University of Nevada

Reno

The Geology of the Black Mountain Area, Mineral County, Nevada

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science
in Geology

by

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June 1969

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Reno

June 1969

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ABSTRACT

The Black Mountain area, just outside the town of Schurz, Mineral County, Nevada, was investigated and a geologic map of the area was prepared. Rock samples were collected and studied in hand specimen and thin section. Approximate chemical analyses were calculated from modal analyses. From the data thus obtained, an interpretation of the origins of the rocks of the area was made.

The Black Mountain area is underlain by four intrusive rock bodies. These intrusives are a dioritic rock type, two granodiorites, and a quartz monzonite, which were all intruded during the Jurassic(?) and Cretaceous. Roof pendants of Triassic(?) metavolcanics, recrystallized limestone, and metamorphosed shallow intrusives are present. Parts of the area are overlain by Tertiary intermediate volcanic rocks and Quaternary mafic volcanic rocks. Good examples of range front faulting are present at the base of the eastern slope of the mountain. The intrusive rocks are thought to be the products of the differentiation of a single magma.

INTRODUCTION

Geographic Setting and Accessibility

Black Mountain is located immediately south of the 39th Parallel in the northwest part of Mineral County, Nevada, and is the northernmost peak in the Wassuck Range. It is immediately west of the town of Schurz, Nevada, and of the junction of Route 95 and Alternate Route 95. The steep eastern face of the mountain rises from an elevation of 4120 feet in the town of Schurz to 8102 feet at the summit, over a distance of three to four miles to the west. The eastern slope of the mountain lies in the Walker River Indian Reservation, whose center of activity is the town of Schurz.

Access to the eastern face of the mountain is in the form of five dirt roads. The northernmost is the road to the Black Mountain Copper Mine, which produced a small amount of copper during World War I (Ross, 1961, Table 6.3). This road extends to within 1000 feet of the summit. Farther south, a Bell Telephone Microwave Station service road, which is graded and well maintained, extends up to 6143 feet. The next road south is a completely washed out jeep and foot trail which ends at 6100 feet. The two southernmost roads in the map area extend merely to the foot of the mountain and were once access roads to some small prospects which are at the roads' terminations.

Access to the southwestern slope of the mountain is provided by a dirt road which once serviced the Northern Lights Mine, which also produced a small amount of copper during World War I (Ross, 1961, Table 6.3). This road has been extended up into the graben valley,

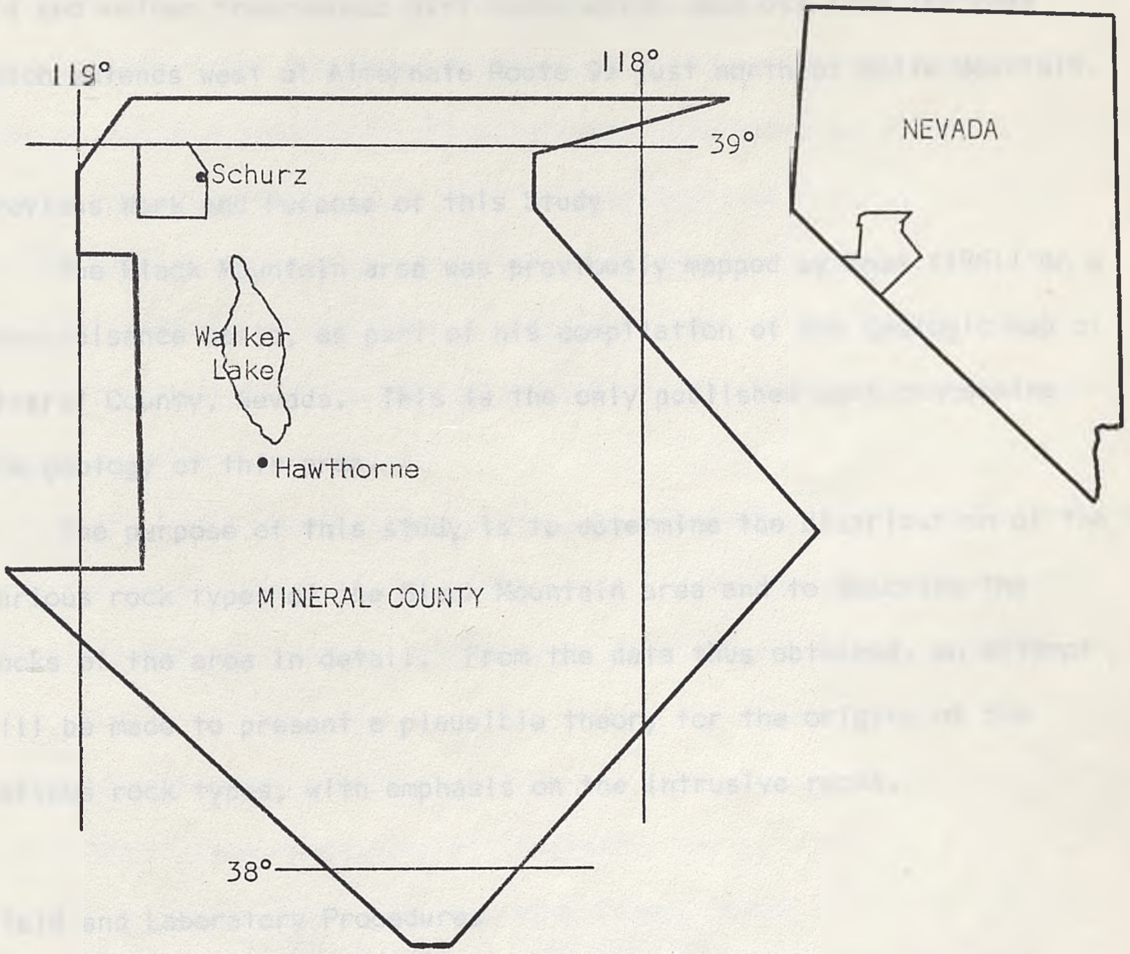

FIGURE (1). Index map showing the location of Mineral County and of the map area.

immediately west of the summit of the mountain, by the Bear Creek Mining and Exploration Company.

The northwestern part of the mountain can be reached by several old and rather treacherous dirt roads which lead off from the road which extends west of Alternate Route 95 just north of White Mountain.

Previous Work and Purpose of this Study

The Black Mountain area was previously mapped by Ross (1961) on a reconnaisance basis, as part of his compilation of the Geologic Map of Mineral County, Nevada. This is the only published work concerning the geology of this area.

