Descriptive Petrography of Three Large Granitic Bodies In the Inyo Mountains California

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 601

Prepared in cooperation with the
California Department of Conservation
Division of Mines and Geology

U.S. DEPARTMENT OF THE INTERIOR

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Precipitous outcrops of the varicolored dark contaminated facies of the Pat Keyes pluton along the east front of the Inyo Mountains. Light-colored rocks on skyline, more than 5,000 feet above the valley floor, are contact-metamorphosed Paleozoic carbonate rocks.

Descriptive Petrography of Three Large Granitic Bodies In the Inyo Mountains California

By DONALD C. ROSS

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DESCRIPTIVE PETROGRAPHY OF THREE LARGE GRANITIC BODIES IN THE INYO MOUNTAINS, CALIFORNIA

By Donald C. Ross

ABSTRACT

Granitic rocks make up about half of the pre-Tertiary exposures in that part of the northern Inyo Mountains covered by the Independence and Waucoba Wash 15-minute quadrangles. The rocks make up three large plutons, which aggregate more than 130 square miles. The plutons are considered to be part of the composite Sierra Nevada batholith.

More than 50 square miles of the Inyo Mountains south of the Paiute Monument mass is underlain by the Pat Keyes pluton, which is considered a part of the Hunter Mountain Quartz Monzonite, a composite batholithic body of several hundred square miles in outcrop area. The Pat Keyes pluton, in contrast to the other plutons of the Inyo Mountains, varies in composition. Three facies are distinguished: (1) a medium-grained seriate quartz monzonite that looks much like the Paiute Monument mass, but is finer grained, forms a central core, (2) a fine-grained quartz monzonite-granodiorite forms the northwest margin of the pluton, and (3) dark-colored rocks ranging in composition from quartz monzonite to contaminated rocks of gabbroic composition that range considerably in grain size form the eastern and southwestern part of the pluton. These dark rocks have widely varying amounts of brown biotite and green hornblende, but in general, biotite exceeds hornblende. Clinopyroxene is fairly widespread, and orthopyroxene is found locally.

Along the crest of the Inyo Mountains, about 40 square miles is underlain by coarse-grained massive rock of the Paiute Monument Quartz Monzonite. These rocks are coarsely seriate with pale-red-purple K-feldspar crystals as much as 25 mm long. The average percentage of dark minerals is about 5, and brown biotite exceeds green hornblende.

Along the west slope of the northern Inyo Mountains, about 40 square miles is underlain by the Santa Rita Flat pluton, which is considered a part of the Tinemaha Granodiorite that crops out across Owens Valley in the Seirra Nevada. The Santa Rita Flat mass is a medium- to coarse-grained quartz monzonite, about 15 percent of which consists of dark minerals. Green hornblende is about twice as plentiful as brown biotite in this body.

Petrographic and chemical data support the field observations that these rocks are an intrusive suite of magmatic rather than of replacement origin. The quartz monzonite of the Santa Rita Flat pluton, the Paiute Monument Quartz Monzonite, and the seriate quartz monzonite facies of the Pat Keyes pluton are relatively homogeneous, whereas the other two facies of the Pat Keyes pluton are heterogeneous and probably reflect varying amounts of contamination from assimilated wallrock.

Contact (thermal) metamorphism affected the Paleozoic wallrocks of these plutons as much as 2 miles from the exposed granitic contacts. Farthest from the contacts are mineral assemblages characteristic of the albite-epidote hornfels facies, which give way toward the contact to assemblages of the hornblende hornfels facies. Near some contacts, assemblages with wollastonite may be transitional to the pyroxene hornfels facies.

Radiometric age determinations on 15 samples consisting of biotite, hornblende, and zircon from nine samples of granitic rocks of the Inyo Mountains indicate that the three large plutons are Jurassic. The granitic rocks of the Santa Rita Flat and Pat Keyes plutons are presumably Early Jurassic, and the Paiute Monument Quartz Monzonite, which intrudes the Pat Keyes pluton, is considered to be Middle Jurassic.

INTRODUCTION

This paper is one of a series of geologic reports (Ross, 1962, 1965, 1967) describing a 500-square-mile cross section of the northern Inyo Mountains. Within this cross section, granitic rocks make up about half of the pre-Tertiary exposures. These granitic rocks are part of the composite Sierra Nevada batholith. Indeed all the area shown on the index map (pl. 1) is part of the batholith if we use the commonly accepted definition, namely, that the batholith includes those areas where at least half of the exposed pre-Tertiary rocks are granitic. The east edge of the index map, by this definition, is also approximately the east edge of the Sierra Nevada batholith. The Inyo Mountains thus include some of the easternmost components of the batholith.

The three granitic bodies to be discussed are the Pat Keyes pluton of the Hunter Mountain Quartz Monzonite, the Santa Rita Flat pluton of the Tinemaha Granodiorite, and the Paiute Monument Quartz Monzonite (pls. 1, 2). All three exceed the minimum size generally accepted for batholiths (40 sq. mi. in outcrop extent). Yet referring to them as batholiths might cause confusion because they are components of the Sierra Nevada batholith. In this report, therefore, they will be referred to as bodies, masses, and plutons; the term "batholith" will be reserved for the Sierra Nevada batholith, which is a composite batholith. A further distinction is made between the terms "Sierra Nevada" and "Sierra Nevada batholith." Sierra Nevada as used in this report refers to the mountain range. The Sierra

Nevada batholith extends some distance east of the range and covers the area shown on plate 1. It is not restricted to the Sierra Nevada.

A coarsely porphyritic quartz monzonite of Cretaceous age, the Papoose Flat pluton, that crops out along the northern part of the area (pl. 1) will not be described here. It was described briefly by Ross (1965, p. 042–044) and is now being studied in detail by C. A. Nelson and several of his colleagues. Also not described in this report are the dikes and small stocks of rather nondescript aplite, alaskite, and pegmatite that are commonly peripheral to the large plutons.

The Pat Keyes pluton of the Hunter Mountain Quartz Monzonite and the Paiute Monument Quartz Monzonite are here correlated with other granitic rocks to the south and east (pl. 1); the Santa Rita Flat pluton was correlated with the Tinemaha Granodiorite in the Sierra Nevada (Ross, 1962) and then subsequently assigned to it (Ross, 1965). Because of the critical location of these three granitic bodies in the Inyo Mountains, their physical characteristics are described in some detail, and their modal and chemical data are tabulated and interpreted. This report is designed to serve as a petrographic tie point for the rocks along the east margin of the Sierra Nevada batholith.

Some brief petrographic descriptions have already been published for part of this area. The short paper on the correlation of the Santa Rita Flat pluton with the Tinemaha Granodiorite in the Sierra Nevada (Ross, 1962) included some petrographic data. The geologic report on the Independence quadrangle (Ross, 1965) gave a brief petrographic description of these granitic bodies. Numerous geologic reports have been published that include discussions of the petrography of the granitic rocks in the nearby Sierra Nevada. These include the geology of the Mount Pinchot quadrangle (Moore, 1963), the Bishop area (Bateman, 1965), and the Mount Morrison quadrangle (Rinehart and Ross, 1964). In addition, a progress report on U.S. Geological Survey work in the Sierra Nevada (Bateman and others, 1963) summarizes some of the petrographic data from an east-west belt across the central Sierra Nevada.

METHODS OF STUDY

The granitic rocks are readily distinguished from one another chiefly on the basis of color, grain size, and amount and kind of dark minerals. The granitic bodies generally are structureless except for locally well-developed joints.

Many hand specimens were collected, and about 190 thin sections were made and examined with a petrographic microscope to obtain data on textures, structures, paragenesis, and alteration products. Mineral percentages (modes) were determined from 61 of the thin sections. Some specimens, particularly those of the Paiute Monument Quartz Monzonite, were too coarse grained to yield representative modes from the small area of a standard thin section; consequently, rock specimens were sawed to obtain slab surfaces generally about 8–12 square inches in area. The slab surface was etched with hydrofluoric acid and then stained in the manner described by Bailey and Stevens (1960). This procedure produces a slab surface on which plagioclase is red, K-feldspar is yellow, quartz is unchanged, and dark minerals stand out as black or dark green. Modal mineral percentages of plagioclase, K-feldspar, quartz, and total dark minerals can be readily obtained from such a stained slab by using a dot-patterned glass plate and a binocular microscope. The percentages of the individual dark minerals are difficult to determine from a stained slab; therefore, the percentages of biotite, hornblende, and, where present, pyroxene and dark opaque minerals, were determined from thin sections. The amount of dark minerals in a thin section commonly agrees closely with the amount in a stained slab. If there was a variation between the percentage of dark minerals in the slab and the percentage in the thin section, generally the total percentage in the slab was used, but the ratio of the dark minerals was determined from thin-section counts.

The composition of the plagioclase was determined by powder X-ray methods for some specimens of the Paiute Monument Quartz Monzonite. To prepare samples, the rock was crushed, sieved to proper size, washed in hydrofluoric acid, and then immersed in sodium cobaltinitrite solution which stained the K-feldspar. The white-frosted plagioclase grains could be readily hand picked from the stained aggregate. These grains were finely ground, mixed into a slurry with water on a glass slide, and then X-rayed. The percent of anorthite, essentially an average for the specimens, was then determined by measuring certain peak intervals, particularly 220–$1\bar{3}1$ and 131–$1\bar{3}1$. Most of the specimens from the Pat Keyes and Santa Rita Flat masses contain plagioclase whose anorthite content exceeds that which can be accurately determined by the powder X-ray method. For these specimens, the maximum anorthite content, and the anorthite range of zoned crystals, was determined by measuring the extinction angle of the albite twinning in sections of plagioclase cut perpendicular to both the 001 and 010 cleavages.

Chemical analyses of 12 granitic specimens were obtained by the so-called rapid method described by Shapiro and Brannock (1956). Also, semiquantitative spectrographic analyses from some 60 elements were obtained for these same 12 specimens.

GRANITIC ROCK TYPES

TINEMAHA GRANODIORITE

The Tinemaha Granodiorite was named by Bateman (1961, p. 1529) for exposures in the vicinity of Mount Tinemaha in the eastern Sierra Nevada (pl. 1). The type area of the Tinemaha Granodiorite covers an area of about 32 square miles (Bateman, 1965, p. 68).

SANTA RITA FLAT PLUTON

NAME AND DISTRIBUTION

The Santa Rita Flat pluton takes its name from an area of well-exposed, easily accessible bouldery outcrops[1] (fig. 1) on and near Santa Rita Flat in the Independence quadrangle. The Santa Rita Flat pluton, correlated by Ross (1962, p. D86) with the Tinemaha Granodiorite, is now considered part of the Tinemaha Granodiorite. It underlies an area of about 40 square miles along the west front of the Inyo Mountains. The exposed part of the pluton lies almost wholly within the Independence quadrangle; only the north end extends into the Waucoba Mountain quadrangle (Nelson, 1966). The pluton also extends an unknown distance north and west under the alluvium of Owens Valley. In the Mount Pinchot quadrangle, west of the Independence quadrangle, a 12-square-mile elongate pluton, the Woods Lake mass, has also been assigned to the Tinemaha Granodiorite by Moore (1963), p. 77, pl. 1).

Figure 1.—Well-developed joint set in bouldery outcrop of the Santa Rita Flat pluton along west flank of the Inyo Mountains.

OUTCROP APPEARANCE AND MEGASCOPIC CHARACTER

The rocks of the Santa Rita Flat pluton occur typically as reddish-brown-stained hummocky outcrops and boulder piles and as isolated boulders partly buried in coarse sandy debris or grus (fig. 1). The reddish-brown staining is common on joint surfaces also. In fresh exposures of the rock viewed from a distance, the constituents blend to give the rock a medium gray to medium dark gray color, but close observation (fig. 2) shows that the rock consists of black hornblende and biotite, clear to light-gray quartz, and white to gray feldspar. Dark dioritic inclusions are scattered throughout and occur locally as small swarms. In general they are ovoid to almost spherical and measure from 1 to 3 inches in largest dimension; rarely they are as much as 10 inches. Foliation is uncommon and nowhere is it well developed. The scarcity of well-alined minerals or inclusions in this pluton contrasts with the foliation shown by inclusions and dark minerals in the Tinemaha Granodiorite of the Sierra Nevada.

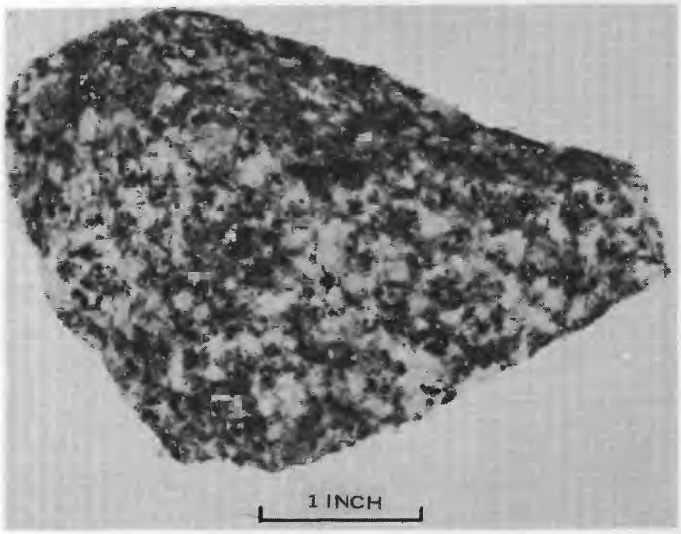

Figure 2.—Typical hand specimen of Tinemaha Granodiorite. Specimen 35.

Probably the most distinctive feature of the rock is the subhedral hornblende, in scattered crystals that are as long as 20 mm. These crystals are sprinkled through the body like shiny black twigs. The hornblende crystals plus black flakes of biotite generally make up about 15 percent of the rock, although in some samples the dark mineral percentage is as high as 27. In many hand specimens, honey-brown sphene crystals are visible.

Quartz and feldspar are light shades of gray. The quartz is commonly clear to medium light gray and not as readily distinguishable from feldspar in hand specimens as in the other large masses in the Inyo Mountains. The two minerals are difficult to distinguish partly be-

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[1] The weathering of granitic rocks in arid regions commonly produces slopes that are a combination of hummocky outcrops and boulders partially submerged in grus. Figure 1 is a good example of this kind of desert-weathered granitic rock. The term "bouldery outcrop" hopefully conveys a picture of this intimate mixture of outcrop and boulders.

cause the quartz is interstitial and partly because it is nearly the same color as much of the K-feldspar. The medium-light-gray K-feldspar, which locally has a slight pinkish cast, is evenly distributed through the rock. The K-feldspar ranges from small interstitial grains to poikilitic, somewhat ragged crystals as much as 25 millimeters long. These large K-feldspar crystals are much less abundant than those in the Paiute Monument Quartz Monzonite. The plagioclase crystals are white, commonly chalky white or faintly greenish, from alteration products, chiefly epidote.

Epidote, both as veins and as pervasive disseminations several feet across, is so common it may be considered characteristic of the rock. Such an abundance seems too great to be solely the result of the alteration of dark minerals and plagioclase; some epidote may have been introduced from an outside source.

The texture of the Santa Rita Flat pluton is medium to coarse grained. Crystals range from 2 to 5 mm and are generally equigranular. The texture is seriate where large K-feldspar phenocrysts are prominent.

MICROSCOPIC DESCRIPTION

In most thin sections, the plagioclase, much of the hornblende, and some of the biotite are subhedral. In contrast, quartz and K-feldspar are anhedral and irregular. This rock has a hypautomorphic granular to weakly seriate texture that is characteristic of most of the granitic rocks of the Sierra Nevada batholith.

The K-feldspar, as elsewhere in the Inyo Mountains, has aggressively attacked and engulfed other minerals, particularly plagioclase. The larger grains commonly enclose scalloped corroded grains of other minerals. In places, the K-feldspar is grid twinned; elsewhere it is almost without twinning. Faint perthitic laminated grains are also common.

Plagioclase, as abundant, fresh to intensely saussuritized, subhedral, twinned and zoned crystals, is the most striking constituent in the average thin section. These crystals are generally no longer than 5 mm, although locally somewhat larger plagioclase crystals contribute to the weakly seriate texture of the Santa Rita Flat pluton. The anorthite content of the plagioclase has a considerable range; some individual crystals are zoned from calcic andesine cores to sodic oligoclase rims. The maximum anorthite content of individual specimens is generally intermediate to calcic andesine; locally cores are sodic labradorite. Much of the plagioclase is intensely saussuritized (fig. 3). Some grains that are extremely clean and fresh in one part are riddled with saussuritic alteration products in other parts. Wormy myrmekite is locally common at boundaries between plagioclase and K-feldspar.

Quartz is generally interstitial in small grains. Locally, however, it occurs as grains as much as 5 mm in largest dimension, and some of these are markedly poikilitic with plagioclase and other minerals (fig. 4). Invariably the quartz has undulatory extinction; less commonly it is mosaicked and has sutured and somewhat granulated intragranular contacts (fig. 5). Surprisingly, quartz from specimens within a few feet of some prominent shear zones shows only minor suturing and mosaicking, which suggests that the shear effects were not transmitted to the rocks beyond the zone of visible shearing.

Hornblende is the dominant dark mineral in the Santa Rita Flat pluton. This dominance is rather unusual in rocks of the Sierra Nevada batholith and was one of the key criteria in the correlation of this pluton with the Tinemaha Granodiorite (Ross, 1962, p. D87). The hornblende is generally in subhedral to euhedral crystals that tend to form clusters, which are commonly

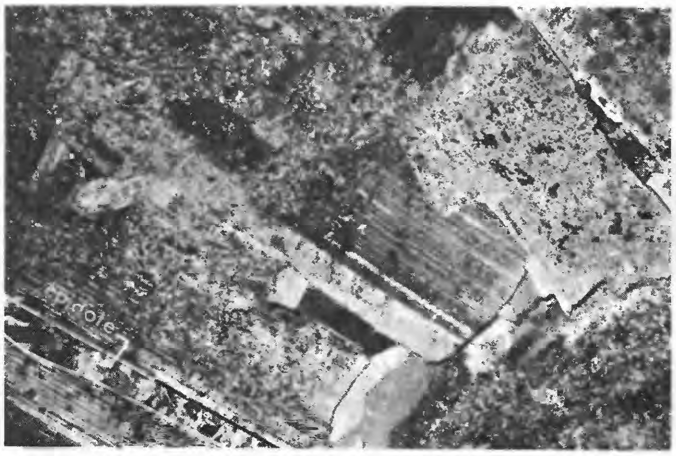

FIGURE 3.—Santa Rita Flat pluton. Intense, but variable saussuritization of plagioclase in specimen 62. Also note small epidote veinlet. × 30.

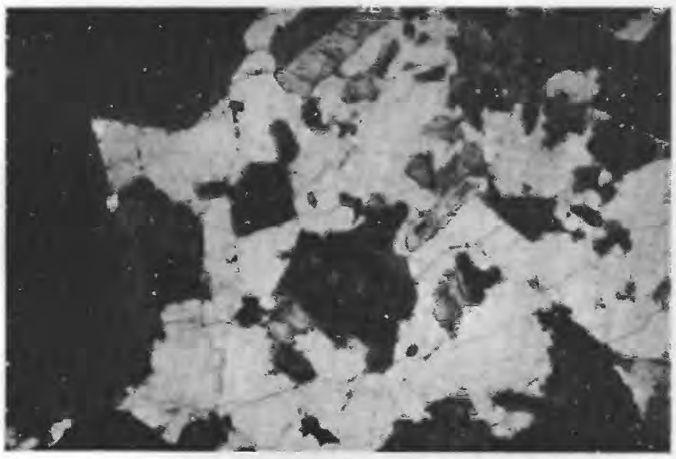

FIGURE 4.—Santa Rita Flat pluton. Part of a large (5 mm) poikilitic quartz crystal engulfing other constituents, particularly plagioclase, in specimen 40. × 30.

the host for small magnetite crystals (fig. 6). The hornblende content ranges from 1 to 12 percent and averages about 7 percent. The hornblende-to-biotite ratio, though ranging from about 1:3 to 1:1 in various specimens, averages about 2:1. The hornblende is markedly pleochroic according to the following formula: X=moderate greenish yellow and less commonly grayish yellow green; Y=light olive and less commonly light olive brown; and Z=light olive to pale green to grayish green. Most of the hornblende is unaltered, in sharp contrast to the intensely altered biotite. Epidote has formed from hornblende locally; some penninite(?) shreds are found in hornblende crystals, but this chlorite mineral might be altered biotite, since the hornblende and biotite are commonly intergrown.

Biotite is present as strongly pleochroic brown flakes that range from small shreds to well-formed crystals; commonly the biotite is in clusters of grains associated with the other dark minerals. The biotite content ranges from 1 to 11 percent, the average being about 4 percent. The pleochroism is as follows: X=grayish orange to pale yellowish orange and less commonly dark yellowish orange and grayish yellow; Z=moderate brown to light olive brown, and much less commonly, other shades of brown. The biotite was extremely susceptible to alteration; in some specimens no fresh biotite remains, and almost all the biotite is somewhat altered. This alteration ranges from slight chloritization of rims and thin slivers in biotite books to complete pseudomorphing of biotite crystals by chlorite (penninite?). The pseudomorphs include abundant thin slivers and elongate crystals of sphene arranged along the former cleavage of the biotite. Epidote is a much less common alteration product. It may have come in part from the alteration of the hornblende that is commonly intergrown with biotite. Some specimens also have shredded aggregates of biotite that are pseudomorphs of hornblende crystals.

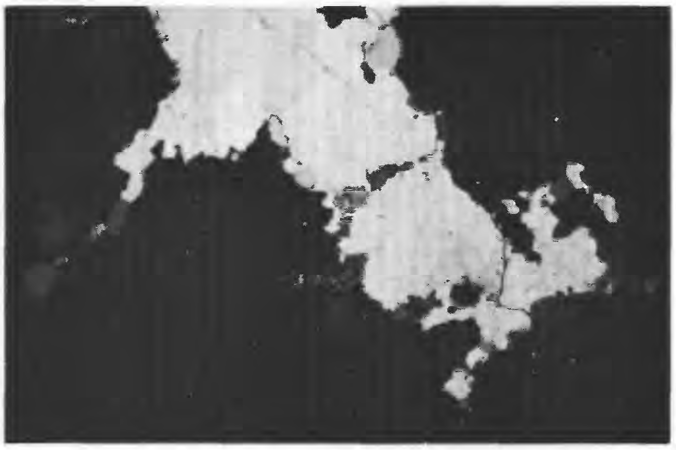

FIGURE 5.—Santa Rita Flat pluton. Incipient granulation between quartz grains in specimen 3. × 30.

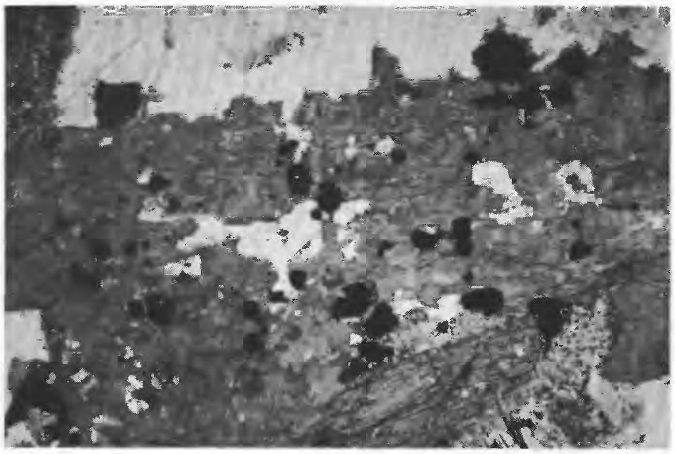

FIGURE 6.—Santa Rita Flat pluton. Part of a large subhedral hornblende crystal studded with magnetite crystals in specimen 29. × 30.

Of the common accessory minerals, sphene and metallic opaques (largely magnetite) are most common. Sphene is particularly conspicuous in euhedral wedge-shaped crystals that are commonly associated with dark mineral clusters (fig. 7). Magnetite is also abundant, and small crystals liberally pepper the hornblende crystals (fig. 6); this feature makes separation of hornblende from biotite relatively easy in crushed samples—a hand magnet readily separates the magnetite-bearing hornblende from the largely magnetite-free biotite. Zircon and apatite are also widespread in these rocks. Allanite is much less common, but its euhedral brown strongly pleochroic crystals are easily recognized.

MODAL DATA

The modes of 81 specimens of the Santa Rita Flat pluton are given in table 1. The quartz and feldspar con-

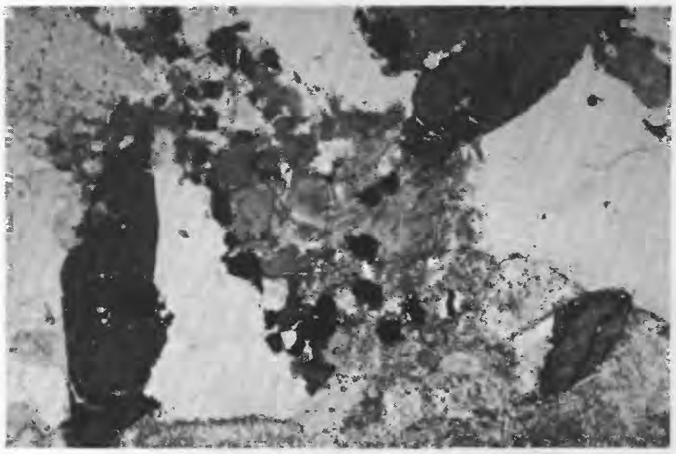

FIGURE 7.—Santa Rita Flat pluton. Subhedral to euhedral sphene crystals with cluster of dark minerals, mostly hornblende studded with small magnetite crystals, in specimen 1. × 30.

stituents of these specimens are recalculated to 100 percent in figure 8*A* to show a concentration of points near the center of the quartz monzonite field.[2] A few modes fall in the granodiorite field, one is in the diorite field, and all others are in the quartz monzonite field.

Comparison of the modal field with that of the type area of the Tinemaha Granodiorite in the Sierra Nevada (fig. 8*B*) shows more points in the granodiorite field in the Sierra mass, although the majority of points are in the quartz monzonite field. On the triangular plot, quartz appears superficially to be more abundant in the Sierra mass, but the average quartz content of the two bodies is very close. The field of the Sierra mass is more elongate and stretches along the central part of a line from the plagioclase corner to the midpoint on the K-feldspar–quartz join. The Santa Rita Flat field is also somewhat elongate in this direction, but not as noticeable, and a bisector of the field intersects the K-feldspar–quartz join at about K-feldspar$_{60}$ rather than near K-feldspar$_{50}$, where the bisector of the field of the Sierra mass intersects it. Also, the plot of the Sierra mass is somewhat offset toward increased plagioclase. Nevertheless, the two masses are not markedly different in total modal pattern.

