# Petrography of Some Granitic Bodies in the Northern White Mountains, California-Nevada

GEOLOGICAL SURVEY PROFESSIONAL PAPER 775

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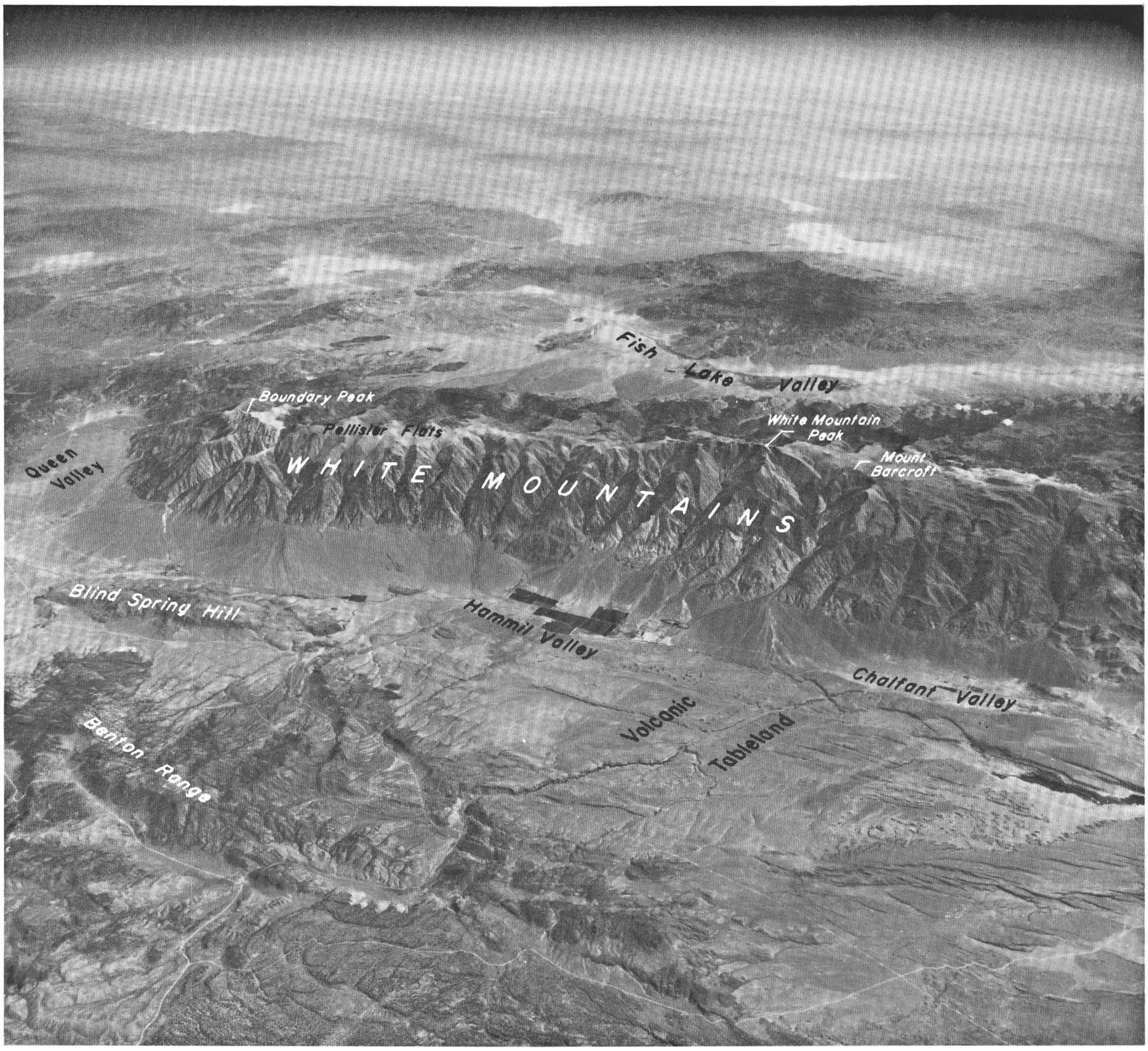


View of the northern White Mountains showing the location of major granitic masses. The White Mountains have a maximum relief of 10,000 feet and are topped by White Mountain Peak (14,246 ft).

# Petrography of Some Granitic Bodies in the Northern White Mountains, California-Nevada

*By* DWIGHT F. CROWDER *and* DONALD C. ROSS

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# PETROGRAPHY OF SOME GRANITIC BODIES IN THE NORTHERN WHITE MOUNTAINS, CALIFORNIA-NEVADA

By DWIGHT F. CROWDER and DONALD C. ROSS

ABSTRACT

Mesozoic granitic rocks dominate the pre-Tertiary basement of the northern White Mountains. Although collectively called the Inyo batholith, there is little doubt that, under the Cenozoic overburden, they are physically continuous with the Sierra Nevada batholith to the west, rather than part of a separate body. These rocks are petrographically similar to the granodiorite and quartz monzonite of this region except that the granodiorite of Mount Barcroft is definitely quartz poor and the quartz monzonite and granite of Pellisier Flats is anomalously rich in K-feldspar. Both the Mount Barcroft and Pellisier Flats units are characterized by irregular patchy dark minerals that in part look secondary; these occurrences, patches of dark minerals in nearby metavolcanic wallrocks, and albitized granitic rocks suggest all were subject to some later, postmagmatic period of alteration.

Chemical analyses of 11 samples from these bodies show that CaO content is markedly lower and $K_2O$ content markedly higher than in other granitic suites in California. A Peacock index of about 54 places these rocks well into the alkali-calcic field, in contrast to the calc-alkalic and calcic nature of other California granitic suites.

The southern part of the quartz monzonite and granite of Pellisier Flats and the adjacent metavolcanic wallrocks have been extensively albitized over an area of at least 50 square miles. These rocks are characterized by fresh secondary albite ($An_{1-5}$). The most intensely altered rocks are composed entirely of albite and quartz but retain a medium-grained granitic texture.

The rocks of the northern White Mountains have long been considered a classic example of regional granitization. This report supports the conclusions of D. O. Emerson that these granitic rocks are of magmatic intrusive origin, have assimilated wallrocks during intrusion, and were later subjected to alteration and albitization. The plutons of the White Mountains are typical of granitic rocks from this part of California and Nevada—they exhibit definite intrusive relations, relatively sharp contacts, and chemical characteristics compatible with magmatic origin, and they show only minor effects of assimilation, contamination, or granitization.

## INTRODUCTION

From 1964 to 1969 Dwight F. Crowder made a detailed geologic study of the pre-Tertiary rocks of the White Mountain Peak and Benton quadrangles in the rugged northern White Mountains of California and Nevada. He had completed the geologic mapping, had nearly completed preparation of the geologic maps for publication, and was about to begin writing of the reports when, in April 1970, he was killed in an automobile accident. I (Ross) was assigned the job of completing the maps for publication and preparing such reports as might be suitable. The field data for this report were almost entirely Dwight's. Unfortunately, the words and conclusions of the report had to be solely mine. This report is a synthesis of as much data as could be gleaned from Dwight's notes and my own study of hand specimens and thin sections. I made a 2-week trip to the field area to familiarize myself with the rock units, but as anyone who knows the awesome topography of the White Mountains can appreciate, the limitations of such a brief visit are severe. In interpreting Dwight's data for the granitic rocks of the White Mountains, I hope that I have said, at least in part, what Dwight would have said.

The northern White Mountains are underlain by large plutonic bodies (fig. 1) that are part of what has been termed the "Inyo batholith" (Anderson, 1937, p. 8). The petrography of these rocks and their almost certain connection beneath Cenozoic overburden with granitic rocks of the Sierra Nevada strongly suggests that they are part of the much larger composite Sierra Nevada batholith. Furthermore, the name "Inyo batholith" seems to imply a separate and distinct entity, which creates a false impression; for this reason, the term "Inyo batholith" is of dubious value.

The granitic rocks of the northern White Mountains have received considerable attention since Anderson (1937, p. 66) proposed that one of the largest granitic masses, which he named the Pellisier Granite, originated by the granitization of metasedimentary rocks by solutions from a younger intrusive rock, which he called the Boundary Peak Granite (fig. 2). Since Anderson's paper, the northern White Mountains have been repeatedly cited in the literature as a prime example of large-scale granitization.

In the 1940's and 1950's, detailed field studies were undertaken in the granitic terrane immediately to the west, where it was shown that the granitic rocks were dominantly of intrusive origin and that granitization had played only a minor role (Rinehart and Ross, 1957,

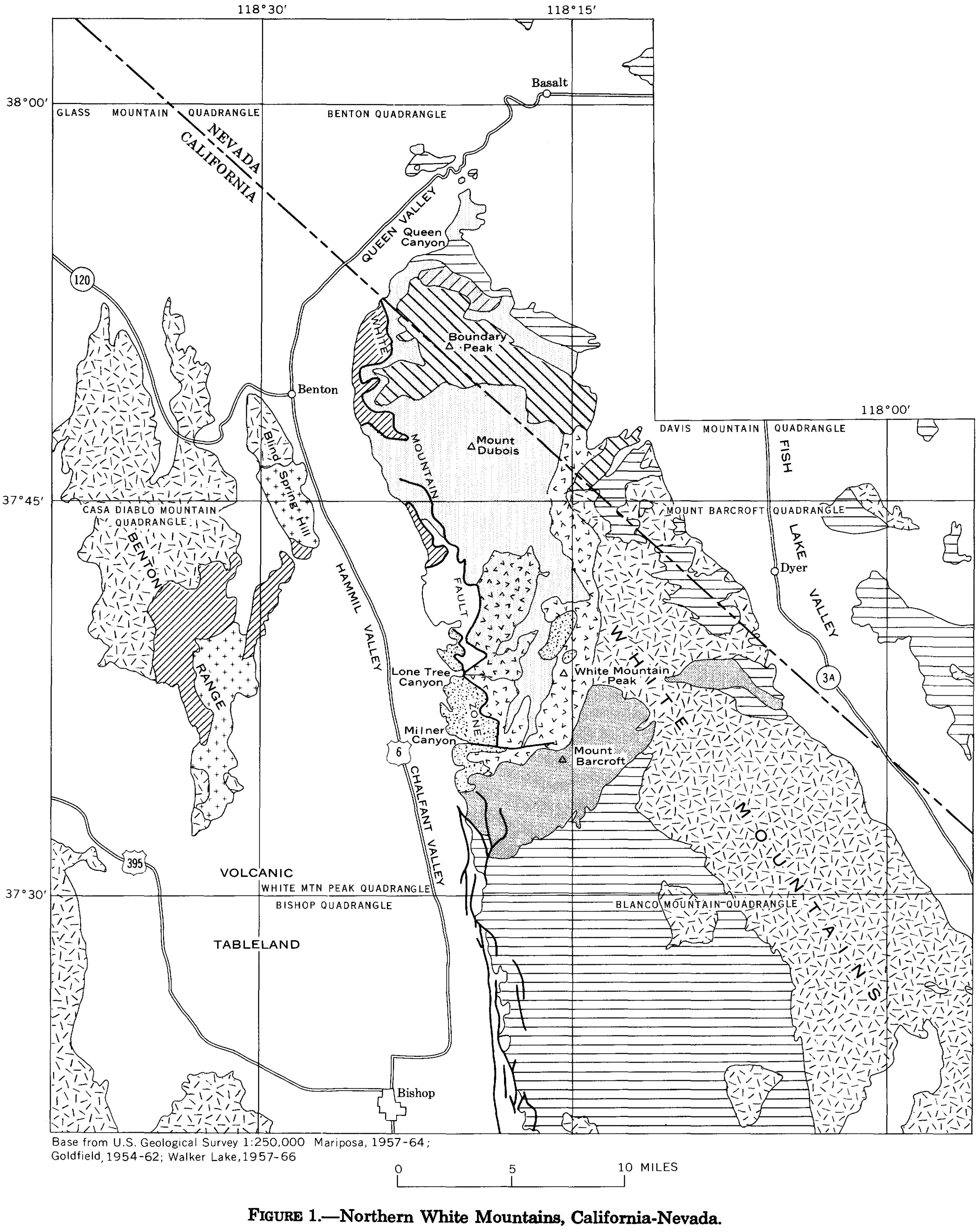
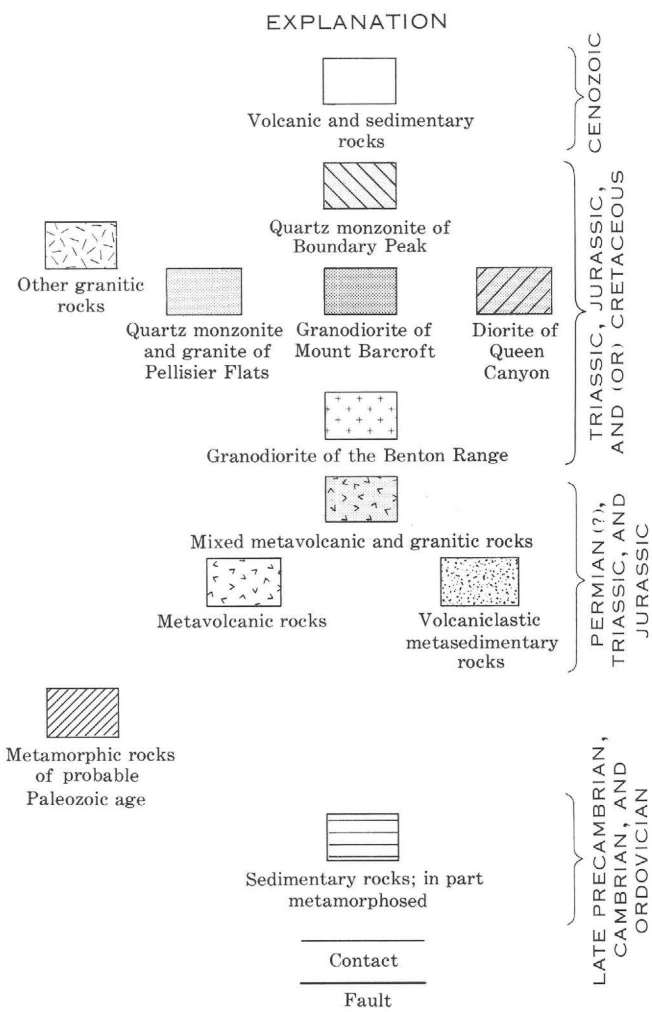



**FIGURE 1.—Northern White Mountains, California-Nevada.**

1964; Bateman, 1965; Moore, 1963). Reconnaissance studies in Nevada, immediately north and east of the White Mountains, led to similar conclusions (Ross, 1961; Albers, 1964). The northern White Mountains lay virtually untouched, chiefly because of their rugged terrain and the lack of base maps, although Ross (1961) and Albers and Stewart (1965) worked along their edges. The first modern studies of the granitic basement of the northern White Mountains were begun in 1950 by D. O. Emerson, who made a petrographic study of the granitic masses of the Mount Barcroft quadrangle (immediately east of the White Mountain Peak quadrangle). Emerson's (1959, 1966) work showed that Anderson had included several discrete plutonic units as well as metamorphic rocks in his Pellisier Granite and that the granitic rocks of the quadrangle are predominantly intrusive (Emerson, 1966, p. 146–147). Subsequent geologic mapping of the Mount Barcroft quadrangle by Krauskopf (1968) corroborated Emerson's findings, as did detailed studies of the quartz monzonite of Boundary Peak by Harris (1967).




The dominantly granitic terrane of the west slope of the White Mountains, however, was still virtually unmapped, requiring a combination hard-rock geologist and mountaineer. In 1964 Dwight Crowder was persuaded to bring his ice ax from his beloved Cascade Mountains to the White Mountains, where he proceeded to map and study the rocks on this rugged mountain front. The work was halted by his death in 1970. This report records some of Crowder's findings and helps refute the concept that the White Mountains are a locale of large-scale granitization.

The petrography and chemistry of these rocks are stressed in this report, which does not deal with the wallrocks or other aspects of the regional geology. For further information on the regional geology, the reader is referred to the following geologic quadrangle maps and accompanying explanatory texts: White Mountain Peak (Crowder and Sheridan, 1973), Benton (Crowder, Robinson, and Harris, 1973), Mount Barcroft (Krauskopf, 1971), Davis Mountain (Robinson and Crowder, 1973), and Casa Diablo Mountain (Rinehart and Ross, 1957). On both the White Mountain Peak and Benton maps, the term "adamellite" has been used, but it has been changed in this report to the equivalent term "quartz monzonite" for the comparable units, as that term is more commonly used in this region.

Sample localities for modes and chemically analyzed rocks are shown in figure 3. Potassium-argon radiometric age dates for these granitic rocks are discussed in a report by Crowder, McKee, Ross, and Krauskopf (1973). The quartz monzonite of Boundary Peak is probably Late Cretaceous, and the Mount Barcroft and Pellisier Flats units are probably Triassic or Jurassic, although there are problems in dating these two altered granitic units. The granodiorite of the Benton Range is probably Triassic.