The purpose of this study is to determine the distribution of the various rock types of the Black Mountain area and to describe the rocks of the area in detail. From the data thus obtained, an attempt will be made to present a plausible theory for the origins of the various rock types, with emphasis on the intrusive rocks.

Field and Laboratory Procedures

During the late summer and early fall of 1967, and the entire summer of 1968, approximately 30 square miles of the Black Mountain area were investigated by the writer. Geologic mapping was done on U.S. Geological Survey Preliminary Topographic Maps at a scale of 1:24,000. Aerial photographs of the eastern front of the range were made available early in 1969 and were used to plot the prominent range front faults.

Approximately one hundred of 275 specimens collected were thin sectioned. Several thin sections from each unit, which were considered to be representative of that unit, were studied and described in detail. Mineral determinations were made in thin section and the modes were determined by point-counting with a mechanical stage. The average accuracy limit for the modes determined by 1000 point point-counts is plus or minus 2.5 percent. For the modes determined by 500 point point-counts the average accuracy limit is plus or minus 4 percent. These limits were determined by using the chart developed by Van der Plas and Tobi (1965). Plagioclase compositions were determined by the a-normal method, and the 2V measurements of the K-feldspar were made on a four axis universal stage.

Approximate chemical analyses of the intrusive rocks were calculated from the modal data, utilizing the Sigma 7 computer at the University of Nevada and the program developed by Dietrich and Sheehan (1964).

Definition of Terms

Grain size ranges for all rocks:

.1mm	very fine-grained
.1-1mm	fine-grained
1-3mm	medium-grained
3mm	coarse-grained

The intrusive rocks were assigned names on the basis of the relative percentages of quartz, plagioclase, and K-feldspar in the rock. These names are assigned according to the following scheme:

Rock Name	% Plagioclase of Total Feldspar
Quartz Monzonite	35 - 65
Grandiorite	65 - 95
Diorite	95 - 100

These rock names were confirmed by plotting the granitic rocks on the ternary diagram used by Johannsen (1939, Vol. I, p. 144, Fig. 107). See FIGURE (2).

The usage of all the other terms in this thesis is based on the definitions in the American Geological Institute's <u>Glossary of Geology and Related Sciences with Supplement</u> (1960).

Acknowledgments

Professor Malcolm J. Hibbard guided the research and writing of this thesis. Martin Fogel, research advisor at the Computer Center at the University of Nevada, assisted in the utilization of the Sigma 7 computer. The Walker-Martell Mining Company provided housing in the field. Many of the thin sections were prepared by J. Bartlett Murphy, mineral preparator at the Mackay School of Mines. The Nevada Bureau of Mines financially supported much of the field work, and the Mackay School of Mines Graduate Research Fund supported much of the laboratory research. Fellow graduate students at the Mackay School of Mines provided critical comments, insights and assistance in all stages of the research and writing.

The above guidance, criticism, and assistance is gratefully acknowledged.

METAMORPHIC ROCKS

Introductory Statement

The metamorphic rocks occur scattered throughout the area and have been mapped as three separate units, two on the basis of their color in the field and the third on the basis of its mineralogy. There is a light colored unit (the Felsic Metatuff Unit), a dark colored unit (the Fine-Grained Metadiorite Unit), and a Crystalline Limestone Unit. All of these rocks have been metamorphosed. Within the Felsic Metatuff Unit are several altered aplite dikes. The Crystalline Limestone Unit occurs only in the southernmost part of the area and forms the steep slope above the Northern Lights Mine. The Fine-Grained Metadiorite Unit is a fine-grained meta quartz diorite to metadiorite. The dark and light units occur interfingered in the south and north-central parts of the area.

The southwest side of White Mountain is very complex, containing dikes of the White Mountain Granodiorite, inclusions of both the light and dark colored units, and very small areas of intermediate volcanic rocks. The dike rocks have a foliation which may be due to flow-banding, and some of the dark colored metamorphic rocks of this area are schistose.

Descriptions

The Crystalline Limestone Unit is a medium- to coarse-grained light gray rock. It is entirely made up of twinned calcite grains; the rock has been highly fractured, and the individual mineral grains have been cracked. The calcite grains have a tendency toward polygonal mosaics, indicating that some recrystallization has taken place. Also, the textures in the rock are very similar to those in the photographs by Griggs, et al (1960), of calcite subjected to an annealing recrystallization process in the laboratory.

The rocks of the Felsic Metatuff Unit are white to yellow to brown. The darker colors are iron oxide stains from the weathering of pyrite. Rounded to sub-angular clasts are present in a very fine- to fine-grained groundmass of quartz and feldspar. The clasts are quartz grains, which are rounded and irregularly shaped, and plagioclase, which has been partially to totally replaced by sericite and what is probably kaolinite. Also present, in varying amounts in the rock, are clinopyroxene, epidote, pyrite, actinolite, apatite, biotite, and muscovite. Limonite and hematite line and fill some of the many fractures and cracks in the rock, and small quartz veins are also present. On knoll 7236, just southeast of and above the Black Mountain Copper Mine, the quartz grains are strongly fractured and the rock contains small amounts of jarosite. Near the contacts of this unit and the Black Mountain Granodiorite there are several small, altered aplite dikes. These aplites are very fine- to fine-grained white to pink rocks, and some have iron staining. Fragments of plagioclase crystals up to 3mm long are present, and have been almost totally replace by sericite. The groundmass consists of quartz and feldspar grains, and biotite, epidote, muscovite, pyrite, and magnetite are also present. The rocks are fractured, and again, these fractures are lined and filled with limonite and hematite. Quartz veins are also present. No foliations or lineations were observed in this rock type.

The rocks of the Fine-Grained Metadiorite Unit are fine-grained and gray with rare plagioclase phenocrysts up to 1.5mm long. The specimens studied have had their original textures and mineralogies obscured to varying degrees by the metamorphism. The freshest specimen studied is of quartz dioritic to dioritic composition. It contains plagioclase which has normal and oscillatory zoning, ranging from An_{25} to An_{37}, an average composition of An_{30}, and is partially replaced by sericite. Also present is clinopyroxene, altered to hornblende and magnetite. Much of the hornblende has been replaced by biotite, and the biotite has been partly replaced by chlorite. Making up the remainder of the rock is sphene, calcite, epidote, apatite, and quartz. The more strongly metamorphosed portions of this unit have had their original textures almost completely obscured. The clinopyroxene and hornblende have been almost completely replaced, and the percentages of the very fine- to fine-grained epidote, sericite, biotite, and magnetite are greatly increased, to the extent that it is impossible to make any determinations of the plagioclase composition. However, in a few places where the plagioclase has not been completely replaced, it is possible to obtain relative refractive indices. Some of the grains have higher, some lower, and some approximately the same indices as balsam, indicating that some albitization of the plagioclase has taken place. No foliations or lineations were observed in this rock type.