The modal plot of the Woods Lake mass of Moore (1963, p. 77), on the other hand, is quite different (fig. 8*C*). The field is somewhat elongate but tipped in the opposite way. Also, although the modal average of plagioclase and K-feldspar is similar to that of the Sierra mass, the quartz average is some 5 percent greater. The most anomalous difference, however, between the Woods Lake mass and the other two is the difference in the ratios of the dark minerals. The Woods Lake mass averages a little over 8 percent biotite and less than 3

TABLE 1.—*Modes, in volume percent, of the Santa Rita Flat pluton*

[n.d., indicates values not determined]

Thin sections

Sample	Plagioclase	K-feldspar	Quartz	Biotite	Hornblende	Opaque and accessory	Specific gravity
1	44	24	13	8	9	2	2.72
3	35	23	36	3	1	2	2.69
11	37	28	27	4	3	Trace	2.67
12	38	29	20	9	4	---	2.68
15	28	34	28	6	2	2	2.63
22	26	44	24	4	1	1	2.66
25	25	39	17	11	8	---	2.72
31	30	32	25	3	8	2	n.d.
35	40	28	20	3	7	2	2.67
36	40	24	25	5	8	---	2.67
40	44	21	21	4	10	---	2.71
46	38	28	19	2	11	2	2.73
51	42	26	16	4	12	---	2.73
57	41	31	19	2	7	---	2.70
62	37	32	18	4	4	5	2.68
63	42	27	21	2	5	3	2.70
65	43	28	22	2	6	2	2.70
Average	37	29	22	4	6	2	2.69
Standard deviation	6.2	5.8	5.4	n.d.	n.d.	n.d.	.03

TABLE 1.—*Modes, in volume percent, of the Santa Rita Flat pluton*—Continued

Stained rock slabs

Sample	Plagioclase	K-feldspar	Quartz	Mafic minerals (Biotite : hornblende percentages from thin section in parentheses)	Specific gravity
2	34	26	24	16	2.70
3	27	38	19	16	2.69
4	40	19	23	18	2.73
5	38	31	17	14	2.68
6	28	32	20	20	2.68
7	30	35	23	12	2.67
8	38	23	19	22	2.74
9	51	16	6	70	2.78
10	48	20	15	17	2.72
11	25	36	25	14	2.67
12	30	33	21	16	2.68
13	35	26	23	16	2.71
14	32	29	26	13	2.65
16	27	31	23	19	2.65
17	29	35	19	17	2.69
18	30	35	21	14	2.68
19	33	30	24	13	2.67
20	33	23	20	24	2.70
21	32	27	23	18	2.68
22	29	36	22	13	2.66
23	26	35	25	14	2.68
24	32	31	21	16	2.68
25	34	31	19	16	2.72
26	29	30	21	20	2.71
27	29	37	17	17	2.70
28	31	33	25	11(5:6)	2.68
29	31	29	26	14(5:9)	2.69
30	29	38	21	12	2.69
32	34	30	22	14	2.69
33	35	31	20	14	2.70
34	33	34	22	11	2.68
37	32	34	20	14	2.68
38	37	31	15	17	2.69
39	30	34	19	17	2.70
41	38	30	20	12	2.70
42	40	30	18	12	2.69
43	34	33	17	16(4:12)	2.71
44	34	31	21	14	2.71
45	38	29	21	12	2.71
46	36	32	20	12(2:10)	2.73
47	37	26	18	19	2.70
48	38	31	19	12	2.70
49	32	31	20	17	2.71
50	37	41	7	15	2.70
51	38	25	18	19	2.73
52	34	35	19	12	2.68
53	39	28	21	12	n.d.
54	36	32	20	12	2.68
55	42	27	13	18	2.70
56	38	33	15	14	2.68
57	36	34	18	12	2.70
58	37	26	19	18	2.71
59	45	20	14	21	2.74
60	37	32	17	14	2.70
61	37	32	21	10	2.67
63	41	26	20	13	2.70
64	41	26	18	15	2.72
66	38	30	13	19	2.70
67	39	33	13	15	2.71
68	37	28	21	14	2.70
69	32	39	19	10(1:9)	2.70
70	33	35	22	10	2.64
71	37	29	20	14	2.72
72	43	25	18	14	2.68
Slab average	35	30	20	15	2.70
Standard deviation	5.1	4.9	3.8	3.8	.02
Grand average (slabs, sections)	35	30	20	15	2.70
Grand standard deviation	5.4	5.1	4.3	3.7	.02

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[2] The quartz and feldspar of the slab modes have been plotted on a triangular diagram, following the general method of Johannsen (1939, p. 152; see also, Bateman, 1961, p. 1524). The contours in figure 8 and all succeeding modal distribution triangles in this report show the concentration of data points (modal plots) relative to random distribution on the triangle. For example, within the "20" contour there are 20 times more data points than would be present if the points were randomly distributed over the entire triangle. A counter of 1 percent of the area of the triangle was used to provide the data for plotting the contours. The method is similar to that described for petrofabric diagrams by Knopf and Ingerson (1938).

percent hornblende and has a hornblende-to-biotite ratio of only about 1 : 3. This contrast to the typical, and almost unique, feature of hornblende exceeding biotite in the Tinemaha suggests that the Woods Lake mass may not be a part of the Tinemaha. Presumably, however, they bear a strong resemblance in the outcrop, for Moore (1963, p. 77) correlated the Woods Lake with the Tinemaha on the basis of "similarity of composition and texture and on an abundance of mafic dikes in both masses".

Variation between all pairs of modal constituents in 81 specimens of the Santa Rita Flat pluton are plotted in figure 9. To quantify the data and to see if the visual plots had statistical meaning, the correlation coefficients and significance level were determined for each mineral pair.[3] Highly significant negative correlations exist for all the pairs in the figure except plagioclase : mafic minerals and quartz : K-feldspar.

Contours of specific gravity and modal percentages of the various minerals (pl. 3) show some rather strong zonation in the Santa Rita Flat pluton. Zoning is particularly well shown on the maps of specific gravity and mafic minerals (pl. 3*A*, *D*). They show higher mafic mineral content and consequently higher specific-gravity readings along the east wall of the pluton and also along the west side of the exposures in Owens Valley. This pattern suggests that a contact with some older unit may be present, but buried, in Owens Valley west of the present outcrop limit and that the elongated north-northwest shape of the present exposures is close

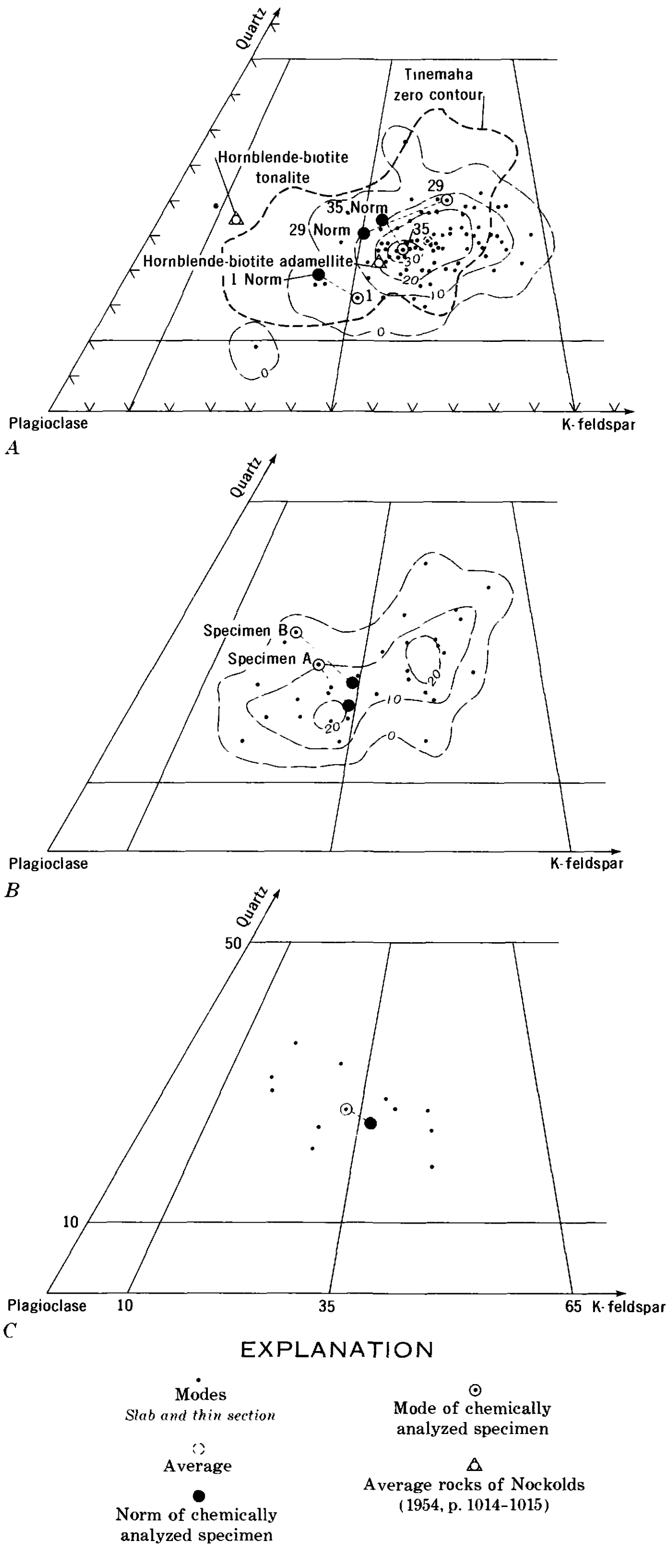

FIGURE 8.—Modal distribution of quartz, K-feldspar, and plagioclase. *A*. 81 specimens of the Santa Rita Flat pluton of the Tinemaha Granodiorite. *B*. 30 specimens from the type area of the Tinemaha Granodiorite; modified from Bateman (1965, p. 71, fig. 27). *C*. 12 specimens of the Woods Lake mass of the Tinemaha Granodiorite (Moore, 1963, p. 78, fig. 33).

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[3] Correlation coefficients, determined by a computer program, are recorded in figure 9 for the Santa Rita Flat pluton and in figures 14 and 28 for the other granitic bodies. A standard symbol *r* is used for correlation coefficient. The level of significance of the correlation coefficients is dependent on the coefficient and on the number of samples. The significance level is noted on the figures in terms of the odds that a particular distribution came about by chance. For example, the ratio of plagioclase to K-feldspar in figure 9 has a negative correlation coefficient of 0.73 for 81 specimens. From a table of significance levels, it can be seen that there is less than one chance in a thousand that the correlation could have resulted by chance. Hence, statistically, this correlation is highly significant. Ratios whose significance level is lower than one chance in ten are noted as not significant (ns).

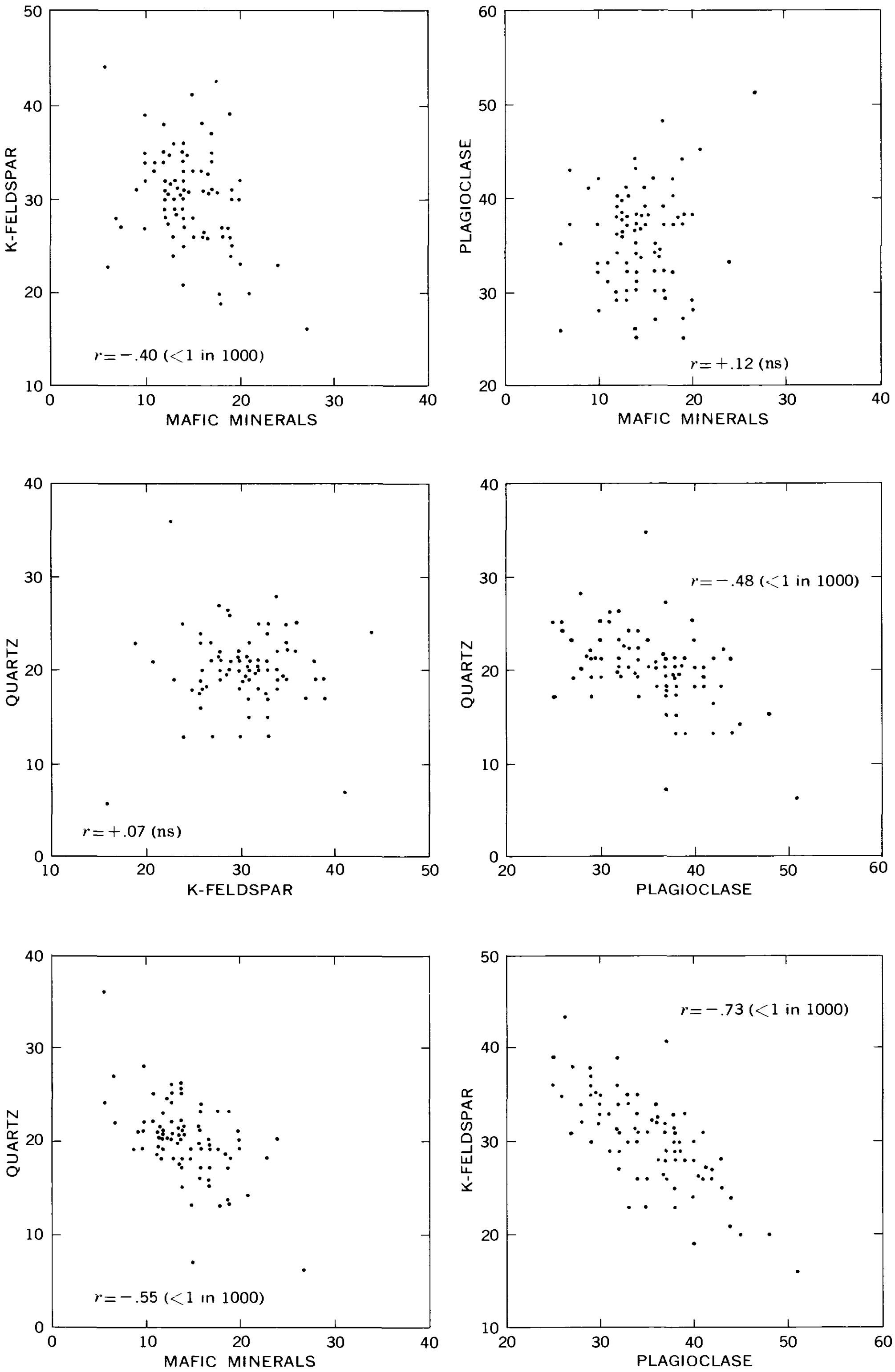

Figure 9.—Variation between pairs of modal constituents in volume percent for 81 samples of the Santa Rita Flat pluton (r=correction coefficient; significance level in parentheses, ns=not significant).

to the true shape of the pluton. The contoured percentages of K-feldspar and quartz shown on the contour maps support this idea, but those of plagioclase are much less definitive, particularly along the west margin of the pluton.

CHEMICAL DATA

Chemical analyses (table 2) have been made for specimen 1 near the north margin of the Santa Rita Flat pluton and for specimens 29 and 35 from the east-central part of the mass in Santa Rita Flat (pl. 2). These specimens represent the compositional range of the pluton as already shown on the contour maps (pl. 3*A*–*E*). Specimen 1 near the margin has a specific gravity of 2.72 and a color index of about 19. It is almost on the boundary of the quartz monzonite field, as indicated by its modal plot, and is near the edge of the modal field. In contrast, specimen 35 has a specific gravity of 2.67 and a color index of about 10. It falls near the center of the modal plot and comes very close to the average modal composition for the whole pluton. Specimen 29 is somewhat intermediate with a color index of 14 and a specific gravity of 2.69.

Specimen 1 is much higher in K_2O, lower in SiO_2, and somewhat lower in total iron than Nockolds' (1954, p. 1015) average for 22 hornblende-biotite tonalites. Specimen 1 has more K-feldspar than a tonalite, yet seems to have an anomalously low SiO_2 content for its rather large amount of K-feldspar.

TABLE 2.—*Chemical data of the Santa Rita Flat pluton and correlative masses within the Tinemaha Granodiorite*

[Chemical analyses of Santa Rita Flat pluton by P. L. D. Elmore, I. H. Barlow, S. D. Botts, and G. Chloe. Semiquantitative spectrographic analyses of specimens 1 and 35 of Santa Rita Flat pluton by H. W. Worthing; specimen 29, by C. Heropoulos. Looked for but not found in specimens 1, 29, and 35: Ag, As, Au, Bi, Cd, Ce, Cs, Dy, Er, Eu, Gd, Ge, Hf, Hg, Ho, In, Ir, Li, Lu, Mo, Nd, Os, Pd, Pr, Pt, Rb, Re, Rh, Ru, Sb, Sn, Sm, Ta, Tb, Te, Th, Tl, Tm, U, W, Zn. Quantitative spectrographic analyses for type area of Tinemaha Granodiorite by P. R. Barnett. Looked for but not found: Ag, As, Au, Bi, Cd, Ge, In, Mo, Pt, Sb, Sn, Ta, Th, Tl, U, W. Not determired, n.d.; not available, n.a.]

	Santa Rita Flat pluton[1]			Type area of the Tinemaha Granodiorite[2]		Woods Lake mass[1]	Hornblende-biotite tonalite[3]	Hornblende-biotite adamellite[4]
	1	29	35	A	B			
				Chemical analyses (weight percent)				
SiO_2	61.3	66.7	66.4	62.82	65.77	67.4	64.41	65.88
Al_2O_3	15.9	15.1	14.9	15.44	14.34	15.8	15.95	15.07
Fe_2O_3	3.1	1.9	2.6	2.59	2.10	1.7	1.46	1.74
Total Fe as FeO	(5.8)	(3.6)	(4.3)	(5.50)	(4.53)	(3.7)	(5.12)	(4.30)
FeO	3.0	1.9	2.0	3.17	2.62	2.2	3.81	2.73
MgO	2.2	1.6	1.6	2.35	2.02	1.3	2.45	1.38
CaO	5.3	3.6	3.9	5.04	4.24	3.1	5.36	3.36
Na_2O	3.3	3.5	3.0	3.15	3.18	3.5	3.39	3.53
K_2O	3.4	4.0	4.1	3.72	3.76	4.2	1.45	4.64
H_2O	.85	.82	.73	.65	.56	.48	.80	.52
TiO_2	.64	.43	.48	.64	.60	.42	.62	.81
P_2O_5	.36	.27	.26	.30	.24	.14	.20	.26
MnO	.10	.09	.08	.11	.10	.12	.10	.08
CO_2	$<.05$	$<.05$	$<.05$	.01	.08	.05	----	----
Total	99.45	99.91	100.05	99.99	99.61	100.41	100.00	100.00
				Spectrographic analyses (weight percent[5])				
B	0	0	0.003	0.001	n.d.	n.d.	----	----
Ba	.15	.15	.07	.2	n.d.	n.d.	----	----
Be	.00015	.0002	.00015	0	n.d.	n.d.	----	----
Co	.003	.001	.003	.002	n.d.	n.d.	----	----
Cr	.0007	.0015	.0007	.001	n.d.	n.d.	----	----
Cu	.007	.005	.007	.001	n.d.	n.d.	----	----
Ga	.0007	.0015	.0007	.002	n.d.	n.d.	----	----
La	.003	.007	.003	.01	n.d.	n.d.	----	----
Nb	0	0	0	.002	n.d.	n.d.	----	----
Ni	.003	.001	.007	.0008	n.d.	n.d.	----	----
Pb	.00015	0	.00015	.002	n.d.	n.d.	----	----
Sc	.0007	.001	.0007	.001	n.d.	n.d.	----	----
Sr	.15	.07	.15	.09	n.d.	n.d.	----	----
V	.007	.01	.003	.01	n.d.	n.d.	----	----
Y	.0015	.003	.0015	0	n.d.	n.d.	----	----
Yb	.00015	.0003	.00015	.0004	n.d.	n.d.	----	----
Zr	.015	.015	.015	.02	n.d.	n.d.	----	----
Ce	----	.015	----	----	n.d.	n.d.	----	----

See footnotes at end of table.

TABLE 2.—*Chemical data of the Sonta Rita Flat pluton and correlative masses within the Tinemaha Granodiorite*—Continued

[Chemical analyses of Santa Rita Flat pluton by P. L. D. Elmore, I. H. Barlow, S. D. Botts, and G. Chloe. Semiquantitative spectrographic analyses of specimens 1 and 35 of Santa Rita Flat pluton by H. W. Worthing; specimen 29, by C. Heropoulos. Looked for but not found in specimens 1, 29, and 35: Ag, As, Au, Bi, Cd, Ce, Cs, Dy, Er, Eu, Gd, Ge, Hf, Hg, Ho, In, Ir, Li, Lu, Mo, Nd, Os, Pd, Pr, Pt, Rb, Re, Rh, Ru, Sb, Sn, Sm, Ta, Tb, Te, Th, Tl, Tm, U, W, Zn. Quantitative spectrographic analyses for type area of Tinemaha Granodiorite by P. R. Barnett. Looked for but not found: Ag, As, Au, Bi, Cd, Ge, In, Mo, Pt, Sb, Sn, Ta, Th, Tl, U, W. Not determined, n.d.; not available, n.a.]

	Santa Rita Flat pluton[1]			Type area of the Tinemaha Granodiorite[2]		Woods Lake mass[1]	Hornblende-biotite tonalite[3]	Hornblende-biotite adamellite[4]
	1	29	35	A	B			
				Norms (weight percent)				
Q	15.8	21.6	23.4	16.69	21.42	21.8	22.7	18.8
or	20.2	23.7	24.2	22.20	22.24	25.0	8.3	27.2
ab	28.1 } An$_{40}$	29.6 } An$_{32}$	25.4 } An$_{37}$	26.71 } An$_{38}$	27.25 } An$_{33}$	29.3 } An$_{33}$	28.8 } An$_{45}$	29.9 } An$_{28}$
an	18.6	13.7	15.1	16.68	13.34	14.5	23.9	11.7
wo	2.3	1.0	1.1	2.60	2.72	-----	.6	1.4
en	5.5	4.0	4.0	6.01	5.20	3.3	6.1	3.4
fs	2.1	1.4	.9	2.69	2.01	2.0	4.9	2.4
mt	4.5	2.8	3.8	3.74	3.02	2.6	2.1	2.6
il	1.2	.8	.9	1.22	1.22	.8	1.2	1.5
ap	.9	.6	.6	.69	.34	.3	.5	.6
C	-----	-----	-----	-----	-----	.2	-----	-----
Total	99.2	99.2	99.4	99.23	98.76	99.8	99.1	99.5
				Niggli numbers				
si	214.2	275.9	270.3	220.0	260.0	282.0	-----	-----
al	32.7	36.8	35.8	32.4	33.2	38.9	-----	-----
fm	28.7	22.7	24.8	29.0	26.8	21.6	-----	-----
c	19.8	16.0	17.0	19.3	18.1	13.8	-----	-----
alk	18.8	24.6	22.4	19.3	21.9	25.4	-----	-----
qz	39.2	77.5	80.4	42.8	72.4	80.4	-----	-----
k	.40	.43	.47	-----	-----	-----	-----	-----
mg	.40	.44	.39	-----	-----	-----	-----	-----
				Modes (volume percent)				
Plagioclase	44	31	40	45.8	n.a.	45.2	-----	-----
K-feldspar	24	29	28	17.4	n.a.	22.0	-----	-----
Quartz	13	26	20	22.8	n.a.	23.9	-----	-----
Biotite	8	5	3	5.6	n.a.	4.9	-----	-----
Hornblende	9	9	7	7.2	n.a.	2.7	-----	-----
Opaques	1	Trace	1	1.3	n.a.	.4	-----	-----
Other	1	Trace	1	1.3	n.a.	.9	-----	-----
Total	100	100	100	100.1	-----	100.0	-----	-----

[1] Rapid rock analysis.

[2] Standard rock analysis.

[3] Avg of 22 hornblende-biotite tonalites (quartz diorites) from Nockolds (1954, p. 1015).

[4] Avg of 41 hornblende-biotite adamellites (quartz monzonites) from Nockolds (1954, p. 1014).

[5] Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1 etc.; which represent approximate midpoints of interval data on a geometric scale. The assigned interval for semiquantitative results will include the quantitative value about 30 percent of the time.

Location of specimens:
1. North boundary of Independence quad.; NW cor. sec. 16, T. 11 S., R. 35 E.
29. Independence quad.; Santa Rita Flat, 700 ft SE. of SE cor. sec. 34, T. 11 S., R. 35 E.
35. Santa Rita Flat, Independence quad.; about 2,500 ft SE. of Santa Rita Spring.
A. Big Pine quad., Birch Mountain area west of McMurry Meadows (Bateman, 1965, p. 63, table 3).
B. Big Pine quad., South Fork of Big Pine Creek southwest of Glacier Lodge (Bateman, written commun., 1962).
Woods Lake mass. Mount Pinchot quad., at north end of intrusive mass; just south of Twin Lakes (center of quad.) (Moore, 1963, p. 43, 78).

Specimens 29 and 35 are somewhat higher in silica and lime and somewhat lower in soda and potash than Nockolds' (1954, p. 1014) average of 41 hornblende-biotite adamellites. This difference suggests that the Santa Rita Flat pluton has somewhat more quartz and a lower ratio of K-feldspar to plagioclase than the average hornblende-biotite adamellite.

Chemical comparison of the Santa Rita Flat pluton and the Sierra mass is restricted, as only a few chemical analyses have been made. The chemical range of analyses for the Sierra mass is within the values for the Santa Rita Flat pluton, and certainly there is nothing incompatible in their correlation on chemical grounds.

Only one analysis is available from the Woods Lake mass (Moore, 1963, p. 43), and it is generally comparable with the analyses from the Santa Rita Flat and Sierra masses except for the somewhat lower MgO and CaO content. One characteristic seems different, however: it has the highest SiO_2 content of any of the analyses and almost the highest Al_2O_3 content; in all the others, the higher the SiO_2, the lower the Al_2O_3. One specimen may not be a fair sample for the whole mass, but this possible chemical difference, plus the different modal characteristics of the Woods Lake mass, further suggests it is not a part of the Tinemaha.

Normative orthoclase is rather consistently a few percent lower than modal K-feldspar in all three samples from the Inyo Mountains. The solid solution of Ab in the K-feldspar, which would not be observable in the mode, may account for this relation. The K_2O of the biotite, which is calculated in the normative orthoclase, raises the normative orthoclase relative to modal K-feldspar. Possibly this effect has been more than counterbalanced by the effect of Ab in the K-feldspar.

The comparisons of norm and mode for specimens 1 and 35 are relatively consistent, but specimen 29 does not fit this same pattern. Its mode may not be representative, although a fresh and homogeneous-looking slab was selected both for the mode and for the chemical analysis.

HUNTER MOUNTAIN QUARTZ MONZONITE

The Hunter Monutain Quartz Monzonite was named by McAllister (1956) for extensive exposures in the Ubehebe Peak quadrangle. The main mass of the Hunter Mountain Quartz Monzonite in the Ubehebe Peak area underlies an area of about 200 square miles. Some small masses, called biotite-hornblende quartz monzonite, in the Darwin quadrangle (Hall and MacKevett, 1962) may also be age correlatives of the Hunter Mountain (pl. 1). The extent of similar rocks in the dominantly granitic Argus and Coso Ranges is unknown because detailed work has not yet been done on the rocks of this region. If, as seems likely, the Hunter Mountain is continuous under Saline Valley with the Pat Keyes mass, this is a major size batholith, several hundred square miles in areal extent (pl. 1).

PAT KEYES PLUTON

NAME, DISTRIBUTION, AND CORRELATION

The Pat Keyes pluton takes its name from the Pat Keyes trail (pl. 1) in the southern part of the Independence and Waucoba Wash quadrangles. This trail goes more than halfway across the pluton and is probably the best place to see a representative cross section of this granitic mass.

The Pat Keyes pluton crops out over an area of about 35 square miles across the Inyo Mountains. The pluton extends southward into the New York Butte and Lone Pine quadrangles, where it underlies an additional 20 square miles (W. C. Smith, oral commun., 1964). In addition, several small stocks in the New York Butte quadrangle that are considered to be part of the Hunter Mountain Quartz Monzonite (W. C. Smith, oral commun., 1964) are physically similar to Pat Keyes rocks.

The Pat Keyes pluton is heterogeneous in contrast to the remarkably homogeneous Paiute Monument Quartz Monzonite. Three rock types or facies that grade into one another make up the pluton (fig. 10): type 1, a medium-grained seriate quartz monzonite, forms the central core; type 2, a fine-grained quartz monzonite-granodiorite, forms the northwest margin of the pluton; and type 3, a variety of rather mafic rocks ranging in composition from quartz monzonite to gabbro, forms the eastern and southwestern part of the pluton in the mapped area. In addition, a small mass of less than a square mile near Willow Creek mine camp (pl. 2) is believed to be part of the Pat Keyes pluton. Modally it is similar to type 1, but it is sufficiently different in general appearance to suggest that it may be a separate intrusive.

