73.97 to 76.46 percent (averages 75.3 percent), CaO ranges from 0.35 to 0.64 percent (averages 0.49 percent), FeO+MgO ranges from 0.90 to 2.15 percent (averages 1.52 percent), Na_2O ranges from 3.05 to 3.60 percent (averages 3.31 percent), and K_2O ranges from 4.59 to 4.99 percent (averages 4.87 percent). The principal major-oxide differences between the fine-grained granite and the porphyritic granites are in their CaO, FeO, MgO, and TiO_2 contents. On average, these oxides are much less abundant in the fine-grained granite than in the porphyritic granite. SiO_2, Na_2O, and K_2O are relatively similar between the fine-grained granite and the porphyritic granites, although there is a 3-percent SiO_2 gap between the most felsic porphyry and the least felsic fine-grained granite (fig. 6).

The trace-element data (table 1) show strong differences between fine-grained granite and porphyritic granite. Compared to the porphyritic granites, fine-grained granite is strongly depleted in most trace elements, including Ni, Cr, Sc, V, Ba, Sr, Zr, Y, Nb, La, Ce, Th, and Nd (fig. 7). Overall, base-metal concentrations in all of the granites are low; Cu is generally lower (0 to 9 ppm) and Zn is distinctly lower (30 to 53 ppm) in the fine-grained granite versus the porphyritic granite. Cesium has variable concentrations (14 to 58 ppm), and uranium has low concentrations (3 to 7 ppm) in all the granites. The Taylor Mountains granites, even the very felsic fine-grained granite, are not highly evolved in their trace-element contents.

Figure 5. Photograph of a hand specimen of fine-grained granite, Taylor Mountains, southwestern Alaska.