Age and Correlation

The metamorphic rocks of the Black Mountain area have been called part of the Excelsior Formation by Ross (1960). He mapped them as intermediate to felsic volcanics with local areas of limestone. The age of the Excelsior is still in question and may be either Permian or Middle Triassic (Muller and Ferguson, 1936, Ferguson and Cathcart, 1954, and Ross, 1961, p. 20-21).

Cross-cutting relationships can be seen on the Black Mountain Copper Mine road, where the Fine-Grained Metadiorite Unit is cut by dikes of a younger dioritic unit. This younger dioritic unit will be described in the next section. Near the contacts of the metamorphic rocks and the various intrusive rocks of the area, dikes of the intrusives can be seen in the metamorphics, and inclusions of the metamorphics in the intrusives are common.

The field evidence indicates that the metamorphic rocks are the oldest rocks in the area, and there is no evidence which is not consistent with assigning a Triassic age to the premetamorphic rocks.

Petrogenetic Conclusions

The close association of the three metamorphic units implies that they are very close to the same age. The presence of the Crystalline Limestone Unit, which is assumed to be a marine formation, indicates that at some time during the formation of the metamorphic rocks a submarine environment existed. The Felsic Metatuff Unit is volcanic in origin, and the Fine-Grained Metadiorite Unit is probably a shallow intrusion. The metadiorite unit has magmatic textures such as the normal and oscillatory zoning of the plagioclase (Vance, 1962). The grain size of this unit is too large to classify the unit as a volcanic rock, but it is smaller than that of the other intrusives. The rock has been described as a shallow intrusion on the basis of the grain size.

The metamorphism of these rocks appears to be transitional between the albite-epidote hornfels facies and the hornblende hornfels facies. This facies assignment is based on the presence of albite, epidote, and hornblende in the rocks. Another explanation for the presence of the mineral assemblages characteristic of both of these facies is that the rocks have been subjected to two or more periods of metamorphism. These periods of metamorphism may have coincided with the various intrusions of the area, or the rocks may have been subjected to a regional thermal metamorphism followed by the contact metamorphism associated with the intrusive rocks. The rocks seem to tend toward a hornfelsic texture, and there is a lack of metamorphic tectonite structures. On this basis it appears that these rocks have been subjected to a static thermal contact metamorphism and/or a regional thermal metamorphism.

The character of the metamorphism appears to be independent of its distance from the contacts with the intrusive rocks, which leads to the conclusion that the metamorphic rocks are roof pendants, possibly metamorphosed by a regional thermal metamorphism preceeding or contemporaneous with the emplacement of the intrusive rocks.

The proximity of the aplite dikes in the metatuff unit and the Black Mountain Granodiorite implies that the aplites are probably related to the late intrusive stages of the granodiorite. The plagioclase grain fragments in the aplites are probably small inclusions of the metatuff unit.

DIORITIC ROCK UNIT

Introductory Statement

The Dioritic Rock Unit forms the very steep ridges and valleys at the foot of the eastern slope of the mountain and is also present in smaller areas in the central and northwestern parts of the map area. All of these rocks have been metamorphosed, but the textures and mineralogies of the original rock types are still evident. In several places in the eastern part of the area a gneisose structure is present, and the orientations of some of these structures have been plotted on the map. The original rock types are diorite, quartz diorite, and diorite to quartz diorite porphyry. Modal analyses of these rocks are presented in TABLE (I).

Descriptions

The mineralogy of all of the rocks in this unit is essentially the same. They contain plagioclase, quartz, biotite, hornblende, sphene, epidote, apatite, and magnetite, with varying amounts of K-feldspar, chlorite, actinolite, and clinopyroxene. Texturally these rocks have a wide variation, both megascopically and microscopically. The dioritic and quartz dioritic rocks range from fine-grained to fine- to coarse-grained, to coarse-grained and it appears that the coarser grained rocks have the largest percentages of quartz. The plagioclase in all the rocks has normal zoning, oscillatory zoning with a normal trend, and patchy zoning. The highest compositional range observed in a single crystal is An_{20} to An_{80}, the lowest An_{35} to An_{55}, and the average composition of the

Specimen No.	Plagioclase Percent	Plagioclase Composition	K-feldspar Percent	Quartz Percent	Biotite Percent	Hornblende Percent	Epidote Percent	Accessories Percent
BM-104	51.8	An_{45}	---	7.4	16.8	19.0	1.8	3.2
Bm-109	33.0	An_{50}	---	9.4	15.8	40.2	0.6	1.2
BM-123	56.8	An_{55}	---	1.4	11.8	25.4	0.4	4.2
BM-257	55.0	An_{55}	---	5.0	17.0	17.6	2.6	2.8
BM-274	69.0	An_{50}	---	5.2	19.0	2.0	2.2	3.0
BM-277	31.6	An_{45}	2.8	6.6	10.2	46.6	1.0	1.0
AVERAGE	49.5	An_{50}	0.5	5.8	15.1	25.1	1.4	2.8
BM-138	42.8	An_{60}	3.2	13.2	21.0	11.2	6.0	2.4
BM-186	52.4	An_{45}	---	15.0	23.0	7.2	1.2	1.4
AVERAGE	47.6	An_{52}	1.6	14.1	22.0	9.2	3.6	1.9
BM-108	53.0	An_{42}	0.8	16.6	15.4	11.2	1.8	1.4
BM-139	70.4	An_{45}	---	8.2	5.8	11.6	0.7	4.3
BM-140A	69.4	An_{48}	---	2.8	6.2	15.6	2.0	4.0
BM-247	66.8	An_{50}	---	12.0	8.0	9.8	1.0	2.6
AVERAGE	64.9	An_{46}	0.2	9.9	8.8	12.0	1.6	2.9

TABLE (1). Modal analyses of the Dioritic Rock Unit based on 500 point point-counts of each specimen. All specimens show varying amounts of metamorphism. The first group is the dioritic rock type; the second, the quartz dioritic rock type; and the third, the dioritic to quartz dioritic porphyry rock type.

plagioclase in the entire unit is about An_{49}. The K-feldspar is microcline, identified by its characteristic cross-hatched twinning, and some is microperthitic. The hornblende is present both as fresh euhedral crystals with twinning and as grains partially altered to biotite. Some subhedral to euhedral biotite is present, and in some cases the biotite is partially replaced by chlorite. Sericitization of the plagioclase has occurred in varying amounts, and secondary epidote is common. Relict clinopyroxene, probably augite, is seen in some of the samples, and is invariably almost completely replaced by hornblende. Actinolite is present in some of the rocks as small aggregates of radiating crystals, and the magnetite commonly seems to be an alteration product of both hornblende and biotite.