No mappable contacts were observed between the three facies of the Pat Keyes pluton, and thus the lines in figure 10 are subjective. Numerous examples of gradations between the three facies suggest that the central core represents the original magma and that the two marginal facies are contaminated to varying degrees by the assimilation of wallrock, type 2 being much less contaminated than type 3. The terrain underlain by this pluton, particularly the eastern part, is almost impassable (see frontispiece); consequently, sampling had to be done with the aid of a helicopter. The sample density shown by the index maps (pl. 2; fig. 10) indicates that this pluton has not been examined in detail.

For the sake of convenience the three main facies of this pluton, as well as the small Willow Creek pluton, will be described separately. It should be emphasized again that these are probably not separate intrusive phases, but result from variable assimilation by a magma that would normally have crystallized as a quartz monzonite. The parts of the pluton are distributed in a definite pattern; they are not as mixed and heterogeneous as would appear from a first glance at the modal data, or from a quick look at the hand specimens.

TYPE 1, SERIATE QUARTZ MONZONITE

OUTCROP APPEARANCE AND MEGASCOPIC CHARACTER

The quartz monzonite forms medium-gray bouldery outcrops that commonly consist of hummocky, outcrops, boulder piles, and grus slopes typical of desert-weathering granitic rocks. Generally, the boulders are smaller than those of the Paiute Monument Quartz Monzonite (fig. 11). The overall color of these rocks is somewhat darker than the color of Paiute Monument specimens, which they most closely resemble (fig. 12),

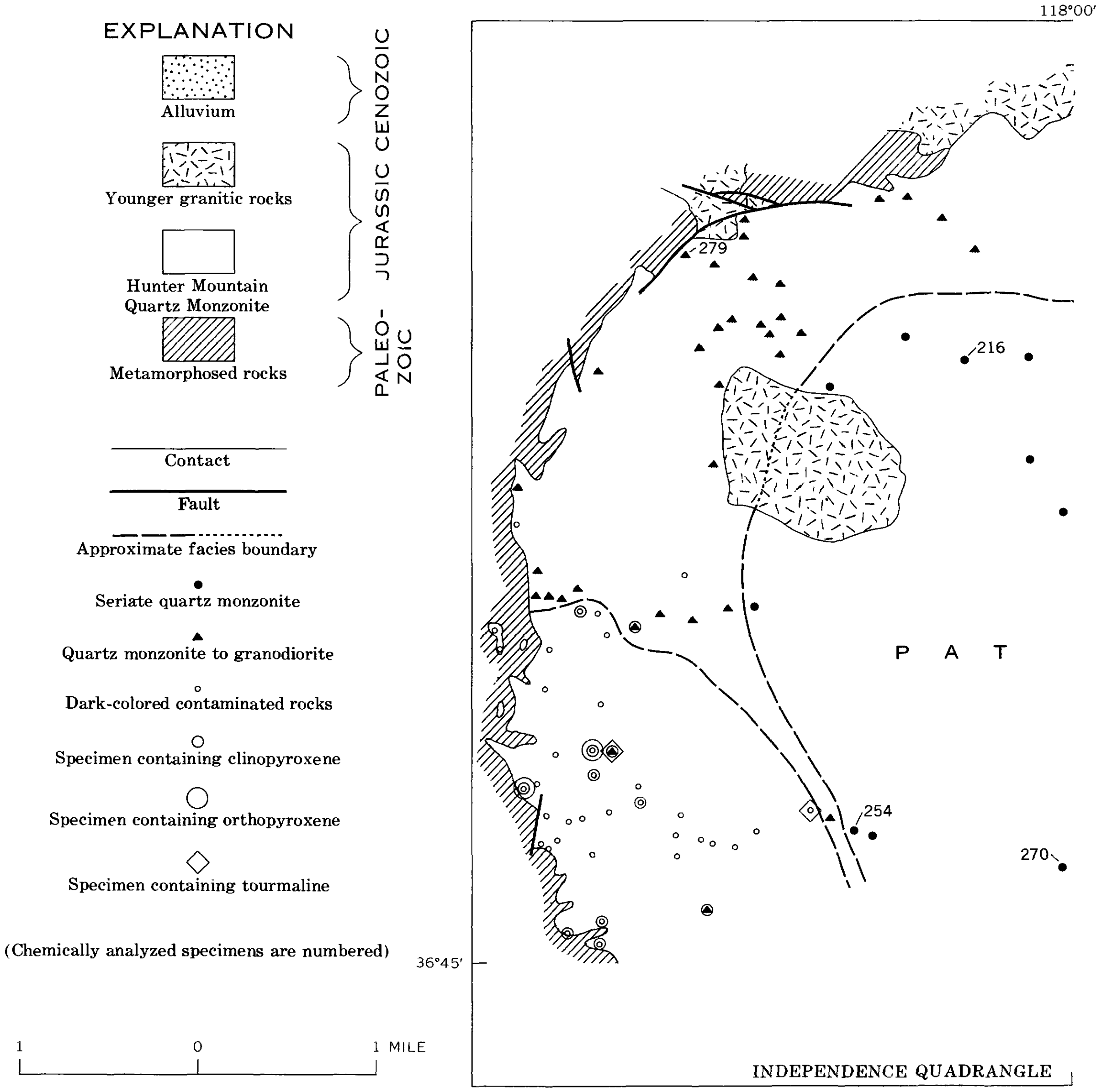

Figure 10.—Facies distribution in the Pat Keyes pluton.

because they contain a somewhat higher percentage of dark minerals, a finer grain size, and a darker colored plagioclase.

The most conspicuous feature of hand specimens is pale-red to pale-red-purple K-feldspar plenocrysts locally as much as 10 mm, but more commonly no more than 5 mm, in largest dimension. The phenocrysts are poikilitic and generally grade downward to the groundmass grain size of 2–3 mm; thus they give the rock a seriate rather than a porphyritic texture.

The plagioclase is light to medium light gray and on unstained surfaces tends to blend with the gray quartz. This lack of contrast between the two minerals helps to distinguish this rock from the Paiute Monument Quartz Monzonite in which the whiter plagioclase stands out more prominently from the darker quartz. Dark minerals are rather evenly distributed through the mass, and both biotite and hornblende stand out as black crystals and clusters. Small honey-brown sphene crystals are also visible in hand specimens.

MICROSCOPIC DESCRIPTION

The microscopic character of this rock is much like that of the Paiute Monument Quartz Monzonite. Most specimens are hypautomorphic seriate. Plagioclase, biotite, and hornblende crystals are generally well formed. The K-feldspar ranges from poikilitic crystals 10 mm across to interstitial grains. Quartz is generally inter-

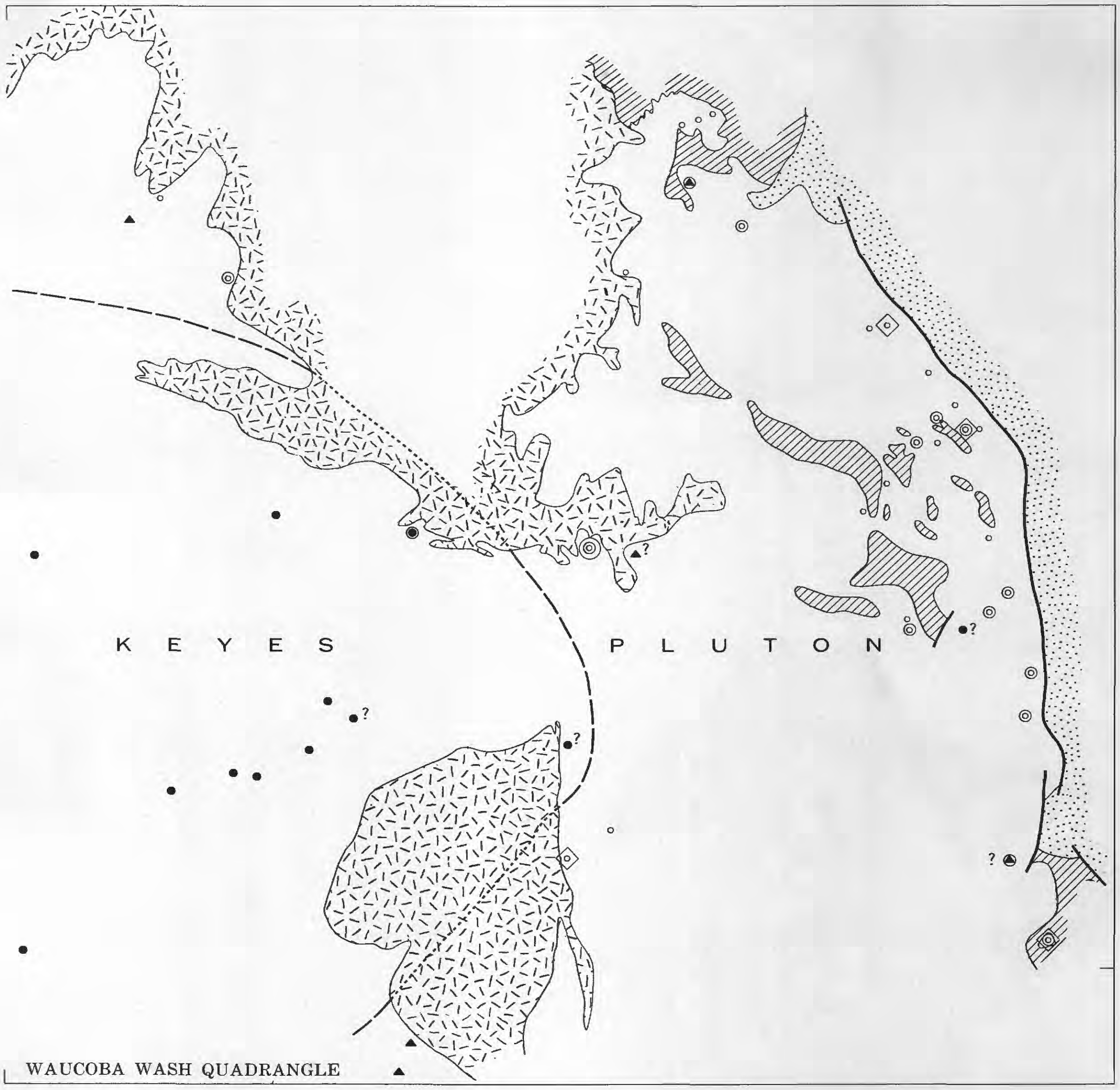

FIGURE 10.—Continued

stitial, but forms a few crystal aggregates as large as the K-feldspar phenocrysts. Some quartz is granulated or in sutured mosaics.

The plagioclase is generally fresh; saussuritic alteration is minor. Most of the plagioclase is moderately zoned and ranges from sodic andesine to calcic oligoclase, with an average of about An $_{30}$. Biotite is brown and mostly fresh; some is altered to chlorite (penninite?), epidote, and sphene. The pleochroic formula for biotite is X=grayish orange to pale yellowish orange and Z=moderate brown and less commonly grayish brown. Green hornblende is also common and generally is unaltered. It is pleochroic according to the formula: X=moderate greenish yellow, Y=light olive to moderate olive brown, Z=grayish green to moderate yellowish green to light olive. The percentage of dark minerals averages about 7, but ranges from 5 to 16. Generally biotite is about twice as abundant as hornblende.

Ghostlike remnants of clinopyroxene were found in one hornblende crystal in specimen 222. The common accessory minerals—magnetite, apatite, sphene, zircon, and allanite—are widespread and scattered. These accessory minerals, especially magnetite, tend to cluster with the dark minerals, hornblende in particular.

MODAL DATA

In figure 13, the quartz and feldspar data from table 3 are recalculated to 100 percent for 19 modes of the

FIGURE 11.—Contact between the Pat Keyes pluton of the Hunter Mountain Quartz Monzonite and the Paiute Monument Quartz Monzonite on east slope of the Inyo Mountains. Dark outcrops on left are of the dark contaminated facies of the Pat Keyes pluton; light-colored bouldery outcrops on right are of the Paiute Monument Quartz Monzonite. Photograph taken near specimen 224.

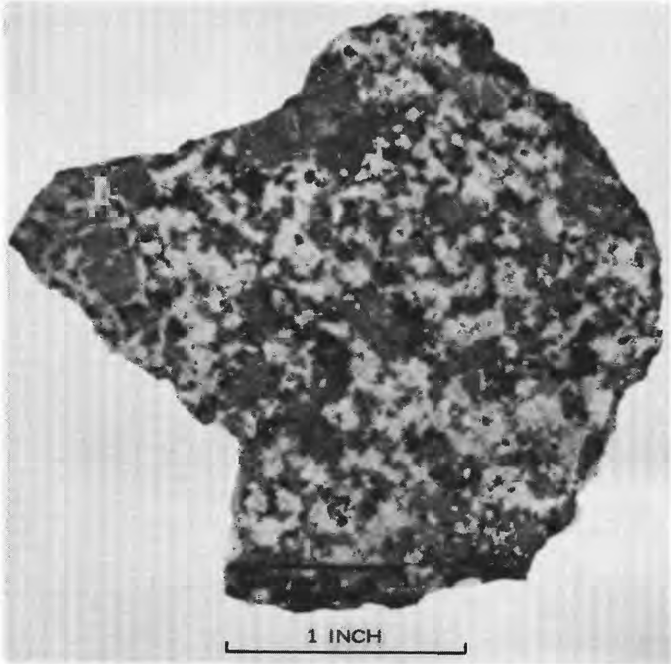

FIGURE 12.—Hand specimen of medium-grained seriate quartz monzonite of the Pat Keyes pluton. Specimen 270.

seriate quartz monzonite facies of the Pat Keyes pluton. Seventeen of these points form a grouping on the calcic side of the quartz monzonite field and spill over slightly into the granodiorite field. Compared with those of the field of the Paiute Monument Quartz Monzonite (fig. 27), these points are displaced somewhat toward the plagioclase corner. This displacement bears out the general relation between the two rocks, for the field of the seriate quartz monzonite with its somewhat higher color index and somewhat more calcic plagioclase was expected to shift this way. Comparison of the modes of the Pat Keyes pluton with those of presumably related masses is shown in figure 13*B* for 32 specimens of the Hunter Mountain Quartz Monzonite of the Ubehebe Peak quadrangle and is shown in figure 13*C* for 20 specimens of the biotite hornblende quartz monzonite of the Darwin quadrangle.

TABLE 3.—*Modes, in volume percent, of the Pat Keyes pluton*

[n.d., indicates values not determined]

SERIATE QUARTZ MONZONITE

Thin sections

Sample	Plagioclase	K-feldspar	Quartz	Biotite	Hornblende	Opaque and accessory	Specific gravity
216	38	26	26	5	4	1	2.64
220	40	31	22	5	1	1	2.65
254	44	23	22	6	3	2	2.67
Average	41	27	23	5	3	1	2.65

Stained rock slabs

Sample	Plagioclase	K-feldspar	Quartz	Mafic minerals (biotite hornblende proxene percentages from thin section in parentheses)	Specific gravity
214	43	25	21	11	2.70
217	32	35	26	7	2.65
218	46	22	19	13	2.69
221	43	24	27	6 (4:2:0)	2.65
222	45	31	17	7 (3:4:Tr.)	2.68
227?	42	23	19	16 (16:0:0)	2.69
246	42	23	19	16	2.70
247	40	31	24	5 (4:1:0)	2.65
255	39	29	22	10	2.71
256	45	25	25	5 (3:2:0)	2.66
257	43	30	20	7 (4:3:0)	2.65
258	40	30	25	5 (3:2:0)	2.65
259	45	24	23	8 (6:2:0)	2.66
260?	45	35	5	15 (5:10:0)	2.71
270	40	27	23	10 (6:3:0)	2.65
271	46	26	20	8 (5:3:0)	2.70
Average	42	28	21	9	2.68
Grand average	42	28	21	9	2.67
Standard deviation (thin sections included)	3.5	4.1	4.8	3.6	.02

QUARTZ MONZONITE-GRANODIORITE

Thin sections

Sample	Plagioclase	K-feldspar	Quartz	Biotite	Hornblende	Clinopyroxene	Opaque and accessory	Specific gravity
203	31	22	20	8	8	--------	11	n.d.
205	36	32	19	8	4	--------	1	2.68
207	40	29	20	5	5	--------	1	2.72
208	43	24	18	5	8	--------	2	2.69
210	48	25	18	1	4	--------	4	2.70
211	43	23	20	4	6	--------	4	2.69
219	49	17	14	6	12	--------	2	2.73
240	46	26	17	3	6	--------	2	2.68
243	41	25	9	4	17	--------	4	2.76
249	41	30	12	9	4	2	2	2.76
250?	38	29	12	10	8	1	2	2.72
266	39	27	14	8	6	3	3	2.74
279	42	26	22	2	7	--------	1	n.d.
282	39	30	11	10	4	5	1	n.d.
Average	41	26	16	6	7	1	3	2.72

TABLE 3.—*Modes, in volume percent, of the Pat Keyes pluton*—Con.

Stained rock slabs

Sample	Plagioclase	K-feldspar	Quartz	Mafic minerals (Biotite:hornblende:pyroxene percentages from thin section in parentheses)	Specific gravity
201	40	34	15	11	2.67
204	50	16	19	15	2.72
206	36	33	16	15	2.68
207	41	29	18	12	2.72
211	47	23	16	14	2.69
212	43	29	15	13	2.68
213	43	22	20	15	2.68
215	47	18	22	13	2.70
225?	40	43	8	9 (5:4:0)	2.66
231	47	23	9	21 (9:12:Tr.)	2.73
241	47	30	10	13	2.71
244	42	23	15	20	2.72
245	41	30	18	11	2.68
264?	48	25	8	19 (12:2:5)	2.74
273	45	31	7	17 (4:13:0)	2.74
274	45	28	8	19 (9:7:3)	2.75
Average	44	27	14	15	2.70
Grand average	42	27	15	16	2.71
Standard deviation (thin sections included)	4.4	5.5	4.6	4.7	.03

DARK-COLORED CONTAMINATED ROCKS

Thin sections

Sample	Plagioclase	K-feldspar	Quartz	Biotite	Hornblende	Clinopyroxene	Opaque and accessory	Specific gravity
202	54	4	8	9	24		1	2.80
242	55	3	Tr.	11	3	20	8	2.95
251	43	23	10	9	12		3	2.75
252	44	25	10	6	7	6	2	2.73
265	49	21	11	9	7		3	2.71
267	49	13	6	9	17	1	5	2.80
268	49	17	8	10	7	5	4	2.81
269	50	16	6	9	8	8	3	2.82
275	55	15	11	9	3	5	2	2.77
278	42	29	6	4	8	9	2	n.d.
280	58	1		19	7	10	5	n.d.
281	55	11	5	14	11	2	2	n.d.
283	48	19	13	10	1	6	3	n.d.
284	45	25	11	8	2	6	3	n.d.
285	43	26	6	9	6	8	2	n.d.
286	55	17	3	4	8	11	2	n.d.
287	43			8	44	4	1	n.d.
288	47			11	30	5	7	n.d.
Average	49	15	6	9	12	6	3	2.79

Stained rock slabs

Sample	Plagioclase	K-feldspar	Quartz	Mafic minerals (Biotite:hornblende:pyroxene percentages from thin section in parentheses)	Specific gravity
209	53	17	7	23 (7:15:1)	2.78
223	54	23	1	22 [1](7:7:8)	2.83
224	59	2	2	37 (15:22:Tr.)	2.87
226	57	9	15	19 (19:0:0)	2.71
228	40	30	4	26 (10:16:Tr.)	2.77
229	45	28	5	22 (9:13:0)	2.78
230	51	2	8	39 (21:11:7)	2.89
232	65	3	5	27 (22:5:0)	2.75
233	55	5	13	27 (15:12:0)	2.77
238	47	12	15	26	2.76
248	29	53	9	9 (5:4:0)	2.62
253	46	18	8	28	2.82
261	51	14	11	24 (9:14:0)	2.81
262	41	35	11	13	2.68
263	55	25	1	19 (12:6:1)	2.70
271	46	26	20	8 (5:3:0)	2.70
272	59	8	3	30 (19:11:Tr.)	2.78
276	45	34	9	12 (6:6:Tr.)	2.64
277	48	15	2	35 (10:25:Tr.)	2.78
Average	50	19	8	23	2.76
Grand average	50	17	7	26	2.77
Standard deviation (thin sections included)	6.8	11.8	4.9	10.6	.07

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[1] 3 percent of pyroxene is orthopyroxene.

TABLE 3.—*Modes, in volume percent, of the Pat Keyes pluton*—Con.

SMALL MASS NEAR WILLOW CREEK MINE CAMP

Stained rock slabs

Sample	Plagioclase (An)	K-feldspar	Quartz	Mafic minerals (Biotite:hornblende:pyroxene percentages from thin section in parentheses)	Specific gravity
234	42 (24)	26	22	10 (10:0:0)	2.67
235	36 (25)	32	24	8 (5:3:0)	2.66
236	46 (25)	30	22	2	2.65
237	41 (37)	31	22	6 (5:1:0)	2.64
239	35 (25)	32	17	16	2.71
Average	40	30	22	8	2.67
Standard deviation	4.5	2.5	2.6	5.2	.03
All Pat Keyes pluton:					
Average	45	23	14	18	2.72
Standard deviation	6.4	9.8	7.4	10.4	.06

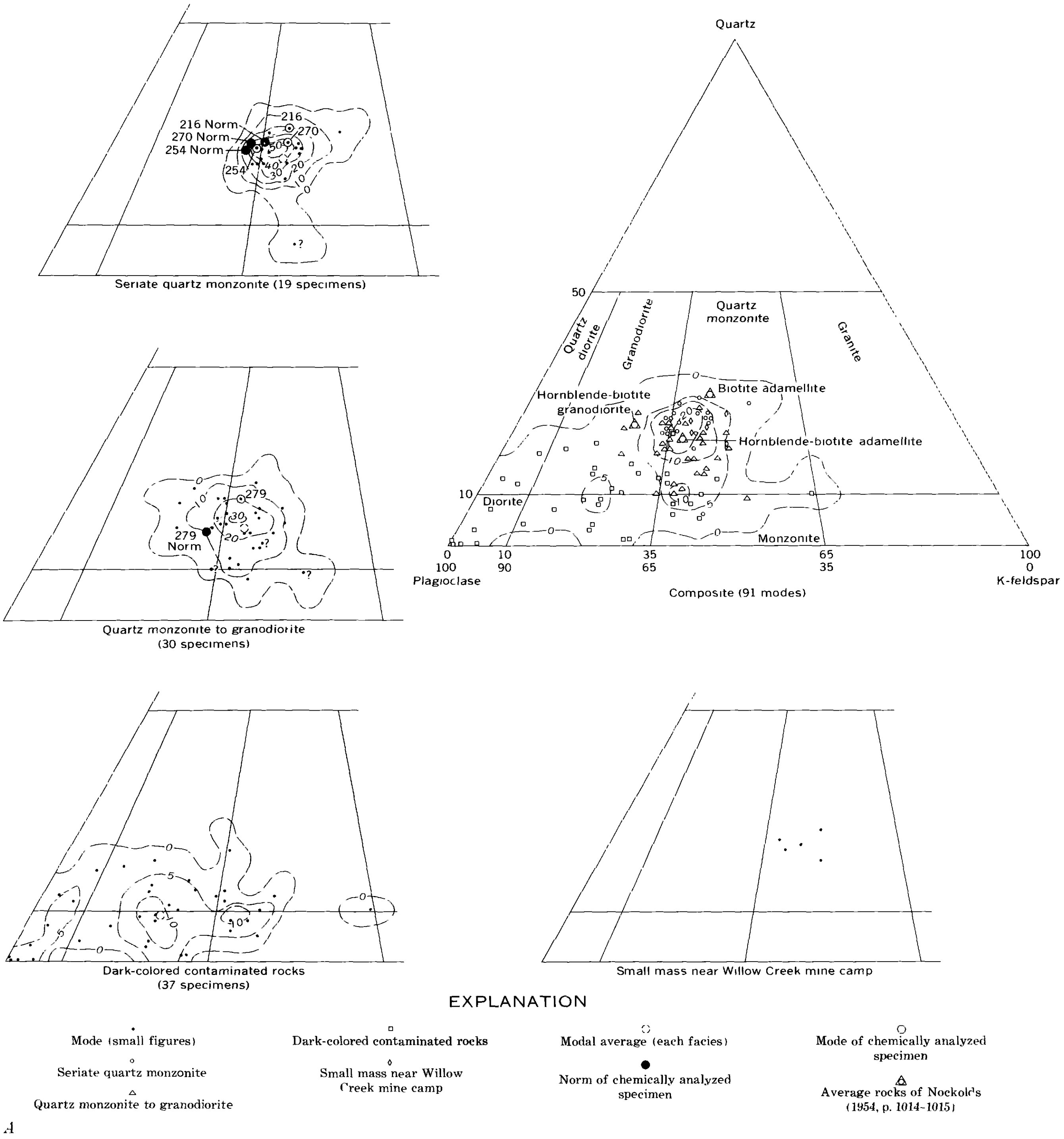
The triangular plot (fig. 13*A*) also emphasizes that the seriate quartz monzonite is the most homogeneous and the most salic differentiate relative to the other facies in the Pat Keyes pluton. The considerable overlap with the quartz monzonite-granodiorite facies further suggests the gradational relationship. The position of the seriate quartz monzonite in relation to the other facies is also shown in the plot of modal mineral pairs (fig. 14).

The negative correlation between quartz and mafic minerals has only moderate significance in this facies. The negative correlations between quartz and K-feldspar and between plagioclase and K-feldspar are lower, but still significant.

CHEMICAL DATA

Three chemical analyses were run on the seriate quartz monzonite facies of the Pat Keyes pluton; the results and norms calculated from the analyses are shown in table 4. Two of the samples (pl. 2, 216, 270) are from near the center of the mass, and one (254) was collected from near the contaminated border. The two from near the center of the mass are somewhat higher in silica and lower in CaO than the specimen from nearer the border, but otherwise all three are very similar.

Specimen 254 fits well with Nockolds' (1954, p. 1014) average for 41 hornblende-biotite adamellites (quartz monzonites), but Nockolds' average is lower in CaO, TiO_2, and Al_2O_3 and higher in K_2O and total Fe as FeO, a difference that could be accounted for largely by a variation in feldspar proportions. Nockolds' average of 65 hornblende-biotite granodiorites is not quite so good a fit. It is lower in silica and K_2O and higher in FeO, MgO, Na_2O, and CaO, a difference which suggests that Nockolds' average hornblende-biotite granodiorite has more plagioclase and mafic minerals than specimen 254. The specimens from the center of the mass (216, 270) fall somewhere between Nockolds' average bio-


Seriate quartz monzonite (19 specimens)

Quartz monzonite to granodiorite (30 specimens)

Composite (91 modes)

Dark-colored contaminated rocks (37 specimens)

Small mass near Willow Creek mine camp

FIGURE 13.—Modal distribution of quartz, K-feldspar, and plagioclase in various facies of the Pat Keyes pluton of the Hunter Mountain Quartz Monzonite and related masses. *A*, Pat Keyes pluton. *B*, Hunter Mountain Quartz Monzonite, Ubehebe Peak quadrangle (McAllister, 1956). *C*, Biotite-hornblende quartz monzonite, Darwin quadrangle (Hall and MacKevett, 1962, p. 30).