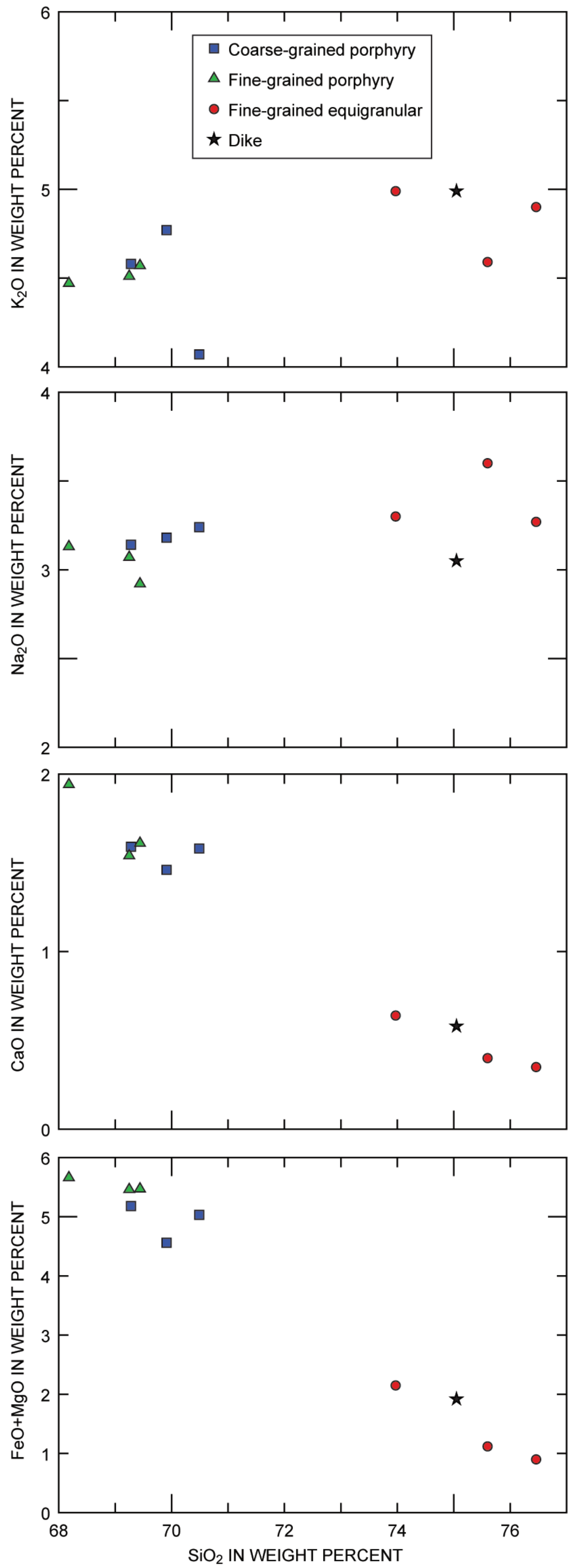

Figure 6. Harker diagrams showing variation of major oxides with silica content for samples of the Taylor Mountains igneous rocks, southwestern Alaska.

For example, compared to tin granites of Seward Peninsula, Alaska (Hudson and Arth, 1983), the Taylor Mountains granites have low average concentrations of U (5 versus 17 ppm), Th (7 versus 46 ppm), Cs (27 versus 40 ppm), and Rb (230 versus 570 ppm).

Age of the Taylor Mountains Pluton

A sample of the coarse-grained-groundmass porphyritic granite was dated by the $^{40}Ar/^{39}Ar$ method at the Geochronology Laboratory, University of Alaska, Fairbanks. A single biotite crystal was hand picked for analysis after the sample was crushed, washed, and sieved. Analytical methods are described in detail in appendix 1. This biotite yielded a plateau age of 63.4±0.3 Ma (fig. 8, table 2).

Reifenstuhl and others (1985) earlier reported four conventional K-Ar ages (three biotite and one muscovite) for the Taylor Mountains pluton. These ages are 64.5±1.9, 65.0±2.0, 65.3±2.0, and 67.6±2.0 Ma (fig. 9). All four of these ages, and our one new Ar/Ar age, are from what we interpret to be the oldest phase—the porphyritic granite containing a coarse-grained groundmass (fig. 2). By using all five ages, the median age for the Taylor Mountains pluton is calculated to be 65±2 Ma. The pluton apparently was emplaced in the earliest Tertiary or the latest Cretaceous. It is slightly younger than the hypabyssal felsic intrusive rocks and related gold mineralization at the Shotgun prospect (70 to 68 Ma; Hudson, 2001), 70 km (44 mi) to the southwest, and slightly older than the epizonal granite and related tin mineralization at the Sleitat prospect (56.8±2.8 Ma; Burleigh, 1991), 103 km (64 mi) to the south-southeast of the Taylor Mountains.

The Taylor Mountains pluton was emplaced in several phases between 67 and 63 Ma, putting it near the middle of the Late Cretaceous and early Tertiary episode of magmatism (75 to 50 Ma; Moll-Stalcup, 1994) widely distributed through southern and interior Alaska. Emplacement of the Taylor Moun-