The fine-grained rocks seem to have larger percentages of sericite than the coarser grained rocks and have small areas of elongate hornblende and biotite crystals in random orientations, with associated epidote. Quartz is evenly distributed throughout the rock, and in some areas is present as phenocrysts. In these larger grains of quartz there are poikilitic inclusions of plagioclase, biotite, and hornblende.

In the fine- to coarse-grained rocks, biotite and hornblende are present as poikilitic inclusions within large, optically continuous grains of plagioclase. Quartz is present both interstitially and within the large plagioclase crystals.

In some of the medium- and coarse-grained rocks, and to a lesser extent in the porphyry rocks, small plagioclase grains are present within larger plagioclase grains. Some of these small grains seem to be localized along fractures in the larger grains, and others seem to be randomly distributed in the larger grains. Where two or more of these small crystals are in contact their interfaces are straight and have no relationship to the crystal structure. The large grains have normal, oscillatory, and patchy zoning, and the small grains have normal and patchy zoning. The compositions of the small grains are very close to those of the large grains. Some actinolite is present in at least two of the specimens studied which contain this texture. These rocks also contain small patches of lath shaped hornblende and biotite crystals with random orientations.

The porphyry rocks have very fine- to fine-grained matrices with plagioclase phenocrysts as large as 10mm and biotite and hornblende phenocrysts as large as 5 mm.

The foliations present in these rocks are alternating layers of light and dark minerals and are best seen in outcrop. Their orientations are quite evident and are easily measured. In thin section the dark layers are concentrations of hornblende and biotite with only a very slight preferred orientation.

Age and Correlation

Ross (1961, p. 28) has mapped the dioritic rocks of this area as diorites and hornblende gabbros of uncertain age. He goes on to suggest that the close association of the dioritic rocks with the metavolcanic rocks throughout the county may indicate that the diorite was an intrusion of approximately the same age as the metavolcanics. He also notes that since inclusions of the metavolcanic material are common in the granitic rocks, many of the dioritic rocks may be the result of contamination of the granitic rocks by the metavolcanics. Also, the similarity of these rocks to those known to be contaminated granitic rocks in the Sierra Nevadas helps to support this hypothesis (Ross, 1961, p. 28).

In the field, the dioritic rocks intrude the metamorphics and are intruded by the granitic rocks. Near the contacts of the dioritic rocks and the Quartz Monzonite Unit, spindle-shaped inclusions of the dioritic rocks in the quartz monzonite are common. Similar inclusions of the dioritic rocks are also present in the intermediate volcanic rocks. The dioritic rocks have also been metamorphosed to an extent similar to the metamorphism of the older metamorphic rocks. On the basis of this evidence, the dioritic rocks are here interpreted as being of questionable Jurassic age.

Petrogenetic Conclusions

The Dioritic Rock Unit has magmatic textures such as the normal, oscillatory, and patchy zoning of the plagioclase (Vance, 1962 and 1965). Intrusive relationships are evident in the field, where the dioritic rocks can be seen to have intruded and included the older metamorphic rocks. The variation in overall texture throughout the rock unit is expressed by the differences in texture between the diorite to quartz diorite and the diorite to quartz diorite porphyry. Three hypotheses will be proposed to explain this texture variation.

First, the different rock types may have been the result of two or more simultaneous intrusions. This hypothesis fails to explain the metamorphism of the dioritic rocks and on this basis has been rejected.

Second, the different rock types may have been the result of two or more periods of intrusion. Third, the differences may have been the result of one long slow period of intrusion, the later parts of which intruded the already crystallized earlier parts. It should be recognized that these latter two hypotheses are very similar, differing only in the length of time between the different periods of intrusion. Because of the close similarities of these two hypotheses, they will be considered as the one hypothesis on which conclusions will be based.

The dioritic rocks have been metamorphosed, as indicated by the replacement of many of the primary minerals by the metamorphic minerals and the metamorphic assemblages of epidote, hornblende-actinolite, biotite, and magnetite. The small plagioclase crystals within the larger plagioclase phenocrysts have been interpreted as being the result of minor recrystallization of the rock and provide additional evidence for metamorphism of the dioritic rocks.

Since the foliations in the dioritic rocks do not extend into the older metamorphic rocks, and since the older metamorphic rocks show no evidence of a regional dynamothermal metamorphism, it is proposed that the metamorphism of the dioritic rocks is the result of autometamorphism. Earlier stages of the dioritic intrusion were metamorphosed by the later stages. On the basis of this hypothesis, two explanations for the formation of the foliations will be proposed. First, the foliations may be explained as the result of the inclusion of long thin portions of the older metamorphic rocks which were subsequently metamorphosed by later intrusive stages of the diorite. The foliations often occur at the very base of the range and near the contacts of the diorite and the other intrusive rocks. This seems to indicate that the foliated areas may have also been metamorphosed by later intrusions. Second, the foliations may be the result of flow or drag banding of the later stages of the diorite intrusion, as they intruded the earlier stages. Either one or both of these explanations seems quite plausible.

The dioritic rocks contain mineral assemblages characteristic of both the albite-epidote horfels facies and the hornblende hornfels facies. This may be the result of a metamorphism transitional between the two facies, or it may be the result of two or more periods of metamorphism. From the temperature-pressure diagrams in Turner (1968, p. 366) the conditions of metamorphism for the dioritic rocks have been interpreted as being between 1-1/2 and 2-1/2 kilobars pressure, and a temperature between 400°C and 500°C.

Therefore it can be concluded that the dioritic rocks crystallized from a dioritic magma in several stages. Each succeeding stage metamorphosed the previous stage at a relatively shallow depth.