## DESCRIPTION OF GRANITIC UNITS

### GRANODIORITE OF THE BENTON RANGE

#### GEOLOGIC SETTING AND GENERAL DESCRIPTION

Less than 10 square miles of the granodiorite of the Benton Range is exposed in the southern part of Blind Spring Hill (frontispiece). These rocks are physically separate from, but texturally and mineralogically similar to, the granodiorite of the Benton Range abundantly exposed in the adjoining Casa Diablo Mountain quadrangle (Rinehart and Ross, 1957). Similar rocks

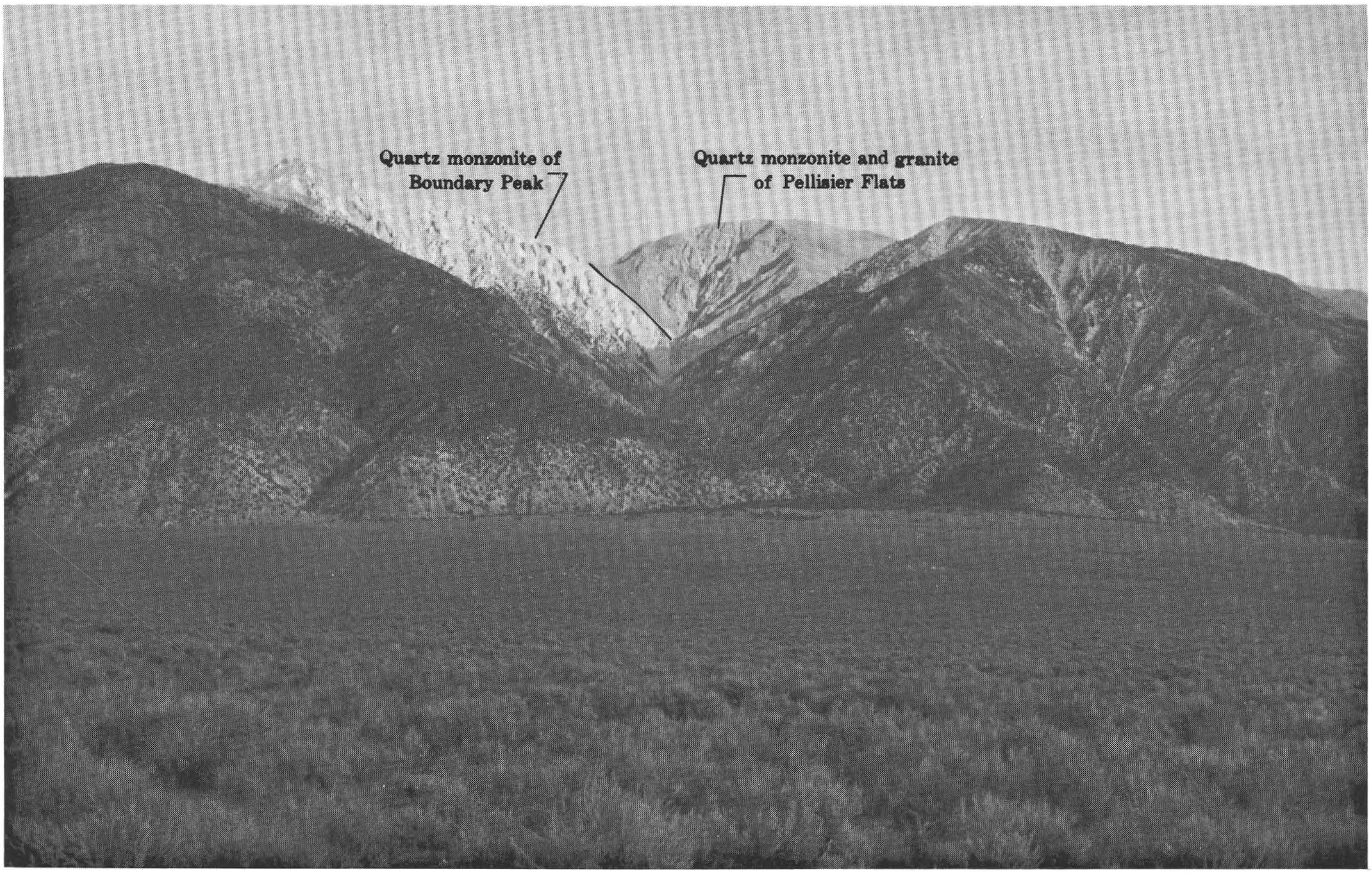



FIGURE 2.—Contact of light-colored quartz monzonite of Boundary Peak with the dark-colored quartz monzonite and granite of Pellisier Flats. Taken from U.S. Highway 6; view southeastward into the White Mountains. High point on the skyline is Boundary Peak, 13,140 feet, the highest point in Nevada. The sage-covered valley floor is about 6,000 feet above sea level.

are present to the northwest in the Glass Mountain quadrangle, but their extent is not known. This granodiorite is a major basement rock type underlying more than 200 square miles and possibly has a much greater area, as judged by probably correlative rocks in the Sierra Nevada (Rinehart and Ross, 1964, p. 47). Near the north end of Blind Spring Hill, it is intruded by the granite of Casa Diablo Mountain in a complicated contact zone containing abundant dioritic material and felsic dikes.

The granodiorite is medium to dark gray and strongly porphyritic in places, with euhedral K-feldspar phenocrysts as much as 50 mm long (fig. 4). Subhedral to euhedral hornblende crystals as long as 10 mm, but more commonly 5 mm, are another striking characteristic. Ovoid dioritic inclusions are common. The few modes from Blind Spring Hill show a wide range (fig. 5; table 1), as do the modes from the Casa Diablo quadrangle (table 2). Although this mass is indeed variable, it is easy to recognize in the field because the hornblende is so abundant and generally exceeds biotite, features which set this mass apart from other granitic bodies of the region.

TABLE 1.—*Modes of granodiorite of the Benton Range from Blind Spring Hill*

[n.d.=not determined]

| Sample | Plagioclase | K-feldspar | Quartz | Biotite | Hornblende | Specific gravity |
|---|---|---|---|---|---|---|
| 20 | 40 | 33 | 15 | 1 | [1]10 | 2.70 |
| 21 | 40 | 29 | 23 | 2 | 6 | 2.68 |
| 22 | 40 | 34 | 15 | 1 | 10 | n.d. |
| 23 | 33 | 37 | 24 | 2 | 4 | 2.66 |
| 24 | 50 | 18 | 9 | $<1$ | 23 | 2.77 |
| 25 | 41 | 28 | 14 | 6 | 11 | 2.73 |

[1]1 percent metallic opaque minerals.

TABLE 2.—*Modes of granodiorite of the Benton Range by Rinehart and Ross (1964, p. 43)*

| Sample | Plagioclase | K-feldspar | Quartz | Biotite | Hornblende | Accessory minerals |
|---|---|---|---|---|---|---|
| R-1 | 34 | 17 | 20 | 12 | 16 | 1 |
| R-2 | 48 | 11 | 25 | 5 | 9 | 2 |
| R-3 | 51 | 7 | 23 | 7 | 11 | 1 |
| R-4 | 50 | 8 | 21 | 7 | 13 | 1 |
| R-5 | 42 | 26 | 25 | 2 | 4 | 1 |
| R-6 | 53 | 18 | 8 | 6 | 14 | 1 |
| R-7 | 38 | 30 | 24 | 4 | 5 | .... |
| R-8 | 58 | 13 | 15 | 4 | 9 | 1 |
| R-9 | 56 | 13 | 11 | 10 | 10 | .... |
| R-10 | 40 | 15 | 34 | 6 | 3 | 2 |
| R-11 | 54 | 10 | 24 | 8 | 3 | 1 |
| R-12 | 57 | 11 | 20 | 8 | 2 | 2 |
| R-13 | 40 | 26 | 28 | 4 | .... | 2 |
| R-14 | 31 | 29 | 36 | 4 | .... | .... |
| R-15 | 36 | 21 | 37 | 6 | .... | .... |

In general the petrography of this mass, in particular the abundance of dark dioritic inclusions and euhedral hornblende, suggests a much greater affinity with Sierra Nevada granitic masses than with masses of the Inyo-White Mountains region. For some as yet unexplained reason, dark ovoid dioritic inclusions characteristic of large granodiorite masses of the Sierra Nevada are notably uncommon in rocks of the same general composition in the Inyo-White Mountains region. The contrast between the inclusion-poor Mount Barcroft and Pellisier Flats units and the inclusion-rich granodiorite of the Benton Range is striking.

### MICROSCOPIC DESCRIPTION

The overall texture of the granodiorite of the Benton Range is hypautomorphic-granular, but sprinkles of rounded quartz crystals commonly give a somewhat aplitic aspect to the rock that culminates locally in an aplitic (or granoblastic) groundmass of quartz and feldspar in which much larger anhedral to euhedral crystals are set. Also present are square to rounded quartz crystals as large as 5 mm across that have been eaten into and embayed by the "aplitic" groundmass. Their general form suggests that they crystallized as beta quartz that formed discrete and in part euhedral crystals as large as, or larger than, the plagioclase crystals. In outcrop, the rocks with atypical aplitic groundmass resemble normal porphyritic granitic rock with euhedral hornblende. Thus, the texture, as it appears in thin section, is unexpected (fig. 6). A specimen from the Benton Range (specimen 2, Rinehart and Ross, 1964, p. 43) shows this same "aplitic" matrix inset with clean, well-formed crystals of feldspar and dark minerals. It seems likely that crystallization in most of the granodiorite of the Benton Range was completed, with no great change in conditions, and yielded a normal granitic texture. Locally, however, when the crystal mush was still bathed in liquid, a marked change in conditions of crystallization caused very rapid freezing to give the "aplitic" groundmass.

Plagioclase is subhedral, remarkably fresh, and sharply twinned; oscillatory zoning with numerous small reversals is also characteristic. K-feldspar occurs in irregular grains of various size, but most strikingly as large poikiloblasts. Quartz is in irregular masses of various size and ranges from mosaicked grains with undulatory extinction to granulated, slivered aggregates.

Biotite is a minor constituent in the rocks exposed in Blind Spring Hill but appears to be generally more abundant in correlative rocks in the Benton Range (Rinehart and Ross, 1964, p. 43). The small ragged crystals and intergrowths with hornblende are pleochroic from X=grayish yellow and orange to Z=moderate brown.

Generally, hornblende overwhelmingly exceeds biotite in these rocks, and in part hornblende is the only dark mineral. Much of it is in large conspicuously subhedral to euhedral crystals, whereas other crystals are ragged and in part intergrown with biotite. In some specimens, hornblende occurs both as euhedral crystals and as fine-grained ragged aggregates. The hornblende has the following pleochroism: X=moderate greenish yellow, Y=light olive to light olive brown, and Z=grayish green to dark yellowish green. The dominance of hornblende appears to decrease to the south in the Benton Range, and the southernmost outcrops have none (fig. 7).

Magnetite is scattered abundantly through these rocks and is particularly common in the hornblende. Apatite, sphene, and zircon are present, and allanite occurs in minor amounts. Sparse chlorite, epidote, and sericite are alteration products.

## QUARTZ MONZONITE AND GRANITE OF PELLISIER FLATS

### GEOLOGIC SETTING AND GENERAL DESCRIPTION

The Pellisier Flats unit forms a belt of outcrop, as much as 8 miles wide at the latitude of Pellisier Flats, that is pierced by younger granitic rocks to the north; presumably correlative rocks extend to within 2 miles of the north boundary of the Benton quadrangle. The belt of outcrop also extends southward as far as Milner Canyon, where it fingers out. The irregular body and isolated small masses now cover an area somewhat less than 100 square miles. Although the main body of the Pellisier Flats unit closely approaches the largest mass of the Mount Barcroft unit, they are not in contact in the known exposures. Nearly all exposures are in the Benton and White Mountain Peak quadrangles; small areas protrude into the Mount Barcroft and Davis Mountain quadrangles. The term "Pellisier Granite" was first used on a geologic map by Anderson (1937) and included rocks on the east side of the range that Emerson (1966) and Krauskopf (1972) later found to be separate masses. The terms "quartz monzonite and granite of Pellisier Flats" or "Pellisier Flats unit" will be used throughout this report to avoid confusion with Pellisier Granite originally described by Anderson.

The Pellisier Flats unit has a dull-gray cast and is characterized by abundant dark minerals. Much of this dull appearance is imparted by the dark minerals, which are rarely discrete shiny crystals but rather fuzzy aggregates and irregular shreds that give the rock a dirty, messy texture. The dark minerals tend to form very distinctive scattered ovoid clusters or clots several millimeters across. Dioritic inclusions, a few inches to


**FIGURE 3.**—Location of modally and chemically analyzed specimens.

2 or 3 feet across, are widespread and locally common, but in general are much less common than in Sierra Nevada granitic rocks of equivalent composition.

The most noteworthy feature of hand specimens of this rock is the abundance of K-feldspar. Casual field observation suggests that the rock is a granodiorite; however, close observation reveals abundant pinkish feldspar in many specimens, and staining shows that K-feldspar predominates. The modes (fig. 8; table 3) show a field that blankets the quartz monzonite range and extends across much of the granite field. Because of the large number of points that fall within the granite field, the modal field is unusual in comparison with that of most other granitic bodies of the Sierra Nevada and the White and Inyo Mountains.

EXPLANATION

Quartz monzonite and granite of Pellisier Flats
*Overprint indicates albitized mixed metavolcanic and Pellisier rocks*

Granodiorite of Mount Barcroft

Quartz monzonite of Boundary Peak

Granodiorite of the Benton Range

Diorite complex

Contact

Fault

SAMPLE LOCALITIES
Numbers are keyed to tables in text

o 128
New mode
*1-7, diorite complex; 10-17, quartz monzonite of Boundary Peak; 20-25, granodiorite of the Benton Range; 30-62, granodiorite of Mount Barcroft; 101-165, quartz monzonite and granite of Pellisier Flats*

• H-20
Mode from another source
*Letter prefix keyed to reference list: E, Emerson (1959); H, Harris (1967); R, Rinehart and Ross (1969, p. 43); M, Ross (1961, p. 34)*

□ 163
Chemically analyzed sample
*Three specimens from Boundary Peak (in parentheses-116, 214, and 241) do not have modal analyses*

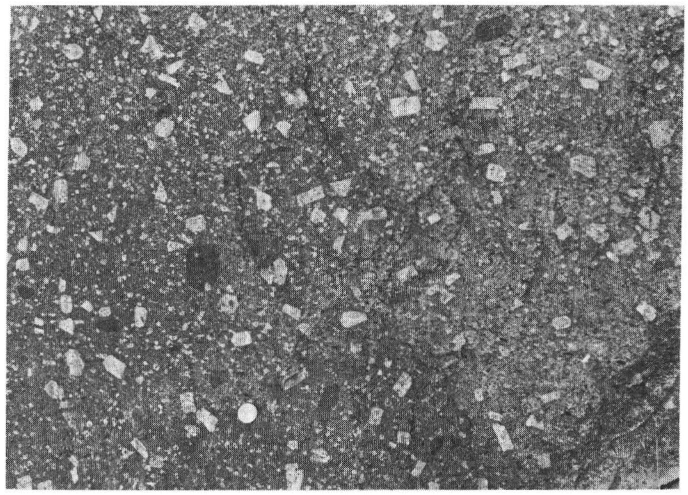


**FIGURE 4.—Granodiorite of the Benton Range. Abundant euhedral K-feldspar phenocrysts, small dioritic inclusions, and euhedral hornblende crystals are visible. Quarter for scale.**

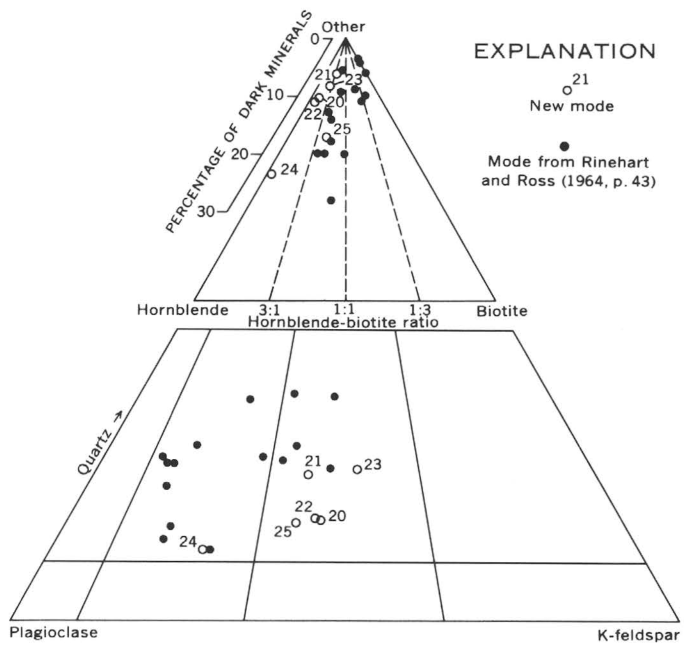



**FIGURE 5.—Modal distribution of quartz, K-feldspar, and plagioclase of the granodiorite of the Benton Range.**

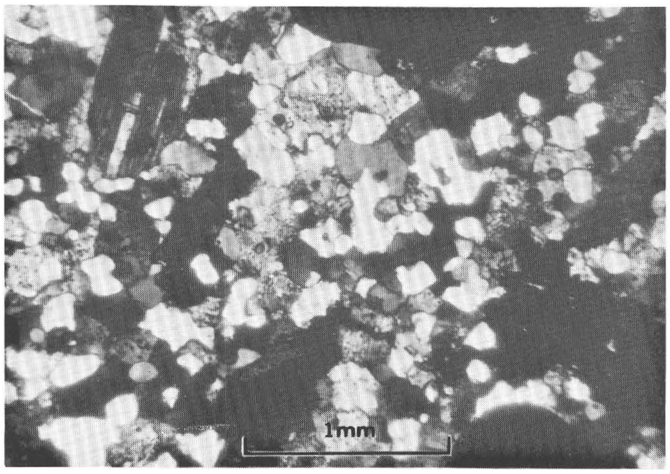



FIGURE 6.—Photomicrograph of fine-grained "aplitic" groundmass of specimen 25 from the granodiorite of the Benton Range.

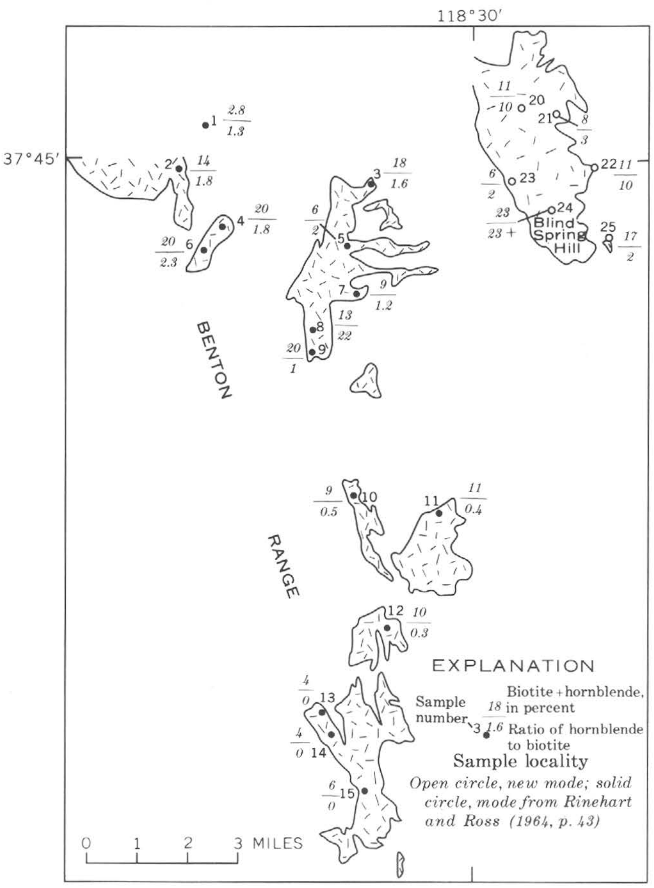



FIGURE 7.—Sample localities, dark-mineral content, and ratio of hornblende to biotite in specimens in the granodiorite of the Benton Range.