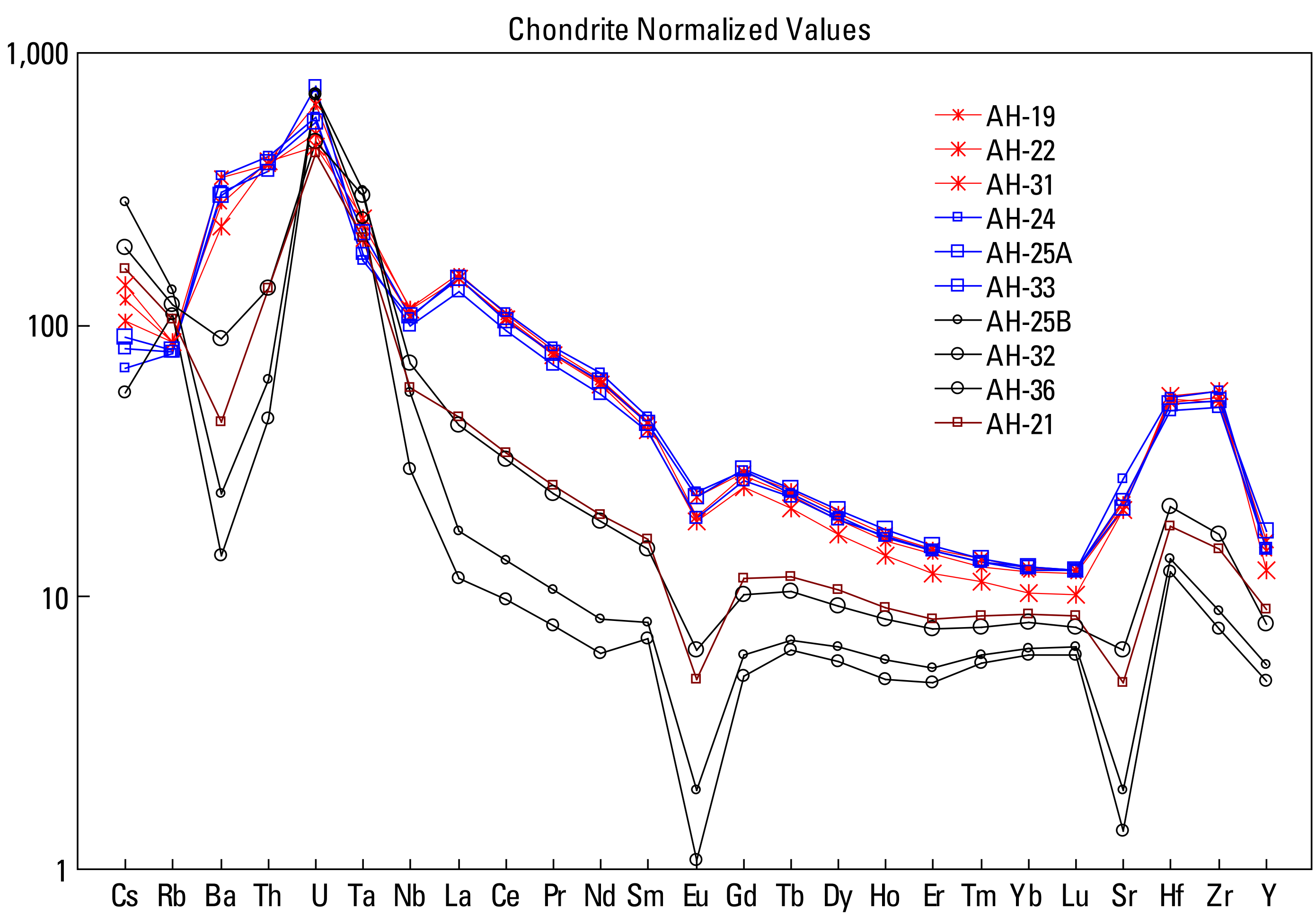

Figure 7. Trace-element variation diagram for Taylor Mountains igneous rocks (chondrite normalized), southwestern Alaska.

tains pluton also was during the peak magmatism (72 to 65 Ma) in the Kuskokwim mineral belt (Bundtzen and Miller, 1997).