GRANITIC ROCKS

Black Mountain Granodiorite

Introductory Statement

The Black Mountain Granodiorite occurs in three places in the map area, none of which exceed a square mile. The unit has no particular topographic feature and has approximately 25 percent outcrop exposure. It is a fine- to medium-grained rock, colored gray with a pinkish tinge, and it commonly includes the older diorite and metamorphic rocks. Modal analyses of this unit are presented in TABLE (2).

Description

This granodiorite consists of quartz, alkali feldspar, plagioclase, biotite, hornblende, augite, sphene, apatite, epidote, sericite, and magnetite. The mineral grains are subhedral to anhedral and range in size from .1mm to 3mm, and porphyritic texture is common.

The average plagioclase composition is An_{28}, and the plagioclase has normal and euhedral oscillatory zoning which ranges from An_{20} to An_{40}. The amount of sericite which has replaced the plagioclase varies from sample to sample and within samples. Some of the plagioclase contains very little sericite, while other grains, near fractures or veins in the rock, are almost completely sericitized. Minor myrmekite and some micrographic texture is found at the boundaries of some of the more highly sericitized plagioclase grains.

The alkali feldspar is mostly microcline with some orthoclase and is

Specimen No.	Plagioclase Percent	Plagioclase Composition	K-feldspar Percent	Quartz Percent	Biotite Percent	Hornblende Percent	Accessories Percent
BM-121	51.5	An_{27}	12.4	13.8	1.8	14.3	6.6
BM-140B	54.5	An_{27}	8.5	11.2	4.2	13.3	8.4
BM-141	48.1	An_{28}	21.2	12.2	---	13.1	5.5
BM-147	47.8	An_{34}	16.5	12.8	1.9	12.4	8.7
BM-202	49.9	An_{25}	8.7	13.2	4.9	12.5	8.0
BM-224	43.0	An_{25}	17.2	23.1	7.3	5.3	3.1
BM-281	54.7	An_{29}	8.5	9.2	4.2	13.7	9.7
AVERAGE	49.9	An_{28}	13.3	13.6	3.5	12.1	7.1

TABLE (2). Modal analyses of the Black Mountain Granodiorite based on 1000 point point-counts of each specimen.

weakly perthitic, with film and braid perthite. The microcline has a negative 2V of 88° and the orthoclase a negative 2V of 62°. In some of the more highly sericitized samples all of the alkali feldspar is micrographic. Small plagioclase grains are commonly found within some of the larger K-feldspar grains and are aligned with certain K-feldspar crystallographic directions.

The augite found in this unit is slightly titaniferous and is invariably almost completely replaced by hornblende.

White Mountain Granodiorite

Introductory Statement

The White Mountain Granodiorite occurs on White Mountain and forms the steep eastern slope of the mountain. This slope is about 25 percent outcrop. This granodiorite is a coarse-grained white rock and is in contact with the metamorphic rocks near the summit of the mountain. Aplite dikes are common throughout the unit. Modal analyses of this unit are presented in TABLE (3).

Description

This granodiorite consists of quartz, alkali feldspar, plagioclase, biotite, hornblende, epidote, sphene, apatite, sericite, and pyrite. The mineral grains are subhedral to anhedral and range in size from 3mm to 10mm.

The average plagioclase composition is An_{25}, and the plagioclase has

Specimen No.	Plagioclase Percent	Plagioclase Composition	K-Feldspar Percent	Quartz Percent	Biotite Percent	Hornblende Percent	Accessories Percent
BM-111	53.2	An_{28}	13.1	28.9	3.1	1.3	0.4
BM-324	48.2	An_{24}	19.1	20.9	6.8	1.2	3.8
BM-327	42.0	An_{23}	14.4	31.0	2.3	5.9	4.6
AVERAGE	47.8	An_{25}	15.5	26.9	4.1	2.8	2.9

TABLE (3). Modal analyses of the White Mountain Granodiorite based on 1000 point point-counts of each specimen.

normal and euhedral oscillatory zoning ranging from An_{20} to An_{28}. Sericitization is weak throughout the unit, except near some of the aplite dikes, where sericitization of the plagioclase is almost complete, and large grains of muscovite are present.

The alkali feldspar is chiefly microcline with some orthoclase and is strongly microperthitic, with film, braid, and lens microperthite. The microcline has an average negative 2V of 90° and the orthoclase a negative 2V of 61°. Myrmekitic and micrographic textures are rare and occur at the contacts of the alkali feldspar and plagioclase. Carlsbad twinning is evident in some of the larger microcline grains. Both microcline and orthoclase can be seen together in some of the larger crystals and there is a zoning, seen as undulatory extinction, between them. Some of the larger K-feldspar grains also contain small plagioclase crystals.

Quartz Monzonite Unit

Introductory Statement

In the field, the Quartz Monzonite Unit is a highly chemically and mechanically weathered rock, with approximately 40 percent outcrop exposure. The outcrops are often covered with a thin layer of gruss. The unit is hummocky on the ridge lines and forms steep canyons and ridges. It is a medium- to coarse-grained, very light gray rock and is commonly friable. Widely scattered throughout the unit are small areas of alaskite. Modal analyses of this unit are presented in TABLE (4).

Specimen No.	Plagioclase Percent	Plagioclase Composition	K-Feldspar Percent	Quartz Percent	Biotite Percent	Hornblende Percent	Accessories Percent
BM-209	20.3	An_{26}	30.1	44.5	2.9	0.7	1.6
BM-256	35.4	An_{24}	48.2	14.9	1.3	0.1	0.2
BM-266A	31.4	An_{25}	33.0	33.7	2.4	0.8	0.5
BM-278	40.0	An_{27}	25.5	23.7	6.8	1.0	3.0
BM-328	30.4	An_{25}	35.6	26.3	4.5	0.8	2.5
BM-347	37.5	An_{23}	28.5	28.5	3.6	0.4	1.5
AVERAGE	32.5	An_{25}	33.5	28.6	3.6	0.6	1.6

TABLE (4). Modal analyses of the Quartz Monzonite Unit based on 1000 point point-counts of each specimen.

Description

The quartz monzonite consists of quartz, alkali feldspar, plagioclase, biotite, hornblende, sphene, apatite, zircon, epidote, sericite, and pyrite. The mineral grains are subhedral to anhedral and range in size from 3mm to 10mm.

The average composition of the plagioclase is An_{25}, and the plagioclase grains have normal and euhedral oscillatory zoning ranging from An_{21} to An_{35}. The plagioclase is partially replaced by sericite and clay minerals, varying from a few specks in the freshest samples to almost complete sericitization in the more highly weathered samples.

