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By

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MAFIC AND ULTRAMAFIC ROCKS FROM A LAYERED PLUTON AT MOUNT FAIRWEATHER, ALASKA

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Abstract.--Reconnaissance mapping in the Fairweather Range of south-central Alaska has revealed that a layered mafic and ultramafic pluton, the Fairweather pluton, underlies much of the Mount Fairweather area. The mafic rocks, which constitute most of the pluton, are magnetite- and ilmenite-bearing two-pyroxene gabbros and clinopyroxene-olivine gabbros. The ultramafic rocks consist mainly of sulfide- and chromite-bearing wehrlite, pyroxenite, and dunite, and locally contain significant concentrations of chromium, cobalt, copper, nickel, and platinum-group elements. The pluton is probably a source for ilmenite, magnetite, platinum, and other heavy minerals that have been found as placer beach deposits along the adjacent Gulf of Alaska coast.

During a geochemical sampling program in the Yakutat quadrangle and adjacent areas in 1968, the authors traced float of mafic and ultramafic rocks in glacial moraines to a previously undescribed small layered pluton at Mount Fairweather (fig. 1). The discovery is

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Figure 1 near here

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noteworthy because it extends a known belt of layered mafic plutons in the Fairweather Range some 20 miles northwestward, and

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OPEN FILE MAP

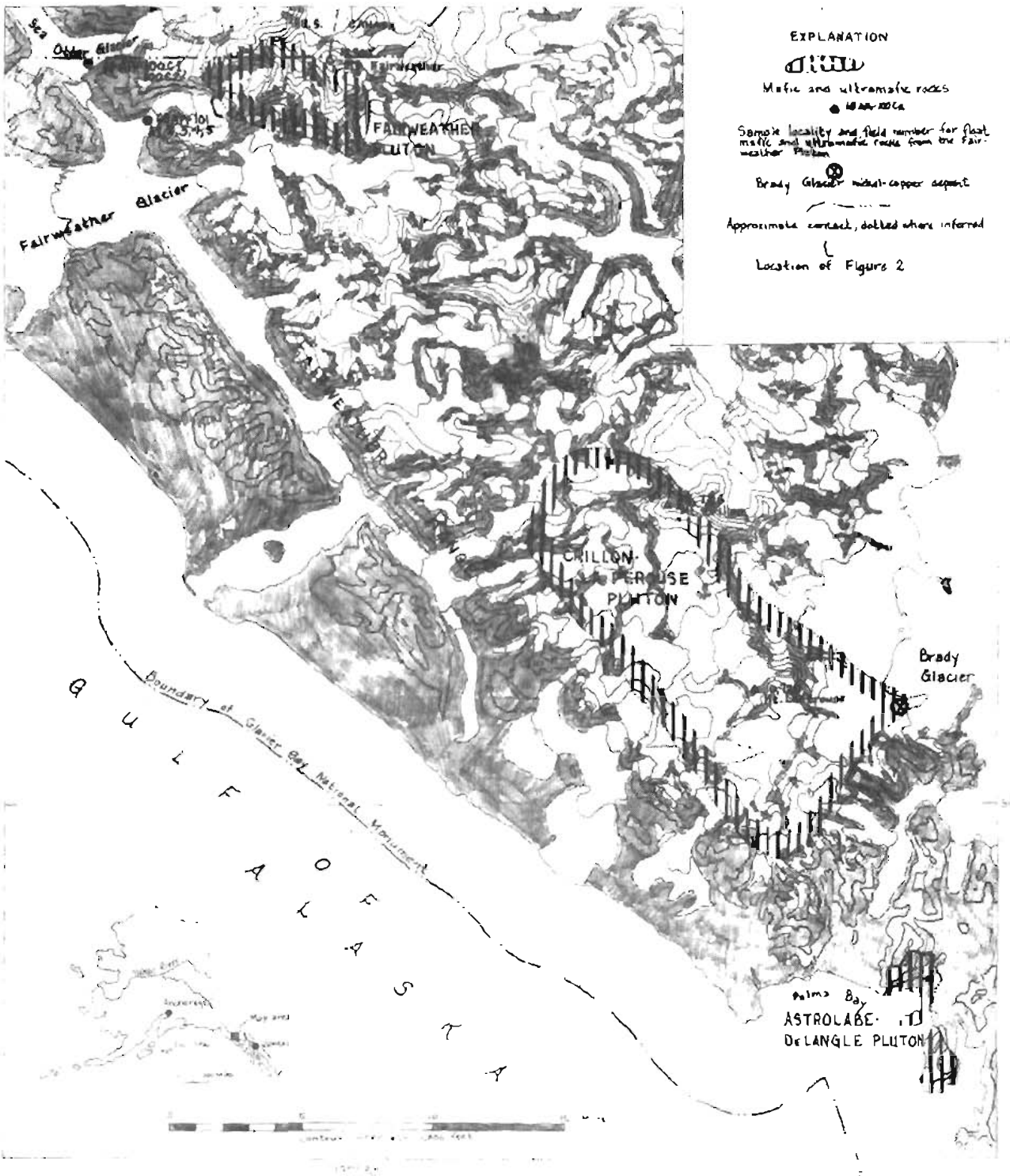

Figure 1 Index map showing the approximate location of the Fairweather pluton and other layered mafic plutons in the Fairweather Range Crillon-LaPerouse and Astrolabe-DeLangle plutons after Rossman (1963).

because the pluton contains ultramafic rocks with concentrations of chromite, nickel, copper, and platinum-group metals. Ultramafic rocks have possible economic importance at the one other locality in the Fairweather Range where they have been found. The purpose of this paper is to outline the general setting of the Fairweather pluton, as determined from a brief aerial reconnaissance, and to present the results of petrologic and chemical analyses of some samples of float rock that were derived from the pluton.