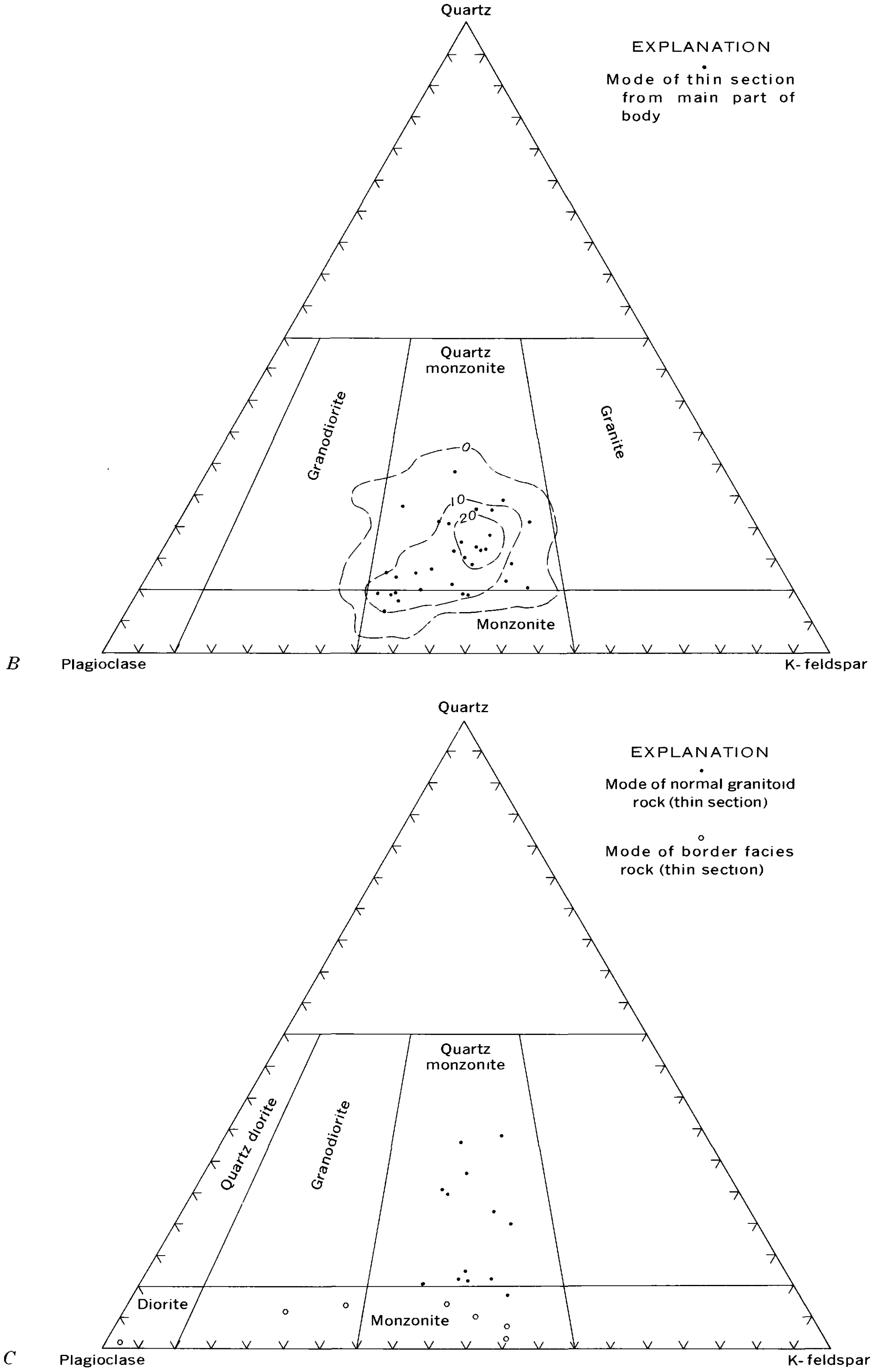


FIGURE 13.—Continued

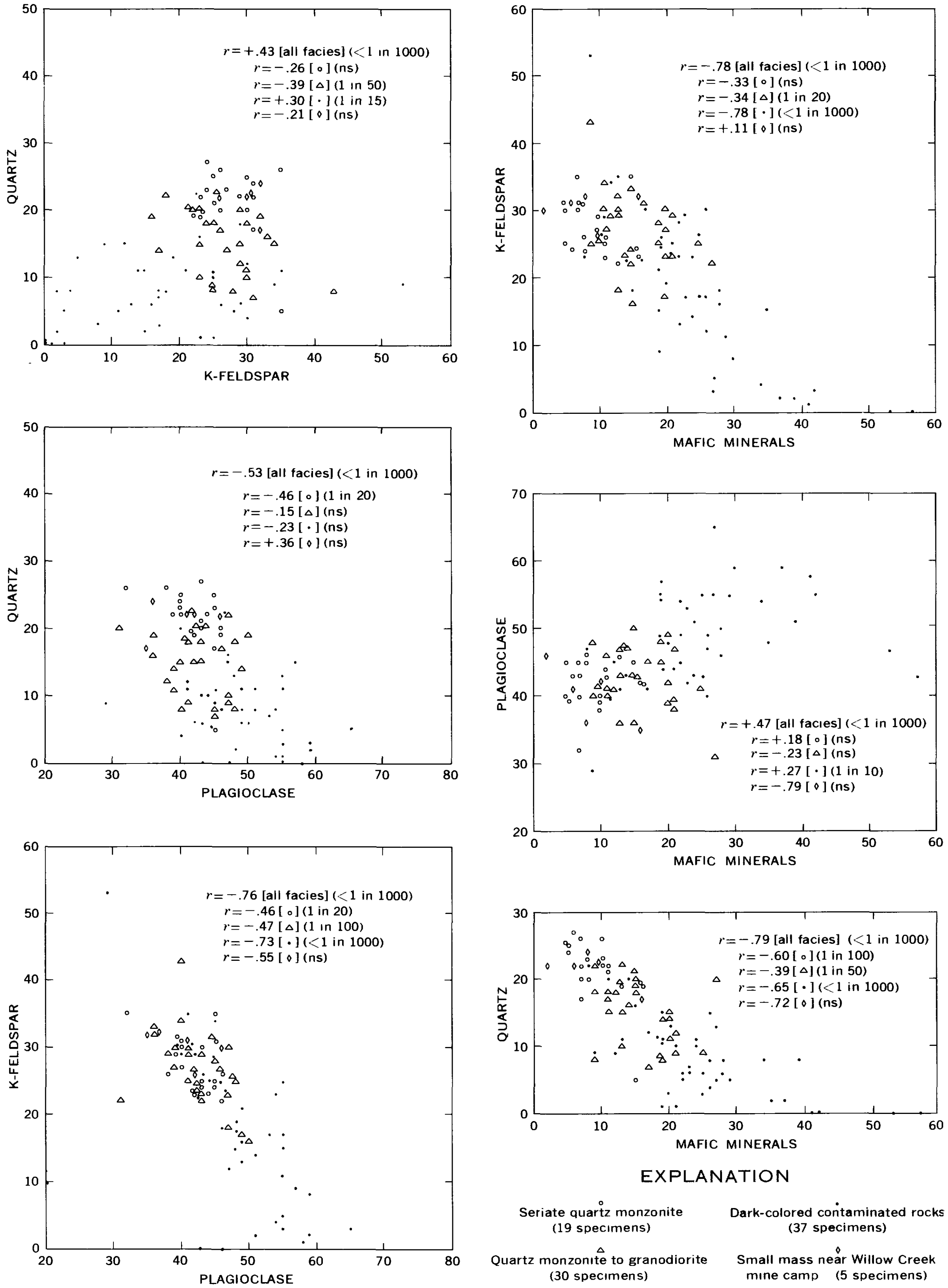


FIGURE 14.—Variation between pairs of modal constituents (volume percent) in 91 samples from the three facies of the Pat Keyes pluton of the Hunter Mountain Quartz Monzonite (r=correlation coefficient; significance level in parentheses, ns=not significant).

TABLE 4.—*Chemical data of the Pat Keyes pluton*

[Rapid chemical analyses by P. L. D. Elmore, I. H. Barlow, S. D. Botts, G. Chloe, and H. Smith. Semiquantitative spectrographic analyses of specimens 216 and 254 by H. W. Worthing; specimen 270, by J. D. Fletcher; specimen 279, by Chris Heropoulos. Looked for but not found in specimens 270 and 279: Ag, As, Au, Bi, Cd, Eu, Ge, Hf, Hg, In, Li, Mo, Nd, Pd, Pr, Pt, Re, Sb, Sm, Ta, Te, Th, Tl, U, W, Zn. Preceding plus following not found in specimens 216 and 254: Cs, Dy, Er, Gd, Ho, Ir, Lu, Os, Rb, Rh, Ru, Tb, Tm]

	Seriate quartz monzonite			Quartz monzonite-granodiorite 279	Hornblende-biotite granodiorite [1]	Biotite adamellite [2]	Hornblende-biotite adamellite [3]
	216	254	270				
Rapid chemical analyses (weight percent)							
SiO_2	67.2	65.9	67.7	65.6	65.50	71.03	65.88
Al_2O_3	15.2	15.5	15.5	16.5	15.65	14.31	15.07
Fe_2O_3	1.8	1.8	2.0	2.1	1.63	.95	1.74
Total Fe as FeO	(3.2)	(3.6)	(3.4)	(3.4)	(4.3)	(2.8)	(4.3)
FeO	1.6	2.0	1.6	1.5	2.79	1.96	2.73
MgO	1.0	1.1	1.1	1.2	1.86	.75	1.38
CaO	3.5	4.0	3.3	3.4	4.10	1.89	3.36
Na_2O	3.5	3.6	3.7	4.4	3.84	3.33	3.53
K_2O	4.0	3.7	3.7	4.0	3.01	4.66	4.64
H_2O	.65	.80	1.0	.7	.69	.50	.52
TiO_2	.50	.50	.50	.45	.61	.39	.81
P_2O_5	.25	.27	.30	.25	.23	.17	.26
MnO	.06	.06	.06	.08	.09	.06	.08
Total	99.26	99.23	100.46	100.18	100.00	100.00	100.00
Semiquantitative spectrographic analyses (weight percent [4])							
B	0.003	0.003	0	0	--	--	--
Ba	.15	.15	.1	.2	--	--	--
Be	.0003	.0003	.0001	.0002	--	--	--
Ce	0	0	.02	0	--	--	--
Co	.0015	.003	.0005	.007	--	--	--
Cr	.0007	.0007	.003	.0005	--	--	--
Cu	.0003	.003	.0007	.0007	--	--	--
Ga	.0007	.0007	.001	.0015	--	--	--
La	.015	.007	.015	.005	--	--	--
Nb	.0007	.0007	.003	0	--	--	--
Ni	.007	.007	.001	.0003	--	--	--
Pb	.0003	.003	.001	0	--	--	--
Sc	.0003	.0003	.0007	.0007	--	--	--
Sn	0	.0003	.0005	0	--	--	--
Sr	.15	.15	.1	.1	--	--	--
V	.003	.003	.007	.007	--	--	--
Y	.0015	.0015	.002	.002	--	--	--
Yb	.00015	.00015	.0002	.0002	--	--	--
Zr	.015	.015	.03	.015	--	--	--
Norms (weight percent)							
Q	23.5	21.5	23.8	16.5	20.0	27.7	18.8
or	23.8	22.0	21.8	23.6	17.8	27.8	27.2
ab	29.8 } An$_{32}$	30.7 } An$_{33}$	31.2 } An$_{32}$	37.2 } An$_{26}$	32.5 } An$_{34}$	28.3 } An$_{23}$	29.9 } An$_{28}$
an	14.1	15.3	14.4	13.4	16.4	8.6	11.7
wo	.7	1.2	--	.7	.9	--	1.4
en	2.5	2.8	2.7	3.0	4.6	1.9	3.4
fs	.7	1.5	.6	.4	2.9	2.2	2.4
mt	2.6	2.6	2.9	3.0	2.3	1.4	2.6
il	1.0	1.0	.9	.9	1.2	.8	1.5
ap	.6	.6	.7	.6	.6	.3	.6
C	--	--	.1	--	--	.5	--
Total	99.3	99.2	99.1	99.3	99.2	99.5	99.5
Niggli numbers							
si	293.6	274.7	292.4	263.7	--	--	--
al	39.1	38.1	39.5	39.1	--	--	--
fm	18.5	19.7	19.6	18.9	--	--	--
c	16.4	17.9	15.3	14.7	--	--	--
alk	26.0	24.4	25.7	27.4	--	--	--
qz	89.7	77.2	89.7	54.1	--	--	--
k	.43	.40	.40	.37	--	--	--
mg	.35	.35	.36	.38	--	--	--

See explanations and footnotes at end of table.

TABLE 4.—*Chemical data of the Pat Keyes pluton*—Continued

	Seriate quartz monzonite			Quartz monzonite-granodiorite 279	Hornblende-biotite granodiorite [1]	Biotite adamellite [2]	Hornblende-biotite adamellite [3]
	216	254	270				
Modes (volume percent)							
Plagioclase	38	44	40	42	---	---	---
K-feldspar	26	23	27	26	---	---	---
Quartz	26	22	23	22	---	---	---
Biotite	5	6	10	2	---	---	---
Hornblende	4	3		7	---	---	---
Opaques	1	1		1	---	---	---
Other	---	1		---	---	---	---
Total	100	100	100	100	---	---	---

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[1] Avg of 65 hornblende-biotite granodiorites from Nockolds (1954, p. 1014).

[2] Avg of 45 biotite adamellites (quartz monzonites) from Nockolds (1954, p. 1014).

[3] Avg of 41 hornblende-biotite adamellites (quartz monzonites) from Nockolds (1954, p. 1014).

[4] Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1 etc., which represent approximate midpoints of interval data on a geometric scale. The assigned interval for semiquantitive results will include the quantitative value about 30 percent of the time

Location of specimens (Independence quad.):
216. Head of Coyote Canyon about 4,000 ft NNW. of VABM 10,081.
254. On Pat Keyes Trail about 1½ miles NW. of SE. cor. quadrangle.
270. East boundary of quadrangle ½ mile N. of SE. cor. quadrangle.
279. About 500 ft S. of Betty Jumbo mine.

tite adamellite and his hornblende-biotite adamellite, and thus fit the displacement of the modal field in relation to the field of the Paiute Monument Quartz Monzonite.

Specimens 216 and 270 also show normative decreases in "or" and an increase in plagioclase relative to the feldspar of the modes, which may be a reflection of the Ab in the K-feldspar, probably as microperthite. Because specimen 254 has an almost identical mode and norm, the amount of K_2O in the biotite may be essentially balanced by the amount of Ab in the K-feldspar. To have a mode and a norm so similar is unusual; however, considering the generally low precision of modal counts, this similarity may be due to chance.

TYPE 2, QUARTZ MONZONITE-GRANODIORITE

OUTCROP APPEARANCE AND MEGASCOPIC CHARACTER

Medium-gray to medium-dark-gray outcrops on bouldery to rubbly slopes characterize the fine-grained quartz monzonite-granodiorite. These rocks are darker and finer grained than the seriate quartz monzonite (figs. 15, 16); the darker color is due to a higher percentage of dark minerals, a darker plagioclase feldspar, and the finer grain size. Because of the finer grain size and generally darker gray color, most of the other minerals are not distinguishable in hand specimen, but the purplish tint from K-feldspar is distinctive. Crystals of the pale-red to pale-red-purple K-feldspar are as much as 5 mm in largest dimension.

Some specimens are seriate but on a finer scale than the seriate quartz monzonite. There seems to be a gradational grain-size increase toward the seriate quartz monzonite of the core, particularly in specimens 211, 212, 213, and 215 (pl. 2). In specimens 214, 216, and 218 this gradation is well shown. Also, in the area of 204 and 207, specimens become noticeably more seriate toward the central core.

MICROSCOPIC DESCRIPTION

Thin sections of specimens of the quartz monzonite-granodiorite facies have about the same general character as those of the seriate quartz monzonite. The K-feldspar crystals, though generally smaller, engulf the other constituents to form poikilitic crystals and small (3–5 mm) phenocrysts. Corroded plagioclase grains are

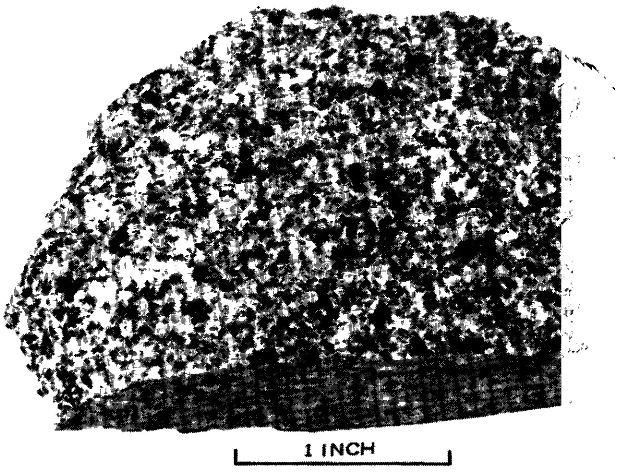

FIGURE 15.—Hand specimen of fine-grained quartz monzonite-granodiorite of the Pat Keyes pluton. Specimen 249.

FIGURE 16.—Sharp contact of the coarse-grained Paiute Monument Quartz Monzonite on the left with rocks of the Pat Keyes pluton on the right. Near specimen 203. Penny on contact indicates scale.

the most common inclusions in the late K-feldspar crystals. In some specimens, nearly euhedral plagioclase gives an almost diabasic look to the rock, but in general the plagioclase ranges from anhedral to subhedral and is not so well formed as that in the seriate quartz monzonite. The saussuritic alteration of the plagioclase is spotty; some grains are fresh, whereas nearby grains may be intensely altered. Cores of crystals are generally more altered than their rims.

Quartz is commonly granulated in this mass. Small mosaicked and sutured aggregates are also common. Some scattered granular quartz is particularly noticeable near the rims of poikilitic K-feldspar crystals.

Biotite ranges from fresh unaltered brown crystals to completely altered masses of chlorite (penninite?), epidote, and sphene in blebs and stringers along cleavage planes. Fresh biotite has a pleochroic formula of X=grayish orange to less commonly pale yellowish orange and Z=moderate brown. Hornblende is green, generally somewhat less altered than the associated biotite and slightly more abundant than biotite on the average. The pleochroic formula for hornblende is X=moderate greenish yellow and less commonly grayish yellow green, Y=light olive and less commonly moderate olive brown, and Z=grayish green. Both biotite and hornblende seem to be similar in habit and pleochroism to those same minerals in the seriate quartz-monzonite facies.

Clinopyroxene is a minor, but distinctive, constituent; it is very pale green to colorless and generally occurs as a core or a ghostlike, lacy remnant in hornblende crystals (fig. 17). The rather persistent, but minor amount, of clinopyroxene in this mass contrasts with its rare occurrence in the seriate quartz monzonite. The accessory minerals, of which magnetite is the most common, tend to be associated with the dark mineral clusters (fig. 18). Also relatively widespread are sphene, apatite, zircon, and less commonly, allanite.

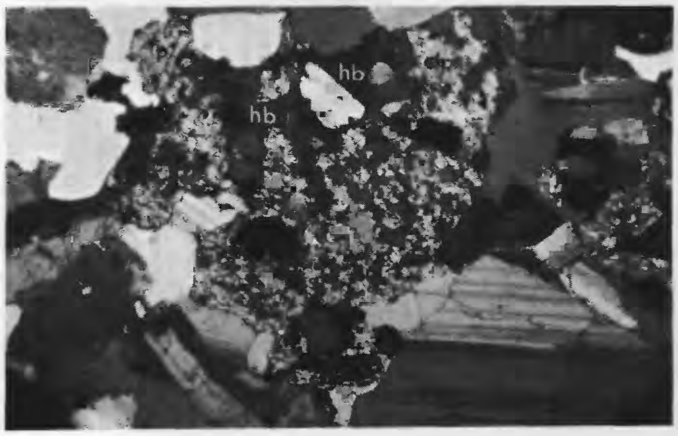

FIGURE 17.—Ghostlike remnants of clinopyroxene (clp) partly replaced by hornblende (hb) in specimen 282 of the Pat Keyes pluton. × 30.

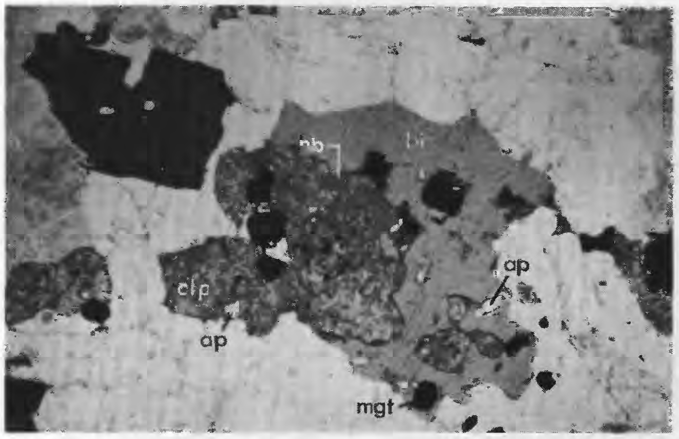

FIGURE 18.—Cluster of dark minerals in specimen 282 of the Pat Keyes pluton showing clinopyroxene (clp), hornblende (hb), biotite (bi), magnetite (mgt), and apatite (ap) in a quartz-feldspar matrix. × 30.

MODAL AND CHEMICAL DATA

The modes of 30 specimens of the finer grained quartz monzonite-granodiorite are given in table 3, and the quartz and feldspar constituents, recalculated to 100 percent, are shown for these modes in figure 13*A*. This facies shows considerably more compositional spread than the seriate quartz monzonite (type 1). Together these two facies make a reasonably well-defined field with some tailing off to the quartz-poor and plagioclase-rich fields. These two facies in turn grade into the more contaminated facies (type 3) of the Pat Keyes pluton.

As shown by the triangular diagram, this facies is intermediate between the seriate quartz monzonite and the more contaminated rocks. The diagram shows clearly that there is considerable overlap with the seriate quartz monzonite, but much less with the contaminated rocks of the pluton. The plotted modal mineral pairs (fig. 14) also show this relation. Correlation coefficients between all the mineral pairs except plagioclase: quartz and plagioclase: mafic minerals are significant, but at a moderate to low level.

Specimen 279 (table 4), which is characteristic in physical appearance and petrography of the fine-grained quartz monzonite-granodiorite facies, was analyzed chemically. This sample is higher in alumina and soda and lower in silica than the specimens of the seriate quartz monzonite. This difference is further emphasized by the norm (table 4), which is lower in "Q" and higher in "ab" and, as a consequence, has a more sodic normative plagioclase than the seriate quartz monzonite. In thin section, however, the plagioclase appears to be andesine. That the norm is lower for "or" than the mode is for K-feldspar indicates the possible influence of the Ab molecule in the K-feldspar of the specimen.

TYPE 3, DARK-COLORED CONTAMINATED ROCKS

OUTCROP APPEARANCE AND MEGASCOPIC CHARACTER

These rocks, which are in part dark reddish brown on weathered surfaces, form somber medium- to dark-gray slopes (frontispiece; fig. 11). They also present some of the most forbidding slopes on either side of the Inyo Mountains, as they form much of the precipitous east front of the Inyos south of the Willow Creek mine camp (frontispiece) and a segment of the somewhat less precipitous, but still rugged, west slope at about the latitude of Independence. Access to this mass is limited, and the rocks are quite variable. For these reasons the description of this mass is much less complete than the description of the other granitic rocks in the area.

The distribution of this facies is shown in figure 10. The west front of the Inyo Mountains south of Coyote Spring is underlain by these dark-colored rocks, and they extend southward into the Lone Pine quadrangle. On the east slope, most of the front south of the Willow Creek mine camp and west to the constriction between the two large prongs of the Paiute Monument Quartz Monzonite is also underlain by these rocks.

Along the west slope of the Inyo Mountains several attempts were made to map this facies separately from the finer grained quartz monzonite-granodiorite. Because gradation between the two facies is common, it was concluded they were variations of one intrusive mass rather than separate intrusives. The arbitrary boundary in figure 10, which groups together most of the dark-colored rocks, is not a mapped contact.

Much of the mapping of the steep upper slopes of the east front of the Inyos was based on rapid reconnaissance and sampling, since it was done in very limited time with the aid of a helicopter. In this area the data on plate 4, which show mineral percentages and specific gravity, suggest that the dark rocks east of the Paiute Monument Quartz Monzonite constriction are possibly a separate mass; however, experience on the west slopes, where no contact could be mapped, dictates caution should be taken in assuming that those rocks along the east slope represent a separate intrusive. The contouring on plate 4 does suggest that there may be a facies east of the constriction similar to that to the west. More detailed sampling might even disclose an area of less contaminated granitic rock that approaches the composition of the seriate quartz monzonite.

Probably the most distinctive feature of rocks of the contaminated facies is their dark color (fig. 19) and variable grain size. They form hummocky and bouldery slopes. Also, these darker rocks are badly weathered, probably in part because of the abundance of easily weathered dark minerals and in part because shearing has made them more susceptible to weathering. Particularly "rotten" rocks are found near the east base of the Inyo Mountains where there is strong evidence for a zone of shearing.

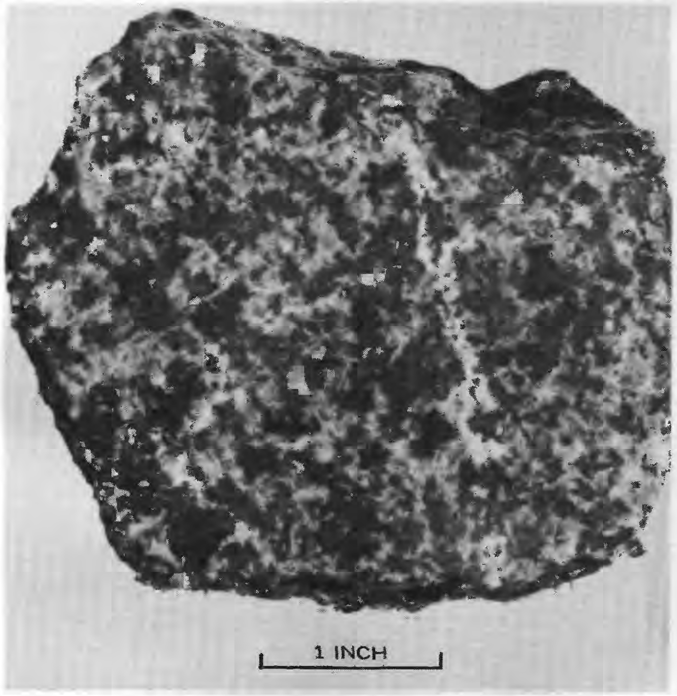

FIGURE 19.—Hand specimen of dark-colored contaminated rocks of the Pat Keyes pluton. Specimen 230.

There is no typical rock in this variable mass, but possibly most common are medium- to fine-grained dark-gray rocks with plagioclase, dark minerals, and, surprisingly, rather abundant K-feldspar. Some very dark rocks that look like diorite have 20 percent or more K-feldspar. Though the K-feldspar is faintly pinkish in some specimens, which suggests a tie with the other facies of the pluton, the K-feldspar is generally only obvious when a rock sample has been stained. Both hornblende and biotite look black in hand specimens, and in some rocks the hornblende occurs as crystals several tens of millimeters long. Weathering to dark-reddish-brown shades is diagnostic, both on newly broken joint surfaces and on other exposed surfaces.

MICROSCOPIC DESCRIPTION

As already noted in the megascopic description, this variable body of rock does not lend itself to a clean-cut description of an average or dominant type. Some general characteristics, however, help to distinguish this body from the other intrusive masses and also to separate it from the other parts of the Pat Keyes pluton.

One of the most interesting features of these dark-colored rocks is the abundance of K-feldspar in many of the specimens that are medium dark gray to dark gray and medium to fine grained; the rocks have color indexes as high as 25–30. From 20 to 35 percent of K-feldspar is not unusual in these rocks. Most is interstitial, and only rarely is it segregated as small phenocrysts. The exceptions are some of the medium- to coarse-grained varieties of monzonitic composition that are found along the east slope of the Inyo Mountains. These varieties do have coarser K-feldspar crystals and phenocrysts.