The alkali feldspar is generally microcline with some orthoclase and is strongly microperthitic. Film, braid, and lens microperthite are present. In addition to the common cross-hatched pericline and albite twinning, Carlsbad twinning is also present in the microcline, and euhedral zoning defined by small grains of albite is common. The microcline exists both as separate grains and in the same grains. In both cases they are distinguished by the presence or lack of cross-hatched twinning and by their respective 2V's. The microcline has a negative 2V of 85° and the orthoclase a negative 2V of 66°. Small plagioclase grains can be found within some of the K-feldspar grains, and are aligned with certain K-feldspar crystallographic directions.

Minor myrmekite and micrographic textures occur where the microperthitic microcline is in contact with the plagioclase. Micrographic texture makes up approximately 80 percent of the rock found near the quartz monzonite - limestone contact.

There is no evidence of any metamorphism of the Quartz Monzonite

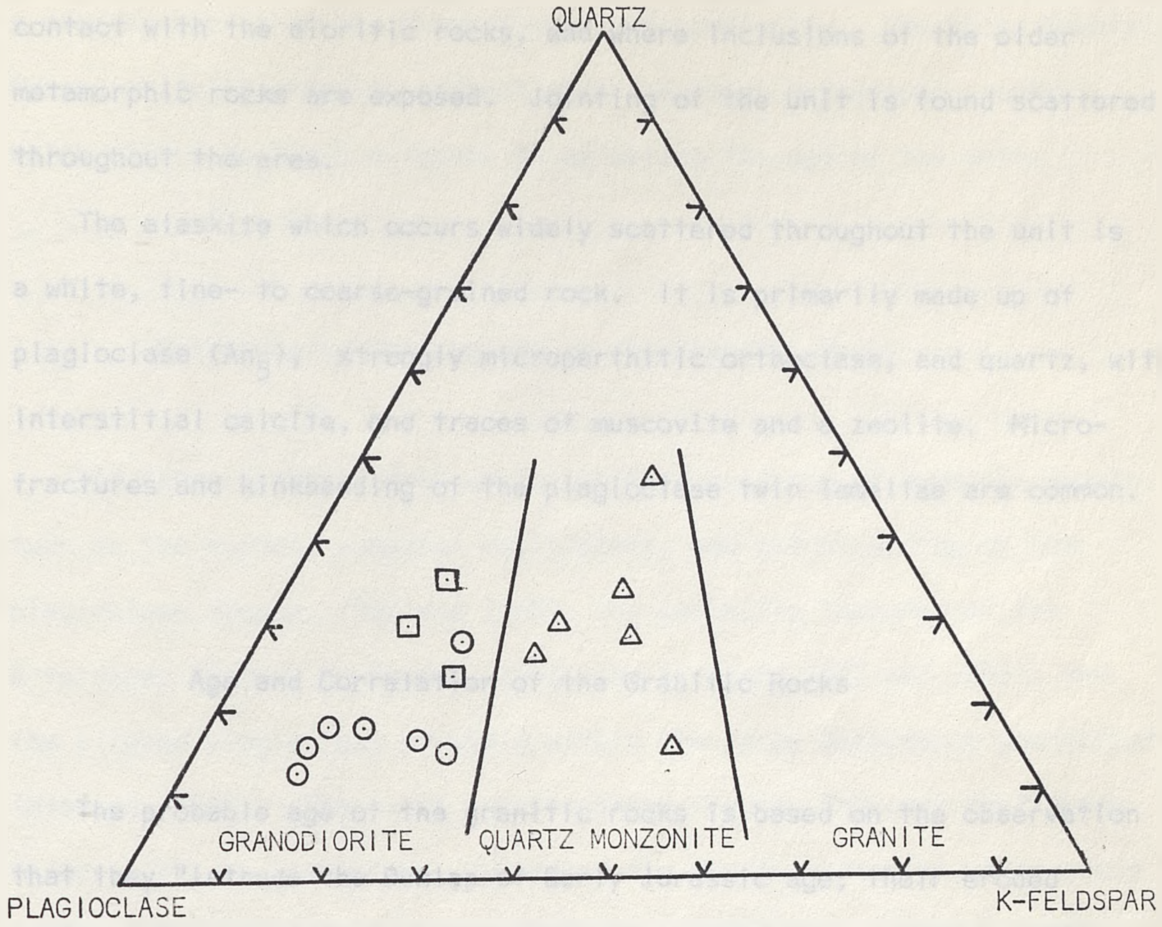

FIGURE (2). Graphical representation of the modal data of the granitic rocks. Each point on this diagram represents a specimen for which the modal quartz and feldspar have been recalculated to 100%. The triangles represent the Quartz Monzonite Unit, the circles, the Black Mountain Granodiorite, and the squares, the White Mountain Granodiorite. The fields on this diagram are based on the classification of Johannsen (1939, Vol. I, p. 144, Fig. 107). Tick marks occur at 10% intervals.

Unit. Some flow banding can be seen where the quartz monzonite is in contact with the dioritic rocks, and where inclusions of the older metamorphic rocks are exposed. Jointing of the unit is found scattered throughout the area.

The alaskite which occurs widely scattered throughout the unit is a white, fine- to coarse-grained rock. It is primarily made up of plagioclase (An_5), strongly microperthitic orthoclase, and quartz, with interstitial calcite, and traces of muscovite and a zeolite. Microfractures and kinkbanding of the plagioclase twin lamellae are common.

Age and Correlation of the Granitic Rocks

The probable age of the granitic rocks is based on the observation that they "intrude the Dunlap of Early Jurassic age; their eroded surfaces are overlain by mid-Tertiary deposits" (Ross, 1961, p. 35). Ferguson, Muller, and Cathcart (1954), show cross-cutting relationships in the Mina Quadrangle which are consistent with assigning a Cretaceous age to the granitic rocks in that area. The determination of this age is also supported by the close lithological similarity and probable association of the granitic rocks of Black Mountain and the Cretaceous intrusions of the Sierra Nevada Batholith.

The contact of the Quartz Monzonite Unit is poorly exposed, but can be observed in road cuts of the Black Mountain Microwave Station road. Although the exposure is poor, it appears that there are quartz monzonite dikes in the granodiorite, and granodiorite inclusions in the quartz monzonite. On this basis, the quartz monzonite has been assigned a younger age than the Black Mountain Granodiorite. The White Mountain Granodiorite is only in contact with the older metamorphic rocks, which offers no field evidence to establish the age of the unit.