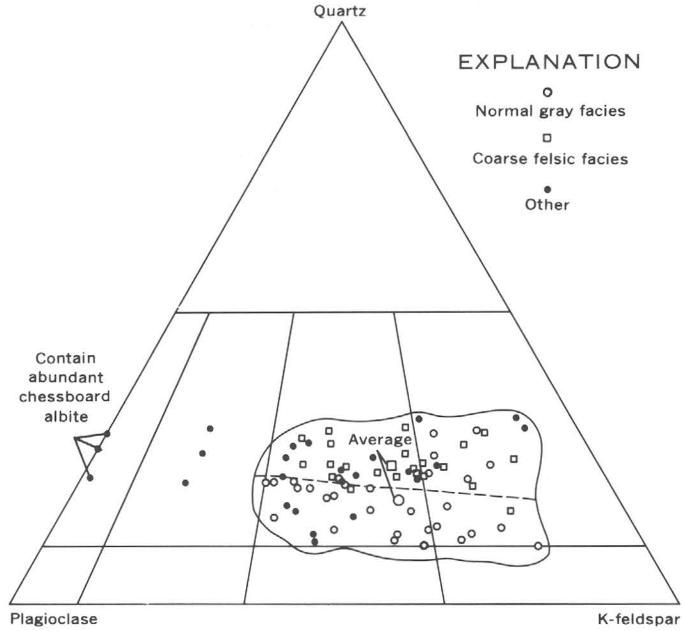



FIGURE 8.—Modal distribution of quartz, K-feldspar, and plagioclase in the quartz monzonite and granite of Pellisier Flats.

**TABLE 3.**—*Modes of quartz monzonite and granite of Pellisier Flats*

[n.d.=not determined]

| Sample | Plagioclase | K-feldspar | Quartz | Mafic minerals | | Specific gravity |
|---|---|---|---|---|---|---|
| | | | | Biotite | Hornblende | |
| **Normal phase** | | | | | | |
| 103 | 32 | 30 | 15 | 18 | 5 | 2.70 |
| 104 | 41 | 22 | 17 | 19 | 1 | 2.69 |
| 105? | 31 | 38 | 17 | 5 | [1]8 | 2.68 |
| 106? | 40 | 37 | 12 | 1± | 10 | 2.65 |
| 108 | 33 | 29 | 14 | 20 | 4 | 2.68 |
| 109? | 35 | 42 | 15 | <1 | 8 | 2.64 |
| 110? | 41 | 25 | 12 | 22 | .... | 2.73 |
| 111 | 37 | 25 | 17 | 18 | 3 | 2.73 |
| 117 | 35 | 35 | 18 | 9 | 3 | 2.68 |
| 121 | 41 | 24 | 17 | 9 | 9 | 2.70 |
| 122 | 30 | 30 | 17 | 23 | .... | 2.70 |
| 124? | 20 | 44 | 23 | 13 | .... | 2.62 |
| 132 | 22 | 56 | 11 | 10 | 1 | 2.62 |
| 134 | 20 | 45 | 27 | 8 | .... | 2.62 |
| 148? | 14 | 52 | 29 | 5 | .... | 2.63 |
| 150 | 24 | 45 | 19 | 12 | .... | 2.64 |
| 151 | 27 | 46 | 8 | 19 | .... | 2.63 |
| 153 | 23 | 50 | 15 | 12 | .... | 2.62 |
| 154 | 16 | 46 | 17 | 21 | .... | n.d. |
| 155 | 24 | 47 | 11 | 18 | .... | 2.68 |
| 156 | 26 | 46 | 11 | 17 | .... | 2.67 |
| 157 | 28 | 39 | 8 | 25 | .... | 2.69 |
| 158 | 13 | 49 | 20 | 18 | .... | 2.65 |
| 159 | 18 | 62 | 12 | 8 | .... | 2.62 |
| 160 | 13 | 58 | 8 | 21 | .... | 2.69 |
| 161 | 21 | 48 | 9 | 22 | .... | 2.65 |
| 162 | 30 | 44 | 10 | 16 | .... | 2.65 |
| 163 | 24 | 39 | 12 | 25 | .... | 2.70 |
| 164 | 37 | 29 | 16 | 10 | 8 | 2.70 |
| 165 | 39 | 27 | 17 | 11 | [1]5 | 2.70 |
| Avg. | 28 | 40 | 15 | 15 | 2 | 2.66 |

TABLE 3.—*Modes of quartz monzonite and granite of Pellisier Flats*—Continued

| Sample | Plagioclase | K-feldspar | Quartz | Mafic minerals | | Specific gravity |
|---|---|---|---|---|---|---|
| | | | | Biotite | Hornblende | |
| **Coarse phase** | | | | | | |
| 101?.......... | 38 | 35 | 23 | 4 | .... | 2.63 |
| 102?.......... | 39 | 28 | 21 | 12 | .... | 2.66 |
| 118............ | 24 | 47 | 22 | 7 | .... | 2.62 |
| 119............ | 22 | 49 | 22 | 7 | <1 | 2.62 |
| 123............ | 25 | 42 | 24 | 9 | .... | 2.64 |
| 125............ | 34 | 35 | 22 | 9 | .... | 2.64 |
| 126............ | 27 | 46 | 22 | 5 | .... | 2.62 |
| 127?.......... | 36 | 38 | 18 | 8 | .... | 2.65 |
| 128............ | 29 | 39 | 20 | 12 | .... | 2.65 |
| 129............ | 23 | 40 | 28 | 9 | .... | 2.64 |
| 130?.......... | 20 | 57 | 20 | 3 | .... | 2.64 |
| 131............ | 12 | 61 | 24 | 3 | .... | 2.60 |
| 133............ | 37 | 35 | 21 | 7 | .... | 2.62 |
| 135?.......... | 35 | 32 | 26 | 7 | .... | 2.63 |
| 136?.......... | 36 | 32 | 29 | 3 | .... | 2.62 |
| 137?.......... | 40 | 28 | 28 | 4 | .... | 2.64 |
| 138............ | 26 | 45 | 21 | 8 | .... | 2.62 |
| 139............ | 29 | 44 | 20 | 7 | .... | 2.62 |
| 140?.......... | 13 | 55 | 29 | 3 | .... | n.d. |
| 141?.......... | 15 | 61 | 15 | .... | 9 | 2.63 |
| 142?.......... | 16 | 46 | 17 | 21 | .... | 2.60 |
| 143?.......... | 25 | 46 | 20 | 9 | .... | 2.66 |
| Avg... | 29 | 41 | 22 | 8 | .... | 2.63 |
| **Other samples** | | | | | | |
| 107?.......... | 65 | 1 | 18 | 16 | .... | 2.64 |
| 112............ | 40 | 33 | 10 | .... | 17 | 2.71 |
| 113............ | 50 | 13 | 17 | 19 | 1 | 2.70 |
| 114............ | 32 | 32 | 19 | 17 | .... | 2.67 |
| 115............ | 39 | 32 | 9 | 1 | 19 | 2.73 |
| 116............ | 30 | 33 | 18 | 19 | | 2.69 |
| 120............ | 68 | 0 | 25 | 7 | .... | 2.60 |
| 144............ | 22 | 42 | 30 | 6 | — | ...... |
| 145[2] .......... | 71 | 0 | 29 | 0 | | 2.60 |
| 146[3] .......... | 22 | 49 | 23 | 6 | .... | 2.62 |
| 147[3] .......... | 8 | 57 | 30 | [4]5 | .... | 2.62 |
| 149[3] .......... | 8 | 61 | 29 | 2 | .... | 2.63 |
| 152............ | 23 | 40 | 19 | 18 | | ...... |
| **Rocks of Harris (1967)** | | | | | | |
| H–1............ | 43 | 28 | 27 | 2 | | ...... |
| H–2............ | 53 | 15 | 29 | 3 | | ...... |
| H–3............ | 39 | 29 | 26 | 6 | | ...... |
| H–7............ | 35 | 34 | 19 | 12 | | ...... |
| H–8............ | 54 | 15 | 24 | 7 | | ...... |
| H–9............ | 40 | 27 | 14 | 19 | | ...... |
| H–10.......... | 39 | 28 | 13 | 20 | | ...... |
| H–11.......... | 37 | 40 | 13 | 10 | | ...... |
| H–21.......... | 28 | 49 | 22 | 1 | | ...... |
| H–31.......... | 47 | 29 | 21 | 3 | | ...... |
| **Rocks of Ross (1961)** | | | | | | |
| M–30.......... | 30 | 39 | 23 | 8 | | ...... |
| M–31.......... | 38 | 24 | 21 | 17 | | ...... |

[1] 1 percent metallic opaque minerals and sphene.
[2] Albite granite (type 1).
[3] Albitized leucocratic Pellisier Flats (type 3).
[4] Altered to chlorite.

A coarser grained more felsic central core facies of the Pellisier Flats unit can be distinguished in the hand specimens collected. In the area of Mount Dubois, it forms a northeast-trending belt (fig. 9) that contains more quartz and fewer mafic minerals than the normal part of the Pellisier Flats unit. Both facies average on the granite side of the quartz monzonite field and have similar amounts of plagioclase and K-feldspar (fig. 8). The coarser facies was not mapped in the field, which suggests it is not an obviously separate intrusion. Moreover, outcrops of the Pellisier Flats unit north of the quartz monzonite Boundary Peak contain possibly transitional rocks that are coarser than the normal part of the Pellisier but contain more dark minerals than the coarser facies. Some rocks south of the quartz monzonite of Boundary Peak, as well as rocks tentatively assigned to the coarser facies west of this pluton, may be transitional. The dull-gray rock probably is normal Pellisier that grades to a coarser more felsic central core facies that crystallized last. On the other hand, the coarse felsic facies may represent nearly pure Pellisier, and the dull-gray Pellisier may be a contaminated altered variant as in the Pat Keyes pluton in the Inyo Mountains to the south (Ross, 1969, p. 11). The virtual absence of hornblende in the coarser facies, however, suggests that the dull-gray rock is typical of the Pellisier Flats unit.

### MICROSCOPIC DESCRIPTION

Biotite occurs in shreds, slivers, and irregular aggregates or clots and is liberally sprinkled through altered plagioclase in these rocks. The distinctive clots seen in hand specimen are aggregates of biotite, metallic opaque minerals, sphene, and epidote. The shape of some biotite aggregates suggests pseudomorphs after hornblende (fig. 10). The biotite is rather uniformly pleochroic from X=grayish yellow or grayish orange to Z=light olive or light olive brown.

Plagioclase is thinly twinned and commonly is richly peppered with sericite, epidote-zoisite, biotite, and some calcite. The pervasive saussuritization of what presumably was intermediate plagioclase has been very thorough, for all the plagioclase now seems to be albite (or oligoclase). Thin-section study of the plagioclase was supplemented by limited X-ray diffraction studies. The anorthite content of three specimens from the coarse felsic facies was about $An_{1-5}$, although the patterns were somewhat irregular. Plagioclase from three typical rocks of the gray normal facies from the Benton quadrangle north of the coarse felsic facies showed $An_{14}$, $An_{20}$, and $An_{23}$. These specimens probably are representative of the unalbitized parts of the Pellisier Flats unit. Four specimens from the gray normal facies of the Pellisier Flats unit south of the coarse felsic facies were picked; the specimens had intensely altered plagioclase, but no chessboard albite, and looked like dark normal rocks of the Pellisier Flats unit. These

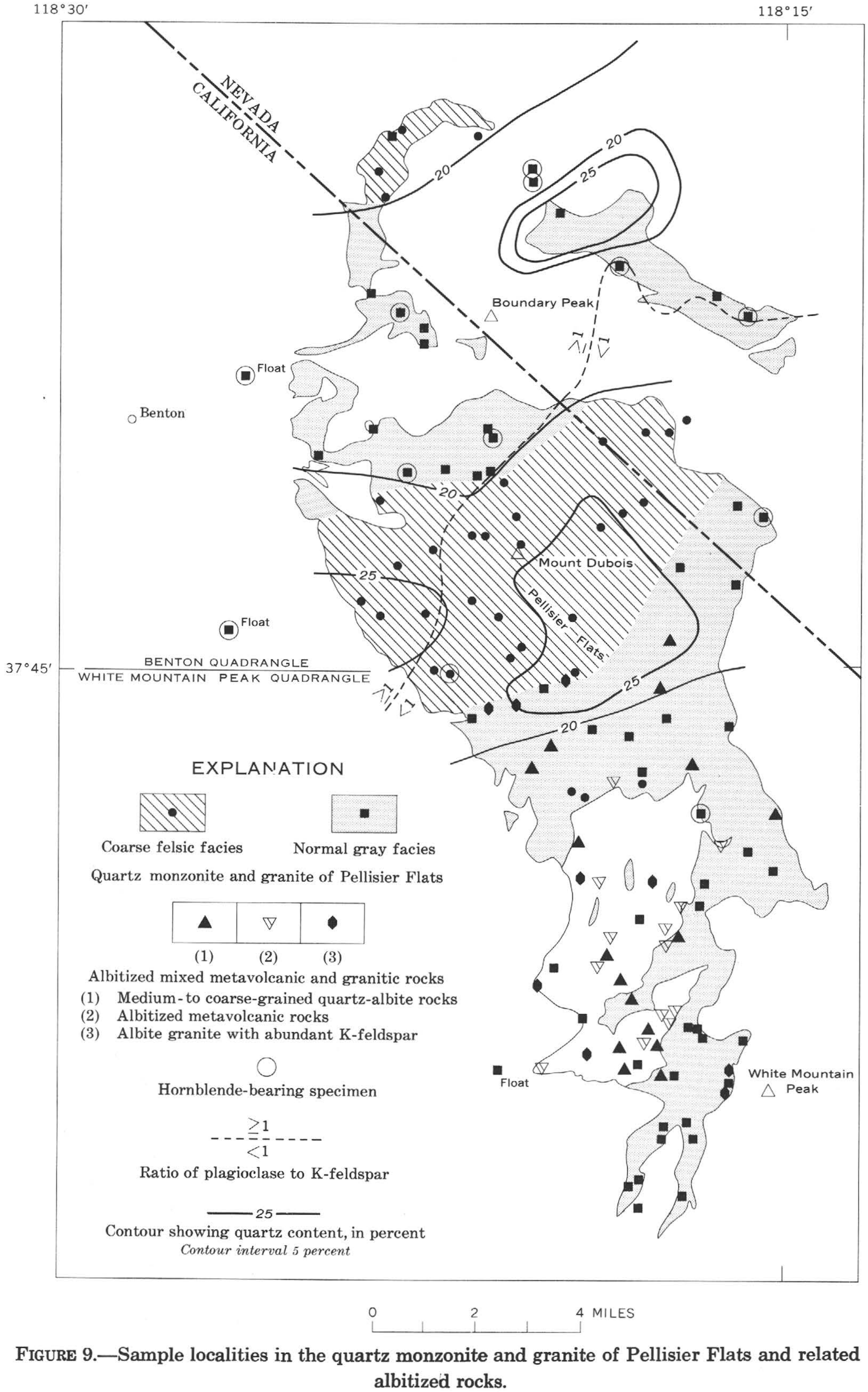



**FIGURE 9.**—Sample localities in the quartz monzonite and granite of Pellisier Flats and related albitized rocks.

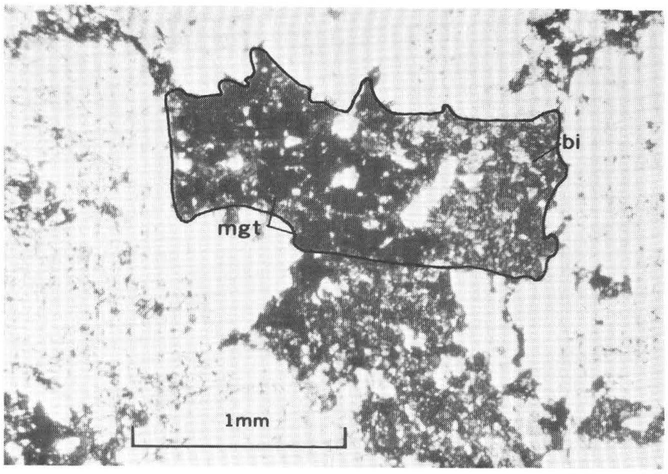



FIGURE 10.—Photomicrograph of aggregate of small biotite flakes (bi) and magnetite grains (mgt) that probably pseudomorphs a hornblende crystal in quartz monzonite and granite of Pellisier Flats.

rocks all showed X-ray diffraction patterns that suggest $An_{0-5}$, but the patterns were by no means conclusive for some specimens. The alteration products may mask the plagioclase peaks, or the alteration-product-soaked plagioclase may give weaker-than-normal peaks. Nevertheless, the plagioclase is probably sodic and probably albite in much of the area south of the coarse felsic facies.

K-feldspar is dominant in most specimens, ranging from small interstitial grains to large irregular to subhedral crystals. Some is distinctly grid twinned; more characteristic is splotchy irregular perthite in which finely twinned albite is locally distinct.

Quartz, though in part in fairly normal irregular crystals that show undulatory extinction and rather normal mosaicking, is typically in granular almost hornfelsic aggregates. The overall appearance is one of a metamorphic fabric, not a cataclastic one. Anderson (1934, p. 185) noted this feature and suggested the term "pseudo-cataclastic" to identify it; he associated the texture with replacement.

Hornblende is rare south of the coarser facies (fig. 9) but widespread north of the coarser facies and even dominant in some specimens (table 1). In some of the northern rocks, hornblende is in discrete subhedral crystals, but more commonly it is intergrown in clusters with fine-grained aggregates of biotite, metallic opaque minerals, and sphene. Although hornblende is rare in the southern rocks, the presence of scattered grains, as well as pseudomorphs after hornblende, suggests that the paucity of hornblende reflects a secondary effect related to alteration of the rocks, not a primary difference in the mineralogy. The hornblende is pleochroic from X=moderate greenish yellow and Y=grayish to dark yellowish green, to Z=various shades of blue green, yellowish green, and moderate green.

Metallic opaque minerals present are sphene, apatite, and, less commonly, zircon. Sphene is abundant as irregular masses in some rocks, and only rarely is in euhedral crystals.

### MIXED METAVOLCANIC AND GRANITIC ROCKS

An "enclave" about 10 square miles in area has been called "mixed metavolcanic and granitic rocks" on the White Mountain Peak geologic map (Crowder and Sheridan, 1973). These rocks, exposed from Lone Tree Canyon north for several miles, were first thought to be a separate felsic intrusive. In fact, many of the outcrops are light colored and superficially resemble aplite and alaskite. Within this outcrop are patches and intrusive(?) areas of the Pellisier Flats unit. The "enclave" also contains abundant metavolcanic rocks with clearly recognizable porphyritic volcanic textures.

It is here proposed that the "enclave" is an area of metavolcanic rocks that has been extensively intruded by the Pellisier Flats unit and, even more significant, has been drenched in the solutions that altered and albitized the southern part of the Pellisier Flats unit. In fact, some of the kinds of intensely albitized rocks common in the "enclave" are found some distance away within outcrops of the Pellisier Flats unit (fig. 9).