The composition of the dark-colored contaminated rocks (type 3) ranges from that of rocks similar to the finer grained quartz monzonite-granodiorite (type 2) to that of dark-colored diorite and gabbro. Such a range further suggests the gradational relation between these two facies.

The plagioclase in these rocks ranges from obligoclase to andesine. In general, the rocks most clearly related to the finer grained quartz monzonite-granodiorite contain oligoclase or sodic andesine, and the more dioritic rocks contain andesine and commonly calcic andesine. In some specimens, labradorite is present. Saussuritization of the plagioclase is probably more prevalent here than in the other facies of the Pat Keyes pluton. Some very intense saussuritization has formed pseudomorphs of sericite and members of the epidote family. Also, some specimens are evenly clouded with saussuritic alteration products, whereas in others the alteration is spotty and completely altered grains adjoin fresh twinned plagioclase crystals.

The quartz in these rocks is not particularly diagnostic. It ranges greatly in amount and is almost invariably interstitial. Granulation and other shearing effects are seen in some specimens.

Dark minerals are abundant in these rocks, and many rocks are extremely dark; however, the percentage of dark minerals averages only about 27, and only two specimens have more than 50 percent. Biotite, hornblende, and clinopyroxene, listed in order of decreasing abundance, are the characteristic accessory minerals. Also, in one specimen, a small amount of orthopyroxene is present.

The biotite content ranges from a few percent to somewhat more than 20 percent and averages about 9 percent. In a few of the dark rocks, biotite is absent. Chloritization of the biotite is common, and in some specimens almost complete. The pleochroism shows some range but generally is as follows: X = predominantly grayish orange and much less commonly, pale yellowish orange, dark yellowish orange, or very pale orange; Z = dominantly moderate brown or moderate to dark reddish brown and, less commonly, grayish brown or moderate yellowish brown.

The hornblende content ranges from 1 percent to 44 percent in a few specimens; the average is about 9 percent. Hornblende crystals tend to be subhedral to euhedral and generally are much less altered than the associated biotite. Grain size is noticeably variable in the hornblende; it ranges from small grains to crystals several tens of millimeters across in the coarse, almost pegmatitic, dioritic rocks that are locally present. The pleochroism is as follows: X = moderate greenish yellow; Y = dominantly light olive and, less commonly, light olive brown or moderate olive brown; Z = several shades with grayish green most common and light olive, pale green, moderate green, and dark yellowish green less common. In general, the hornblende is green, but some is much paler than the green hornblende in, for example, the Santa Rita Flat pluton. The paler green hornblende is locally fibrous and may be in part actinolite.

The clinopyroxene content ranges from 0 to 20 percent and averages about 4 percent. The mineral is almost colorless with very faint green tints. Most clinopyroxene is in ghostlike, lacy intergrowths with hornblende, but some specimens contain euhedral clinopyroxene with only minor replacement by hornblende.

The common accessory minerals, magnetite, apatite, sphene, and zircon, as well as the less common, allanite, are present. Most significant are the metallic opaques, mostly magnetite. Metallic opaques averaged about 2 percent and in one specimen were as high as 8 percent. Sphene is not ubiquitous in this facies although it seems to be in all the other granitic rocks of the Inyo Mountains. Its presence or absence seems to be capricious, and its occurrence does not correlate with the mineralogy of the rocks.

MODAL DATA

Modes of 37 specimens of these darker contaminated rocks are given in table 3. It should again be emphasized that for these extremely variable rocks, the modes are only a crude sample; averages and ranges should be considered only as approximations of the bulk of this mass. The ternary plot in figure 13*A* further emphasizes the variability of this facies. Points range from near the center of the quartz monzonite field into the diorite corner; they overlap somewhat with the field of the finer grained quartz monzonite-granodiorite, but in addition, they tail off to the plagioclase-rich, quartz-poor part of the triangle. The same relationship is evident on the plot of modal mineral pairs (fig. 4). Correlation coefficients are highly significant for the pairs K-feldspar: mafic minerals, quartz: mafic minerals, and K-feldspar: plagioclase; only the quartz: plagioclase correlation is not significant. The overlapping of these plotted points with the points of the other facies further strengthens the case that these facies of the Pat Keyes pluton are all parts of one variably contaminated intrusive mass.

CONTOURED MINERAL PERCENTAGES AND SPECIFIC GRAVITY

A map of the outcrop area of the Pat Keyes pluton in the Independence and Waucoba Wash quadrangles was used as a base on which to plot and to contour the mineral volume percentages of plagioclase, K-feldspar, quartz, mafic minerals, and specific gravity for the modally analyzed specimens. These contour maps are shown on plate 4*A*–*E*.

The general area of the seriate quartz monzonite appears as a bull's-eye of high K-feldspar and quartz and of low plagioclase and mafic minerals; consequently, it represents an area of low specific gravity. The areas of finer grained quartz monzonite-granodiorite and the contaminated facies show much less distinction of highs and lows.

East of the constriction formed by the two prongs of Paiute Monument Quartz Monzonite in the Waucoba Wash quadrangle, there appears to be a specific gravity, mafic mineral, and plagioclase low and a quartz high; here K-feldspar is too sporadic to contour. Data are extremely sparse, but we cannot rule out the possibility that the rocks to the east of the constriction are a separate mass. Although these rocks locally have some affinities with the seriate quartz monzonite and the finer grained quartz monzonite-granodiorite, they are dominantly of the contaminated facies and are somewhat more variable and in general more mafic than the contaminated rocks along the west side of the pluton. The variability seems to be one of degree; so, for the present they are considered to be one large variable pluton with three facies that indicate differential contamination.

Figure 20 shows the relation of specific gravity to the percentage of dark minerals of the Pat Keyes pluton, other plutons of the Inyo Mountains, and granitic rocks of the eastern Sierra Nevada. Expectably, there is a strong positive correlation with a high level of significance, because the percentage of dark minerals is the major control of specific gravity variation in these rocks.

Figure 20*A* (Pat Keyes pluton) has a definite elongate trend and also shows the gradational relation between the three major facies of the pluton. Figure 20*B* (Paiute Monument Quartz Monzonite), although it has a general positive correlation trend, indicates the homogeneity of the mass by the close clustering of most of the points. The percentage of dark minerals and the specific gravity have a narrow range of variation, but the correlation is nevertheless highly significant.

Figure 20*C* (Santa Rita Flat pluton) has much more spread in dark-mineral content than its specific gravity range indicates. The reason for this is not clear. If, however, the outlying dots are neglected, the pattern is not far different from that of figure 20*B*—a fairly close clustering, but a positive correlation trend.

When the data from the three plutons are plotted on a single figure (fig. 20*D*), the positive correlation trend of the great bulk of the data is overwhelming. Some of the spread away from the positive correlation trend in these figures is caused by specimens whose color index was determined from a thin section and whose specific gravity was determined from a hand specimen. Generally the dark minerals are evenly distributed, but in some specimens a thin section is not an adequate sample because of the clustering of the dark minerals.

For comparison, the relation of the percentage of dark minerals and specific gravity for the granitic rocks of the Bishop district and Mount Pinchot quadrangle in the eastern Sierra Nevada are plotted in figures 20*E* and 20*F*. They show trends quite comparable to the composite plot for the Inyo Mountains (fig. 20*D*).

WILLOW CREEK MASS

OUTCROP APPEARANCE AND MEGASCOPIC CHARACTER

Just west of the Willow Creek mine camp a small instrusive mass, tentatively correlated with the Pat Keyes pluton, crops out over less than half a square

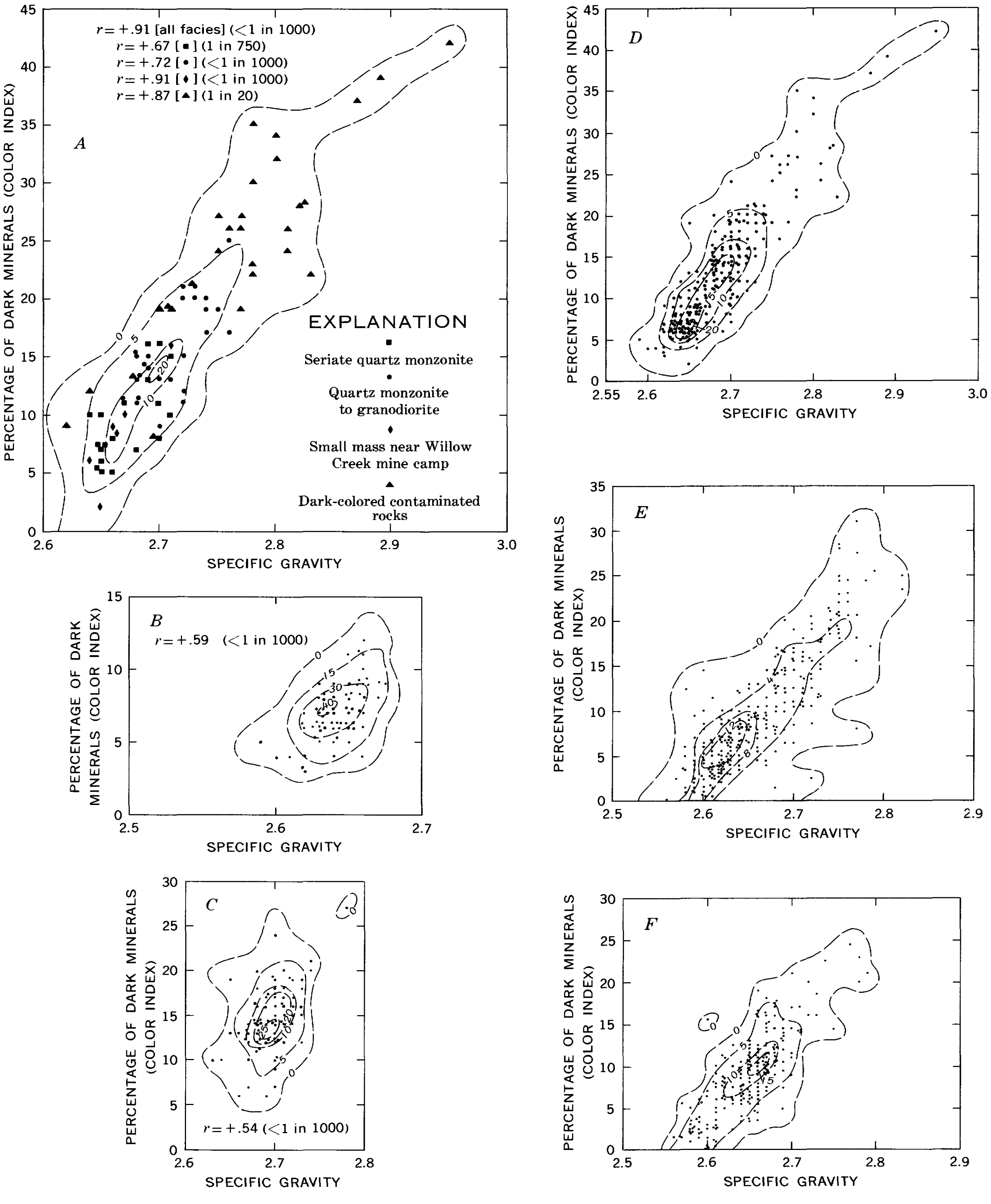

FIGURE 20.—Correlation of dark mineral percentage and specific gravity of selected granitic rocks in the Inyo Mountains and Sierra Nevada. *A*. Pat Keyes pluton. *B*. Paiute Monument Quartz Monzonite. *C*. Santa Rita Flat pluton. *D*. Inyo Mountains (composite of *A*, *B*, and *C*). *E*. Bishop District, Sierra Nevada (Bateman, 1965). *F*. Mount Pinchot area Sierra Nevada (Moore, 1963). Correlation coefficient is *r*; significance level is in parentheses.

mile. These rocks are various shades of medium to dark gray and are intruded by dikes and small masses of light-colored Paiute Monument Quartz Monzonite. The variability of this mass, from seriate quartz monzonite with somewhat pinkish K-feldspar to fine-grained dioritic rock, suggests that it is an offshoot of the Pat Keyes pluton.

The less contaminated portions of this mass are medium gray to medium light gray, medium grained, and notably seriate; K-feldspar crystals are as long as 5 mm. Although the K-feldspar is locally pink, particularly in weathered exposure, it is more commonly light gray. Plagioclase is also light to medium gray, in contrast to the somewhat darker interstitial quartz. The dark minerals are sprinkled through the rock as small shredlike crystals.

Some of the specimens resemble the seriate quartz monzonite of the main Pat Keyes pluton, but the relation is not certain enough to warrant a positive correlation. This small mass could be a separate felsic intrusive, or it could be part of the Pat Keyes pluton that is different because of the small size of the mass and variable amounts of contamination. The close proximity to the large mass of the Pat Keyes pluton, however, does suggest a correlation.

The Willow Creek mass has the only granitic outcrops in the area with prominent foliation shown by drawnout mafic inclusions. Near the north end of the mass this foliation is N. 70° E. and dips 55° N. Alinement of the dark minerals emphasizes this foliation. Recognizable xenoliths are also present in this same area; elsewhere they are uncommon.

MICROSCOPIC DESCRIPTION

In thin section, the rocks of the Willow Creek mass show a typical granitic (hypautomorphic) texture. The largest grains are ragged-edged somewhat poikilitic K-feldspars, a few as much as 10 mm long, but generally no more than 5 mm long. A range in grain size from these large crystals down to small interstitial stringers gives the rock a distinctly seriate texture. The plagioclase is euhedral to subhedral, at least in the less contaminated specimens. Polysynthetic twinning and zoning are weakly visible. Most of the plagioclase is oligoclase, about An_{25}, but some of the plagioclase has been albitized. The quartz ranges from interstitial wormy crystals to masses as large as the plagioclase crystals (2–3 mm).

The only dark mineral in some specimens is biotite; it is pleochroic from X=grayish orange to Z=light olive to locally moderate reddish brown. In other specimens both biotite and hornblende are present, but biotite is always predominant. The hornblende is pleochroic according to the formula X=moderate greenish yellow, Y=dusky yellow green, Z=dark yellowish green.

Magnetite, sphene, zircon, apatite, and allanite are also present. One specimen (236) contains tourmaline that is pleochroic from very pale orange to dark yellowish orange. This specimen is also distinguished by many pleochroic halos and by abundant saussuritization of the plagioclase.

Most of this mass seems to be sheared. Much of the quartz is mosaicked, strongly sutured, and locally granulated. At least some of the granulated quartz seems related to the emplacement of the body or at least formed before complete solidification of the magma, because small granules of quartz are included in the rims of late-growing K-feldspar crystals. Impressive shear zones, however, are also present in this mass. These are undoubtedly related to the family of northwest-trending faults in the metamorphosed sedimentary rocks west of the small Willow Creek mass. Thus some of the granulation is probably cataclastic.

MODAL DATA

Modal data on this mass were obtained for only five specimens of the least contaminated rocks (table 3). The plot of these modal points in figure 13*A* shows that they generally coincide with the field of the seriate quartz monzonite and thus lend support to a tentative correlation. The plot of these points in figure 14, which also compares modal mineral pairs, shows they are most similar to the seriate quartz monzonite.

PAIUTE MONUMENT QUARTZ MONZONITE

NAME, DISTRIBUTION, AND CORRELATION

The Paiute Monument Quartz Monzonite is here named for its type locality, Paiute Monument, a granitic monolith 74 feet high (fig. 21) that forms a prominent landmark on the crest of the Inyo Mountains 10 miles east-northeast of Independence, Inyo County.

The main mass of the Paiute Monument Quartz Monzonite, an irregularly shaped area of about 40 square miles, essentially spans the Inyo Mountains near Paiute Monument. In addition, three smaller masses aggregating about 5 square miles stick up through older granitic rocks of the Pat Keyes pluton south of the main mass of the Paiute Monument Quartz Monzonite (pl. 1). Thus in total extent, about 45 square miles in the Inyo Mountains are underlain by rocks of the Paiute Monument Quartz Monzonite. In the Darwin and Panamint Butte quadrangles, about 6 square miles are underlain by a leucocratic quartz monzonite (Hall and MacKevett, 1962, p. 31; Hall and Stephens, 1963, p. 17) that is probably correlative with the Paiute Monument Quartz Monzonite.

FIGURE 21.—Paiute Monument, the type locality of the Paiute Monument Quartz Monzonite, as viewed from the west. Prominent 74-foot-high joint remnant of quartz monzonite on the Inyo skyline.

Bateman (1965, p. 71) has noted that "porphyritic granodiorite somewhat similar in appearance to the Tinemaha Granodiorite also is found * * * at the Jumbo mine in the Inyo Range * * *." These outcrops are within the Paiute Monument Quartz Monzonite and are not correlative with the Tinemaha Granodiorite. Reddish K-feldspar is not common in the Tinemaha (see p. 3, Santa Rita Flat pluton), whereas it is a characteristic feature of the Paiute Monument Quartz Monzonite.

OUTCROP APPEARANCE AND MEGASCOPIC CHARACTER

The Paiute Monument Quartz Monzonite is a distinctly light-colored rock. From a distance it is light gray, but at close range many outcrops are pinkish. Characteristically, the quartz monzonite weathers to bouldery outcrops (fig. 11). The large size of the hummocky outcrops and boulders are distinguishing features of the Paiute Monument mass. Seemingly this is a function of the coarse grain size and massive structure of the rock; boulders many feet across are common, and some are as large as 50 feet in diameter. This weathering characteristic also produces large monoliths, the most impressive of which is Paiute Monument (fig. 21).

Hand specimens (fig. 22) are remarkably similar in appearance throughout this mass; in fact, homogeneity is one of its outstanding features. Most noteworthy is the abundance of pale-red-purple K-feldspar crystals as large as 25 mm in longest dimensions. These crystals, which at first glance appear to be euhedral phenocrysts, are found on closer inspection to be almost invariably irregular with lacy poikilitic edges. Surfaces that have been stained for K-feldspar emphasize these poikilitic crystals. Another striking feature of this rock is the tendency for the quartz to concentrate in irregularly sized masses as much as 15–20 mm across. The clear to smoky-gray quartz masses contrast with anhedral crystals of milky white to slightly greenish plagioclase. These plagioclase crystals may be as much as 10 mm in largest dimension.

Biotite and hornblende are scattered through the rock as single crystals and in small clusters. The dark minerals make up about 5–6 percent of the rock; biotite is predominant. Of the accessory minerals, only honey-brown euhedral crystals of sphene are seen in hand specimens.

The overall texture is coarse grained and seriate (figs. 16, 23); these rocks are essentially structureless. Fine-

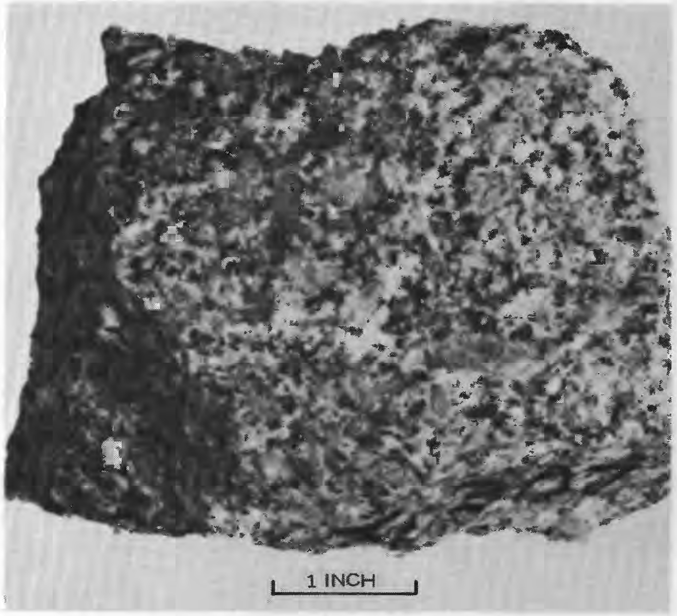

FIGURE 22.—Typical hand specimen of Paiute Monument Quartz Monzonite. Specimen 140.

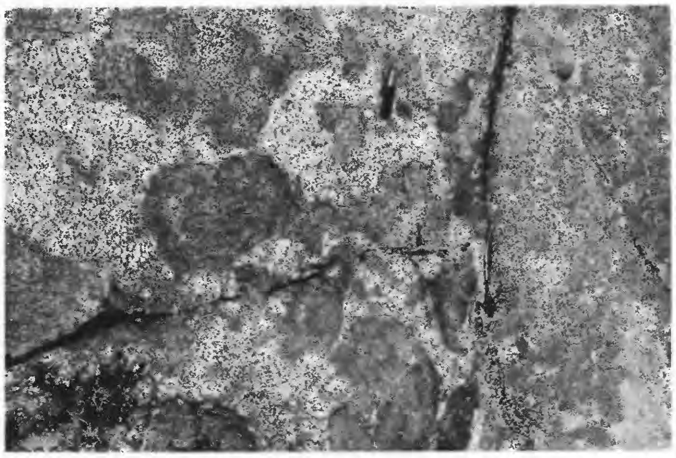

FIGURE 23.—Intrusion breccia of dark contaminated facies of the Pat Keyes pluton in the Paiute Monument Quartz Monzonite. Photograph taken west of specimen 261. Pocket knife indicates scale.

grained dark-colored dioritic inclusions, though present, are widely scattered and are generally only a few inches in maximum dimension. The inclusions are mostly spheroidal to ellipsoidal.

MICROSCOPIC DESCRIPTION

Thin sections of the Paiute Monument Quartz Monzonite show a hypautomorphic seriate texture of subhedral plagioclase, biotite, and hornblende, contrasting with anhedral quartz and K-feldspar (table 5). One of the most obvious features, both in thin section and on stained slab surfaces, is the K-feldspar frozen in the act of engulfing most of the other constituents of the rock. Plagioclase in particular is found in scallop-edged corroded grains in K-feldspar (fig. 24). Small plagioclase crystals are also alined near the margins of some K-feldspar crystals and indicate growth zoning. Much of the K-feldspar shows the grid twinning associated with microcline, and some is perthitic.

FIGURE 24.—Scalloped, corroded plagioclase crystals immersed in perthitic K-feldspar crystal, from the Paiute Monument Quartz Monzonite. (Splotchy K-feldspar surface results from staining.) Specimen 106. × 30.

The reason for the milky color and slight greenish tinge of plagioclase in outcrops is obvious in thin section. Though much plagioclase is in polysynthetically twinned crystals that are fresh and unaltered, saussuritic alteration to sericite and members of the epidote family is common. In some specimens, cores of plagioclase crystals are altered intensely, whereas the rims are relatively fresh. In other specimens, a sprinkling of saussuritic minerals permeates entire crystals. The anorthite content of about 35 plagioclases was determined by the X-ray diffraction method described on page 2. On all but three specimens the plagioclase was in the range of An_{18-12} (calcic oligoclase), and the variation did not appear to be systematic. For three specimens (139, 150, and 151) the anorthite content was in the albite range. These three specimens are from the east margin of the Paiute Monument Quartz Monzonite. Only a few samples were taken from this part of the body; so the significance and extent of this marginal albitization is not known. These albitic rocks appear, however, to be part of a local border facies (see p. 29).

The large quartz masses, so evident in hand specimens, generally consist of clusters of mosaicked grains, whose borders are commonly sutured. Undulatory extinction is common, and granulation of quartz, though less common, is present in many specimens.

Biotite and hornblende are subhedral to euhedral and unaltered in most specimens. The general homogeneity of the body is further emphasized by the uniform character of the dark minerals. Biotite is generally pleochroic according to the formula X=grayish orange or pale yellowish orange and, less commonly, dark yellowish orange and Z=moderate brown and, less commonly, grayish brown. Most of the biotite is remarkably fresh with only minor chloritization; however, in some specimens near contacts with wallrocks or with the older Pat Keyes pluton, the biotite is extensively altered to chlorite (penninite?) and a black opaque material that is probably magnetite or other iron oxides (fig. 25).

The hornblende of the Paiute Monument mass is generally unaltered and is pleochroic according to the formula X=moderate greenish yellow, Y=light olive or light olive brown, and Z=grayish green and, much less commonly, moderate yellowish green.

The ubiquitous accessory minerals, sphene, zircon, apatite, and magnetite, tend to occur in clusters associated with biotite and hornblende (fig. 26). Sphene, the only accessory mineral coarse enough to be readily visible in hand specimens, is also particularly striking in thin section in its distinctively weldge-shaped crystals. Scattered crystals of allanite, intensely pleochroic in shades of brown, are found in many specimens.

One part of the otherwise notably uniform Paiute Monument mass may be a separate small intrusive mass, but it is more likely an albitized local border facies. Dikes of this rock type (specimen 123) intrude the Pat Keyes pluton west of the Willow Creek mine camp (pl. 2; table 5) and are also found along the east margin of the Paiute Monument mass where it intrudes mixed rocks of the Pat Keyes pluton and metasedimentary rocks (specimens 138, 139). The rocks of this small mass are light gray and medium grained (2–5 mm). They contain white to creamy K-feldspar, albitic plagioclase, and a sprinkling of dark minerals, dominantly biotite. Near the border of the Paiute Monument mass, they seem to grade to normal Paiute Monument Quartz Monzonite, but no more definite statement can be made. If these rocks compose a border facies, they are local, as most contacts with the Paiute Monument show no change, except possibly that grain size decreases slightly and that pink feldspar is almost invariably present. These anomalous rocks contain about 5 percent biotite and minor hornblende. The biotite is pleochroic according to the formula X=light brown and Z=moderate reddish brown; pleochroic halos are abundant, in contrast to the brown biotite and sparse pleochroic halos in the rest of the Paiute Monument mass. Also, these border rocks have primary muscovite and lack sphene. A minor amount of sphene in one specimen appears to be an alteration product associated with chloritized biotite.

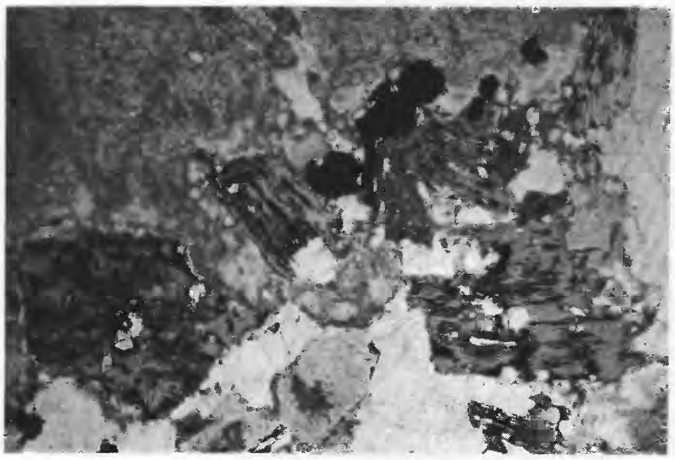

FIGURE 25.—Pseudomorphs of chlorite (penninite?) after biotite from the Paiute Monument Quartz Monzonite. Black opaque material in pseudomorphs is mostly magnetite or other iron oxide material. Apatite crystals appear unaffected by alteration. Specimen 134. × 30.

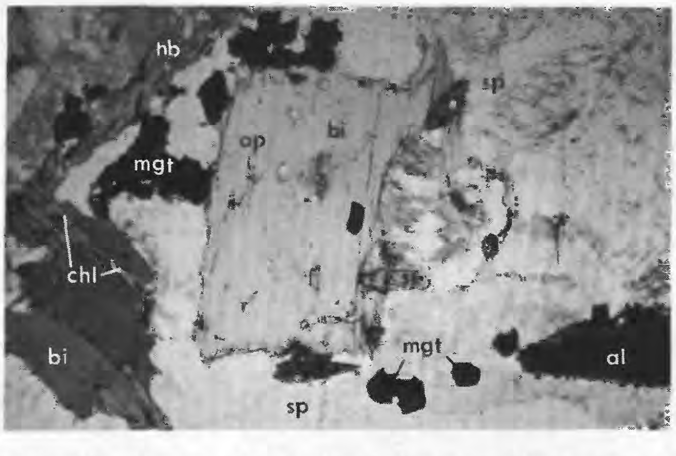

FIGURE 26.—Cluster of dark minerals in quartz-feldspar matrix, from the Paiute Monument Quartz Monzonite. Biotite (bi), partially chloritized (chl), hornblende (hb), magnetite (mgt), sphene (sp), apatite (ap), allanite (al). Specimen 140. × 30.