The Fairweather pluton is the most northerly of three layered mafic intrusives that lie roughly along the axis of the northwest-trending Fairweather Range (fig. 1). Its existence in the general vicinity of Mount Fairweather was correctly inferred by Rossman (1963, p. F11) from float of gabbroic rocks found in the moraines of Fairweather Glacier. However, the location of the source pluton was not known, and no ultramafic rocks were reported in the float. The belt of layered intrusives extends southeastward through Yakobi Island and western Chichagof Island where several smaller bodies of gabbroic rock similar in composition to those of the Fairweather Range are exposed (Rossman, 1963, p. F11). Other than at the Fairweather pluton, ultramafic rocks in the range have been found only in small isolated nunataks at the Brady Glacier nickel-copper prospect (fig. 1), which is believed to lie near the margin of the Crillon-La Perouse pluton (Cornwall, 1967).

SETTING

The Fairweather pluton probably underlies an area of more than 15 square miles along the southwest flank of Mount Fairweather between

the trunk stream of Fairweather Glacier and Sea Otter Glacier (fig. 1). Its general configuration and its relation to the adjacent metamorphic and granitic rocks were deduced by close observation from a helicopter. Our knowledge of the lithology of rocks in the pluton and inferences regarding the distribution of ultramafic rocks within it are based entirely on examination of moraines of the glaciers that drain towards the west and southwest from the Mount Fairweather area. The combination of rugged terrane and high altitude precluded landings within the pluton (fig. 2). Technical mountaineering capabilities would be required for

Figure 2 near here

a ground study. Virtually all of the pluton, except for the extreme northwestern end, is within the Glacier Bay National Monument.

The Fairweather pluton appears to be at least 6 miles long and 3-1/2 miles wide, the long axis trending approximately northwestward. It is elongated parallel to the structural grain of the adjacent foliated country rocks, which are mainly steeply dipping amphibolite and mica schist cut by granitic stocks and sills. Dark, layered mafic and ultramafic rocks are exposed in sheer cirque walls and knife-edged arêtes along the southwest margin of the pluton from an altitude between 7,000 and 10,000 feet, to the general vicinity of the summit, which rises 15,300 feet above sea level (fig. 2). The layered igneous rocks on the southwest flank of Mount Fairweather appear to dip northeast at a moderate angle. The northeastern contact of the pluton is largely concealed beneath the extensive snow and ice cover on the highest part