Three main rock types make up the body of mixed metavolcanic and granitic rocks. The most abundant (judging by collected specimens) is a medium- to coarse-grained rock that looks alaskitic in hand specimen, but is composed almost entirely of albite and quartz. This rock is generally fresh looking in thin section and features cleanly twinned chessboard albite and thin discontinuous twins that seem to be a variant of chessboard twinning (fig. 11). It has no K-feldspar and virtually no dark minerals. Some specimens of the Pellisier Flats unit appear to be transitional to the albite-quartz rocks (fig. 12), which may have originally been part of the Pellisier Flats unit.

The next most abundant rock type is metavolcanic rock with striking porphyritic texture and a granoblastic groundmass. Some phenocrysts as much as a few millimeters across are euhedral; they are now mostly chessboard albite to finely, discontinuously twinned albite. The fine-grained to dense groundmass is composed dominantly of quartz and albite; K-feldspar is abundant in the groundmass of some specimens. Flow structure is preserved in part, and some specimens

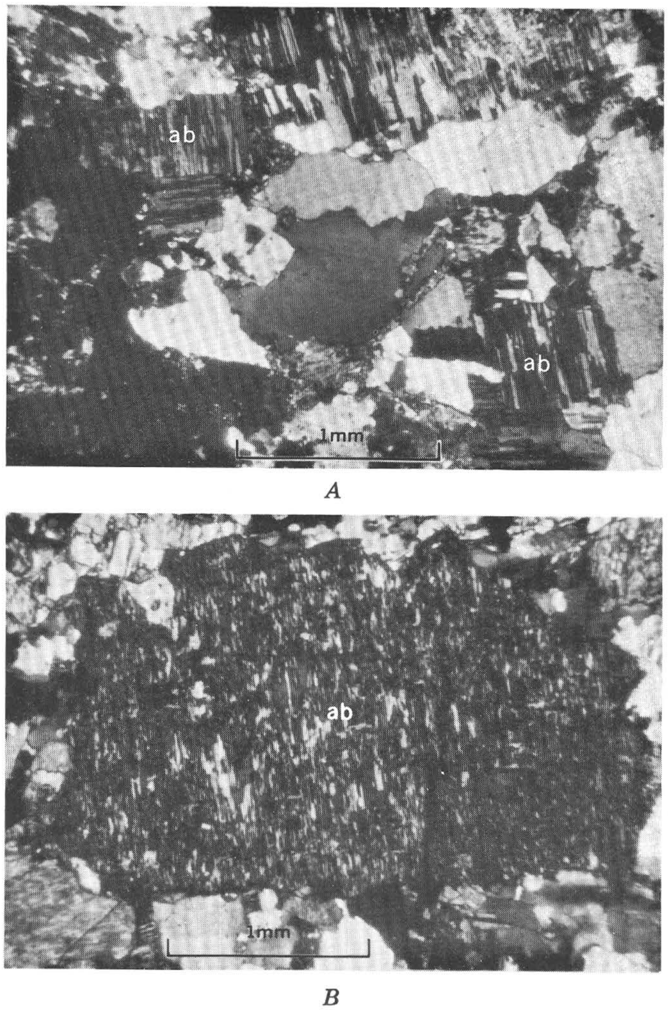



FIGURE 11.—Photomicrographs of fresh secondary albite (ab) with discontinuous and chessboard twinning in intensively albitized rocks of the Pellisier Flats unit. *A*, discontinuous twinning; *B*, chessboard twinning.

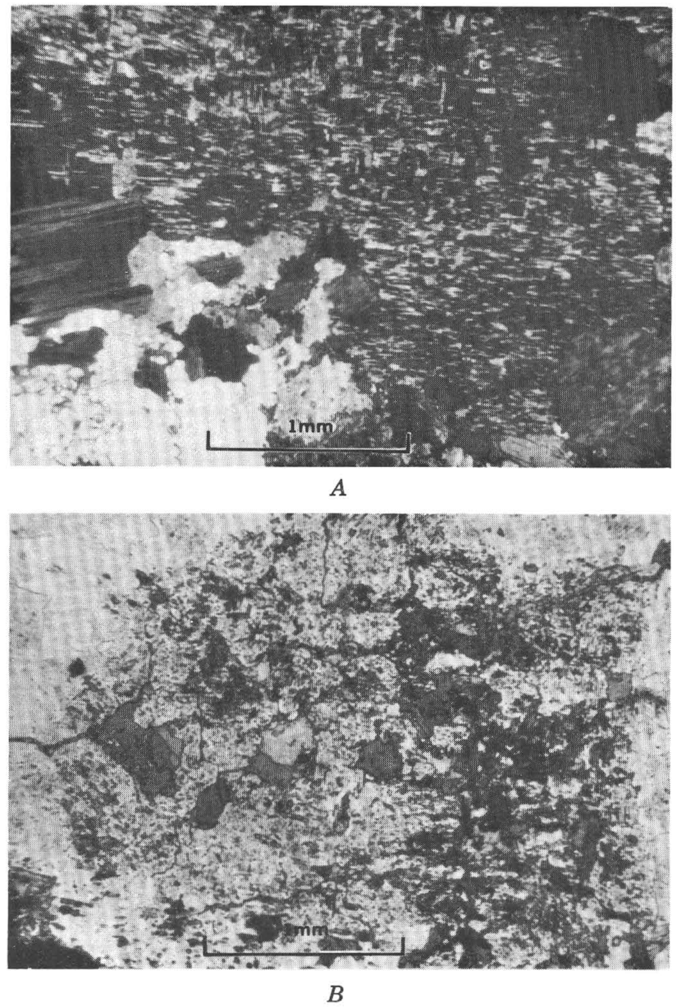



FIGURE 12.—Photomicrographs of fresh secondary albite and saussuritized original plagioclase from same specimen, Pellisier Flats unit. *A*, fresh secondary albite showing chessboard and discontinuous twinning; *B*, saussuritized plagioclase crystal liberally sprinkled with biotite shreds and flakes.

look tuffaceous. The groundmass of some still has a felty aspect. There can be little doubt that these rocks were originally volcanic. In the field, some of these rocks are easily confused with quartzite or aplite, particularly where the original volcanic texture is subtle or absent. Abundance of aplite locally in this "enclave" of mixed rocks further complicates the problem of field identification.

The other common rock type in the mixed area is albite granite with abundant K-feldspar. Its texture is granitic, but dark minerals are commonly minor or absent. Some specimens are aplitic to alaskitic, but have some chessboard-twinned albite. In these rocks, much of the albite is cloudy and only incompletely altered from the originally more calcic plagioclase. These rocks may represent a transitional stage on the way to albite-quartz rocks.

The K-feldspar-bearing albite granites and the medium- to coarse-grained albite-quartz rocks occur not only in the "enclave" but also in the main mass of the Pellisier Flats unit, where they appear to be transitional to normal rocks of the Pellisier Flats unit, suggesting that these albite-rich rocks are variously altered Pellisier rocks mixed in with the metavolcanic rocks.

## DIORITE COMPLEX OF QUEEN CANYON

Along the south side of Queen Canyon on the north side of the quartz monzonite of Boundary Peak is a 4-mile-long belt of outcrop of various dioritic rocks mixed with felsic rocks (fig. 3; table 4) that may be related to the Pellisier Flats unit. Although some Pellisier-rocks are present, the complex also contains a variety of hornblende diorite and related rock types

TABLE 4.—*Modes of diorite complex of Queen Canyon*
[× indicates mineral present, but no mode run]

| Sample | Plagioclase | K-feldspar | Quartz | Biotite | Hornblende | Specific gravity |
|---|---|---|---|---|---|---|
| 1[1] | 50± | .... | .... | .... | 45± | 2.96 |
| 2 | 60± | <5 | .... | .... | 40± | 2.87 |
| 3 | 60± | .... | .... | .... | 40± | 2.87 |
| 4 | (similar to sample 5) | | .... | .... | ........ | 2.70 |
| 5 | 36 | 29 | 11 | 11 | 13 | 2.72 |
| 6 | × | × | × | × | ........ | 2.66 |
| 7 | 50± | .... | .... | 5–10 | 40–50 | 2.89 |

[1]Contains about 5 percent epidote in discrete crystals.

that make it distinctive from the main mass of the Pellisier Flats unit. Aplite, alaskite, pegmatite, and other felsic rocks make up as much as 50 percent of the complex. Presumably, these felsic types are largely offshoots of the quartz monzonite of Boundary Peak. In general, this complex contains dioritic rocks that are probably somewhat older than the Pellisier Flats unit, as well as Pellisier-like rocks and younger felsic rocks that are probably part of the quartz monzonite of Boundary Peak.

Hornblende diorites of various grain sizes probably are the most abundant rock types in the complex. They range from fine-grained aplitic or granoblastic rocks to irregular-textured coarse rocks characterized by large hornblende crystals. The same kinds of hornblende diorite are relatively common in small masses in the granitic terranes of this region and are abundant in the Casa Diablo Mountain quadrangle to the west (Rinehart and Ross, 1957). These diorites are composed chiefly of about equal amounts of andesine and hornblende that is pleochroic from X=moderate greenish yellow and Y=various shades of olive and olive brown to Z=moderate to brilliant green. Small amounts of K-feldspar, quartz, and biotite (pleochroic from X=grayish yellow to Z=moderate reddish brown) are found in some specimens. Sphene is a relatively abundant accessory mineral; metallic opaque minerals are surprisingly rare or absent in most of these rocks.

The diorite appears to grade into medium-gray medium-grained quartz monzonite containing biotite and hornblende in about equal amounts. The biotite is pleochroic in shades of olive and olive brown, and the hornblende has the same pleochroism as in the diorite. In these rocks, the plagioclase appears to be oligoclase. The quartz monzonite also has abundant accessory sphene; metallic opaque minerals are rare or absent.

In addition to hornblende diorite and related rocks, the diorite complex contains granoblastic to gneissic rocks that have biotite but no hornblende and that are characterized by large pinkish K-feldspar crystals as much as 15 mm long. These rocks with strongly chloritized biotite do contain metallic opaque minerals, both as small particles in the chlorite and as discrete large crystals.

The felsic members of the complex are aplite, alaskite, simple pegmatite, and coarse-grained biotite quartz monzonite that probably is related to the quartz monzonite of Boundary Peak.

## GRANODIORITE OF MOUNT BARCROFT

### GEOLOGIC SETTING AND GENERAL DESCRIPTION

Outcrops of the Mount Barcroft unit extend (fig. 13) over an area of about 15 square miles in the southeastern part of the White Mountain Peak 15-minute quadrangle. They mark a profound structural break between Cambrian sedimentary rocks on the south and a mixed sequence of volcanic and sedimentary rocks of probable Mesozoic or late Paleozoic age on the north. The blunt dike-shaped mass extends northeastward into the Mount Barcroft quadrangle, where it covers an additional 10 square miles (Krauskopf, 1971). A 5-square mile mass of correlative rocks (Emerson, 1966; Krauskopf, 1971) is exposed about 2 miles farther east along the same trend as the main mass. The two masses are separated by younger intrusive rocks. The profound structural break appears to swing north in the Mount Barcroft quadrangle, whereas the trend shown by the two masses of the Mount Barcroft unit cuts across the trend to the northeast. Nevertheless, the western mass of the granodiorite of Mount Barcroft probably is controlled by this major structural break.

The Mount Barcroft unit is made up of medium-gray medium-grained rock that is generally equigranular; rare poikilitic K-feldspar crystals are as large as 10 mm. Along the north margin of the mass, the rocks are distinctly coarser grained than elsewhere. Fresh rocks are dark colored not only because of the abundance of dark minerals but because of dark-appearing feldspar. Some K-feldspar is a purplish pink. Quartz is not readily visible in most hand specimens. Dark minerals occur mostly as iregular aggregates that give a splotchy, messy texture to the rock; only locally are biotite and hornblende in discrete crystals. In some rocks, the dark minerals in part form distinctive rounded clots a few millimeters across. Dark rounded dioritic inclusions generally only a few inches across but as large as 2 feet in largest dimension are widely distributed and locally abundant, though in general much less abundant than one would expect in a granitic rock that contains 20–25 percent dark minerals—at least in the region of the Sierra Nevada batholith. The relative abundance of K-feldspar in these rocks (most modes plot in the quartz monzonite field) is also surprising for rocks this dark.

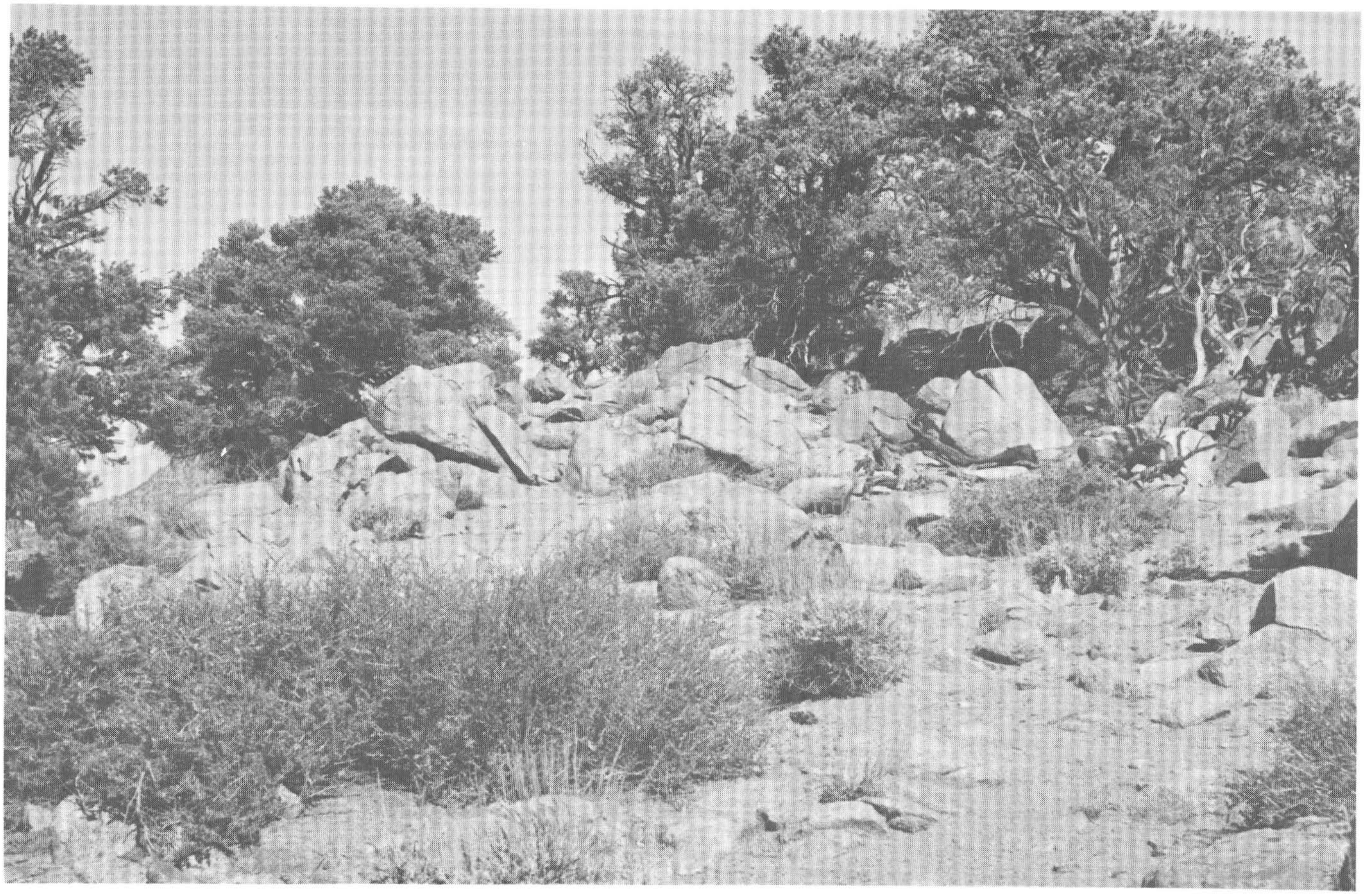


FIGURE 13.—Typical bouldery outcrop of granodiorite of Mount Barcroft.

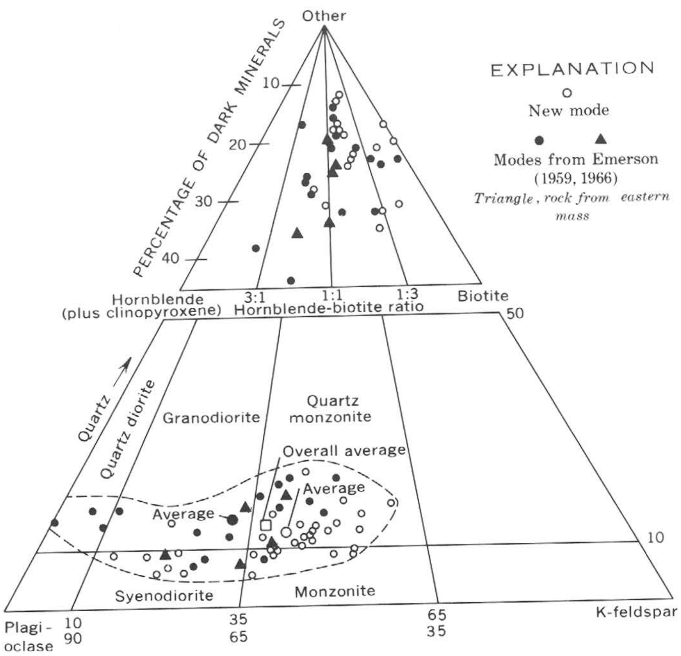



FIGURE 14.—Modal distribution of quartz, K-feldspar, and plagioclase in samples from the granodiorite of Mount Barcroft.

The modes (fig. 14; tables 5, 6) show a considerable spread but have a general clustering of most points in the quartz monzonite field. The tailing off of the field to quartz diorite in part represents plagioclase-rich rocks in the northeastern part of the western mass, but much of the variation has no obvious trend. Emerson (1959, p. 94) noted that the K-feldspar of these quartz diorite specimens has low triclinicity and a low albite to orthoclase ratio relative to the K-feldspar in other samples of the mass. The granodiorite of Mount Barcroft is quartz poor relative to most other granitic rocks in this region, and a number of points plot in the monzonite and syenodiorite fields. In general, the rocks along the southeastern side of the western mass and the western part of the eastern mass are slightly richer in quartz.

The somber gray appearance and the fuzzy, splotchy look of the dark minerals are the most distinctive features of this mass in outcrop.