MODAL DATA

On table 5 are given the modes of 58 stained rock slabs and nine thin sections. The plot of the quartz and feldspar in figure 27 shows a shotgun pattern of points in the central part of the quartz monzonite field; the modal average resembles a bull's-eye in the center of the field.

Figure 27 also demonstrates the considerable spread of the major constiutents in a rock that is seemingly very homogeneous. Part of this spread, particularly of the outlying points, is caused by the fact that even slabs with areas of 10–12 square inches were not representative samples of this extremely coarse grained rock. Large splotchy K-feldspar and quartz crystals, irregularly distributed, were obvious causes of some of the variation. Different slabs of the same large hand specimen showed several percent of variation in the major constituents. And yet almost anyone observing this mass throughout its area of exposure would consider it quite homogeneous.

Several thin-section modes are also given in table 5, but they were not plotted on the triangular diagram, because they were obviously not representative samples of these coarse-grained rocks. The thin sections were helpful in identifying the kinds and amounts of dark minerals, a task that is difficult, if not impossible, on the stained slabs. Percentages of dark mineral obtained from point counts of the thin sections given in table 5 were supplemented by point counts of the biotite and hornblende from several sections taken from the same specimen as the sawed and stained slabs. These percentages compared quite closely with the total percentage of mafic minerals on the slabs, which suggests that the dark minerals are rather equally distributed through the rock and that a thin section does adequately sample

TABLE 5.—*Modes, in volume percent, of the Paiute Monument Quartz Monzonite*

[n.d., indicates values not determined]

Thin sections

Sample	Plagioclase (An)	K-Feldspar	Quartz	Biotite	Hornblende	Opaque and accessory	Specific gravity
106	39 (28)	31	26	2	Trace	2	2.66
108	32	23	36	5	1	3	2.63
114	43 (27)	24	26	4	1	2	2.66
127	41 (18)	20	31	5	1	2	2.63
129	38 (24)	20	35	3	2	2	2.64
130	32 (27)	32	29	4	1	2	2.65
132	40	21	32	3	1	3	2.66
133	35 (24)	39	20	3	1	2	2.65
134	34	23	36	4	1	1	2.63
Average	37	26	30	3	1	3	2.65
Standard deviation	3.9	6.6	5.4	n.d.	n.d.	n.d.	.01

Stained rock slabs

Sample	Plagioclase (An)	K-Feldspar	Quartz	Mafic minerals (Biotite: hornblende percentages from thin section in parentheses)	Specific gravity
101	33 (17)	37	26	4 (4:0)	2.61
102	35 (18)	33	27	5 (4:1)	2.64
103	40	30	23	7	2.62
104	39 (24)	30	25	6 (4:2)	2.64
105	29	30	32	9	2.64
106	38 (28)	25	28	9	2.66
107	37	36	21	6	2.65
109	30 (25)	36	28	6	2.63
110	34 (27)	31	28	7	2.65
111	34 (28)	26	31	9	2.65
112	38 (22)	30	26	6 (4:1)	2.64
113	40 (26)	32	22	6 (3:3)	2.66
114	33 (27)	38	18	11	2.66
115	39	30	27	4 (4:2)	2.64
116	34 (22)	32	28	6 (4:1)	2.63
117	39 (25)	31	18	12 (7:5)	2.66
118	41 (26)	30	20	9 (5:3)	2.67
119	38 (24)	26	25	11 (8:3)	2.66
120	39 (20)	30	23	8 (5:3)	2.63
121	35 (24)	34	23	8 (5:3)	2.64
122	35 (21)	39	19	7 (4:3)	2.65
123	48	28	18	6 (5:0)	2.63
124	39 (19)	34	22	5	2.65
125	41 (27)	28	22	9	2.66
126	35	32	25	8	2.65
127	34 (18)	36	23	7 (5:1)	2.63
128	32	34	27	7	2.63
129	33 (24)	32	29	6 (3:2)	2.64
130	30 (27)	39	23	8	2.65
131	35 (25)	33	24	8	2.66
132	39	32	20	9	2.66
133	34 (24)	38	22	6 (4:1)	2.65
134	27	38	30	5 (4:1)	2.63
135	30 (25)	42	22	6	2.64
136	32 (24)	35	26	7 (4:2)	2.63
137	39 (18)	26	28	7 (5:2)	2.64
138	33	35	26	6 (5:1)	2.63
139	29 (5)	31	36	4 (4:Tr.)	2.62
140	35 (25)	32	25	8 (6:2)	2.66
141	30 (25)	43	22	5	2.64
142	36 (29)	35	20	9	2.67
143	22 (22)	41	33	4 (3:0)	2.60
144	38 (19)	30	27	5 (4:1)	2.63
145	38	32	24	6 (6:Tr.)	2.62
146	33	36	28	3 (3:0)	2.62
147	35	33	26	6 (4:2)	2.64
148	24	29	38	9	2.66
149	39	27	28	6 (6:0)	2.63
150	25 (10)	29	43	3 (3:0)	2.62
151	35 (10?)	44	13	8 (4:3)	2.67
152	30	41	23	6 (5:Tr.)	2.62
153	29 (26)	47	18	6 (4:1)	2.65
154	28 (25)	40	27	5 (5:Tr.)	2.59
155	40 (22)	29	21	10	2.66
156	36 (28)	30	25	9	2.66
157	36	20	33	11	2.65
158	41	29	22	8	2.63
159	36 (26)	30	26	8	2.65
Average	35	33	25	7	2.64
Standard deviation	4.8	5.2	5.2	2.0	.02
Grand average (thin sections included)	35	32	26	7	2.64
Standard deviation	4.7	5.9	5.4	1.9	.02

them. Biotite is always in excess of hornblende; the ratio average about 3 : 1.

To determine the relations between mineral pairs in the Paiute Monument Quartz Monzonite, each constituent determined from modal analysis was plotted against all other modal constituents (fig. 28). Highly significant correlations exist between the quartz : K-feldspar and the plagioclase : K-feldspar pairs. The other pairs have only moderately significant correlations, but much more than would be suspected from observation of the plotted points alone.

CHEMICAL DATA

Two samples of the Paiute Monument Quartz Monzonite have been analyzed chemically (table 6). Sample

TABLE 6.—*Chemical data of the Paiute Monument Quartz Monzonite*

[Rapid chemical analyses by P. L. D. Elmore, I. H. Barlow, S. D. Botts, G. Chloe, and H. Smith. Semiquantitative spectrographic analyses for specimen 140, by H. W. Worthing; for specimen 116, by J. D. Fletcher. Looked for but not found in specimen 116: Ag, As, Au, B, Bi, Cd, Ce, Ge, Hf, Hg, In, La, Li, Mo, Pd, Pt, Re, Sb, Ta, Te, Th, Tl, U, W, Zn, Pr, Nd, Sm, Eu. Preceding plus following not found in specimen 140: Cs, Dy, Er, Gd, Ho, Ir, Lu, Nd, Os, Rb, Rh, Ru, Tb, Tm]

	116	140	Biotite adamellite [1]	Hornblende-biotite adamellite [2]
Rapid chemical analyses (weight percent)				
SiO_2	71.0	70.6	71.03	65.88
Al_2O_3	14.4	14.7	14.31	15.07
Fe_2O_3	1.6	1.7	.95	1.74
Total Fe as FeO	(2.4)	(2.6)	(2.8)	(4.3)
FeO	1.0	1.1	1.96	2.73
MgO	.55	.55	.75	1.38
CaO	2.1	2.4	1.89	3.36
Na_2O	3.4	3.4	3.33	3.53
K_2O	4.6	4.5	4.66	4.64
H_2O	.88	.65	.50	.52
TiO_2	.32	.28	.39	.81
P_2O_5	.22	.17	.17	.26
MnO	.08	.07	.06	.08
Total	100.15	100.12	100.00	100.00
Semiquantitative spectrographic analyses (weight percent [3])				
Ba	0.07	0.15	---	---
Be	.0002	.0003	---	---
Co	.0005	.0003	---	---
Cr	.0002	.0003	---	---
Cu	.0007	.0003	---	---
Ga	.001	.0007	---	---
Nb	.0015	---	---	---
Ni	.0007	.003	---	---
Pb	.002	.0007	---	---
Sc	.0005	.0003	---	---
Sn	.0005	---	---	---
Sr	.07	.07	---	---
V	.003	.0015	---	---
Y	.002	.0007	---	---
Yb	.0002	---	---	---
Zr	.02	.015	---	---
Norms (weight percent)				
Q	28.8	28.0	27.7	18.8
or	27.2	26.6	27.8	27.2
ab	28.8 } An_{24}	28.7 } An_{27}	28.3 } An_{23}	29.9 } An_{28}
an	9.0 }	10.8 }	8.6 }	11.7 }
en	1.4	1.4	1.9	3.4
fs	.1	.3	2.2	2.4
wo	---	---	---	1.4
mt	2.3	2.5	1.4	2.6
il	.6	.5	.8	1.5
ap	.5	.4	.3	.6
C	.5	.3	.5	---
Total	99.2	99.5	99.5	99.5

See explanation and footnotes at end of table.

TABLE 6.—Continued

	116	140	Biotite adamellite [1]	Hornblende-biotite adamellite [2]
		Niggli numbers		
si	356.9	344.8		
al	42.7	42.3		
fm	14.7	15.0		
c	11.3	12.6		
alk	31.3	30.1		
qz	131.6	124.3		
k	.47	.47		
mg	.28	.27		
		Modes (volume percent)		
Plagioclase	34	35		
K-feldspar	32	32		
Quartz	28	25		
Mafics	6	8		
Total	100	100		

[1] Avg of 45 biotite adamellites (quartz monzonites) from Nockolds (1954, p. 1014).

[2] Avg of 41 hornblende-biotite adamellites (quartz monzonites) from Nockolds (1954, p. 1014).

[3] Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1 etc., which represent approximate midpoints of interval data on a geometric scale. The assigned interval for semiquantitative results will include the quantitative value about 30 percent of the time.

Location of specimens:

116. West boundary of Waucoba Wash quad., about 4½ miles N. 80° W. of Willow Creek camp.

140. Southeastern part of Independence quad., about 2,000 ft NE. of the Betty Jumbo mine.

116 (pl. 2) was collected near the contact with the Pat Keyes pluton and Cambrian sedimentary rocks; sample 140 was collected near the center of the main mass. The hand specimens appear similar, and the two chemical analyses further confirm the homogeneity of the granitic mass. Although two analyses are by no means an adequate sample of the mass, the virtually identical oxide percentages from both the center and edge of the mass suggest that there is no systematic zoning in the Paiute Monument Quartz Monzonite.

A comparison of the Paiute Monument analyses with Nockolds' (1954, p. 1014) average for 45 biotite adamellites (quartz monzonite) shows a very close correspondence. Nockolds' figure for total iron is slightly higher, and the Fe_2O_3 : FeO ratio is reversed; MgO is slightly higher, and CaO is slightly lower; the other oxide percentages match Nockolds' figures very closely. The values in Nockolds' average of 41 hornblende-biotite adamellites do not match nearly so well. His average hornblende-biotite adamellite is lower in silica and higher in Al_2O_3 , MgO, CaO, and total iron. Although Nockolds' table of averages does not show hornblende, his hornblende-biotite adamellite presumably contained a

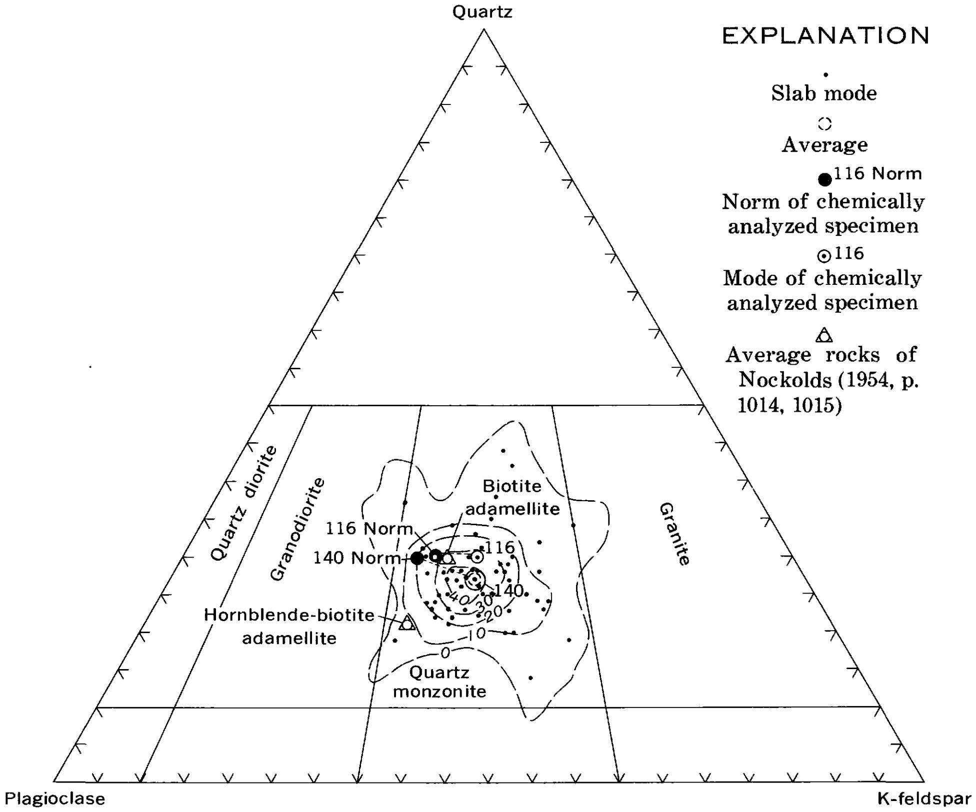

FIGURE 27. Modal distribution of quartz, K-feldspar, and plagioclase in 58 specimens of the Paiute Monument Quartz Monzonite.

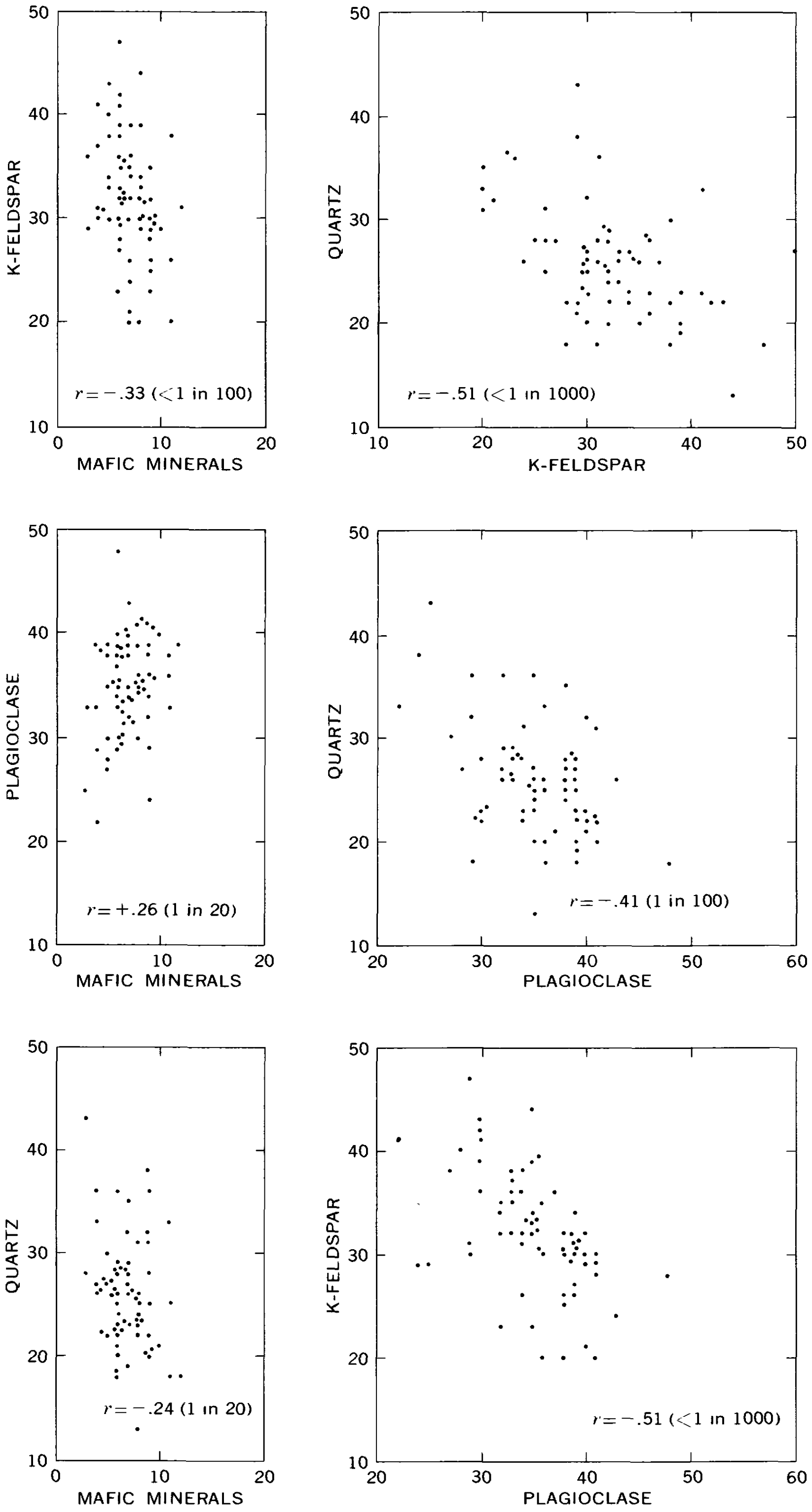

Figure 28.—Variation between pairs of modal constituents in volume percent for 67 specimens of the Paiute Monument Quartz Monzonite (r=correlation coefficient; significance level in parentheses).

considerable amount. The Paiute Monument Quartz Monzonite with only about 1 percent hornblende is thus much closer to Nockolds' biotite adamellite.

A comparison of Nockolds' norm of the average biotite adamellite with the norms of the Paiute Monument Quartz Monzonite shows that Nockolds' average norm is—somewhat surprisingly, considering the close correspondence of analyses—lower in normative quartz, albite, and anorthite, and higher in normative orthoclase. More expectably, in view of the analyses, Nockolds' norm is higher in $MgSiO_3$ and $FeSiO_3$ and lower in normative magnetite. The plot of normative quartz and feldspar of Nockolds' average rock in figure 27 is very close to the plots of normative quartz and feldspar of specimens 116 and 140.

The comparison of the modes and norms (fig. 27) of specimens 116 and 140 shows a decrease in K-feldspar and an increase in plagioclase in the norms relative to the modes. Probably this is related to albite in solid solution in the K-feldspar of this body.

STRUCTURAL FEATURES

One of the most impressive characteristics of the granitic masses described in this report is that they are virtually structureless and almost devoid of obvious foliation and lineation. No attempt was made to find subtle preferred orientations by petrofabric measurements with thin sections, but field criteria were applied, and only rarely were inclusions or dark minerals well enough alined to define a foliation.

The Pat Keyes pluton of the Hunter Mountain Quartz Monzonite shows no noticeable foliation at most outcrops, even though it has abundant dark minerals and widespread inclusions, locally as many as 3–6 per square yard. The inclusions, though generally small, are as large as 2 feet across in some outcrops. Examination of outcrops of the Pat Keyes pluton was hampered by the rugged terrain, and as a result, structural features were looked for less carefully than in the Santa Rita Flat pluton. Nevertheless, obvious foliation was not present in the outcrops examined.

The Santa Rita Flat pluton of the Tinemaha Granodiorite has a dark-mineral content that averages 15 percent, although some specimens have more than 20 percent. Yet even with this abundance of dark reference planes, rarely is foliation well enough developed to measure with any degree of confidence. Dark inclusions are widespread in the Santa Rita Flat pluton, and most are only 1–4 inches in maximum dimension, though locally they are as much as 10 inches. These inclusions are generally widely scattered, and two small inclusions in a square yard of outcrop is about the maximum concentration. The inclusions tend to be subspherical, even near the east margin of the pluton where one might expect flattening to show the sort of marginal foliation so typical of the borders of granitic masses in the Sierras.

The Paiute Monument Quartz Monzonite is coarse grained, has a much lower percentage of dark minerals than the Santa Rita Flat pluton, and contains only scattered inclusions. No discernible foliation was found anywhere in this mass.

Joints were measured somewhat systematically in the Santa Rita Flat pluton. Joints with low dips were disregarded, for they are considered to be largely unloading features related to the land surface. The steeply dipping joints, which are more abundant, have a considerable range of strike and dip, but most commonly strike N. 10°–20° E. or N. 40°–60° W.; the dominant dip is 50°–90° W. These joints appear to be related to the two dominant directions of faulting in this segment of the Inyo Mountains (Ross, 1965, p. 055). They are dominantly Cenozoic features related to the uplift of the range rather than cooling features related to the intrusive history of the granitic rocks. Joints were not recorded systematically in the Pat Keyes and Paiute Monument masses.

CHEMICAL TRENDS

The nine chemical analyses from specimens of the granitic masses described in this paper have already been referred to briefly (tables 2, 4, 6). Three additional analyses and related data from other granitic bodies in this region are shown on table 7. These analyses are included in this paper to supplement the chemical data on the three granitic masses. Two of the analyses of table 7 (W–90 and I–1063) are from the Papoose Flat pluton (Ross, 1965, p. 042–044), and the third (W–77) is from an unnamed felsic body just east of the Waucoba Wash quadrangle in the Dry Mountain quadrangle. Papoose Flat specimen W–90 is typical of the massive eastern part of the pluton, and specimen I–1063 is a saussuritized rock in which all the biotite is altered. Specimen W–77 is a medium-coarse-grained felsic granitic rock characterized by pale-red-purple K-feldspar that is distinctly perthitic. This rock is included as part of the Hunter Mountain Quartz Monzonite by B. C. Burchfiel (written commun., 1965), and though it is unlike either the Paiute Monument or Pat Keyes of the Inyo Mountains, it may well be a felsic relative. The pale-red-purple feldspar suggests kinship with those masses.

The major oxides in the analyses from the Paiute Monument Quartz Monzonite and the Pat Keyes and Santa Rita Flat plutons are shown on a standard silica-variation diagram in figure 29. With increasing silica, these rocks show a rather regular, and expected, trend

TABLE 7.—*Chemical data of miscellaneous granitic rocks of the Inyo Mountains*

[Rapid chemical analyses by P. L. D. Elmore, I. H. Barlow, S. D. Botts, G. Chloe, and H. Smith. Semiquantitative spectrographic analyses of specimens W-90 and W-77 by J. D. Fletcher; specimen I-1063, by H. W. Worthing. Looked for but not found in specimens W-77 and W-90; Ag, As, Au, B, Bi, Cd, Co, Ge, Hf, Hg, In, Li, Mo, Pd, Pt, Re, Sb, Ta, Te, Th, Ti, U, W, Zn, Pr, Nd, Sm, Eu. Preceding plus following not found in specimen I-1063; Cs, Dy, Er, Gd, Ho, Ir, Lu, Nd, Os, Pr, Rb, Rh, Ru, Tb, Tm]

	W-90	I-1063	W-77
Rapid chemical analyses (weight percent)			
SiO_2	71. 8	70. 4	73. 6
Al_2O_3	15. 4	16. 1	13. 9
Fe_2O_3	1. 0	. 9	1. 2
Total Fe as FeO	(1. 8)	(1. 6)	(1. 3)
FeO	. 85	. 83	. 17
MgO	. 34	. 32	. 21
CaO	2. 9	2. 9	1. 1
Na_2O	3. 7	4. 1	4. 0
K_2O	2. 8	3. 4	4. 3
H_2O	1. 14	. 44	. 99
TiO_2	. 28	. 26	. 17
P_2O_5	. 17	. 11	. 04
MnO	. 03	. 04	. 05
CO_2	<. 05	<. 05	. 13
Total	100. 41	99. 80	99. 86
Semiquantitative spectrographic analyses (weight percent [1])			
Ba	0. 1	0. 15	0. 03
Be	. 0001	. 0003	. 0005
Ce	. 03	0	. 01
Cr	. 0001	. 0003	. 0001
Cu	. 005	. 0007	. 0001
Ga	. 002	. 0007	. 0015
La	. 02	. 007	. 008
Nb	. 001	0	. 002
Ni	0	. 003	0
Pb	. 002	. 0015	. 002
Sc	0	. 00015	0
Sn	. 0005	0	0
Sr	. 07	. 15	. 03
V	. 002	. 0015	. 002
Y	. 001	. 0007	. 003
Yb	. 0002	0	. 0005
Zr	. 03	. 015	. 015
Norms (weight percent)			
Q	33. 1	27. 0	31. 8
or	16. 5	20. 1	25. 5
ab	31. 3 $\rbrace An_{29}$	34. 8 $\rbrace An_{28}$	34. 0
an	13. 3	13. 7	4. 4
en	. 8	. 8	. 5
fs	. 3	. 4	0
mt	1. 4	1. 3	. 2
il	. 5	. 5	. 3
ap	. 4	. 3	. 1
C	1. 4	. 7	1. 1
cc	0	0	. 3
hm	0	0	1. 1
Total	99. 0	99. 6	99. 3
Niggli numbers			
si	367. 3	341. 4	423. 2
al	46. 4	46. 0	47. 1
fm	10. 2	9. 1	8. 1
c	15. 9	15. 1	6. 8
alk	27. 5	29. 8	38. 1
qz	157. 3	122. 2	170. 9
k	. 33	. 35	. 41
mg	. 25	. 25	. 22

TABLE 7.—*Chemical data of miscellaneous granitic rocks of the Inyo Mountains*—Continued

	W-90	I-1063	W77
Modes [2] (volume percent)			
Plagioclase	43	28	24
K-feldspar	22	27	37
Quartz	27	25	36
Alteration products, largely epidote and muscovite		20	
Mafic minerals	8		3
Total	100	100	100

---

[1] Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc., which represent approximate midpoints of interval data on a geometric scale. The assigned interval for semiquantitative results will include the quantitative value about 30 percent of the time.

[2] Estimate of mode of unaltered rock (specimen I-1063): plagioclase, 42; K-feldspar, 27; quartz, 25; mafic minerals, 6.

Location of specimens:
W-90. NW. cor. Waucoba Wash quad., about 3,500 ft N. 69° W. of N W cor. sec. 30, T. 11 S., R. 37 E.
I-1063. About 3,500 ft S. 43° W. of NW. cor. Independence quad.
W-77. Near west boundary of Dry Mountain quad., about 2,000 ft S. 40° E. of NW cor. sec. 21, T. 13 S., R. 39 E.

of decreasing A_2O_3, total Fe, MgO CaO, increasing K_2O, and relatively constant Na_2O. Also shown on the diagram is the anorthite content of the normative plagioclase, which decreases with increasing silica; this decrease is predictable from the trend of the CaO. One analysis, for specimen 279 (a sample of the fine-grained quartz monzonite-granodiorite facies of the Pat Keyes pluton), seems to be markedly "out of line" in the variation diagrams. This specimen is notably high in Al_2O_3 and Na_2O and low in total iron and CaO. As a consequence, it has a more sodic normative plagioclase than would be expected for a rock of this silica content in the suite. These anomalies further corroborate the field observation that this rock may be contaminated.