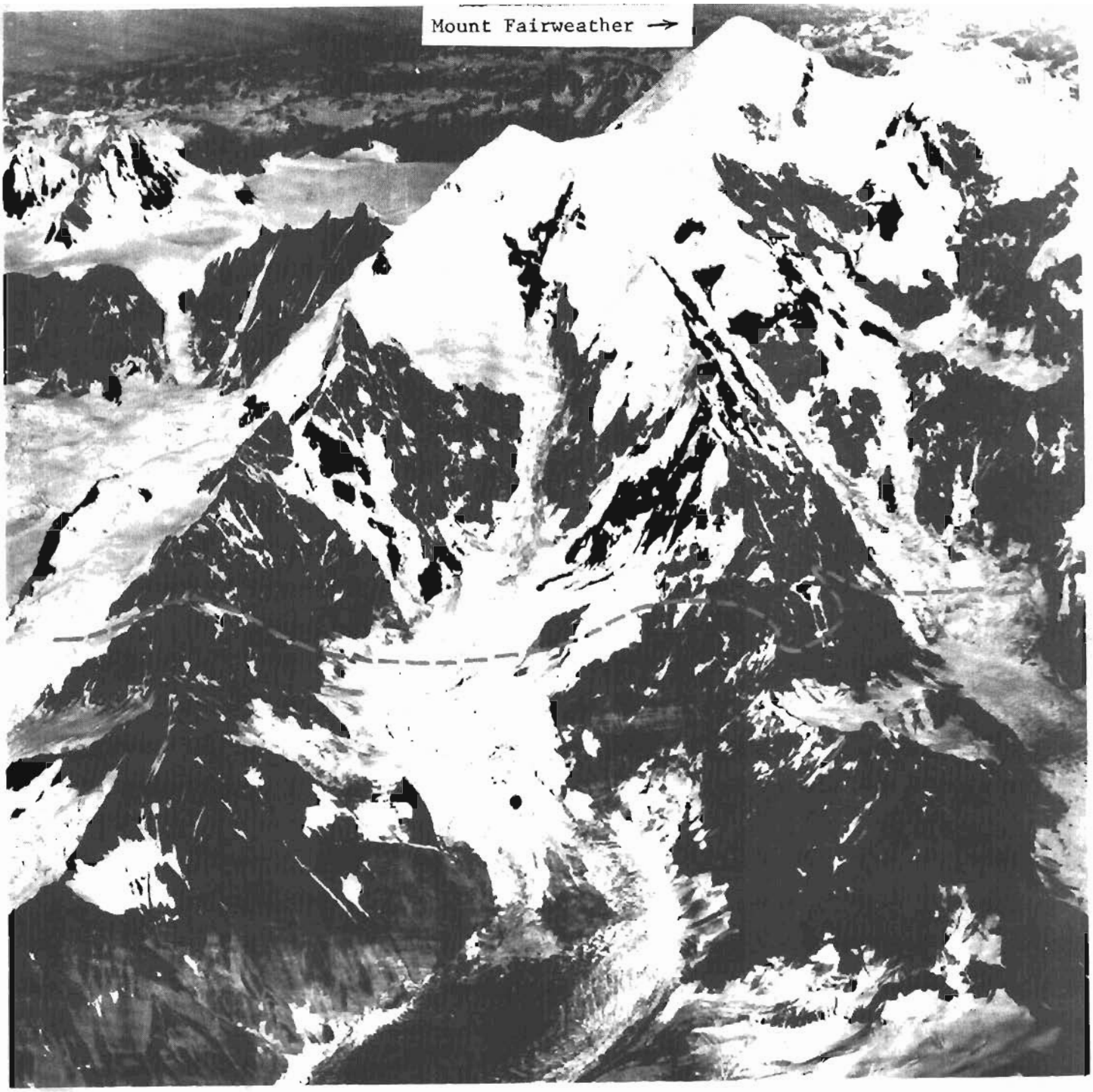

Figure 2.--Aerial view of the western part of the Fairweather pluton (location shown on fig. 1). Dotted line indicates the inferred southwest contact. The conspicuously banded rocks in the foreground are probably intertonguing metavolcanic and metasedimentary country rocks. Photo by Austin Post.

of the mountain; the contact shown on figure 1 is inferred from the distribution of schistose country rock at lower elevations. Massive, blocky, light-colored rocks in part border the layered rocks on the southwest in a zone as much as 2 miles wide, and locally seem to crosscut the darker layered rocks. It was not possible to tell from the air whether the light-gray unit represented a felsic granitic intrusive or a relatively nonlayered leucocratic gabbro. However, the general scarcity of felsic rocks in the moraines of glaciers draining this part of the mountain favor the latter alternative, and the light-gray zone was tentatively mapped as part of the pluton.