MICROSCOPIC DESCRIPTION

Plagioclase is generally well formed and well twinned; it ranges from fresh to highly altered grains rich in

TABLE 5.—*Modes of granodiorite of Mount Barcroft*

| Sample | Plagioclase | K-feldspar | Quartz | Mafic minerals | | | | | Specific gravity |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Biotite | Hornblende | Clinopyroxene | Metallic opaque minerals | Undivided | |
| 30 | 42 | 28 | 8 | .... | .... | .... | .... | 22 | 2.76 |
| 31 | 34 | 38 | 8 | 20 | .... | .... | .... | .... | 2.74 |
| 32 | 38 | 22 | 6 | 24 | 8 | .... | .... | .... | 2.78 |
| 33 | 43 | 25 | 4 | 15 | 9 | 2 | 2 | .... | 2.76 |
| 34 | 43 | 26 | 9 | .... | .... | .... | .... | 22 | 2.76 |
| 35 | 32 | 37 | 10 | 10 | 8 | .... | 1 | .... | 2.72 |
| 36 | 35 | 39 | 7 | .... | .... | .... | .... | 19 | 2.72 |
| 37 | 50 | 15 | 7 | .... | .... | .... | .... | 28 | 2.79 |
| 38 | 33 | 32 | 6 | 12 | 16 | 1 | .... | .... | 2.74 |
| 39 | 46 | 7 | 5 | .... | .... | .... | .... | 42 | 2.83 |
| 40 | 49 | 11 | 6 | .... | .... | <1 | .... | 34 | 2.83 |
| 41 | 39 | 30 | 8 | .... | .... | <1 | .... | 23 | 2.74 |
| 42 | 34 | 36 | 16 | 8 | 5 | <1 | 1 | .... | 2.72 |
| 43 | 37 | 29 | 9 | .... | .... | .... | .... | 25 | 2.76 |
| 44 | 31 | 37 | 12 | 10 | 7 | [1]2 | 1 | .... | 2.74 |
| 45 | 42 | 28 | 7 | 15 | 7 | <1 | 1 | .... | 2.73 |
| 46 | 39 | 25 | 12 | 15 | 8 | <1 | 1 | .... | 2.73 |
| 47 | 46 | 12 | 10 | 15 | 16 | <1 | 1 | .... | 2.78 |
| 48 | 44 | 29 | 8 | 12 | 7 | <1 | .... | .... | 2.73 |
| 49 | 44 | 13 | 4 | .... | .... | .... | .... | 39 | 2.85 |
| 50 | 36 | 31 | 8 | .... | .... | .... | .... | 25 | 2.76 |
| 51 | 41 | 34 | 10 | .... | .... | .... | .... | 15 | 2.74 |
| 52 | 29 | 43 | 15 | 8 | 4 | .... | 1 | .... | 2.70 |
| 53 | 36 | 36 | 12 | .... | .... | .... | .... | 16 | 2.74 |
| 54 | 37 | 33 | 11 | 11 | 7 | .... | 1 | .... | 2.73 |
| 55 | 39 | 29 | 8 | .... | .... | .... | .... | 24 | 2.75 |
| 56 | 36 | 28 | 19 | 17 | .... | .... | .... | .... | 2.74 |
| 57 | 35 | 33 | 10 | .... | .... | .... | .... | 22 | 2.73 |
| 58 | 37 | 29 | 11 | .... | .... | .... | .... | 23 | 2.72 |
| 59 | 37 | 32 | 10 | 18 | 3 | .... | .... | .... | 2.71 |
| 60 | 48 | 13 | 4 | 25 | 10 | .... | .... | .... | 2.82 |
| 61 | 38 | 24 | 7 | 26 | 5 | .... | .... | .... | 2.78 |
| 62 | 47 | 16 | 4 | .... | .... | .... | .... | [2]33 | 2.82 |
| Avg. | 39 | 27 | 10 | 16 | 7 | 1+ | | 25 | 2.75 |
| | | | | | | 24 | | | |

[1]Trace of orthopyroxene

[2]Contains clinopyroxene.

TABLE 6.—*Modes of granodiorite of Mount Barcroft by Emerson (1959, p. 58, 95)*[1]

| Sample | Plagioclase | K-feldspar | Quartz | Biotite | Hornblende | Accessory minerals | Chlorite | Opaque minerals | Accessory and opaque minerals |
|---|---|---|---|---|---|---|---|---|---|
| E-8F | 42.7 | 21.9 | 13.6 | 9.8 | 9.9 | 0.6 | 0.6 | 0.9 | ...... |
| E-8G | 35.1 | 24.2 | 13.9 | 12.9 | 11.6 | .6 | .6 | 1.1 | ...... |
| E-8H | 40.4 | 25.9 | 8.6 | 12.5 | 11.1 | .4 | ...... | 1.1 | ...... |
| E-10A | 50.4 | 18.6 | 5.4 | 19.5 | 3.6 | 1.4 | .1 | 1.0 | ...... |
| E-10B | 56.3 | 7.0 | 12.8 | 21.7 | .6 | 1.5 | ...... | .1 | ...... |
| E-10C | 41.0 | 24.7 | 5.5 | 10.1 | 16.3 | .9 | .5 | 1.0 | ...... |
| E-11A | 46.1 | 18.1 | 5.4 | 12.1 | 16.5 | .2 | ...... | 1.6 | ...... |
| E-11B | 40.3 | 18.9 | 8.0 | 17.9 | 13.9 | .3 | ...... | .7 | ...... |
| E-11C | 36.2 | 25.1 | 17.0 | 14.5 | 5.7 | .6 | ...... | .9 | ...... |
| E-12A | 39.8 | 22.2 | 14.2 | 10.6 | [2]10.0 | .2 | ...... | 3.0 | ...... |
| E-12B | 30.7 | 30.3 | 17.3 | 9.2 | [3]6.5 | [4]4.4 | .8 | .8 | ...... |
| E-13A | 44.1 | 14.6 | 8.9 | 22.6 | 8.8 | .3 | ...... | .7 | ...... |
| E-19 | 38.4 | 20.4 | 4.2 | 12.9 | 22.9 | ...... | ...... | ...... | 1.2 |
| E-20 | 45.8 | 12.9 | 5.9 | 16.7 | 17.2 | ...... | ...... | ...... | 1.5 |
| E-23 | 42.9 | 4.4 | 7.5 | 16.2 | 27.9 | ...... | ...... | ...... | 1.1 |
| E-25 | 55.3 | 3.3 | 12.1 | 9.7 | 17.3 | ...... | ...... | ...... | 2.3 |
| E-26 | 52.3 | ...... | 9.6 | 8.0 | 29.8 | ...... | ...... | ...... | .3 |
| E-29 | 35.3 | 22.6 | 15.9 | 18.4 | 5.3 | ...... | ...... | ...... | 2.5 |
| E-30 | 37.6 | 31.5 | 14.6 | 8.1 | 5.7 | ...... | ...... | ...... | 2.5 |
| E-31 | 39.7 | 25.7 | 13.1 | 11.4 | 7.8 | ...... | ...... | ...... | 2.3 |
| E-32 | 35.9 | 31.8 | 12.9 | 4.9 | 11.5 | ...... | ...... | ...... | 3.0 |
| Avg. | 42.2 | 19.2 | 10.8 | 13.3 | 12.4 | | 2.1 | | |

[1]About 20 percent of sections studied contain augite along with hornblende (Emerson, 1959, p. 60).

[2]Predominantly augite.

[3]1 percent hypersthene, abundant augite, less than 1 percent hornblende.

[4]Predominantly secondary pyrite.

sericite and epidote-zoisite and is liberally sprinkled with biotite flakes (fig. 15). Zoning, in part oscillatory, is mostly in the andesine range; however, some cores are sodic labradorite, and some rims lap over to oligoclase. K-feldspar is generally in irregular interstitial grains of various sizes that grade up to poikilitic crystals several millimeters in diameter than engulf all other minerals in the rock.

Quartz is mostly in thin vermicular but in part straight-sided crystals (fig. 16). All the quartz is somewhat strained and shows a range from grains with undulatory extinction through mosaic grains with sutured contacts to granulated and slivered grains.

The dark minerals show the irregular splotchy nature noted in hand specimen. Biotite is mostly in ragged to slivery patches that are pleochroic from grayish orange to various shades of olive and brown. Alteration to chlorite is common. Many crystals that appear unaltered have trains of sphene droplets concentrated on cleavages; needles that may be rutile are common in the biotite in three directions 120° apart. Much biotite is in greenish aggregates with much epidote and chlorite; some of these aggregates contain remnants of the olive to brown biotite. Hornblende remnants in some indicate they were probably originally hornblende, and the shape of similar biotite aggregates strongly suggests they also were once hornblende. Hornblende occurs most commonly in ragged clusters with biotite, sphene, apatite, and metallic opaque minerals; rarely, hornblende is found in discrete nearly subhedral crystals. Cores of some hornblende crystals contain remnants of clinopyroxene that are in part iron stained, accounting for the reddish spots and cores seen in hornblende in hand specimen. One specimen contains orthopyroxene(?) in a hornblende crystal. Fresh hornblende is green and has the following pleochroism: X=moderate greenish yellow, Y=light olive, and Z=light olive to grayish green and less commonly moderate to dark yellowish green.

The shredded aggregates of biotite that are in part pseudomorphs after hornblende, the overall messy appearance of both hornblende and biotite, and the small dark clots, dominantly biotite (fig. 17), together give some of these rocks a megascopic resemblance to some of the rock of the Pellisier Flats unit. Although

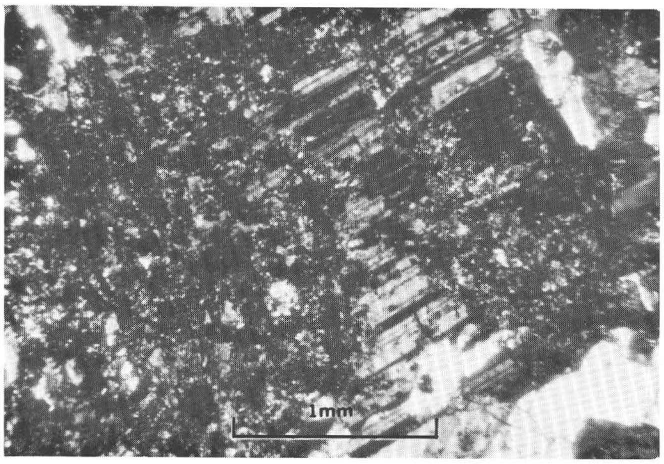



FIGURE 15.—Photomicrograph of plagioclase crystal in the granodiorite of Mount Barcroft flooded with sericite, epidote-zoisite, and biotite.

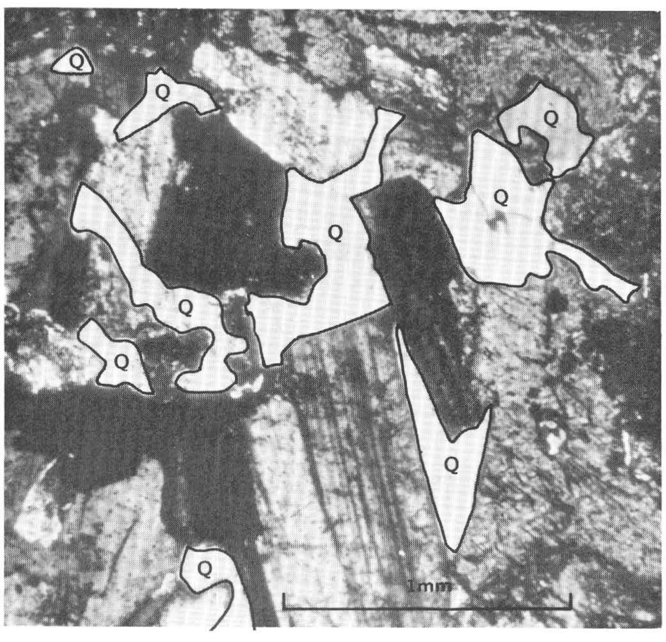



FIGURE 16.—Photomicrograph of distinctive interstitial quartz in the granodiorite of Mount Barcroft.

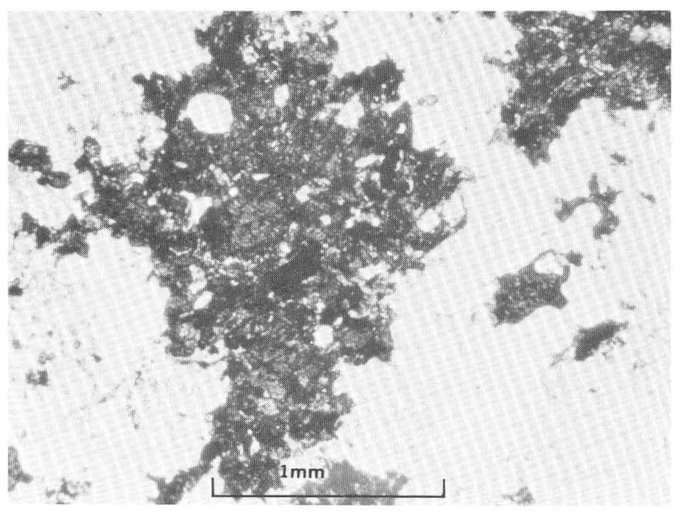



FIGURE 17.—Photomicrograph of irregular aggregate of biotite, hornblende, and magnetite in granodiorite of Mount Barcroft.

there are significant petrographic differences between the two masses and they are definitely not correlative, the similarities of their dark minerals suggest that both masses have undergone similar alteration. The Mount Barcroft unit was less affected, for most specimens still bear hornblende; although the plagioclase is somewhat altered, the average specimen is generally more calcic than the rocks in the Pellisier Flats unit.

Metallic opaque minerals are abundant and are most commonly associated with the dark mineral clusters. Well-formed crystals of apatite and irregular grains of sphene are widespread. Allanite and zircon are present but rare. Bluish pleochroic tourmaline is widely scattered in trace amounts.

## QUARTZ MONZONITE OF BOUNDARY PEAK

### GEOLOGIC SETTING AND GENERAL DESCRIPTION

The Boundary Peak unit crops out over some 25 square miles in the northern White Mountains. The mass underlies some very rugged terrain, culminating at 13,140 feet elevation in Boundary Peak. The dazzling white outcrops led Harris (1967) to liken the Boundary Peak unit to "a shining white fortress set in the somber colored northern White Mountains," an apt description of this vivid contrast (fig. 1). The quartz monzonite of Boundary Peak looks in gross aspect like a great dike whose west-northwest trend sharply cuts across the dominant, more northerly, structural grain of the region. Harris (1967) believed that the Boundary Peak unit is somewhat sheetlike and that it rose from a root zone near the west limit of present outcrops, then spread eastward. The gently dipping roof of granitic and metamorphic rocks certainly suggests that the Boundary Peak unit might be tabular, but this cannot be determined, as the lower contact is not exposed.

The Boundary Peak unit is medium to coarse grained and light gray to dazzling white in outcrop but in part weathers to various shades of tan and buff. In many fresh outcrops, pinkish K-feldspar is easily distinguished from white plagioclase. Coarse masses of clear quartz are evident, and scattered wisps and flakes of biotite are present. Much of the rock, particularly along the west side of the outcrop area, is foliated to gneissic. Where best developed, this foliation is shown by strung-out biotite that gives the rocks an anastomosing structure. Harris (1967) noted that in some of the western outcrops, the quartz grains are sheared into subparallel bands.

The granitic rock is remarkably uniform in appearance, and the compositional homogeneity is shown by the compactness of the modal field in figure 18. (See also tables 7 and 8.) The ratio of plagioclase to K-feldspar is somewhat higher along the west side of the mass,

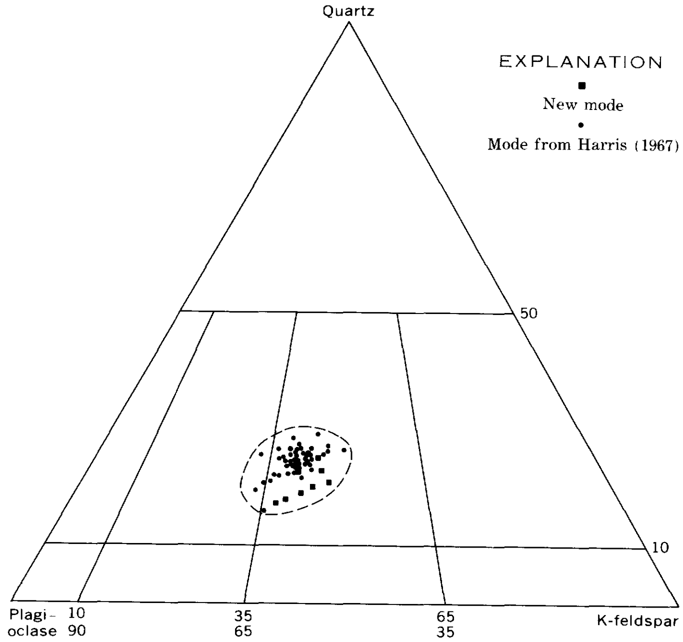



FIGURE 18.—Modal distribution of quartz, K-feldspar, and plagioclase in samples from quartz monzonite of Boundary Peak.

which is also slightly lower in quartz, but the differences are not great. Aplite and pegmatite dikes are surprisingly rare. Harris (1967) noted them at only one locality about 1 mile northeast of Boundary Peak. Aplite and pegmatite are also present about 2 miles north of Boundary Peak. Inclusions are virtually absent, except for fairly obvious wallrock inclusions from the Pellisier Flats unit and from the diorite complex bodies near contacts.

### MICROSCOPIC DESCRIPTION

The plagioclase ranges from fresh to strongly saussuritized and is in part oscillatorily zoned. Harris (1967), using the angular separation of the 131–131 reflections by X-ray diffractometer, reported a range of $An_{10}$ to about $An_{30}$. The plagioclase tends to be a bit more felsic to the southeast. Harris also determined the index of refraction of a number of fused glass beads of plagioclase and reported a range of about $An_{10}$–$An_{25}$, using the curve of Schairer, Smith, and Chayes (1956, p. 196).

Irregular masses of K-feldspar, somewhat less abundant than plagioclase, generally are grid twinned and in part perthitic. Harris (1967, p. 47) analyzed several K-feldspars. Those from the quartz monzonite of Boundary Peak show 84–91 percent orthoclase, 8–14 percent albite, and 1–2 percent anorthite. The orthoclase content is possibly a bit higher in the western, "fat" end of the mass, but very subtly so. Contrastingly, four K-feldspars from the Pellisier Flats unit just north

TABLE 7.—*Modes of quartz monzonite of Boundary Peak*

| Sample | Plagioclase | K-feldspar | Quartz | Mafic minerals | | Specific gravity |
|---|---|---|---|---|---|---|
| | | | | Biotite | Hornblende | |
| 10 | 41 | 36 | 20 | [1]3 | .... | 2.63 |
| 11 | 41 | 32 | 24 | 3 | .... | 2.64 |
| 12 | 43 | 34 | 19 | 4 | <1 | 2.62 |
| 13 | 45 | 33 | 18 | 4 | .... | 2.65 |
| 14 | 40 | 33 | 22 | [1]5 | .... | 2.63 |
| 15 | 48 | 31 | 18 | 3 | <1 | 2.65 |
| 16 | 50 | 30 | 17 | 3 | <1 | 2.65 |
| 17 | 45 | 30 | 22 | 3 | <1 | 2.65 |

[1]Also contains 1 percent muscovite.