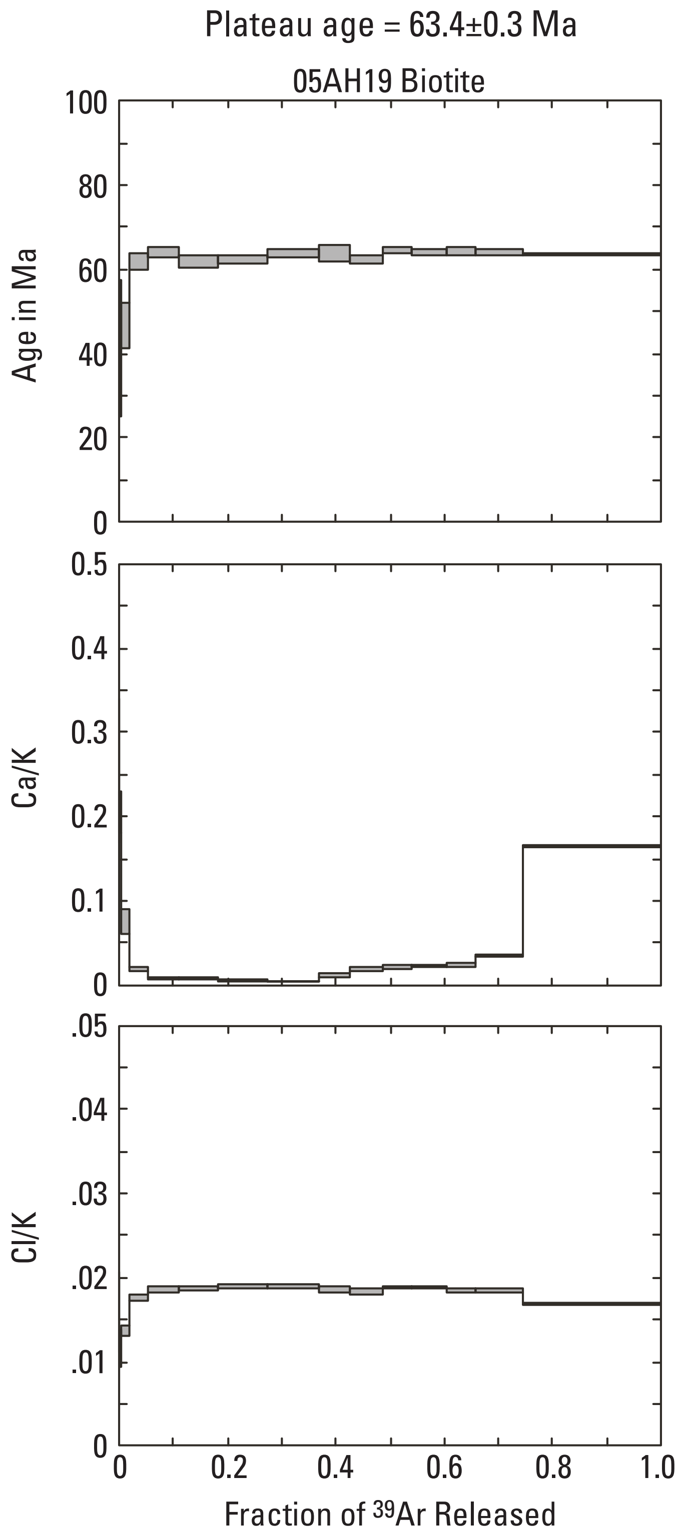

Figure 8. $^{40}Ar/^{39}Ar$ age spectra for sample 05AH19 from the Taylor Mountains, southwestern Alaska. Shown are age, Ca/K, and Cl/K spectra.

Mineral Occurrences

The Taylor Mountains pluton has one area of known hydrothermal alteration. The Whitewater tourmaline occurrence (locality 2, fig. 2) is a fault- or joint-controlled zone of strong tourmaline and quartz replacement of the fine-grained-groundmass porphyritic granite. Rubble crop of massive blocks of black tourmaline and quartz as much as 2 m (6 ft) across are distributed over 30 to 60 m (100 to 200 ft) of a northwest-trending linear zone across the ridge crest (fig. 10). Two samples of this alteration, collected and analyzed by the Bureau of Land Management, have low metal contents; for example, 100 and 300 ppm As, 106 and 107 ppm Cu, 5 and 15 ppm Sn, and 3 to 15 ppm U (Ellefson and others, 2005). An additional two samples collected by the USGS show more elevated metal contents of 89 to 789 ppb Au, 2 ppm Ag, 224-770 ppm As, 209 to 359 Cu, 40 to 103 ppm Sb, and 5 to 28 ppm U (Klimasauskas and others, 2006).

Other mineralization in the Taylor Mountains area is evidenced primarily by placer deposits. A lode occurrence of wolframite in a quartz vein cutting hornfels is reported east of the pluton (Hudson, 2001), but the principal wolframite occurrence is in a small, placer gold deposit on an unnamed

Map No. in fig. 2	Sample number	Age ± 2σ error, in Ma	Method	Mineral
1	82MR309	65.3 ± 2	K/Ar	biotite
2	83MR234c	67.6 ± 2	K/Ar	biotite
2	83MR235	65.0 ± 2	K/Ar	biotite
2	83MR235	64.5 ± 1.9	K/Ar	muscovite
3	05AH19	63.4 ± 0.3	$^{40}Ar/^{39}Ar$	biotite