No data are available on the age of the pluton or of the adjacent foliated rocks. Rossman (1963, p. F10) correlated the schistose rocks of the Fairweather Range with units of Mesozoic age on Chichagof Island. Samples of gabbro from the compositionally and structurally similar Crillon-La Perouse pluton, which have been submitted for radiometric dating (D. A. Brew, oral commun., April, 1969), may provide information on the time of intrusion of the layered rocks.

DESCRIPTION OF THE ROCKS

The compositional layering, textures, and mineralogy of the Fairweather pluton are broadly comparable to that of the layered igneous rocks elsewhere in the Fairweather Range (Rossman, 1957) and in many well-known localities throughout the world such as the Skaergaard, Stillwater, and Bushveld Complexes (Wager and Brown, 1968). Such rocks are generally considered to result from fractional crystallization and crystal settling in a magma of original basaltic composition.

Ultramafic rocks of the Fairweather pluton are restricted to moraines on the south side of Sea Otter Glacier and on the unnamed glacier between Sea Otter and Fairweather Glaciers; gabbroic rocks are abundant in these moraines and in the lateral moraine along the north side of Fairweather Glacier (fig. 1). The distribution of ultramafic float suggests that its source is in the northern part of the pluton in the general area due west of Mount Fairweather.

Samples of float from the Fairweather pluton are composed primarily of virtually unaltered plagioclase, clinopyroxene, olivine, and orthopyroxene. Accessory constituents include sulfides, spinel-group minerals, ilmenite, hornblende, and traces of rutile and apatite. Detailed compositional studies have not been made, but the optical properties suggest that the plagioclase is mostly labradorite (An_{60-70}), the clinopyroxene is probably augite, the olivine has a forsterite content of about 80 percent, and the orthopyroxene is magnesian hypersthene (En_{85}). Augite characteristically is twinned and exhibits schiller structure; the hypersthene contains rare exsolution lamellae and blebs of clinopyroxene. The rock compositions vary from anorthosite or leucocratic gabbro to pyroxenite, wehrlite, and dunite. Chemical analyses of the various rock types samples are presented in table 1.

TABLE 1 NEAR HERE

Gabbroic rocks are by far the most abundant lithologic type in the moraines, and probably constitute the great bulk of the pluton. They are leucocratic to melanocratic rocks in which the layering results from

Table 1.--Chemical analyses of six rock samples from the Fairweather pluton

[Samples analyzed by methods similar to those described in U.S. Geol. Survey Bull. 1144-A, supplemented by Atomic Absorption. Analysts, L. Artis, G. Chloe, P. Elmore, J. Glenn, J. Kelsey, and H. Smith]

Rock type	Dunite	Wehrlite	Two-pyroxene gabbro		Clinopyroxene olivine gabbro	Dunite (sheared)
Lab No.	M106 872W	M106 873W	M106 874W	M106 875W	M106 876W	M106 877W
Field No.	68APr 101A1	68APr 100C2	68APr 101A2	68APr 101A3	68APr 101A4	68APr 101A5
SiO_2	40.5	44.2	44.4	49.5	46.1	38.8
Al_2O_3	1.3	3.7	13.0	23.0	8.0	.81
Fe_2O_3	1.2	1.7	5.0	1.0	2.2	3.2
FeO	9.4	7.6	11.0	2.8	10.6	7.6
MgO	44.4	29.3	11.3	7.2	18.5	43.8
CaO	1.4	10.6	9.9	13.6	12.4	.70
Na_2O	.07	.32	1.2	1.5	.63	.04
K_2O	.05	.08	.10	.10	.08	.10
H_2O-	.07	.08	.10	.07	.05	.24
H_2O+	.80	1.2	.72	.56	.65	4.9
TiO_2	.04	.21	3.2	.13	.73	.03
P_2O_5	.05	.04	.06	.02	.05	.04
MnO	.16	.15	.21	.20	.21	.16
CO_2	.08	<.05	.05	<.05	.08	.05
Sum	100	99	100	100	100	100