To compare the rocks of the Inyo Mountains with nearby analyzed granitic rocks of the eastern Sierra Nevada, a composite silica-variation diagram (fig. 30) was made. This figure incorporates, in addition to the data from figure 29, the data from table 7, and analyses from Bateman (1965), Moore (1963), and Rinehart and Ross (1964). Two main points can be deduced from this diagram: (1) The Papoose Flat specimens, I-1063 and W-90, do not seem to fall on the same trend as the other nine analysis from the Inyo Mountains, whereas the felsic body, W-77, does lie on a continuation of this trend, and (2) total iron oxide, MgO, CaO, and Na_2O trends in the Sierra Nevada are generally similar to those from the Inyo Mountains. However, K_2O is somewhat lower and Al_2O_3 is somewhat higher in the Sierra Nevada analyses, particularly in many of the analyses of Moore (1963) from the Mount Pinchot quadrangle immediately west of the area of this report. The Mount Pinchot rocks are about 1 percent higher in Al_2O_3 than rocks of comparable SiO_2 in the Inyo Mountains.

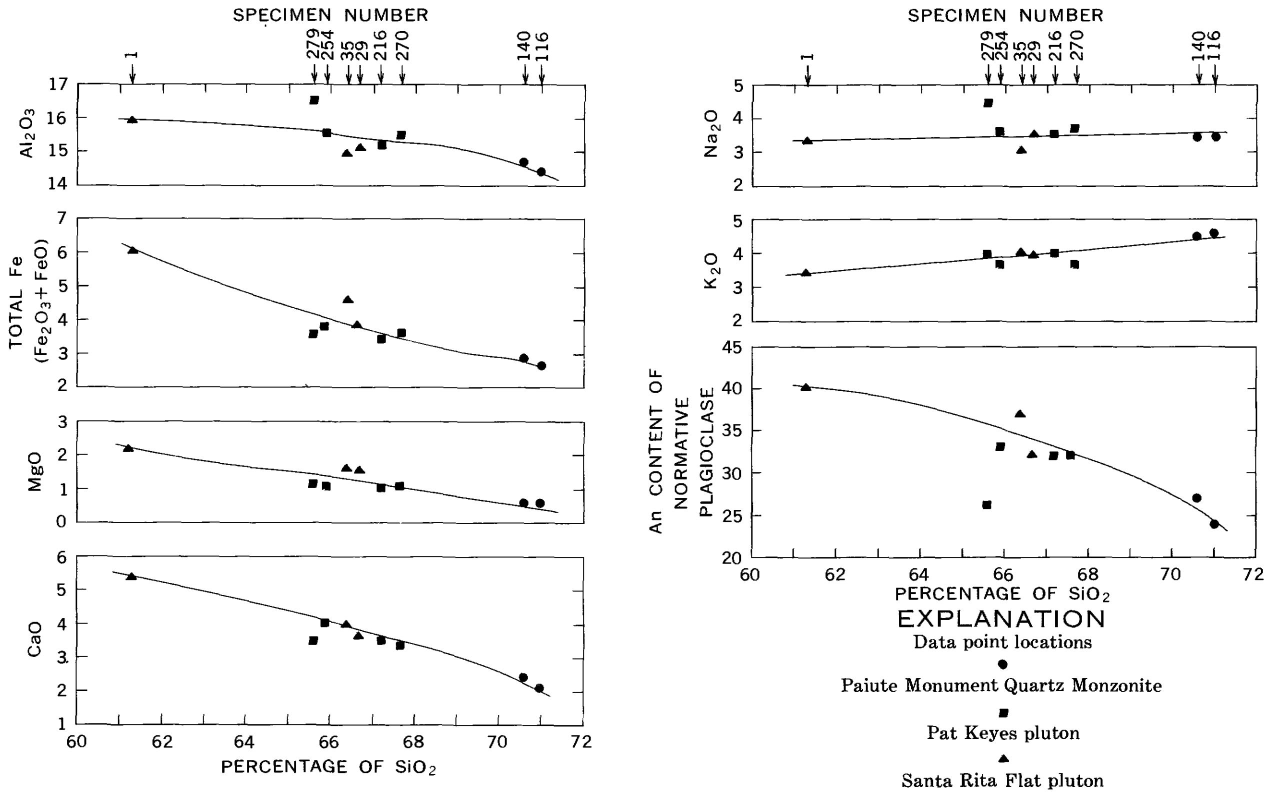

FIGURE 29.—Variation of percentage of common oxides and An content of normative plagioclase plotted against percentage of SiO_2 for specimens from Paiute Monument Quartz Monzonite and the Pat Keyes and Santa Rita Flat plutons.

The anomalous plot of specimens from the Papoose Flat pluton should not be considered very significant until more data are available, but it is interesting to note that the Papoose Flat has a biotite age of about 80 million years (Late Cretaceous) and that the three masses described in this report have isotopic ages generally in the range of Middle to Early Jurassic. This difference suggests that the Papoose Flat is a felsic member of a different suite and that W–77, which seems to be on the same trend as the three large masses from the Inyo Mountains, may be a felsic end member of the Jurassic suite.

For a comparison with the silica-variation diagram, the rocks from the Inyos and eastern Sierra Nevada were plotted on the diagram of Thornton and Tuttle (1960, p. 673). They plotted the various oxides against a differentiation index, which is the sum of normative quartz, orthoclase, and albite in quartz-bearing granitic rocks. The plots of the rocks from the Inyos and eastern Sierra Nevada (pl. 5) are remarkably linear for oxides. They also fall along the same trend as the plots of 5,000 chemical analyses of Washington, which were contoured by Thornton and Tuttle (1960). The slight enrichment in Al_2O_3 and the deficiency in K_2O of the Mount Pinchot rocks in relation to the rocks from the Inyos is detectable on plate 5, but is not as noticeable as in figure 30. Also, the plots of most oxides for the Papoose Flat pluton are much closer to the trend line on plate 5 than they are in figure 30, the silica-variation diagram. For these rocks from the Inyos and Sierra Nevada, the silica-variation diagram seems to show more differences between some of the rocks than does the differentiation index.

To see the relations of selected oxides in this suite without the somewhat overpowering influence of SiO_2, figure 31 was constructed. It plots total iron oxide ($FeO+Fe_2O_3$) against MgO and also total iron oxide plus MgO against CaO. Figure 31*A* shows a good linear trend for all the rocks from the Inyos including specimens from the Papoose Flat. Figure 31*B* also shows a pronounced linear trend, but with somewhat more spread than figure 31*A*. Specimens from the Papoose Flat, however, do not fall on this trend; their low total iron and high CaO are apparent here as well as on the silica-variation diagram.

Specimen 279 of fine-grained quartz monzonite-granodiorite from the border facies of the Pat Keyes pluton falls close to the linear trend line in both figures 31*A* and *B*, even though it is low in both total iron oxide and CaO when compared with SiO_2 (fig. 29). Its position thus suggests that ratios among iron oxide, MgO,

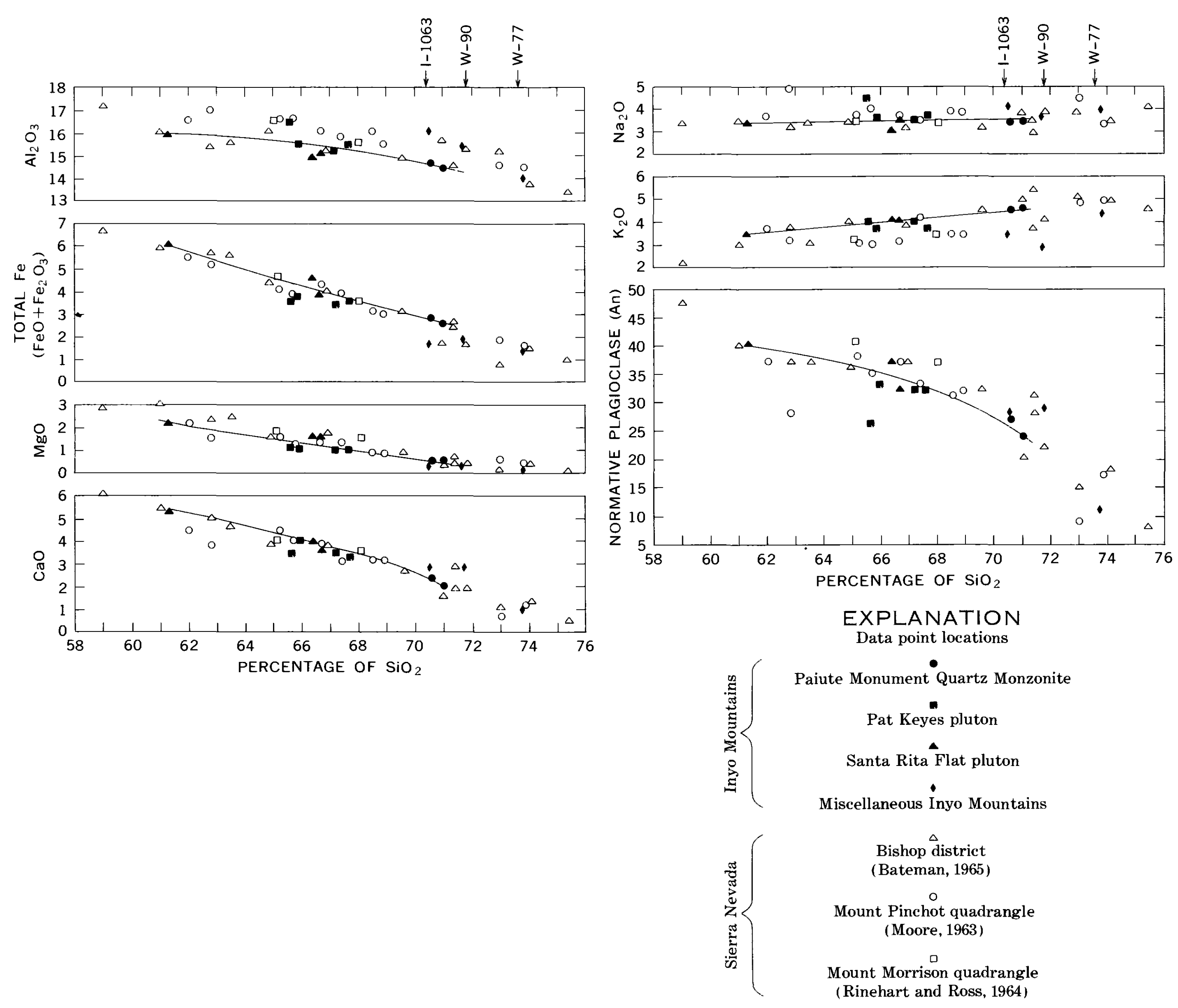

FIGURE 30.—Variation of percentage of common oxides and An content of normative plagioclase plotted against percentage of SiO_2 for specimens from the eastern Sierra Nevada and Inyo Mountains.

and CaO have not been noticeably affected by the contamination of this rock.

As part of a computerized program of norm determinations, various ternary ratios of oxides and normative minerals were calculated for the analyses from the Inyos. Triangular diagrams made from these ratios are shown in figure 32. The Alk–F–M triangle is particularly distinctive. It shows virtually a linear trend along which the different plutons are separated much more clearly than they are on the silica-variation diagrams. This separation suggests that the ratio of total alkalis to iron oxide and magnesia in the rocks from the Inyos is more definitive than the ratio of oxides to silica, or the silica content alone, in illustrating chemical trends and possibly in distinguishing granitic suites of different histories or ages. The plot of these rocks on the A–C–F triangle shows a clustering along the F–An tie line, which is to be expected for unaltered granitic rocks. The three rocks (I-1063, W-90, and W-77) that fall considerably away from the cluster further indicate the differences of these rocks from the other granitic rocks of the Inyo Mountains.

Both the lower triangles of figure 32 show the relations of normative quartz and feldspar. These plots tend to cluster the rocks from the Inyos and do not produce a marked trend. When silica is brought into the ratios, as in Q–Or–Ab+An, specimen 279 plots away from the specimens of the Pat Keyes pluton, whereas, when silica

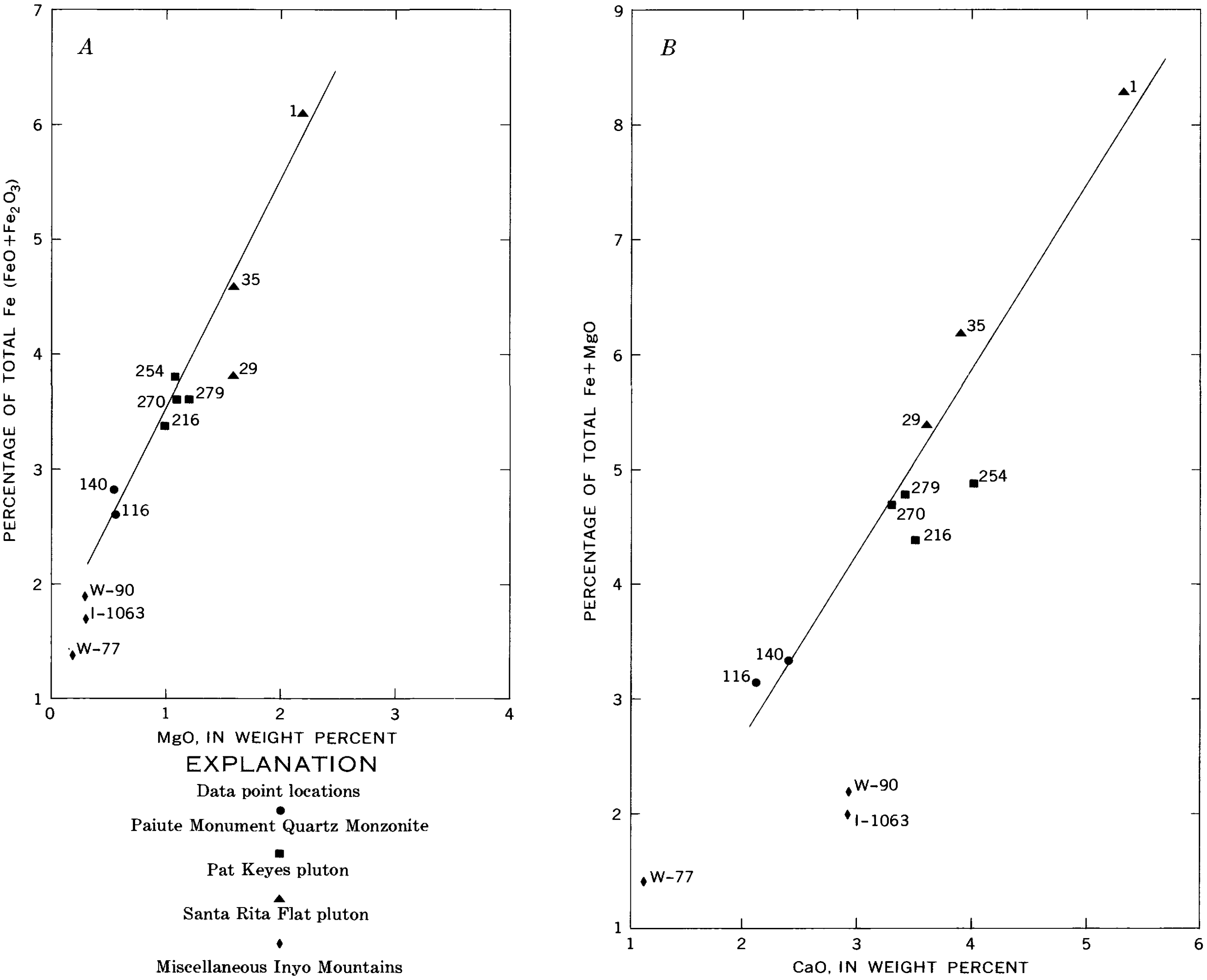

FIGURE 31.—Selected oxide percentages of granitic rock specimens from the Inyo Mountains.

is not considered, as in the upper two triangles of figure 32, specimen 279 plots with the others from the Pat Keyes pluton. In other words, the ratio of some of the oxides (chiefly high Na_2O and low CaO) to silica is what makes specimen 279 anomalous in this suite.

For comparative purposes, the fields of some of Nockolds' average rocks and analyzed granitic rocks of the eastern Sierra Nevada region are superimposed on the triangles of figure 32. The almost perfect match between the rocks from the Sierra Nevada and the Inyos is no surprise and is further evidence that they are part of the same composite batholith.

The much maligned silica-variation diagram still is of service in the Inyo Mountains region to someone who is deciding whether particular rocks belong to the same or different suites, and it also helps to identify anomalous rocks in a suite. The specimens from Papoose Flat and specimen 279 exemplify these points very well. Also, the triangular plot of Alk–F–M in this suite seems to be the best of the standard plots for graphically presenting the oxide data without showing the influence of silica. A dozen analyses in granitic masses that crop out over hundreds of square miles certainly do not permit firm conclusions about chemical trends and relations, but even this small number points out a regularity that agrees with the field-mapping data and corroborates anomalies that were anticipated during the mapping.

The relations of the modal quartz and feldspar to the virtually comparable normative constituents has already been discussed briefly in the section on "Chemical data" for each of the three granitic masses. In summary, all 12 analyses of granitic rocks from the Inyo Mountains show less normative orthoclase than modal K-feldspar. It appears that the amount of the Ab molecule in the K-feldspar more than counteracts the effects of the K_2O in biotite, even in rocks that have significant amounts of biotite. The relation of normative orthoclase to modal K-feldspar from 23 samples

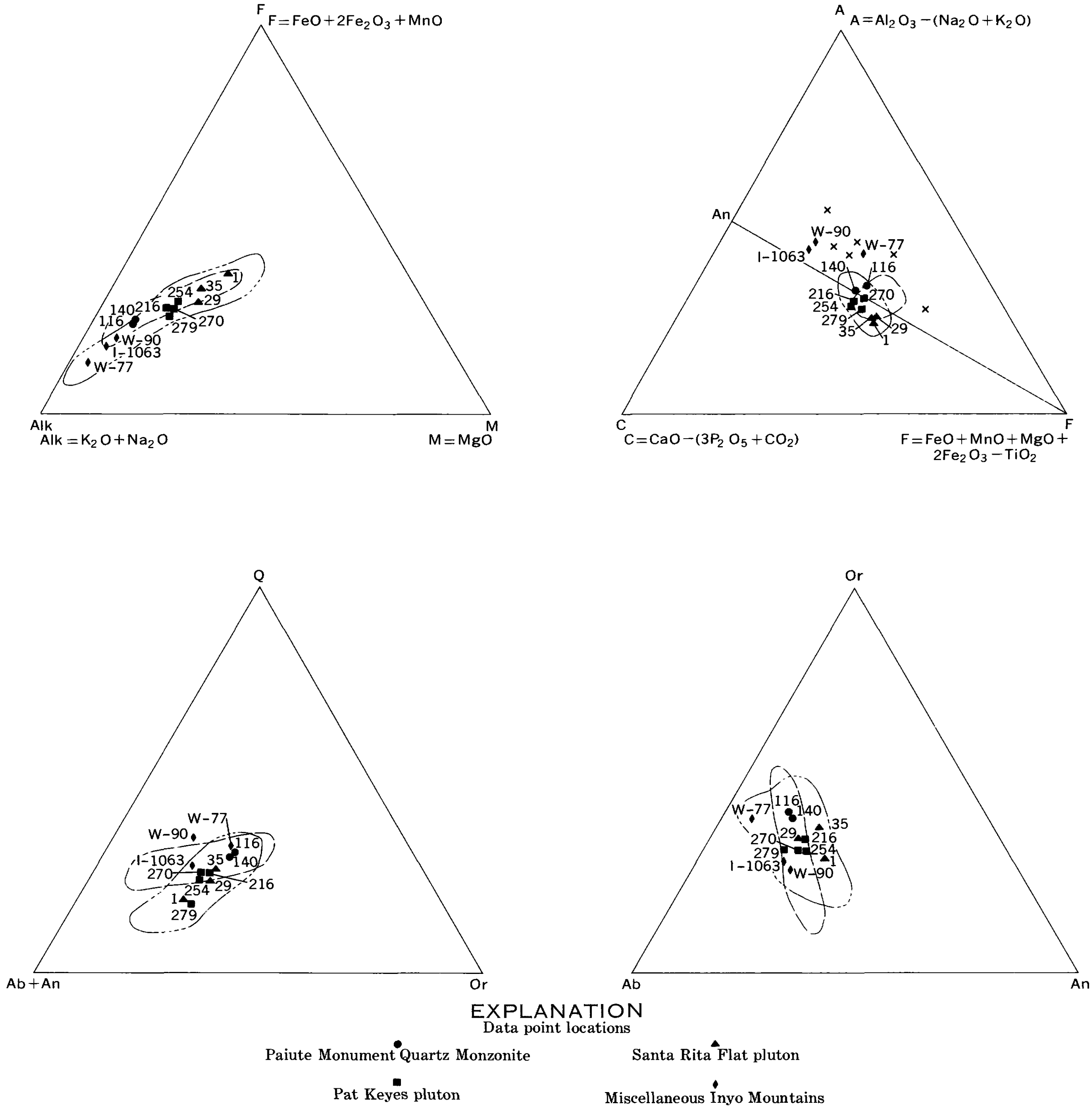

FIGURE 32.—Ternary plots of selected oxides (in mol percent) and normative minerals, Inyo Mountains. Dashed lines enclose field of average calc-alkali granite, rhyolite, adamellite, dellenite, granodiorite, rhyodacite, tonalite, and dacite of Nockolds (1954, p. 1012–1015, table 1, columns 1, 2; table 2, columns 1, 2, 3, 4, 5, and 6). Dotted and dashed lines enclose field of eastern Sierra Nevada granitic rocks (Moore, 1963, p. 43; Rinehart and Ross, 1964, p. 47; Bateman, 1965, p. 63). On A–C–F diagram, X marks rocks that are outside concentrated field of points of eastern Sierra Nevada granitic rocks.

from the eastern Sierra Nevada does not show this consistency. Thirteen samples show less normative orthoclase than modal K-feldspar, but 10 show just the opposite. This variation suggests tentatively that there may be some difference in the K-feldspar of the Sierra Nevada batholith toward its east margin.

PETROGENESIS

Much evidence has been published to attempt to prove that most of the granitic rocks of the Sierra Nevada crystallized from a granitic melt and are not products of some sort of granitization process (Bateman, 1965, p. 115; Moore, 1963, p. 112–114). Certainly nothing in the field relations or the modal and chemical character of the Santa Rita Flat and Paiute Monument masses refutes this concept. Both of these plutons have sharp, clean contacts with their wallrocks and have sent dikes out into the walls. The zoning away from the wallrock contact of the Santa Rita Flat pluton is the kind of mineralogical and chemical zoning one would postulate for an intruded magma cooling progressively from walls to center. The Paiute Monument Quartz Monzonite is markedly homogeneous, lacks signs of marginal assimilation, and was obviously intruded into the wallrock. One segment along this contact, however, is an exception to this sharp, clean relation (pl. 2). From the area near which specimen 138 was collected, north to the area near which specimen 112 was collected, there is some mixing of granitic and metamorphic material. Even here, however, most of the contacts examined are sharp, and the general appearance is one of complex diking rather than chemical reaction.

In contrast to the relatively homogenous Santa Rita Flat and Paiute Monument masses, the Pat Keyes pluton is markedly heterogeneous. What seemed to be a hodgepodge of variation during early fieldwork subsequently became a rather systematic pattern (fig. 10). The medium-grained seriate quartz monzonite, typified by specimen 270, is believed to be the crystallized product of the parent melt of the Pat Keyes pluton. The seriate rock is the central core of the pluton. The other two rock types, a relatively homogeneous fine-grained quartz monzonite-granodiorite and a widely variant dark-colored facies, are believed to be portions of the parent melt that were contaminated with wallrock material. Because the two contaminated facies are generally in sharp contact with the metamorphosed sedimentary wallrocks on the west side of the pluton, the assimilation of the material that contaminated it occurred at some greater depth. Furthermore, the exposed contact does not suggest large-scale assimilation. Seemingly the great bulk of contaminated material should grade through a diffuse, somewhat migmatitic zone to recognizable wallrock, if the bulk of the contamination occurred in place or nearly so. The large inclusions of dominantly carbonate rock in the eastern part of the mass may well be undigested wall remnants, but it is difficult to say whether they are nearly in place, have been carried along with the rising magma, or were frozen here when sinking from the roof.

A heterogeneous mass such as the Pat Keyes might be interpreted by some as a product of granitization. The relatively homogeneous core could have been reconstituted from wallrock material to granitic material, and the marginal facies could be a preserved, partially granitized rim between undigested wallrock and completely digested granitized core rock. Certainly one of the problems here is how one can recognize the difference between a marginal zone of a magma contaminated by assimilated wallrock and a partially granitized mass. Very probably, because of the physical problem of access, this is not a pluton that will provide many answers.

The Pat Keyes pluton has relatively sharp walls and sends out apophyses into its walls. It is in a region of unquestioned magmatic rocks. Its central core is physically and chemically closely related to the magmatic Paiute Monument Quartz Monzonite. The pluton might have become mobilized from wallrock material at some depth, but the possibility that what is visible at the level of present-day exposures is an in situ replacement of granitic rock can be ruled out.

The Hunter Mountain Quartz Monzonite, of which the Pat Keyes pluton is one component part, is notable for heterogeneity in other outcrops also. In the Ubehebe Peak quadrangle, a calcic facies ranges in composition from olivine gabbro to monzonite (McAllister, 1956). In the Darwin quadrangle, a somewhat coarser, darker colored border facies is poor in quartz and probably is the result of assimilation of calcareous country rock by rocks of the Hunter Mountain type (Hall and MacKevett, 1962, p. 29). A rather coarse-grained, quartz-poor patch of monzonitic rock surrounds one of the large carbonate inclusions in the eastern part of the Pat Keyes pluton in what appears to be a similar relation. Also, the presence of orthopyroxene in the contaminated rocks of the Pat Keyes pluton suggests that it is approaching the bizarre varieties described in the Ubehebe Peak quadrangle. Clearly, the Hunter Mountain Quartz Monzonite has had a complex history, but basically it appears to have formed from a magma with a more than average capacity to digest wallrock. As the oldest recognized large intrusive mass in this region, it may be somewhat different from the later intrusives in the Sierra Nevada. For one thing, being early in the intrusive sequence and on the east margin of the Sierra

Nevada batholith, it had access to more nonbatholithic wallrock and may be more contaminated for this reason.

Another distinguishing characteristic of the Hunter Mountain Quartz Monzonite is the local presence of olivine and orthopyroxene in contaminated parts of the body. These high-grade igneous minerals are rare in the granitic suite in the eastern part of the Sierra Nevada. In fact, the only previously mentioned occurrence of them was in the Casa Diablo quadrangle, where small bodies of olivine-hypersthene gabbro remain as residuals from the reaction of quartz monzonite magma on gabbro inclusions (Rinehart and Ross, 1957). This reaction also resulted in hornblende gabbro and diorite of widely variant grain size and composition. These rocks form a zone between the olivine-hypersthene gabbro remnants and the uncontaminated quartz monzonite. Possibly, the olivine and orthopyroxene of the Hunter Mountain Quartz Monzonite are the result of some contamination from earlier gabbroic masses at depth.

The Paiute Monument Quartz Monzonite, although it is a separate and distinct intrusive mass, may well be genetically related to, and part of, the Hunter Mountain Quartz Monzonite. The general physical resemblance of the seriate quartz monzonite of the Pat Keyes pluton and the Paiute Monument Quartz Monzonite, as already noted, is striking and is accented by the pale-red-purple K-feldspar of both masses. The difference between them is largely one of grain size. Also, the spatial relationship, both in the Inyo Mountains and in the Argus-Coso Ranges (pl. 1), suggests that the Paiute Monument and related types may be felsic members of the Hunter Mountain suite; that is they are later pulses from the same magma. Also, on the basis of mineral age determinations both the Hunter Mountain and the Paiute Monument masses seem to belong to the same Jurassic intrusive suite.