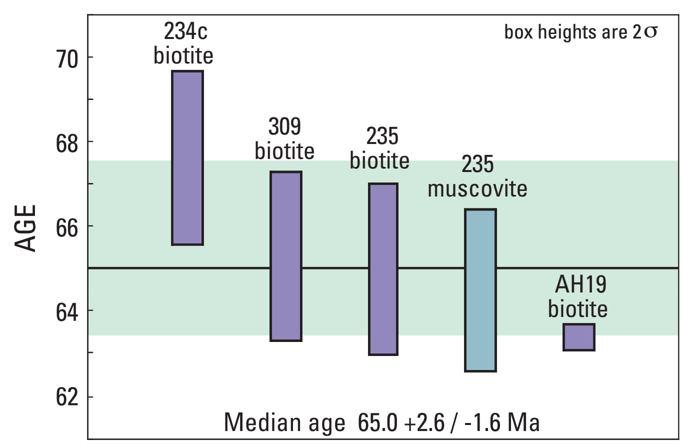

Figure 9. Diagram comparing four previously reported (Reifenstuhl and others, 1985) K/Ar ages and the new Ar/Ar age (sample AH19, this report) , Taylor Mountains, southwestern Alaska. Each age bar is labeled with the sample number and the mineral dated. The calculated median for these ages is shown. Sample locations are shown in figure 2.

Table 2. $^{40}Ar/^{39}Ar$ data for biotite from sample 05AH19, Taylor Mountains, southwestern Alaska.

[Weighted average of J from standards = 3.298e-03±8.605e-06. mW, megawatts. Cum., cumulative]

Laser (mW)	Cum. ^{39}Ar	$^{40}Ar/^{39}Ar$ measured	±	$^{37}Ar/^{39}Ar$ measured	±	measured	±	% Atm. ^{40}Ar	Ca/K	±	Cl/K	±	$^{40}Ar^{*}/^{39}ArK$	±	Age (Ma)	± (Ma)
300	0.0011	152.3549	8.0614	0.13886	0.04655	0.54915	0.03979	106.5	0.2548	0.0854	0.01595	0.00478	-9.938	8.075	-60.11	49.67
500	0.0042	36.1855	0.6046	0.11142	0.01324	0.09873	0.00953	80.7	0.2045	0.0243	0.01163	0.00221	6.992	2.782	41.13	16.18
750	0.0176	20.3620	0.1540	0.04115	0.00779	0.04193	0.00325	60.9	0.0755	0.0143	0.01379	0.00061	7.945	0.960	46.66	5.56
1,000	0.0538	13.8512	0.1195	0.00968	0.00136	0.01105	0.00112	23.6	0.0178	0.0025	0.01758	0.00041	10.557	0.342	61.74	1.97
1,200	0.1116	11.4905	0.0605	0.00375	0.00067	0.00159	0.00063	4.1	0.0069	0.0012	0.01859	0.00036	10.991	0.196	64.23	1.13
1,400	0.1827	11.2337	0.0660	0.00405	0.00066	0.00205	0.00075	5.4	0.0074	0.0012	0.01873	0.00024	10.600	0.231	61.98	1.33
1,600	0.2740	11.1672	0.0755	0.00262	0.00055	0.00160	0.00058	4.2	0.0048	0.0010	0.01895	0.00027	10.666	0.185	62.36	1.07
1,800	0.3671	11.2070	0.1150	0.00212	0.00045	0.00092	0.00040	2.4	0.0039	0.0008	0.01895	0.00027	10.907	0.165	63.75	0.95
2,000	0.4248	11.3113	0.0718	0.00620	0.00132	0.00117	0.00113	3.1	0.0114	0.0024	0.01854	0.00038	10.937	0.341	63.92	1.96
2,400	0.4855	11.3376	0.0831	0.01015	0.00139	0.00224	0.00054	5.8	0.0186	0.0025	0.01844	0.00037	10.649	0.179	62.27	1.03
2,800	0.5405	11.4007	0.0413	0.01136	0.00102	0.00110	0.00039	2.9	0.0208	0.0019	0.01884	0.00021	11.047	0.123	64.55	0.70
3,500	0.6049	11.2907	0.0461	0.01212	0.00091	0.00095	0.00044	2.5	0.0222	0.0017	0.01887	0.00021	10.984	0.138	64.19	0.79
5,000	0.6590	11.3097	0.0556	0.01296	0.00108	0.00081	0.00051	2.1	0.0238	0.0020	0.01847	0.00029	11.042	0.160	64.52	0.92
9,000	0.7432	11.1162	0.0738	0.01871	0.00074	0.00049	0.00037	1.3	0.0343	0.0014	0.01837	0.00025	10.945	0.131	63.96	0.75
9,001	1.0000	11.0135	0.0645	0.08951	0.00084	0.00042	0.00010	1.1	0.1642	0.0015	0.01694	0.00014	10.868	0.071	63.52	0.41
Integrated		11.6457	0.0250	0.02998	0.00030	0.00284	0.00015	7.2	0.0550	0.0006	0.01811	0.00008	10.781	0.050	63.02	0.33