variations in the proportions of plagioclase and ferromagnesian minerals. Individual layers in float on the moraines range from a fraction of an inch to several feet in thickness. The rocks that were collected are fine- to medium-grained two-pyroxene gabbro and clinopyroxene-olivine gabbro with xenomorphic to hypidiomorphic granular textures. Plagioclase in crystals up to 3.5 mm long constitutes 10-60 percent of the gabbros analyzed. In a variant that had a decided purplish cast in the hand specimen, rutilated plagioclase makes up an estimated 85 percent of the rock and the composition borders on anorthosite. The ferromagnesian minerals range up to 2.5 mm in size.

The ratio of clino- to orthopyroxene in the two-pyroxene gabbro is variable and either mineral may predominate in a given rock. Irregular masses of magnetite and ilmenite(?) in grains to 1.5 mm constitute as much as 10 percent of one sample (68APr 101A2). The iron ores occur both interstitially and enclosed within the pyroxenes. The clinopyroxene-olivine gabbro (68APr 101A4) is composed mainly of clinopyroxene and olivine in grains as much as 2.5 mm across; the grains contain about 10 percent plagioclase and a few percent interstitial hypersthene. Opaque minerals make up as much as 5 percent of the rock. The predominant ore mineral is interstitial chalcopyrite in grains of less than 0.5 mm. Other accessory minerals in the gabbros are generally less than 0.5 mm in size and include brown hornblende, green spinel, and rare cubanite, pyrrhotite, magnetite, chromite(?) and pentlandite(?).

The float of the ultramafics consists of black, greenish-black, and olivine-green crystal cumulates with faintly layered structure.

One sample of dunite (68APr 101A1) consists of more than 90 percent fresh euhedral to anhedral olivine in grains ranging from 0.2 to 4.5 mm in size. Some of the grains exhibit twinning and protoclastic textures. The remainder of the rock is composed of euhedral to subhedral chromite crystals 0.1 to 0.5 mm across, a few crystals of pentlandite less than 0.05 mm in size, and minor amounts of interstitial clinopyroxene and hornblende. One sheared dunite specimen (68APr 101A5) was cut by cross-fiber serpentine in closely spaced veinlets less than 0.02 mm wide that make up as much as 20 percent of the rock. The essential mineral of a pyroxenite sample (68APr 100C1) is anhedral clinopyroxene in grains 0.5 to 3.0 mm across with about 25 percent anhedral to subhedral hypersthene is less than 1.0 mm in size. A sample of wehrlite (68APr 100C2) consists of about equal amounts of subhedral and anhedral olivine in grains as much as 2.5 mm across and anhedral, partially poikilitic clinopyroxene as much as 5.0 mm. The clinopyroxene is commonly altered along grain boundaries and cracks to a mixture of fibrous green actinolite and antigorite. The pyroxenite and wehrlite contain as much as 15 percent interstitial sulfides and minor scattered crystals of chromite and spinel from a few microns to 1 mm in size. The sulfide minerals, which occur in irregular scattered masses and microveinlets, are cubanite intergrown with chalcopyrite and pyrrhotite. Some pentlandite is intergrown with chalcopyrite or cubanite, or, more rarely, it occurs in isolated masses.

SPECTROGRAPHIC ANALYSES

Seven isolated float samples were analyzed for total metals by semi-quantitative spectrographic methods, and of these, five ultramafic rocks and one gabbro were analyzed for platinum-group elements by quantitative spectrographic methods (table 2). The rocks analyzed include all the

TABLE 2 NEAR HERE

lithologic types described in the preceding section, some of which had the highest content of disseminated opaque minerals found in the float. With the exception of the pyroxenite (68APr 100C1), chemical analyses are given for these same rocks in table 2.