Petrogenetic Conclusions on the Granitic Rocks

The three granitic rock units all have evidence of magmatic growth, such as the normal, euhedral oscillatory, and patchy zoning of the plagioclase (Vance, 1962 and 1965); the perthitic textures of the K-feldspar (Gates, in Emmons, 1953, and Spencer, 1937 and 1938); and the aligned plagioclase crystals within the large K-feldspar phenocrysts (Hibbard, 1965). The field relationships clearly indicate that these three units are intrusives. Dikes of the two granodiorite units occur in the older metamorphic rocks near the contacts of the metamorphic rocks and the granodiorites. Dikes of the Quartz Monzonite Unit are present in the dioritic rocks and the Black Mountain Granodiorite, near where these rocks are in contact with the quartz monzonite. Inclusions of the dioritic rocks, the older metamorphic rocks, and the Black Mountain Granodiorite occur in the Quartz Monzonite Unit.

ORIGIN OF THE INTRUSIVE ROCKS

The variation in the felsic versus the mafic character of the intrusive rocks implies that the four intrusive units may be the products of the differentiation of a mafic magma. If this is indeed the case, the sequence of intrusion must have been as follows: the Dioritic Rock Unit, the Black Mountain Granodiorite, the White Mountain Granodiorite, and the Quartz Monzonite Unit. This sequence is supported by the field relationships except for the White Mountain Granodiorite, for which there is no data. In order to test this hypothesis of the differentiation of a single magma, approximate chemical analyses were calculated from the modal data obtained on the intrusive rocks. The calculations were accomplished by computer using the program developed by Dietrich and Sheehan (1962). The chemical analyses thus obtained are presented in TABLES (5-9).

From the approximate chemical analyses, silica variation diagrams were constructed by plotting the weight percent of the metallic oxides against the weight percent of silica, FIGURES (4-6). The variation diagrams show fairly smooth, regular changes through the above sequence of intrusions. Especially good curves are the Fe_2O_3 (FIGURE (4)), the FeO (FIGURE (5)), the CaO (FIGURE (6)), and the Na_2O (FIGURE (6)) curves. These diagrams tend to support the hypothesis that all four of the intrusive rock units crystallized from the same magma through a process of differentiation (Krauskopf, 1967, p. 397-398).

From the modal analyses of the granitic rocks a ternary variation diagram was constructed (FIGURE (7)). This diagram shows the relationships of albite, anorthite, and K-feldspar. The dioritic rocks were not plotted on this diagram because of their general lack of K-feldspar. The smooth regularity of the resulting curve also supports the hypothesis that the three granitic rock units are the products of the differentiation of a single magma.

The granitic rocks were plotted on the quartz-albite-orthoclase ternary diagram with eutectic points and cotectic lines used by Winkler (1965, p. 188, Fig. 34). This diagram shows the relationship of the eutectic points of the granitic rocks to the eutectic points determined experimentally at 2000 bars water pressure. (FIGURE (3)).

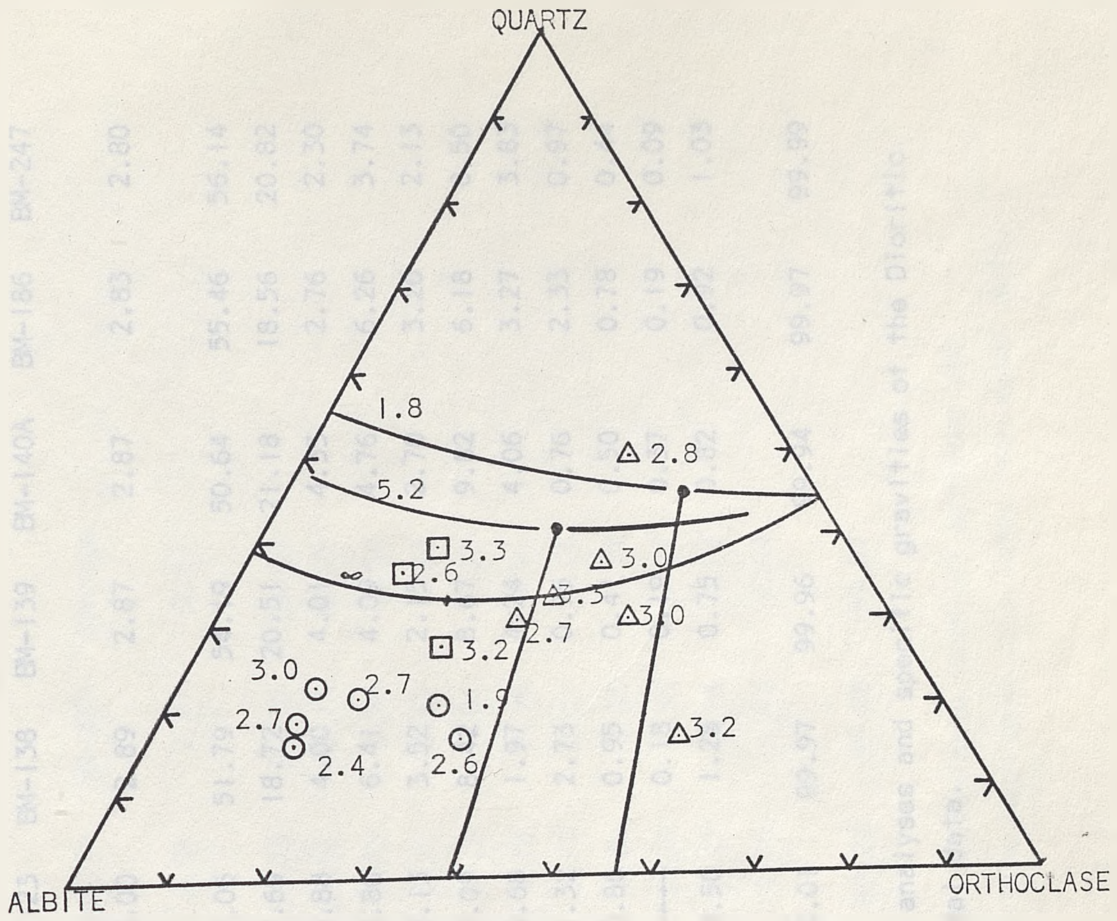

FIGURE (3). Quartz-Albite-Orthoclase system with eutectic points and cotectic lines of Winkler (1965, p. 188, Fig. 34) determined experimentally at 2000 bars water pressure. The compositions of the granitic rocks have been plotted here to show the relationships of their eutectic points to those determined experimentally. The numbers represent the albite:anorthite ratios. The triangles represent the Quartz Monzonite Unit, the circles, the Black Mountain Granodiorite, and the squares, the White Mountain Granodiorite. Tick Marks occur at 10% intervals.