TABLE 8.—*Modes of quartz monzonite of Boundary Peak by Harris (1967, table 1)*

| Sample | Plagioclase | K-feldspar | Quartz | Other |
|---|---|---|---|---|
| H-4 | 43.8 | 27.6 | 25.8 | 2.8 |
| H-5 | 42.4 | 31.2 | 24.4 | 2.0 |
| H-6 | 39.6 | 33.2 | 25.2 | 2.0 |
| H-12 | 42.0 | 30.1 | 24.6 | 3.1 |
| H-13 | 42.6 | 31.6 | 23.6 | 2.6 |
| H-14 | 43.8 | 30.5 | 23.0 | 2.8 |
| H-15 | 48.6 | 24.3 | 25.0 | 2.2 |
| H-16 | 42.4 | 31.2 | 23.5 | 3.1 |
| H-17 | 41.1 | 31.2 | 23.8 | 3.9 |
| H-18 | 42.4 | 30.0 | 25.0 | 2.6 |
| H-19 | 43.2 | 28.9 | 25.6 | 2.2 |
| H-20 | 40.8 | 30.7 | 26.0 | 2.4 |
| H-22 | 43.8 | 30.0 | 24.1 | 2.2 |
| H-23 | 39.0 | 33.6 | 25.8 | 1.6 |
| H-24 | 39.0 | 30.5 | 28.5 | 2.0 |
| H-25 | 41.8 | 32.1 | 22.4 | 3.7 |
| H-26 | 43.3 | 28.8 | 25.2 | 2.6 |
| H-27 | 44.7 | 28.6 | 23.5 | 3.2 |
| H-28 | 44.4 | 29.4 | 23.3 | 3.0 |
| H-29 | 47.0 | 27.6 | 21.0 | 4.3 |
| H-30 | 36.2 | 36.3 | 25.8 | 1.7 |
| H-32 | 45.8 | 28.6 | 23.0 | 2.6 |
| H-33 | 44.1 | 29.0 | 24.0 | 2.8 |
| H-34 | 51.6 | 25.7 | 18.8 | 3.8 |
| H-35 | 47.8 | 27.6 | 21.3 | 3.2 |
| H-36 | 44.0 | 30.3 | 23.4 | 2.3 |
| H-37 | 43.5 | 28.1 | 26.9 | 1.5 |
| H-38 | 50.2 | 26.2 | 20.1 | 3.5 |
| H-39 | 45.2 | 30.0 | 21.9 | 3.0 |
| H-40 | 52.4 | 28.8 | 15.1 | 3.7 |
| H-41 | 41.6 | 28.8 | 25.2 | 4.3 |
| H-42 | 43.7 | 30.0 | 22.6 | 3.6 |
| H-43 | 44.2 | 28.2 | 24.8 | 2.7 |
| H-44 | 45.4 | 29.0 | 21.4 | 4.2 |
| H-45 | 44.8 | 31.7 | 21.0 | 2.6 |
| H-46 | 45.4 | 25.8 | 25.6 | 3.2 |
| H-47 | 45.0 | 27.0 | 24.1 | 3.8 |
| H-48 | 43.5 | 29.2 | 22.3 | 5.0 |
| H-49 | 44.6 | 28.6 | 24.2 | 2.6 |
| H-50 | 43.8 | 29.0 | 24.8 | 2.4 |
| H-51 | 41.6 | 30.8 | 23.9 | 3.6 |
| H-53 | 41.8 | 28.2 | 26.2 | 3.8 |
| H-54 | 38.2 | 33.2 | 26.5 | 2.1 |
| H-55 | 41.6 | 31.3 | 24.9 | 2.2 |
| H-56 | 41.3 | 31.0 | 25.0 | 2.8 |
| H-57 | 49.2 | 27.1 | 20.2 | 3.5 |
| H-58 | 46.5 | 26.8 | 24.2 | 2.4 |
| H-59 | 46.0 | 27.7 | 24.0 | 2.4 |
| H-60 | 42.8 | 27.2 | 27.6 | 2.4 |

of the Boundary Peak unit have 78–81 percent orthoclase, 17–26 percent albite, and 2–4 percent anorthite.

Quartz ranges from irregular masses with undulatory extinction to mosaicked and sutured crystals. In more sheared rocks, the quartz is definitely granulated and slivered into anastomosing trains. Some quartz is sprinkled through the rock in rounded crystals, giving an aplitic look to the rock. Biotite is invariably present in scattered irregular grains. It is pleochroic from X= grayish yellow and grayish orange to Z=light olive to light olive brown. Gray-green to moderate-green hornblende is present in trace amounts in several specimens. Metallic opaque minerals, sphene, apatite, zircon, and allanite (in part rimmed with epidote) are scattered through the mass. The alteration products chlorite, sericite, and epidote are present in variable amounts.

Most thin sections, though structureless, do show some quartz strain and locally have bent and fractured feldspar crystals. Locally rocks of the Boundary Peak unit are foliated and gneissic. Harris (1967, p. 20) noted that deformation was most intense near the western contact and attributed this largely to forcible injection (Harris, 1967, p. 40), speculating that the Boundary Peak unit may have been forcibly emplaced along an early fault zone near its west margin. A rather strong north-trending foliation in the bounding rocks of the Pellisier Flats unit to the west could be a reflection of such a zone of weakness.

## CHEMICAL RELATIONS

During the geologic mapping, Crowder obtained chemical analyses of specimen 44 of the granodiorite of Mount Barcroft, specimens 124 and 134 of the quartz monzonite and granite of Pellisier Flat, and specimens 116, 214, and 241 of the quartz monzonite of Boundary Peak (table 9). Unfortunately, except for specimen 44, thin sections are not available, and the specimens are missing. Owing to fading or illegibility of labels, a number of specimens from Crowder's collection could not be identified and had to be thrown out. Presumably, the missing chemically analyzed specimens were in this group. Nonetheless, it seems worthwhile to record the analyses, even though their petrography is unknown. The remaining five chemical analyses given in table 9 were obtained by Ross from specimens collected for radiometric age dating. The 11 chemical analyses represent a very small and probably unrepresentative sample of the intrusive bodies, as can be seen from figure 3.

The study of numerous thin sections indicates that the chemical analyses of the granodiorite of Mount Barcroft probably represent fairly well the rock type of at least the western mass and that those of the quartz monzonite of Boundary Peak probably represent this unit fairly well. The large, variable, and much-altered Pellisier Flats unit, on the other hand, is far less representatively sampled by the four analyses of table 9. We do not know what specimens 124 and 134 represent; their field location suggests they are part of the

TABLE 9.—*Chemical analyses of granitic rocks in the northern White Mountains*

[Chemical analyses by rapid rock method; analysts: P. L. D. Elmore, Lowell Artis, J. L. Glenn, Gillison Chloe, Hezekiah Smith, and James Kelsey. Semiquantitative spectrographic analyses by Chris Heropoulos. Results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12 . . . , but are reported arbitrarily as midpoints of these brackets, 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1 . . . The precision of a reported value is approximately plus or minus one bracket at 68 percent, or two brackets at 95 percent confidence. Looked for, but not found: Ag, As, Au, Bi, Cd, Mo, Pd, Pt, Sb, Sn, Te, U, W, Zn, Ge, Hf, In, Li, Re, Ta, Th, Tl, Pr, Sm, Eu]

| | Granodiorite of Mount Barcroft | | | Quartz monzonite and granite of Pellisier Flats | | | | Quartz monzonite of Boundary Peak | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 44 | 61 | 62 | 124 | 134 | 163 | 165 | 16 | 116 | 214 | 241 |
| **Chemical analyses (weight percent)** | | | | | | | | | | | |
| $SiO_2$ | 62.6 | 60.1 | 57.8 | 70.0 | 70.0 | 64.8 | 66.1 | 68.7 | 71.4 | 72.4 | 70.4 |
| $Al_2O_3$ | 16.5 | 17.3 | 17.1 | 14.7 | 15.0 | 16.4 | 15.8 | 16.8 | 15.4 | 15.3 | 15.7 |
| $Fe_2O_3$ | 1.9 | 2.1 | 2.2 | 1.4 | 1.2 | 1.8 | 1.5 | 1.0 | .87 | .82 | 1.0 |
| FeO | 3.2 | 3.6 | 4.5 | 1.2 | 1.1 | 2.6 | 2.4 | .96 | .57 | .44 | .42 |
| MgO | 2.2 | 2.5 | 3.4 | .70 | .61 | 1.6 | 1.5 | .43 | .24 | .22 | .24 |
| CaO | 3.9 | 4.6 | 6.0 | 1.3 | 1.2 | 2.8 | 3.0 | 2.4 | 1.7 | 1.3 | 2.0 |
| $Na_2O$ | 3.2 | 3.2 | 2.9 | 4.0 | 3.8 | 3.7 | 3.5 | 4.4 | 4.3 | 4.1 | 4.3 |
| $K_2O$ | 4.4 | 4.3 | 3.6 | 4.7 | 4.9 | 5.0 | 4.6 | 4.2 | 3.8 | 4.0 | 3.8 |
| $H_2O^-$ | 0 | 1.0 | 1.0 | .06 | .05 | .81 | .60 | .35 | .03 | .08 | .10 |
| $H_2O^+$ | .90 | .08 | .10 | .92 | .58 | .12 | .07 | .08 | .57 | .92 | .76 |
| $TiO_2$ | .70 | .80 | .86 | .43 | .44 | .80 | .62 | .34 | .18 | .16 | .21 |
| $P_2O_5$ | .28 | .33 | .42 | .12 | .12 | .24 | .18 | .08 | .05 | .04 | .08 |
| MnO | .10 | .11 | .11 | .05 | .04 | .11 | .07 | .05 | .04 | .04 | .05 |
| $CO_2$ | <.05 | <.05 | <.05 | <.05 | <.05 | .15 | <.05 | <.05 | .10 | <.05 | .05 |
| Total | 99.88 | 100.02 | 99.99. | 99.58 | 99.04 | 99.83 | 99.32 | 99.79 | 99.25 | 99.82 | 99.11 |
| **Semiquantitative spectrographic analyses (ppm)** | | | | | | | | | | | |
| B | 70 | 10 | 10 | ... | ... | ... | ... | ... | ... | 10 | 7 |
| Ba | 1,000 | 1,500 | 1,000 | 700 | 700 | 1,500 | 1,500 | 2,000 | 1,000 | 1,000 | 1,500 |
| Be | 3 | ... | ... | 5 | 5 | 2 | ... | ... | 2 | 2 | 3 |
| Ce | 150 | 150 | 100 | 150 | 100 | 200 | 150 | 150 | ... | ... | ... |
| Co | 20 | 10 | 20 | 5 | 5 | 7 | 7 | ... | ... | ... | ... |
| Cr | 30 | 20 | 50 | 1 | ... | 15 | 15 | ... | ... | ... | ... |
| Cu | 70 | 30 | 70 | 7 | 5 | 20 | 15 | 7 | 3 | 2 | 2 |
| Ga | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 20 | 20 | 20 | 20 |
| La | 50 | 70 | 50 | 70 | 100 | 100 | 70 | 70 | 30 | ... | ... |
| Nb | 15 | ... | ... | 15 | 15 | 15 | 10 | ... | 10 | 10 | 10 |
| Nd | ... | ... | ... | ... | ... | 70 | ... | ... | ... | ... | ... |
| Ni | 20 | 10 | 20 | ... | ... | 7 | 10 | ... | ... | ... | ... |
| Pb | 15 | 15 | 7 | 20 | 20 | 30 | 10 | 20 | 30 | 30 | 30 |
| Sc | 15 | 15 | 20 | 7 | 5 | 10 | 10 | ... | ... | ... | ... |
| Sr | 700 | 1,000 | 1,000 | 200 | 200 | 500 | 700 | 1,500 | 700 | 1,000 | 1,000 |
| V | 150 | 70 | 150 | 30 | 50 | 50 | 70 | 20 | 10 | ... | 20 |
| Y | 30 | 20 | 20 | 30 | 30 | 30 | 30 | 10 | ... | 15 | 10 |
| Yb | 3 | 2 | 2 | 3 | 3 | 3 | 2 | ... | ... | ... | ... |
| Zr | 150 | 100 | 150 | 150 | 150 | 200 | 150 | 100 | 150 | 100 | 150 |
| **CIPW norms (weight percent)** | | | | | | | | | | | |
| Q | 14.9 | 10.9 | 9.0 | 25.4 | 26.2 | 15.5 | 19.1 | 21.4 | 28.6 | 30.6 | 27.0 |
| or | 26.3 | 25.7 | 21.5 | 28.2 | 29.4 | 29.9 | 27.4 | 25.0 | 22.8 | 23.9 | 22.9 |
| ab | 27.4 } $An_{39}$ | 27.4 } $An_{43}$ | 24.8 } $An_{48}$ | 34.3 } $An_{14}$ | 32.7 } $An_{14}$ | 31.7 } $An_{27}$ | 29.8 } $An_{32}$ | 37.5 } $An_{23}$ | 36.9 } $An_{17}$ | 35.1 } $An_{15}$ | 37.0 } $An_{20}$ |
| an | 17.7 | 20.4 | 23.3 | 5.7 | 5.3 | 11.5 | 13.8 | 11.5 | 7.6 | 6.3 | 9.2 |
| wo | ... | .2 | 1.7 | ... | ... | ... | ... | ... | ... | ... | ... |
| en | 5.5 | 6.3 | 8.6 | 1.8 | 1.5 | 3.8 | 3.8 | 1.1 | .6 | .6 | .6 |
| fs | 3.4 | 3.8 | 5.3 | .4 | .4 | 2.6 | 2.3 | .5 | .1 | ... | ... |
| mt | 2.8 | 3.1 | 3.2 | 2.1 | 1.8 | 1.9 | 2.2 | 1.5 | 1.3 | 1.1 | .9 |
| hm | ... | ... | ... | ... | ... | ... | ... | ... | ... | .1 | .4 |
| il | 1.3 | 1.5 | 1.7 | .8 | .8 | 1.5 | 1.2 | .7 | .3 | .3 | .4 |
| ap | .7 | .8 | 1.0 | .3 | .3 | .6 | .4 | .2 | .1 | .1 | .2 |
| C | .1 | ... | ... | 1.0 | 1.6 | .7 | ... | .8 | 1.5 | 2.0 | 1.2 |
| cc | ... | ... | ... | ... | ... | ... | ... | ... | .2 | ... | .1 |
| Total | 100.1 | 100.1 | 100.1 | 100.0 | 100.0 | 100.0 | 100.0 | 100.2 | 100.0 | 100.1 | 99.9 |
| **Niggli numbers** | | | | | | | | | | | |
| si | 229.5 | 204.6 | 179.5 | 348.7 | 355.3 | 258.0 | 272.1 | 317.3 | 375.6 | 396.0 | 361.2 |
| al | 35.6 | 34.7 | 31.3 | 43.2 | 44.9 | 38.8 | 38.3 | 45.7 | 47.7 | 49.3 | 47.5 |
| fm | 27.4 | 28.6 | 32.9 | 15.7 | 14.0 | 22.0 | 22.4 | 10.3 | 8.0 | 7.4 | 7.7 |
| c | 15.3 | 16.8 | 20.0 | 6.9 | 6.5 | 12.0 | 13.2 | 11.9 | 9.6 | 7.6 | 11.0 |
| alk | 21.7 | 19.9 | 15.9 | 34.3 | 34.6 | 27.2 | 26.1 | 32.1 | 34.7 | 35.7 | 33.8 |
| qz | 42.8 | 25.0 | 16.1 | 111.7 | 117.1 | 49.3 | 68.0 | 89.0 | 136.9 | 153.2 | 125.9 |
| k | .5 | .5 | .5 | .4 | .5 | .5 | .5 | .4 | .4 | .4 | .4 |
| mg | .4 | .4 | .5 | .3 | .3 | .4 | .4 | .3 | .2 | .2 | .2 |
| **Specific gravity (bulk)** | | | | | | | | | | | |
| | 2.74 | 2.76 | 2.76 | 2.62 | 2.62 | 2.67 | 2.67 | 2.61 | n.d. | 2.61 | 2.68 |
| **Modes (volume percent)** | | | | | | | | | | | |
| Plagioclase | 31 | 38 | 47 | 20 | 20 | 24 | 39 | 50 | | | |
| K-feldspar | 37 | 24 | 16 | 44 | 45 | 39 | 27 | 30 | | | |
| Quartz | 12 | 7 | 4 | 23 | 27 | 12 | 17 | 17 | | | |
| Biotite | 10 | 26 | } | { 13 | 8 | 25 | 11 | 3 | | | |
| Hornblende | 7 | 5 | } [1]33 | .... | .... | .... | 5 | <1 | | | |
| Clinopyroxene | [2]2 | ... | } | .... | .... | .... | .... | | | | |
| Metallic opaque minerals | 1 | ... | ... | .... | .... | .... | 1 | .... | | | |

[1]Mixed biotite, hornblende, and clinopyroxene with epidote and chlorite.

[2]Trace of orthopyroxene.

Specimen localities (parentheses enclose California Grid System coordinates, zone 4):

44. T. 4 S., R. 33 E., (2,638,000 E., 391,500 N.), White Mountain Peak quadrangle.
61. Sec. 3, T. 5 S., R. 33 E., (2,628,800 E., 388,000 N.), White Mountain Peak quardangle.
62. Sec. 33, T. 4 S., R. 33 E., (2,627,200 E., 393,800 N.), White Mountain Peak quadrangle.
124. T. 2 S., R. 33 E., (2,627,200 E., 482,000 N.), Benton quadrangle.
134. T. 2 S., R. 33 E., (2,625,000 E., 470,700 N.), Benton quadrangle.
163. (Float) T. 3 S., R. 33 E., (2,623,000 E., 422,700 N.), White Mountain Peak quadrangle.
165. (Float) T. 1 S., R. 32 E., (2,596,300 E., 491,000 N.), Benton quadrangle.
16. (Float) T. 1 S., R. 32 E., (2,596,300 E., 491,000 N.), Benton quadrangle.
116. T. 1 S., R. 33 E., (2,614,500 E., 506,800 N.), Benton quadrangle.
214. T. 2 S., R. 33 E., (2,629,300 E., 489,700 N.), Benton quadrangle.
241. T. 1 S., R. 33 E., (2,629,500 E., 502,600 N.), Benton quadrangle.

coarse felsic facies, although Crowder's field notes describe both localities as "typical Pellisier." Specimen 163 is typical gray Pellisier with abundant K-feldspar, highly altered plagioclase, shredded scattered biotite, and no hornblende, a composition associated with the area of widespread albitization, and is probably a representative sample of the Pellisier Flats unit south of the coarse felsic facies. Specimen 165, in contrast, retains original hornblende, has much less altered plagioclase, and is a fair sample of the less altered Pellisier Flats unit north of the coarse felsic facies.