The analyses indicate concentrations of titanium (2 percent) and vanadium (2,000 ppm) in the magnetite- and ilmenite-bearing gabbro that are not unusual for rocks of this type. As much as 5,000 ppm chromium, 5,000 ppm copper, and 5,000 ppm nickel is present in the richest samples of sulfide- and chromite-bearing pyroxenite and wehrlite, and up to 5,000 ppm chromium, and 3,000 ppm nickel, in the chromite-bearing dunite. Noteworthy amounts of cobalt and platinum-group elements were also found in the ultramafic rocks and, to a lesser extent, in the gabbros. The largest amounts of these elements, which were in the sheared dunite (68APr 101A5), totaled 200 ppm cobalt and 0.184 ppm palladium, 0.171 ppm platinum, and detectable rhodium (0.004 ppm).

Disseminated opaque minerals occur in all the float collected from the Fairweather pluton. These minerals are mainly magnetite, ilmenite, sulfides, and chromite, which undoubtedly account for the anomalous metal content of these rocks. Combined magnetite and ilmenite constitute as much as 10 percent by volume of some gabbros. The wehrlite and pyroxenite

Table 2.—Spectrographic analyses of selected float ultramafic and mafic rocks from the Fairweather pluton

[Asterisk indicates quantitative analysis, A. F. Dorrzapf and Marian Schnepfe, analysts; all others are semiquantitative, Chris Heropoulos, analyst. G, major constituents greater than 10 percent; N, not detected. Other elements looked for but not found: As, Au, B, Be, Bi, Cd, La, Mo, Nb, Pb, Sb, Sn, Te, U, W, Zn, Zr, Ce, Ge, Hf, In, Li, Re, Ta, Th, Tl, Eu.

Rock type	Dunite	Dunite (sheared)	Wehrlite	Clinopyroxene olivine gabbro	Two-pyroxene gabbro	Two-pyroxene gabbro	Pyroxenite
Field no.	68APr 101A1	68APr 101A5	68APr 100C2	68APr 101A4	68APr 101A3	68APr 101A2	68APr 100C1
Laboratory nos.	M4949 M106872W	M106877W	M4949 M106873W	M106876W	M106875W	M4949 M106874W	M4949
Element	Weight %						
Fe	10	10	10	G	3	G	7
Mg	G	G	G	10	5	7	10
Ca	0.7	0.5	7	7	7	5	7
Ti	0.05	0.02	0.2	0.5	0.1	2	0.2
Si	G	G	G	G	G	G	G
Al	1.0	0.7	2.0	5.0	G	7.0	2
Na	N	0.02	0.2	0.7	1.0	1.0	0.15
	ppm						
Mn	1500	1500	1000	3000	700	3000	1000
Ag	N	N	1	N	N	N	2
Ba	20	15	30	30	50	50	N
Co	150	200	150	100	30	70	150
Cr	5000	3000	5000	700	300	150	3000
Cu	50	30	3000	700	100	200	5000
Ni	3000	2000	5000	500	150	100	5000
Sc	15	7	70	150	30	70	70
Sr	N	N	15	100	500	200	10
V	50	30	150	500	150	2000	300
Y	N	N	10	10	N	10	N
Ga	3	N	3	7	15	15	N
Yb	1	N	1.5	1	N	N	N
*Pd	[2]/0.006	0.184	[1]/0.056	0.002	-	[1]/0.006	0.066
*Pt	[2]/0.010	0.171	[1]/0.048	0.003	-	[1]/0.009	0.043
*Rh	0.002	0.004	[1]/0.002	N	-	<0.002	<0.002

[1]/Average of two analyses.

[2]/Average of three analyses.

contain up to 15 percent sulfides with minor chromite, and some dunites contain a few percent of chromite with minor sulfides. The sulfides identified in polished section include cubanite, chalcopyrite, pyrrhotite, and pentlandite. No chromitites or massive sulfides were found. The nickel and copper content of the highest grade rocks sampled is about 0.5 percent each. This may be compared with a content of 1.5 percent nickel and 2 percent copper in selected samples of ultramafic rocks from the Brady Glacier prospect which is currently being actively explored by the Newmont Mining Company (Cornwall, 1967, p. 153, table 15).

The Fairweather pluton is probably a major source for magnetite, ilmenite, platinum, and other heavy minerals that occur in association with placer gold in beach deposits along the adjacent Gulf of Alaska coast (Rossman, 1957, 1963; Thomas and Berryhill, 1962).

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