Figure 10. Rubble of tourmaline and quartz replaced granite at the Whitewater occurrence (locality 2, fig. 2) , Taylor Mountains, southwestern Alaska.

north tributary to Kiknik Creek (section 16, T9N, R46W of the Seward Meridian). This placer is 4.8 km (3 mi) south of the southern contact of the Taylor Mountain pluton (south of the area in fig. 2). A pan concentrate sample collected from the placer contained 2,350 ppm Sn and 820 ppm W; a sluice concentrate sample contained 2,330 ppm Sn and 36 percent W (Ellefson and others, 2005). Cassiterite and cinnabar are reported from a gold placer along Taylor Creek, just to the east (about 2 km or 1.2 mi) of the wolframite-rich placer. In general, data from samples taken from within the granite pluton and from peripheral mineralization suggest that a large mineralizing system did not evolve during crystallization of the Taylor Mountain pluton. Veins scattered through hornfels and nearby sedimentary rocks of the Kuskokwim Group could be contributing to the placer deposits.

Discussion

The initially emplaced coarse-grained-groundmass porphyritic granite represents a magma that may have partially crystallized at depth to develop its large K-feldspar phenocrysts, but upon emplacement at epizonal levels, gradually cooled and crystallized in place. The similarity in chemical composition and coarse-grained mineralogy between the two porphyritic granite phases shows that their principal differences are textural. The magma that formed the fine-grained-groundmass porphyritic granite crystallized coarse to very coarse biotite, plagioclase, quartz, and K-feldspar at depth. Mobilization and upward movement of this part of the magma system, along with, and perhaps to slightly shallower levels than, the previously emplaced porphyritic granite, appears to have initiated crystallization of its fine-grained groundmass. The parent magma for both porphyritic granites was very similar.

The fine-grained granite is the late-evolved phase of the Taylor Mountains pluton. Its small size, interior location, texture, and distinctly felsic composition identify it as the residual granite magma in this system. Its composition can be explained by removal of biotite, zircon, and sphene from the magma that formed the porphyritic granites. Fractionation appears to have produced small amounts of residual granite elsewhere in the subsurface of the system as evidenced by fine-grained granite dikes that locally intrude porphyritic granite (fig. 2).

Although fractionation evolved distinctly felsic residual magma in the Taylor Mountains pluton, this magma was not highly enriched in fugitive or volatile components. Muscovite, some intergranular and some replacing biotite and plagioclase, is the common late mineral phase in the granites; it is the principal hydrous phase in the fine-grained equigranular granite. Minor tourmaline is the other late-crystallizing mineral in the granites.

The Late Cretaceous and early Tertiary regional magmatism that includes the Taylor Mountains pluton is scattered across interior Alaska from the Alaska Range north to the Yukon-Koyukuk region and from the Bering Sea east to Canada. Magmas were emplaced across this vast 600 by 1,200 km (370 by 750 mi) province throughout the interval between 76 and 50 Ma (Moll-Stalcup, 1994). The plutonic and volcanic rocks in this magmatic province range from calcic to alkalic, but are mostly calc-alkalic (for example, fig. 5 from Bundtzen and Miller, 1997). Magmas in this province have both mantle and crustal sources (Bergman and others, 1987; Moll-Stalcup, 1994; Arth, 1994). There is an apparent shift in general compositional character at about 63$\pm$3 Ma; younger rocks appear to reflect melting of a larger proportion of lithosphere, including continental crust (Bergman and others, 1987). The Late Cretaceous magmatism has been interpreted as a magmatic arc developed above a fast-converging, shallow-dipping subduction zone (Bergman and others, 1987; Moll-Stalcup, 1994). The early Tertiary rocks in the province may have developed in a post-subduction setting (Bergman and others, 1987).