Despite the limitations of these chemical data, generalizations can be made about the northern White Mountains granitic rocks. The silica variation diagrams (fig. 19) have remarkably linear plots. If Anderson's analyses (1937) were similarly plotted, they would show wide divergences from the trends of figure 19. The variation diagrams reflect the high K-feldspar content of specimens 124, 134, and 163 of the Pellisier Flats unit by their low CaO content and correspondingly high $K_2O$ content. But as these specimens are not enriched in $Na_2O$, it appears that, even though their plagioclase is strongly altered, they are not strongly albitized, for were they, the NaO would be enriched, probably at the expense of $K_2O$ as well as CaO.

The trends of the oxides in the variation diagrams show that CaO is markedly lower and that $K_2O$ is markedly higher than in similar plots for other granitic suites (fig. 20). These proportions mean that not only is the Pellisier Flats unit extremely high in K-feldspar, but also the entire granitic suite is rich in $K_2O$ relative to other granitic suites in the western batholithic belt. Compared with the other granitic suites, the northern White Mountains rocks seem to become relatively enriched in both $Na_2O$ and $Al_2O_3$ as $SiO_2$ increases.

The northern White Mountains rocks have a low Peacock index, about 54, which puts them well into the alkali-calcic field (fig. 21). The eastern and central Sierra Nevada granitic rocks have a Peacock index of about 60, the Coast Ranges about 61, the western Sierra about 63, the Southern California batholith about 65, and the Klamath Mountains about 63 (Ross, 1972; P. E. Hotz, oral commun., 1971). It appears that the entire northern White Mountains suite is rich in alkalis and poor in lime, apparently reflecting a regional trend rather than a local alteration effect. Bateman and Dodge (1970) noted that $K_2O$ increases eastward across the Sierra Nevada batholith and that CaO may decrease eastward.

About 40 miles south of the northern White Mountains in the Inyo Mountains is a suite of granitic rocks in which the $K_2O$ is somewhat higher than in comparable rocks in the Sierra Nevada to the west (Ross, 1969, p. 34, 36). Yet both soda and lime were comparable for the Inyo Mountains and the Sierra. Evidence so far collected shows that the granitic rocks of the Inyo-White Mountains are high in $K_2O$ and that the north end of the range is, in addition, strikingly low in CaO.

Ternary plots of selected oxides and normative minerals show restricted and separate fields for each of the triangles (fig. 22). The pronounced linear trend on the Alk–F–M diagram directly reflects color index. The closest comparison that can be made between modes and norms is the ternary diagram that plots the normative quartz and feldspars (quartz-orthoclase-albite plus anorthite). The northern White Mountains granitic rocks cluster closely near the border between granodiorite and quartz monzonite (if the modal rock classification is superimposed on the normative diagram) (fig. 23). The Mount Barcroft unit, as expected from modes, is lowest in normative quartz. The normative field falls over the center and average values of the modal field. The normative field of the Boundary Peak unit is only slightly displaced away from the K-feldspar corner as compared with the modal field, which probably means the extra $K_2O$ from biotite that becomes orthoclase in the norm is more than compensated for by the albite molecule in the K-feldspar that shows up as albite plus anorthite in the normative plot. As these rocks are very low in dark minerals, this distribution is expectable. The tightness of the normative field of the Pellisier Flats unit in comparison to the great spread of the modal field largely reflects sampling; the chemically analyzed specimens are relatively unaltered, whereas the modal field includes a great variety of altered rocks.

The trace-element contents listed in table 9 and represented by the histograms of figure 24 show mainly that the granodiorite of Mount Barcroft is relatively richer in Co, Cr, Cu, Ni, Sc, and V than the Boundary Peak and Pellisier Flats units, which almost certainly reflects the higher content of dark minerals in the Mount Barcroft unit, with which these trace elements are most commonly associated. Boron was below the detection limit (7 ppm) in all four samples from the Pellisier Flats unit yet ranged from 10 to 70 ppm in the Mount Barcroft unit.

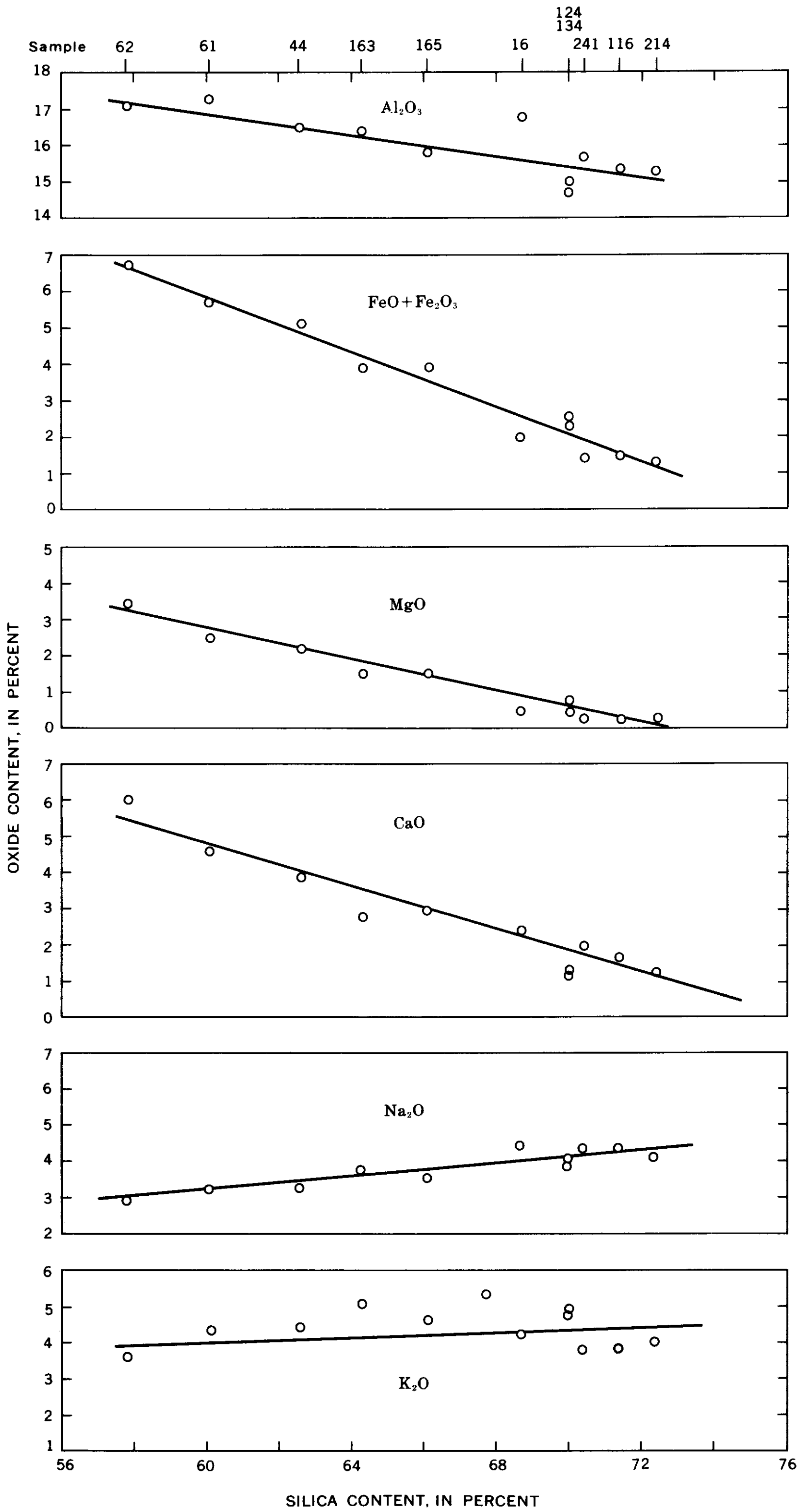



**FIGURE 19.—Silica variation diagrams of granitic rocks, northern White Mountains.**

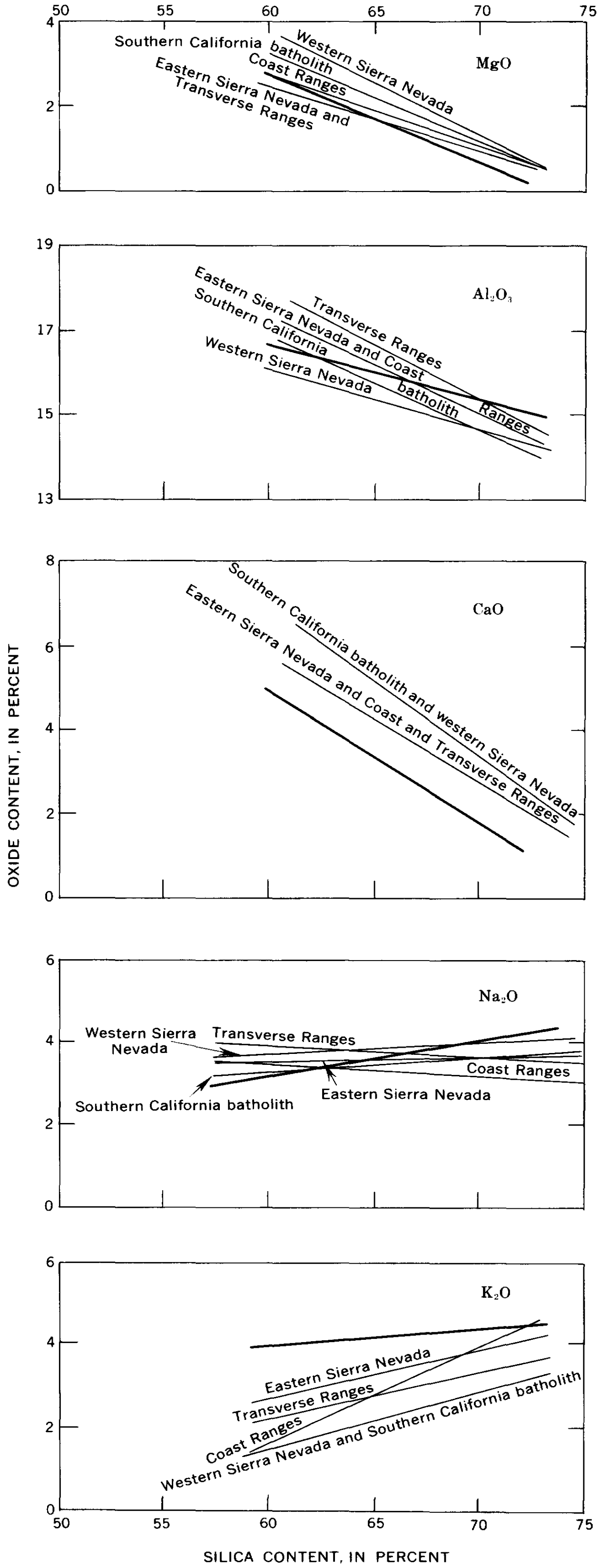



FIGURE 20.—Silica variation diagrams comparing oxide contents of the granitic rocks of the northern White Mountains (heavy line) with other granitic suites.

## ANDERSON'S GRANITIZATION CONCEPT

Anderson (1937, p. 1–74), from his study of the northern White Mountains, concluded that two extensive granitic formations, his Pellisier and Boundary Peak Granites, made up most of the granitic basement. He further concluded that the Pellisier Granite originated by granitization of sediments as a result of heat, pressure, and solutions from the magma that eventually crystallized as the Boundary Peak Granite. The principal lines of evidence cited by Anderson (1937, p. 46) are gradational contacts, partially digested xenoliths, variable composition and texture of the Pellisier Granite, pseudosedimentary layering in the Pellisier Granite, and increased mafic content in the Pellisier Granite near wallrock contacts.

Emerson (1966, p. 146) showed that the purported relict sedimentary bedding in the Pellisier Granite of Anderson is not related to, nor traceable into, the wallrock. Emerson (1966, p. 146), Krauskopf (1971), and Crowder mapped intrusive contacts of Anderson's Pellisier Granite with its wallrocks as generally distinct and relatively sharp, although Krauskopf (1971) did note narrow zones of migmatite at some contacts.

Anderson lumped other granitic masses in the Mount Barcroft quadrangle with his Pellisier Granite (Emerson, 1966; Krauskopf, 1971), which accounts for some of the variability he attributed to this unit. Nonetheless, the part of Anderson's Pellisier Granite now called the Pellisier Flats unit is variable; digestion of metavolcanic wallrock material is evident in the White Mountain Peak quadrangle as well as in the migmatitic border zones in the Mount Barcroft quadrangle (Krauskopf, 1971). Yet the normal facies of the Pellisier Flats unit, with its small biotite clots and dull-gray color, is relatively similar over a large area. The coarse felsic facies of the Pellisier Flats unit looks like either a somewhat younger core facies or a somewhat less contaminated core facies; it is distinctive and recognizable over a large area.

It seems that Anderson, in his reconnaissance study of the granitic rocks of the northern White Mountains, may have extrapolated too much from marginal contamination effects. And his emphasis on broad gradational contacts may have been based on very local observations, for there is a general pattern of relatively sharp contacts of the Pellisier Flats unit with its wallrocks. Anderson was certainly handicapped by the lack of a good topographic base map and aerial photographs, and his study therefore must have stressed thin section petrography rather than field relations. The pitfalls he faced in trying to evaluate hand specimens and thin sections without an adequate understanding of field relations are apparent and serve as a good lesson for any petrographer.

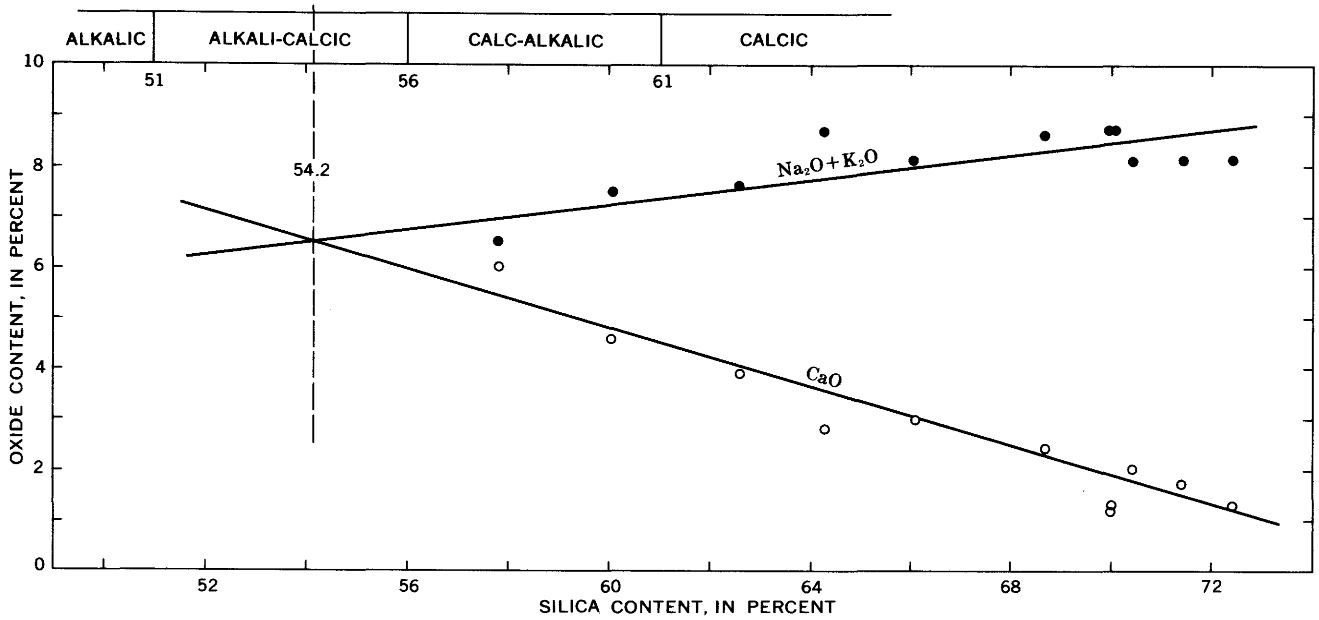



FIGURE 21.—Peacock index of granitic rocks, northern White Mountains.

## ALBITIZATION

Both granitic and metavolcanic rocks are albitized over an area of some 50 square miles. Essentially all the bedrock north of Milner Canyon (fig. 1) in the White Mountain Peak quadrangle, except for some of the metasedimentary rocks, is altered. In thin section, rocks from this area show a considerable amount of clean fresh secondary albite. Sample localities of these rocks are shown in figure 25. Not all rocks within the area are equally albitized, but the extent of alteration in some degree is striking.

The most intensely albitized rocks can be divided into three types: (1) medium- to coarse-grained "alaskitic" rocks composed almost entirely of fresh-looking albite and quartz, (2) similar medium- to coarse-grained rocks containing abundant K-feldspar in addition to albite and quartz, and (3) rocks with well-preserved porphyritic volcanic texture that are almost entirely fresh-looking albite and quartz. The first two types most likely are intensely altered rocks of the Pellisier Flats unit, for transitional rocks that grade into typical rocks of the Pellisier Flats unit are present. The third type is quite obviously the result of albitization of the metavolcanic section.

To confirm the anorthite content of these albitic rocks, X-ray diffraction patterns were run on three typical samples from each of the three varieties. All are more sodic than $An_5$, and most are about $An_1$, nearly pure albite. It has been suggested that such nearly pure albite cannot be a normal primary magmatic product (Gilluly, 1933, p. 74).

The coarse-grained "alaskitic" rocks and some of the finer grained metavolcanic rocks seem at first glance to be alaskite and aplite. Closer study reveals abundant strange chessboard albite twinning and a complete absence of K-feldspar. These features, together with preserved volcanic textures in the "aplitic" rocks and gradation of the "alaskite" to rocks of the Pellisier Flats unit, leave little doubt about the parent rocks of these strange alaskites and aplites.

In addition to these three types of intensely albitized rocks, the Pellisier Flats unit contains abundant evidence of probably related alteration in the same area. Invariably, thin sections of these rocks show intensely saussuritized plagioclase liberally sprinkled to choked with sericite, epidote, and biotite and scattered shreds and aggregates of biotite, but they do not show any amphibole. Some clean fresh albite is found, part of which has chessboard twinning (fig. 12).