CONTACT METAMORPHISM

The processes of contact or, more correctly, thermal metamorphism, have transformed the Paleozoic sedimentary wallrocks and developed metamorphic minerals for distances as much as 2 miles from the granitic contacts. The enormous quantity of heat necessary to accomplish this metamorphism apparently came from the magma that has frozen into the plutons exposed today. The wide zone of contact metamorphism is another line of evidence that indicates a predominantly magmatic origin for the granitic rocks of this region. The metamorphism produced by these large plutons was largely thermal; directed stresses to produce schistose and gneissic structures are notably lacking, and hornfels is the typical metamorphic rock. Locally banded and crudely schistose metamorphic rocks can be accounted for by recrystallization in a thermal environment. Directed stresses may well have been a factor in causing the metamorphic aureole around the Papoose Flat pluton along the north boundary of the map area (pl. 1), but this body, being studied in detail by C. A. Nelson and his colleagues, is not discussed in this report.

Figure 33 illustrates the general distribution of metamorphic minerals in the contact aureole of the three plutons. The letters on the map show the location of metamorphic minerals, identified largely from thin sections; metamorphic feldspar has not been included. It should be remembered that this illustration is not based on a systematic collection of the contact metamorphic rocks, but is a byproduct of the study of specimens selected for a number of purposes. Hence, areas without letters indicate either inadequate data or lack of metamorphism. The blank area enclosed by the dashed line, however, probably reflects an area where metamorphic minerals are virtually absent. Also, the V-shaped area of wallrock directly east of the area enclosed by the dashed line is virtually unmetamorphosed.

Some generalizations can be made from figure 33. Around the south rim of the area having no metamorphic minerals, tremolite, talc, and phlogopite are present in the carbonate rocks, which are dominantly dolomite. These assemblages are characteristic of the albite-epidote hornfels facies, which is typical of the outer margins of contact aureoles (Fyfe and others, 1958, p. 204). These assemblages are also described in the outermost contact metamorphic zones in an area in Arizona where a detailed study of carbonate rocks was made by Cooper (1957, p. 581).

Nearer the granitic contacts a varied suite of calc-silicate minerals has been developed from the carbonate rocks. The minerals include diopsite, forsterite, epidote, scapolite, idocrase, grossularitic garnet, and wollastonite. They occur in a variety of assemblages, some of which follow:

Representative calc-silicate assemblages from Paleozoic wallrocks

Diopside-wollastonite-K-feldspar-quartz-calcite
Diopside-wollastonite-idocrase-calcite
Tremolite-diopside-scapolite-quartz-calcite
Diopside-scapolite-oligoclase-calcite
Forsterite-calcite
Tremolite-scapolite-K-feldspar-quartz-calcite
Wollastonite-scapolite-diopside-grossularite
Diopside-tremolite-epidote-K-feldspar-plagioclase-muscovite
Diopside-wollastonite-calcite
Wollastonite-diopside-grossularite-calcite
Wollastonite-tremolite-diopside-calcite-quartz

The assemblages characterize the hornblende hornfels facies, which persists up to the contact with many granitic rocks (Fyfe and others, 1958, p. 205–209). Cooper

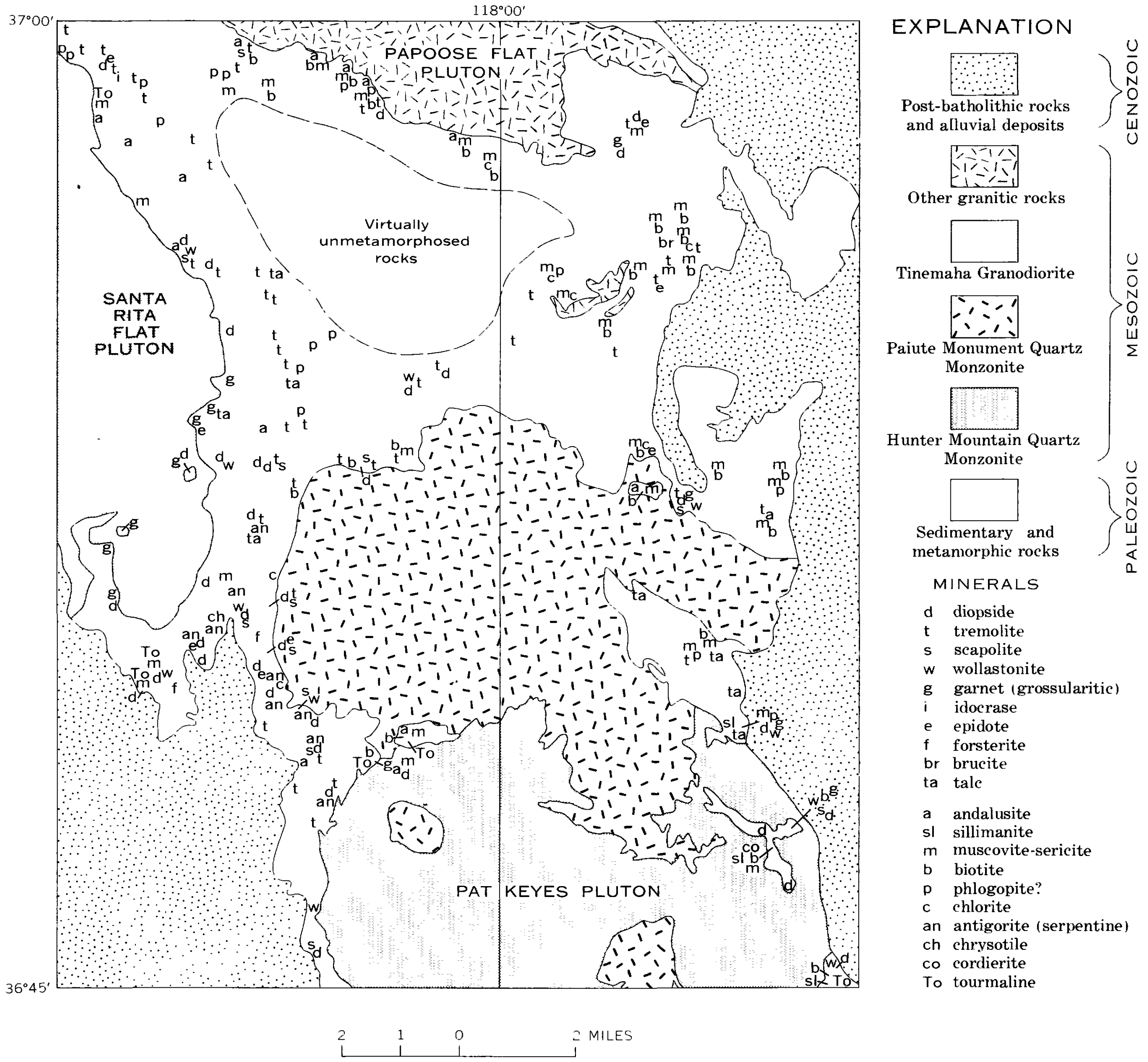

FIGURE 33.—General distribution of contact-metamorphic minerals in the northern Inyo Mountains.

(1957, p. 581) also reported these minerals from the inner zones of his contact aureole in Arizona. The carbonate assemblages in the Inyo Mountains seem to be about like those found around similar granitic rocks elsewhere and are also compatible with the upper metamorphic grade described from the Sierra Nevada (Bateman, 1965, p. 31–33). Most of the pendants in the Sierra Nevada do not seem to show the lower albite-epidote hornfels facies, but Rinehart and Ross (1964, p. 9) suggested that there is a possible transition to this facies in the large Mount Morrison roof pendant. Their suggestion is based on the abundance of epidote and tremolitic amphibole rather than hornblende in the metamorphosed carbonate rocks.

Wollastonite is the highest metamorphic grade indicator in the calc-silicate suite, which may indicate a transition to the pyroxene hornfels facies, according to Bateman (1965, p. 31). All the wollastonite occurrences shown in figure 33, except one, are close to a granitic contact or are in the narrow neck of metamorphosed rock between two large plutons where granitic rock is probably at a shallow depth. The one exception is a wollastonite-diopside-tremolite assemblage, nearly a mile from a granitic contact. Here again granitic rock could underlie the metamorphic rocks at shallow depth. About all that can be said at present is that at least locally, near granitic contacts, the upper limit of the hornblende hornfels facies was approached and possibly passed.

Brucite was found in only one specimen, in abundant fresh-looking flakes that appear to be primary, not pseudomorphous after periclase. Turner (1965, p. 393), in commenting on the genesis of brucite, noted that: "Consideration of available thermodynamic data and the published results of direct experiments * * * permit the following conclusions to be drawn: (1) at very low partial pressures of CO_2 (perhaps of the order of 1 bar) and relatively high partial pressures of water (up to 2,000 bars), dolomite can break down directly to brucite and calcite at temperatures above about 400°C * * * ." The presence of brucite thus indicates temperatures which are also associated with the upper part of the hornblende hornfels facies; however, brucite was the only metamorphic mineral in a silty calcarenite almost a mile from the nearest surface exposure of granitic rock, a small aplite-alaskite body. Bowen (1940, p. 248) noted that brucite is commonly found in contact aureoles formed at shallow depth and is associated with quartz- or chert-bearing marble that does not contain wollastonite. The rarity of brucite in the Inyo-eastern Sierra region (Bateman, 1965, p. 32, also reported only one occurrence in the Bishop district) seems somewhat enigmatic. Suitable temperatures and the proper chemical constituents for its formation seem to have been common near granitic contacts in the Inyo Mountains, yet brucite is extremely rare. Perhaps the rarity of suitable pressure conditions limits the occurrence of brucite in this region.

Metamorphic minerals have formed in the marly and silty clastic rocks of the Paleozoic section as well as in the carbonate rocks. Phlogopite, already mentioned, as well as chlorite, muscovite, and biotite are present in varied amounts in the recrystallized clastic rocks. Andalusite, generally of the chiastolite variety, is particularly abundant in the metamorphosed Mississippian shales near the Santa Rita Flat pluton.

Tourmaline in the metamorphosed wallrocks is worthy of note, even though it is not a contact metamorphic mineral in the strictest sense. Its formation, whether from the reconstitution of boron in the clastic sedimentary rocks or from boron introduced from the granitic rock, is another indication of a thermal environment compatible with a magmatic origin for the granitic rocks. Six occurrences of tourmaline that is not detrital were also noted; most are associated with metamorphic mica in what were formerly fine-grained clastic rocks. The tourmaline could have originated in either of the ways mentioned previously. One occurrence, as coarse-bladed crystals in a quartzite near a granitic contact, probably represents the introduction of material from the granitic melt, but it could also be the result of remobilization of boron from nearby sedimentary rocks.

Along the east margin of the area of the figure 33, in roof pendants of Paleozoic rocks, sillimanite has been identified in three localities. At each locality it is near rocks that have reached a high enough grade of metamorphism to form wollastonite. These are interesting occurrences, for unlike many in this region where suspected sillimanite is in small needles whose optic properties are difficult or impossible to determine, these sillimanite crystals are large enough to be readily identified. Associated with the sillimanite in one specimen is cordierite, the only known occurrence in the area of figure 33.

In summary, the exposed wallrocks in this area have at least at crude zonation from virtually unmetamorphosed rocks through the albite-epidote hornfels facies into the hornblende hornfels facies near the granitic contacts. The presence of wollastonite indicates that the upper limit of the hornblende hornfels facies has been approached and may have been locally exceeded. Also, that wollastonite is some distance from present granitic contacts suggests the possibility that granitic rocks exist at a shallow depth under parts of the Paleozoic terrain. No demonstrable difference in grade or type of metamorphism has been noted from the various plutons. For example, wollastonite occurs at the contact of all the plutons, but because general petrography and chemistry of these plutons is similar, a parallel thermal history would also be expected.

METHODS OF EMPLACEMENT

The plutons described in this report were intruded to their present position as magmatic melts of dominantly fluid material. This concept is based on regional considerations and on local evidence. The mechanism by which they were emplaced is, however, in question. It is commonly believed that a melt can advance upward passively or forcibly. Passive emplacement consists dominantly of replacing the wallrock material with granitic melt material by assimilation and digestion of the bounding-wall material. It may also involve the engulfing of wallrock blocks by stoping, a process which commonly works with assimilation. Forcible emplacement consists of pushing upward and outward on the walls and roof in order to deform them sufficiently to make room for the granitic melt. In the plutons under discussion in this paper, both passive and forcible methods have been used, but their relative importance is somewhat difficult to determine.

Wallrock of the Santa Rita Flat pluton is exposed only on the east side. Here the contact is generally sharp, and there is little evidence of assimilation. Though there are numerous relatively minor irregularities, the contact does not have the blocky embayed look that might indicate block stoping. On the other hand, some of the folds in the upper Paleozoic rocks parallel to the east wall may have resulted from the pushing of the granitic melt against the walls. Although the total area of the body is only speculative, since the west wall is buried beneath the Cenozoic deposits of Owens Valley, mineral and specific gravity zoning suggests a body of about the shape that is presently exposed The west wall may be fairly close to the west limit of outcrop in Owens Valley. Speculation can also be made that the west contact may be straight and relatively steep and that the Santa Rita Flat pluton is virually a large blunt-end dikelike body. Most of the presently exposed wall contact is with Rest Spring Shale (now metamorphosed largely to andalusite hornfels) and thinly bedded carbonates of the Keeler Canyon Formation. Both of these formations strike generally parallel with the contact and may have presented a weak access zone for the magma. There is some evidence that the beds were crumpled by the intruding magma; however, the general strike of the Paleozoic rocks immediately east of the pluton does not seem to fit the several miles of compression needed to accommodate the Santa Rita Flat pluton.

The Paiute Monument Quartz Monzonite has remarkably sharp contacts and is of such a homogeneous composition that it is inconceivable that assimilation and wallrock digestion were large factors in its emplacement. Yet the north wall of this mass is probably the best potential place for stoping and passive encroachment in the region. A belt of overturned Lower Cambrian rocks that strikes along the north wall is interrupted by a giant "bite" of quartz monzonite, but the strike is unaffected. Two, now-isolated, small roof pendants maintain this same strike and thus leave little doubt that along this wall, at least, the later phases of intrusion were passive. Stoping, with the remarkable disappearance of all the stoped blocks, seems the most probable answer for this wall. By contrast, only a short distance southwest, forcible emplacement is indicated by the tightly squeezed nose of a large overturned fold (Ross, 1965, pl. 1). The fold probably predates the intrusion, but the attenuation of the nose of the fold may well be related to the intrusion. There is some question as to whether the Santa Rita Flat or the Paiute Monument intrusion is responsible for the tightening of the fold. Each could have been partly responsible, particularly if the two intrusions are about the same age, as now seems likely.

Steep contacts characterize most of the boundaries of the Paiute Monument mass, but along the south side, and particularly in the irregular lobe that protrudes into the Pat Keyes pluton, gentle dips are common. The gentle dips of this lobe suggest that a somewhat flatlying, sheetlike mass extends out from the main mass of the Paiute Monument mass. Again, the contact is sharp and thus indicates almost no reaction with the wallrock of the Pat Keyes pluton. The protrusion, the dikelike mass farther south, and the small stock of Paiute Monument Quartz Monzonite to the west are probably forcible intrusions. Unfortunately, the wallrock consists generally of massive granitic rocks, which have no good reference planes to show deformation.

The Paiute Monument Quartz Monzonite is a paradox as far as emplacement is concerned. Its map pattern suggests some large-scale stoping, but I cannot conceive of stoping without accompanying assimilation; yet the mass shows no boundary assimilation effects. Apparently this felsic pluton was inert as far as reaction with its walls was concerned; the intrusion must have been almost entirely a mechanical invasion wherein chemical action was nil.

Much of the original northward extension of the Pat Keyes pluton has been engulfed by the younger Paiute Monument mass. Only along the west side of the mass are older wallrocks exposed. Here the contacts are generally sharp and steep. One plunging syncline could have been doubled up by the invading magma, but the fold could as well predate the intrusion. As previously stated (p. 39), the Pat Keyes pluton with its heterogeneous composition seems to have been chemically active, but the present level of exposure is some distance above that at which most assimilation took place. Elsewhere the Hunter Mountain Quartz Monzonite shows evidence of forcible intrusion. In the Ubehebe Peak quadrangle, for example, the portion of the mass making up Ubehebe Peak has punched its way in, almost pistonlike, and crumpled the Paleozoic walls (McAllister, 1956).

AGE

The youngest rocks that are intruded by granitic rocks of the Inyo Mountains suite are fossiliferous Middle Triassic sedimentary rocks in the New York Butte quadrangle (W. C. Smith, oral commun., 1962); they are cut by a granitic rock that is correlative with the Hunter Mountain Quartz Monzonite. The Santa Rita Flat pluton of the Tinemaha Granodiorite intrudes rocks as young as the Keeler Canyon Formation of Pennsylvanian and Early Permian age. The Paiute Monument Quartz Monzonite is in intrusive contact with the questionable Rest Spring Shale of Mississippian age, but nothing younger. All these granitic rocks are partly capped by remnants of late Cenozoic volcanic flows and ash falls.

Field relations, such as intrusive contacts and outcrop patterns, indicate that the Paiute Monument Quartz Monzonite is younger than the Hunter Mountain Quartz Monzonite, as represented by the Pat Keyes pluton. The Tinemaha Granodiorite, as represented by the Santa Rita Flat pluton, is not in contact with other granitic rocks, and, therefore, its relative age cannot be determined from field relations.

Radiometric mineral ages have been determined for 15 mineral separates of biotite, hornblende, and zircon from nine different samples of granitic rock from the Inyo Mountains region (pl. 1). The results of these determinations are summarized in figure 34. New data on four hornblendes and one biotite are shown on table 8. Figure 39 suggests that most of the granitic rocks of the Inyo Mountains range in age from Early to Middle Jurassic, on the basis of mineral ages and the currently accepted systematic boundaries of 135 and 180 m.y. (million years) for the Jurassic. The notable exception is the quartz monzonite of Papoose Flat: the biotite from this rock give a Late Cretaceous age.

The Pat Keyes pluton of the Hunter Mountain Quartz Monzonite was provisionally considered Triassic or Jurassic in age by Ross (1965, p. O48). It has had two hornblende age determinations: the one for specimen 270 (163 ±5 m.y.) is about the same as that from the Paiute Monument Quartz Monzonite, but the other for specimen 279 gives the oldest hornblende age (178 ±5 m.y.) in the Inyo Mountains. The zircon from specimen 270 is also the oldest in the Inyo Mountains (210 ±20 m.y.). Several other age determinations made from other parts of the Hunter Mountain Quartz Monzonite tend to support an older age for the Pat Keyes pluton. Two biotite samples from presumably correlative rocks in the Argus Range give ages of about 180 m.y. (Hall and MacKevett, 1962, p. 31). In addition, a zircon from the Ubehebe Peak quadrangle gives an age of 190 m.y. (W. E. Hall, written commun., 1961), and zircons from the same Argus Range locations as the biotite samples give ages of 180 and 210 m.y. (Hall and MacKevett, 1962, p. 31). All three zircon ages have a possible analytical error of ±20 m.y. Biotite from a presumed felsic differentiate of the Hunter Mountain Quartz Monzonite (W–77) gives a Middle Jurassic age (156 ±4 m.y.), and a biotite sample from the Burgess Mine area in the New York Butte quadrangle (R. W. Kistler, oral commun., 1966) gives a latest Jurassic age (134 m.y.); both of these biotites may have lost argon by reheating. Most of these data suggest an Early Jurassic age for the Hunter Mountain Quartz Monzonite.

Sample 29 from the Santa Rita Flat pluton of the Tinemaha Granodiorite has virtually concordant hornblende and zircon ages and a discordant (considerably younger) biotite age. This same relation holds true in correlative masses in the Sierra Nevada where biotite ages of 79–131 m.y. have been obtained from samples whose hornblende ages range from 150 to 183 m.y. (Kistler and others, 1965, p. 157). The discordance may, at least in part, be due to the argon loss from biotite as a result of the reheating of the Tinemaha by later Cretaceous intrusives in the Sierra Nevada. The Santa Rita Flat pluton may have been similarly affected by younger intrusives, because it is near the Cretaceous quartz monzonite of Papoose Flat. The range in hornblende ages may reflect a similar but less pronounced differential heating effect; in other words, the hornblende may more closely approximate an intrusive age. From the data at hand, the Tinemaha Granodiorite, which includes the Santa Rita Flat pluton and which was assigned a Jurassic or Cretaceous age by Ross (1965, p. O48, pl. 1), is now considered to be Early Jurassic.

From the Paiute Monument Quartz Monzonite there is a concordant age for hornblende (163±5 m.y.) and biotite (157 m.y.) from specimen 140, and a comparable biotite age (156 m.y.) for specimen 116. The Paiute Monument appears to have been less affected by later intrusives than the Santa Rita Flat pluton, and it is somewhat farther away from present exposures of Cretaceous intrusive rocks. The zircon age for specimen 140 (170 ±20 m.y.) compares with the biotite and hornblende ages, but the zircon age from specimen 116 (190 ±20 m.y.) is somewhat greater, although still within the same general age range if the analytical error is considered. Taking into account all the mineral ages

TABLE 8.—*Mineral ages of some granitic rocks of the Inyo Mountains*

[Decay constants: $\lambda\beta=4.72\times10^{-10}$ year^{-1}, $\lambda\epsilon=0.548\times10^{-10}$ year^{-1}. Isotopic abundance: 1.22×10^{-4} gm K^{40}/gm K. Potassium analyses, by Lois Schlocker; age determinations for samples 29, 140, 270, and 279, by R. W. Kistler; age determination for sample W–77, by E. H. McKee]

Granitic body	Sample	Mineral	K (weight percent)	Ar^{40} (moles per gm × 10^{-11})	Radiogenic argon (percent)	Age (m. y.)
Santa Rita Flat pluton of Tinemaha Granodiorite.	29	Hornblende	0. 599	17. 26	85	156±5
Paiute Monument Quartz Monzonite	140	Hornblende	. 569	17. 23	82	163±5
Pat Keyes pluton of Hunter Mountain Quartz Monzonite.	270	Hornblende	1. 05	31. 73	84	163±5
Pat Keyes pluton of Hunter Mountain Quartz Monzonite.	279	Hornblende	. 487	16. 11	79	178±5
Unnamed	W–77	Biotite	6. 740	194. 97	90. 06	156±4

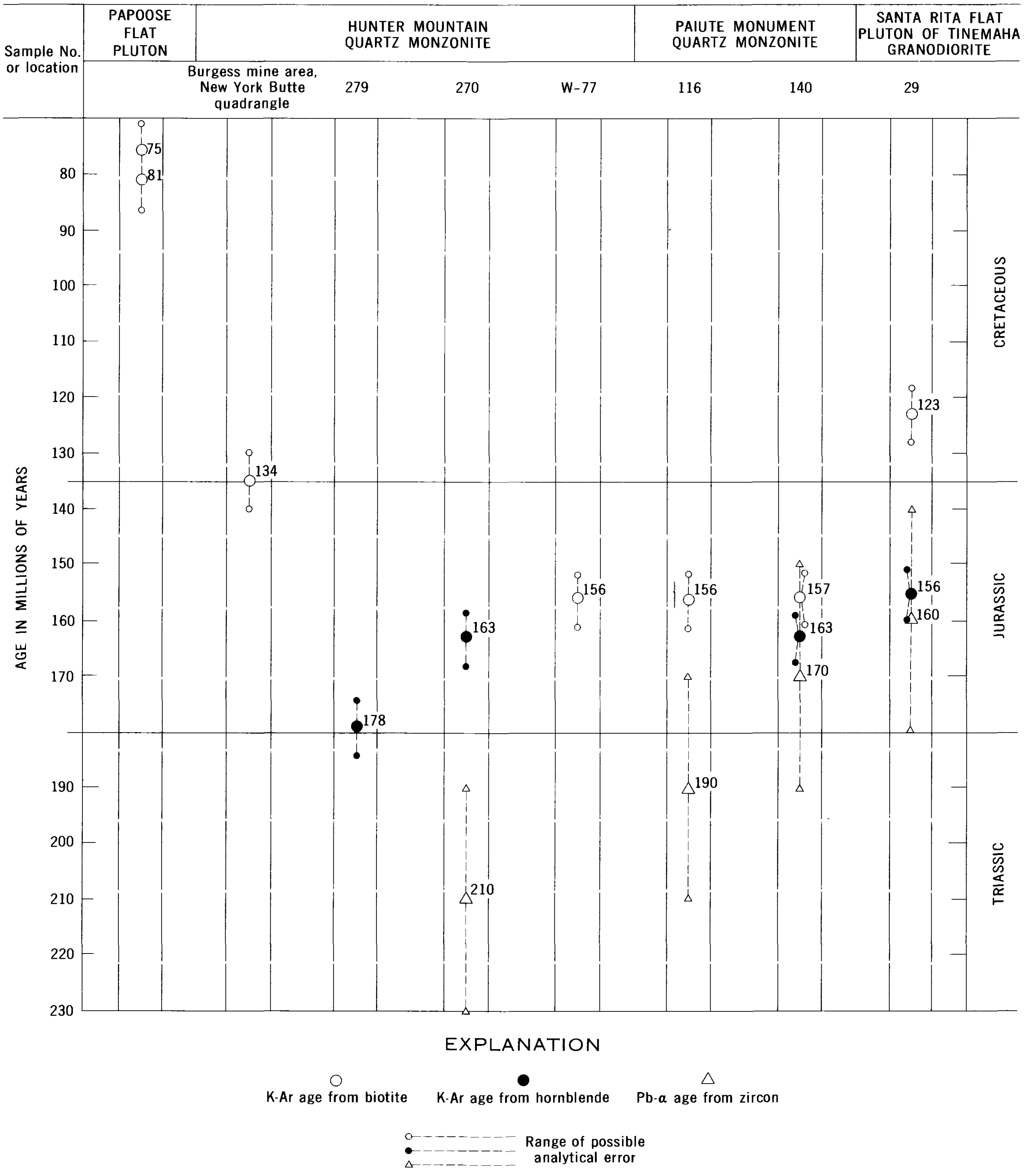

FIGURE 34.—Summary of mineral ages of granitic rocks from the Inyo Mountains. Data for sample from Burgess Mine area in the New York Butte quadrangle from R. W. Kistler (oral commun., 1966). Other data from Ross (1965, p. O47) and table 8 of this report.

from the Paiute Monument Quartz Monzonite, a Middle Jurassic age is suggested from the present data.

In summary, it is believed that both the Hunter Mountain Quartz Monzonite and the Tinemaha Granodiorite are about the same age. Their minimum age is most likely Early Jurassic. The younger Paiute Monument Quartz Monzonite probably has a minimum age of Middle Jurassic.

DISTRIBUTION OF MINOR ELEMENTS

Semiquantitative spectrographic analyses were run on the minor elements in the 12 samples that were chemically analyzed. These data are recorded on tables 2, 4, 6, and 7. For most of the elements, concentrations were in about the same range as those reported by Bateman (1965, p. 63) for minor elements in the granitic rocks of the Bishop district in the Sierra Nevada to the northwest. Some slight variations were noted, however. The Santa Rita Flat pluton appears to be somewhat higher in copper and nickel and lower in niobium than the rocks from the Sierra Nevada. It is noteworthy that copper staining is abundant in and near the Santa Rita Flat pluton (Ross, 1965, p. O60), although commercial production has been minor. The Pat Keyes pluton has a higher content of nickel than the rocks of the Sierra Nevada; this difference is understandable because nickel is a minor element with affinities for the dark minerals, which are found in abundance in the Pat Keyes pluton.

A general comparison was also made of the minor elements in the granitic rocks of the Inyo Mountains with the averages for granitic rocks compiled by Vinogradov (1956) and published in chart form by Green (1959, table 2). In relation to this average, all the granitic masses described in this report are higher in nickel and strontium. The Santa Rita Flat pluton is higher in copper and barium and lower in niobium; the Pat Keyes pluton is higher in barium; the Paiute Monument Quartz Monzonite is lower in copper and lanthanum.

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