The Late Cretaceous tectonic setting produced high heat flow in addition to extensive magmatism in interior Alaska (Daggett, 1987; Miller and others, 2007). The crust in the part of southwestern Alaska that includes the Taylor Mountains is continental in character (Arth, 1994; Saltus and others, 1999). The overall felsic composition of the Taylor Mountains pluton suggests that its parental magmas were derived from melting of this continental crust in response to subduction-related high heat flow.

Conclusion

The 68 to 63 Ma Taylor Mountains pluton is an epizonal, composite biotite-granite stock. The stock is composed primarily of two compositionally similar porphyritic biotite-granite phases having textural differences developed in response to different emplacement histories. Fractional crystallization of the magmas produced a small amount of fine-grained residual granite. The residual granite, although distinctly felsic, is not strongly trace-element or volatile enriched. Mineral deposits in the area are primarily placers whose sources were probably veins in country rocks to the Taylor Mountains pluton rather than hydrothermal systems related to granite crystallization. The Taylor Mountains pluton is thought to represent melted continental crust; its parent magmas developed in a high heat flow setting during the waning stages of Late Cretaceous subduction beneath interior Alaska.

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Appendix—Summary of Analytical Method for $^{40}Ar/^{39}Ar$ Analysis

One sample was submitted to the Geochronology Laboratory at the University of Alaska, Fairbanks for $^{40}Ar/^{39}Ar$ analysis. The sample was crushed, washed, and sieved to either 100–250 or 250–500 micron-size fractions, and hand picked for biotite. The monitor mineral MMhb-1 (Samson and Alexander, 1987), which has an age of 513.9 Ma (Lanphere and Dalrymple, 2000), was used to monitor neutron flux (and to calculate the irradiation parameter, J). The samples and standards were wrapped in aluminum foil and loaded into aluminum cans measuring 2.5 cm in diameter and 6 cm in height. The samples were irradiated in position 5c of the uranium-enriched research reactor of McMaster University in Hamilton, Ontario, Canada for 20 megawatt-hours.

Upon their return from the reactor, the samples and monitors were loaded into 2-mm diameter holes in a copper tray that was then loaded into an ultra-high vacuum extraction line. The monitors were fused, and the samples heated, by using a 6-watt argon-ion laser following the technique described in York and others (1981), Layer and others (1987), and Layer (2000). Argon purification was achieved by using a liquid nitrogen cold trap and a SAES Zr-Al getter at 400°C. The samples were analyzed in a VG-3600 mass spectrometer at the Geophysical Institute, University of Alaska, Fairbanks. The argon isotopes measured were corrected for system blank and mass discrimination, as well as for calcium, potassium, and chlorine interference reactions following procedures outlined in McDougall and Harrison (1999). System blanks generally were 2×10^{-16} mol ^{40}Ar and 2×10^{-18} mol ^{36}Ar, which are 10 to 50 times smaller than fraction volumes. Mass discrimination was monitored by running both calibrated air shots and a zero-age glass sample. Measurements were made on a weekly to monthly basis to check for changes in mass discrimination.

The age, Ca/K, and Cl/K spectra plots are shown in figure 8, and detailed analyses are given in table 2. All ages are quoted to the ±1 sigma level and calculated by using the constants of Steiger and Jaeger (1977). The integrated age is the age given by the total gas measured and is equivalent to a potassium-argon (K-Ar) age. The spectrum provides a plateau age if three or more consecutive gas fractions represent at least 50 percent of the total gas release and are within two standard deviations of each other (Mean Square Weighted Deviation less than ~2.7). Sample 05AH19 meets the plateau criteria.

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