The pattern of present distribution suggests that all rocks of the Pellisier Flats unit south of the coarse felsic facies (fig. 9) underwent considerable alteration of original plagioclase and dark minerals. Within the coarse felsic facies and in the normal gray rocks north of the coarse facies, intense albitization is not found; moreover, the gray rocks of the Pellisier Flats unit north of the coarse facies contain hornblende, which must surely have been originally present in the rocks of the Pellisier Flats unit south of the coarse facies. The most intense alteration of metavolcanic rocks generally coincides with the area of alteration of the Pellisier Flats unit. These relations suggest we are dealing with

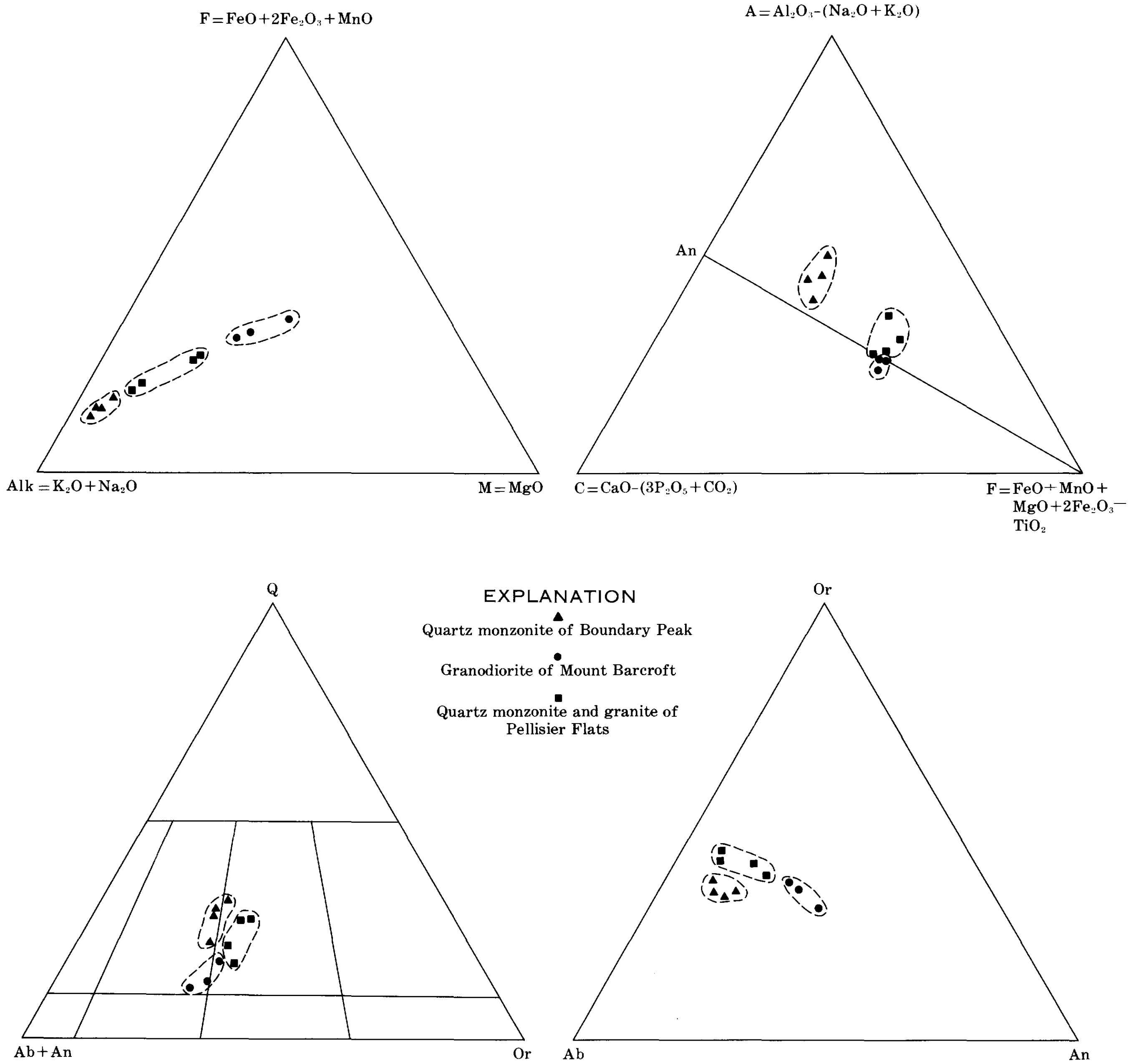



FIGURE 22.—Distribution of selected oxides and normative minerals, northern White Mountains.

a pervasive process that affected a volcanic and granitic terrane of some 50 square miles.

Anderson (1937, p. 50, 72) was the first to recognize the albitization in the White Mountains, but he apparently concentrated his attention on the granitic rocks, because he did not mention the similar intense albitization of associated metavolcanic rocks. He did note that metasediments in contact with what he regarded as Pellisier Granite are similarly albitized (p. 52), probably referring to what are now known to be metavolcanic rocks, but there is little further mention of albitization in the wallrocks. Anderson suggested that the Pellisier Granite formed by replacement; he postulated that the Boundary Peak Granite furnished active granitizing and albitizing solutions that converted sediments into Pellisier Granite by metasomatism. The distribution of the most intensely albitized rocks clearly argues against this thesis. The rocks of the Pellisier Flats unit nearest the quartz monzonite of Boundary Peak are much less albitized and otherwise altered than

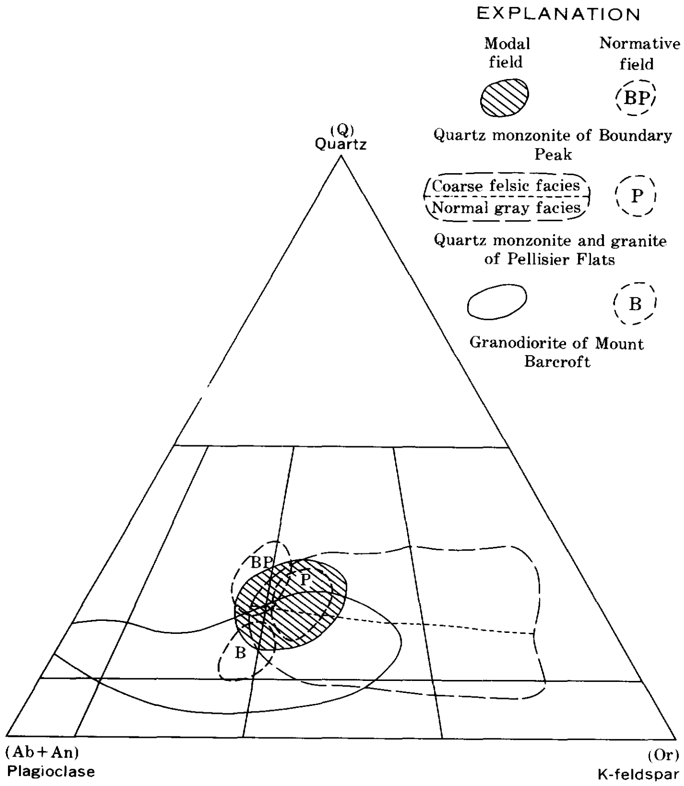



FIGURE 23.—Modal and normative fields for granitic rocks of the northern White Mountains.

the rocks of the Pellisier Flats unit and associated volcanic rocks some distance to the south. It appears that the Boundary Peak unit was not the source of albitizing solutions.

Anderson (1937, p. 15, 41, 67, 70) listed chemical analyses for four samples of Pellisier Granite described as albitized. These rocks contain from 2.7 to 4.6 percent $Na_2O$, 2.5 to 4.8 percent $K_2O$, and 1.1 to 3.8 percent CaO. It is frustrating that there are no modal data for these specimens, but the general chemical character of the rocks is closer to that of the strongly saussuritized rocks that retain their original granitic character than to the intensely albitized rocks with clean secondary albite. Anderson (1937, p. 45) listed chemical analyses for two samples from albite-rich bodies that he believed to be replacement bodies in the "metasediments" near the main batholith. These rocks contain about 6 percent $Na_2O$ and about 1 percent each $K_2O$ and CaO. Anderson described them as being composed almost entirely of chessboard albite and quartz, with minor amounts of biotite, sphene, and magnetite. These rocks probably are part of the intensely albitized terrane. Although no textures are mentioned, they would seem from the setting described to be albitized metavolcanic rock, but they could be albitized rocks of the Pellisier Flats unit that became mobilized and were squirted into the adjacent wallrocks.

Anderson (1934) described and illustrated a texture in these albitized rocks that he called "pseudo-cataclastic." It looks cataclastic, but because the rock contains abundant fresh secondary material, Anderson believed it was a replacement texture. Gilluly (1933) noted that cataclastic rocks were easier prey for replacement solutions in a vast albitized terrane in Oregon. He further noted that in other areas albitization was more common in rocks that had been crushed. Crowder, in his field notes on the White Mountains rocks, was torn between calling these rocks hornfelsed or cataclastically deformed. Nevertheless, many of these intensely albitized rocks show remarkably well preserved original granitic or volcanic textures; therefore, pervasive shearing was not necessary for the albitization. But there is abundant evidence of shearing in this terrane, and it seems likely that numerous channelways were available to albitizing solutions. How or why the area of most intense albitization was localized is not clear. It is tempting to speculate that there is some connection with the White Mountain fault zone (fig. 1).

In summary, the Pellisier Flats unit, with highly altered plagioclase, shredded aggregates of biotite, and loss of hornblende throughout the southern part of the body, probably underwent considerable change since its intrusion. The anomalous abundance of K-feldspar also attests to an unusual, and probably not original, composition. It is perhaps significant that within the area where intense albitization produced rocks from which all the K-feldspar was driven, the granitic rocks of the Pellisier Flats unit are extremely rich in K-feldspar. Possibly the K-feldspar was redistributed in the alteration process, for it seems unlikely that the original magma that produced the Pellisier Flats unit was as rich in potassium as present modes suggest.

It also seems evident that the nearby metavolcanic rocks underwent the same kind of alteration as the Pellisier Flats unit. The metavolcanic rocks were intensely albitized, they lost their original pyroxene and amphibole, and they now contain scattered shreds and aggregates of biotite, in part in the altered plagioclase, much like the Pellisier Flats unit. It is not likely that the Pellisier Flats unit was the "altering agent"; rather, some younger unit probably provided solutions that transformed both the Pellisier Flats intrusive and its metavolcanic wallrocks. Also, the distribution of altered rocks suggests the presently exposed Boundary Peak rocks were not the source of the altering solution. It may be worth noting that the most intense albitization seems to be associated with the area of the mixed Pellisier Flats unit and metavolcanic rocks and that the granitic rocks are most altered where the elongate prong of the Pellisier Flats unit protrudes into the metavolcanic wallrocks.

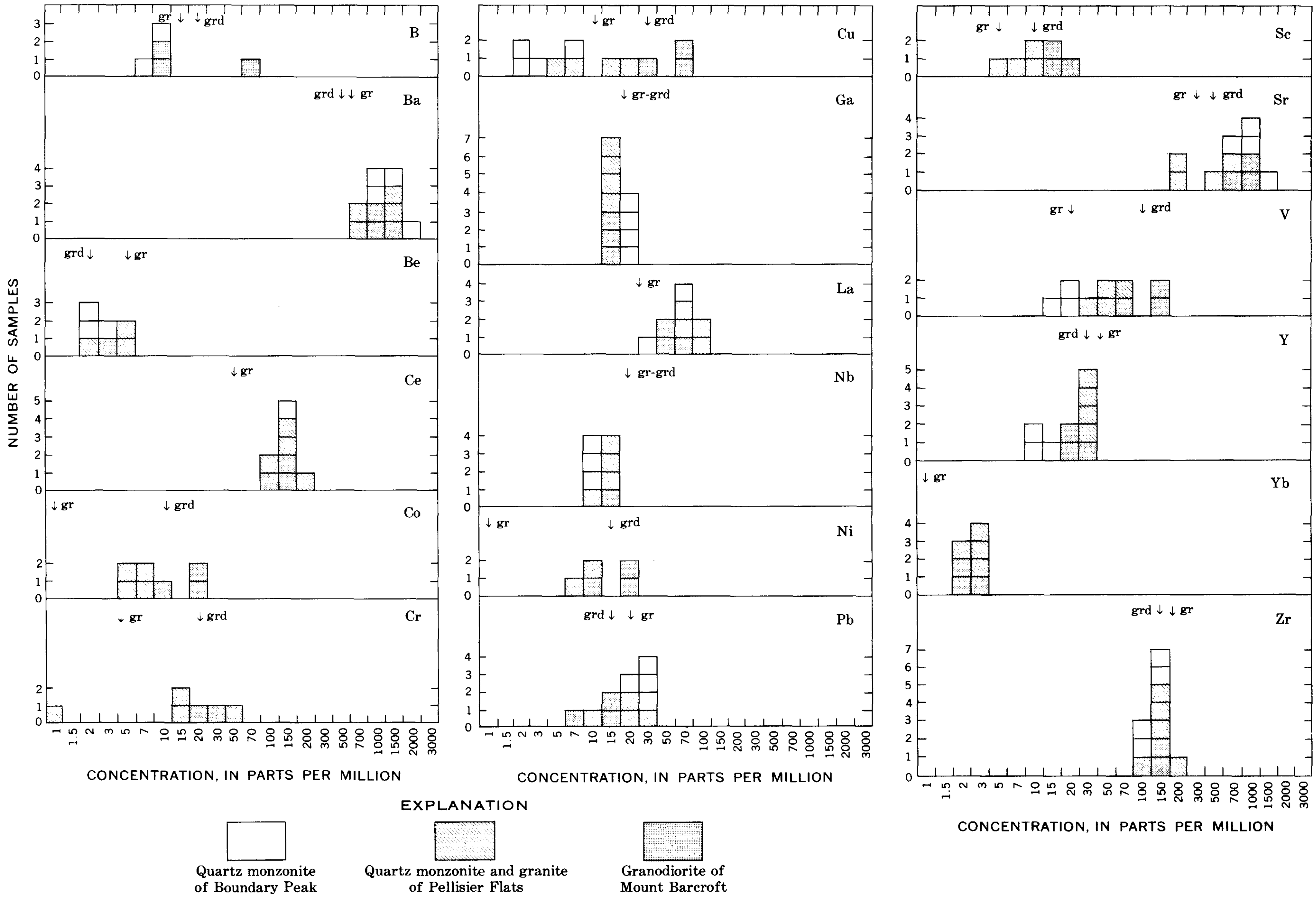



**FIGURE 24.—Trace-element content of granitic rocks, northern White Mountains. Averages for granodiorite (grd) and granite (gr) are from Taylor (1965).**

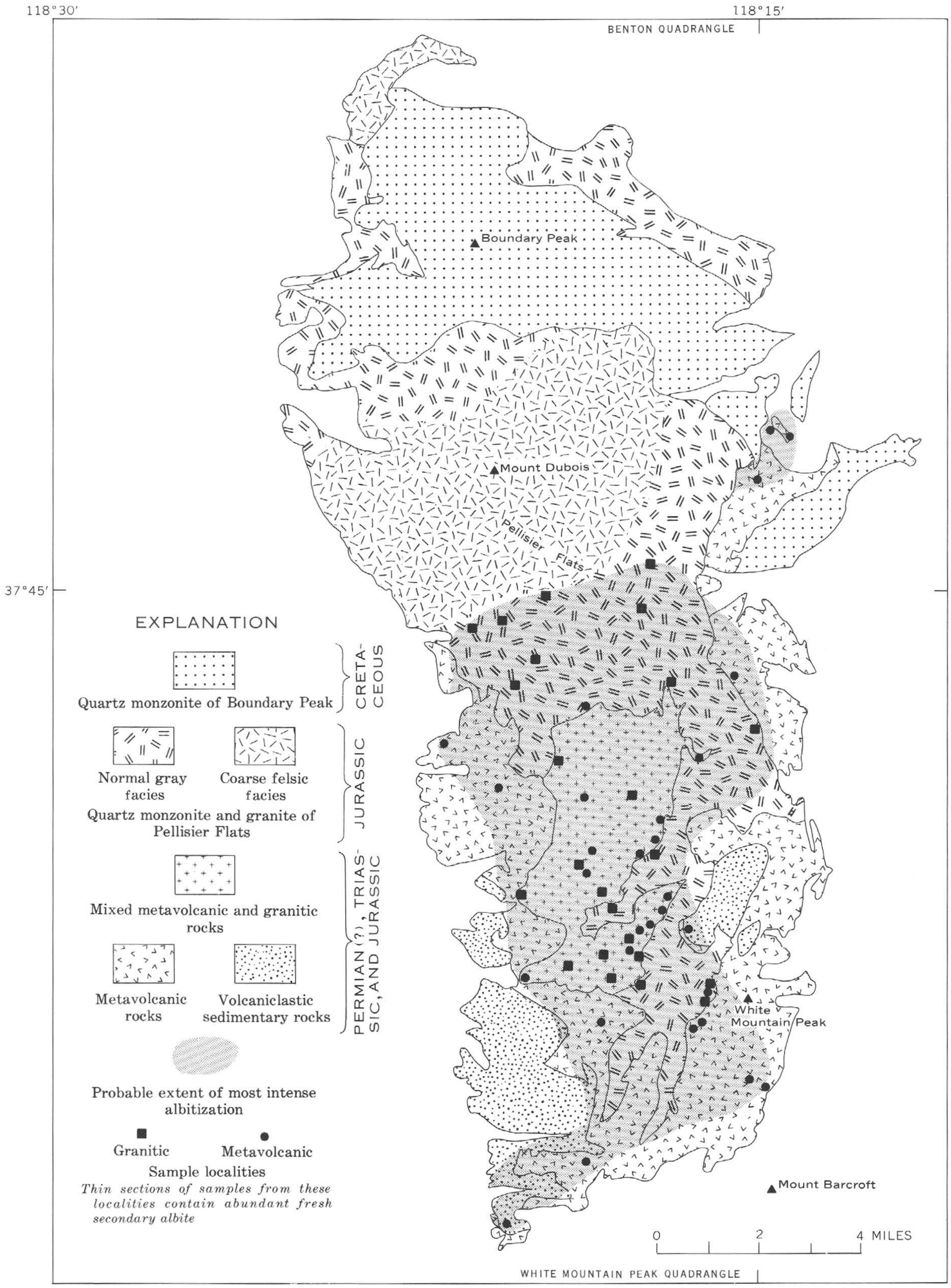



FIGURE 25.—Distribution of albitized rocks in the northern White Mountains.

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