Specimen No.	BM-104	BM-108	BM-109	BM-123	BM-138	BM-139	BM-140A	BM-186	BM-247
Spec. grav.	2.90	2.82	2.95	3.00	2.89	2.87	2.87	2.83	2.80
SiO_2	51.05	57.61	51.38	47.06	51.79	54.19	50.64	55.46	56.14
Al_2O_3	19.13	18.36	14.82	17.69	18.72	20.51	21.18	18.56	20.82
Fe_2O_3	3.09	2.00	3.16	5.88	4.00	4.01	4.33	2.76	2.30
FeO	7.11	4.96	8.89	12.80	6.41	4.09	4.76	6.26	3.74
MgO	4.15	3.05	6.70	2.13	3.52	2.15	2.70	3.26	2.13
CaO	7.69	6.52	8.64	9.09	8.42	8.67	9.82	6.18	8.50
Na_2O	3.09	3.29	2.28	2.68	1.97	4.24	4.06	3.27	3.83
K_2O	2.18	2.17	1.68	1.32	2.73	0.75	0.76	2.33	0.97
H_2O^+	1.13	0.83	1.10	0.86	0.95	0.41	0.50	0.78	0.44
P_2O_5	0.37	0.09	0.09	----	0.18	0.19	0.37	0.19	0.09
TiO_2	0.94	1.11	1.25	0.50	1.28	0.75	0.82	0.92	1.03
Total	99.93	99.99	99.99	100.01	99.97	99.96	99.94	99.97	99.99

TABLE (5). Approximate chemical analyses and specific gravities of the Dioritic Rock Unit calculated from modal data.

Specimen No.	BM-257	BM-274	BM-277	Average
Spec. Grav.	2.90	2.84	2.97	2.89
SiO_2	48.94	50.45	50.35	52.09
Al_2O_3	19.93	22.55	15.15	18.95
Fe_2O_3	4.18	3.82	3.26	3.57
FeO	6.82	5.26	8.61	6.64
MgO	3.97	2.15	6.94	3.57
CaO	9.46	8.13	8.58	8.31
Na_2O	2.94	3.77	2.01	3.12
K_2O	1.63	1.99	2.38	1.74
H_2O^+	0.77	0.63	1.38	0.82
P_2O_5	0.46	0.47	0.18	0.22
TiO_2	0.83	0.70	1.14	0.94
Total	99.93	99.92	99.98	99.97

TABLE (6). Continuation of TABLE (5). Approximate chemical analyses and specific gravities of the Dioritic Rock Unit calculated from modal data.

Specimen No.	BM-121	BM-140B	BM-141	BM-147	BM-202	BM-224	BM-281	AVERAGE
Spec. Grav.	2.83	2.86	2.80	2.84	2.76	2.77	2.86	2.82
SiO_2	58.99	56.17	59.75	57.31	58.41	64.83	55.44	58.70
Al_2O_3	15.55	16.42	16.54	16.69	15.64	14.88	17.14	16.12
Fe_2O_3	4.54	5.51	4.12	4.64	4.23	1.89	4.89	4.26
FeO	4.22	4.90	3.50	4.00	4.67	2.87	4.55	4.10
MgO	2.25	2.40	1.86	2.13	2.70	1.55	2.50	2.20
CaO	6.01	6.09	5.15	6.56	5.95	4.58	6.95	5.90
Na_2O	4.25	4.23	3.75	3.31	4.18	3.63	4.15	3.93
K_2O	2.22	2.16	3.74	3.25	2.21	3.51	2.17	2.75
H_2O^+	0.33	0.52	0.39	0.49	0.48	0.34	0.57	0.45
P_2O_5	0.61	0.56	----	0.61	0.53	0.67	0.60	0.51
TiO_2	0.11	0.94	1.20	0.91	0.91	1.12	0.95	0.88
Total	99.08	99.90	100.00	99.90	99.91	99.87	99.91	99.80

TABLE (7). Approximate chemical analyses and specific gravities of the Black Mountain Granodiorite calculated from modal data.

Specimen No.	BM-111	BM-324	BM-327	Average
Spec. Grav.	2.67	2.71	2.74	2.71
SiO_2	71.46	66.05	69.86	69.12
Al_2O_3	16.10	16.12	13.89	15.37
Fe_2O_3	0.19	1.37	2.29	1.28
FeO	0.86	2.04	1.94	1.61
MgO	0.51	0.87	1.06	0.65
CaO	3.41	3.73	3.88	3.67
Na_2O	4.40	4.12	3.70	4.07
K_2O	2.56	3.81	2.60	2.99
H_2O^+	0.15	0.25	0.26	0.22
P_2O_5	----	----	----	----
TiO_2	0.35	1.64	0.53	0.84
Total	99.99	100.00	100.01	99.82

TABLE (8). Approximate chemical analyses and specific gravities of the White Mountain Granodiorite calculated from modal data.

Specimen No.	BM-209	BM-256	BM-266A	BM-278	BM-328	BM-347	Average
Spec. Grav.	2.65	2.62	2.69	2.70	2.68	2.68	2.67
SiO_2	78.08	68.49	74.16	67.08	68.91	70.65	71.23
Al_2O_3	11.68	17.55	13.79	15.67	15.31	14.76	14.79
Fe_2O_3	0.29	0.20	0.58	1.74	1.61	1.78	1.03
FeO	0.80	0.36	0.81	2.13	1.63	1.56	1.22
MgO	0.41	0.15	0.36	0.85	0.59	0.44	0.47
CaO	1.16	1.77	1.81	3.21	2.69	1.93	2.10
Na_2O	1.65	3.11	2.68	3.33	2.29	3.19	2.71
K_2O	5.58	8.23	5.60	4.86	6.35	5.21	5.97
H_2O^+	0.23	0.08	0.10	0.26	0.21	0.19	0.18
P_2O_5	----	----	----	0.30	0.20	0.05	0.09
TiO_2	0.12	0.05	0.10	0.53	0.18	0.25	0.21
Total	100.00	99.99	99.99	99.96	99.97	100.01	100.00

TABLE (9). Approximate chemical analyses and specific gravities of the Quartz Monzonite Unit calculated from modal data.

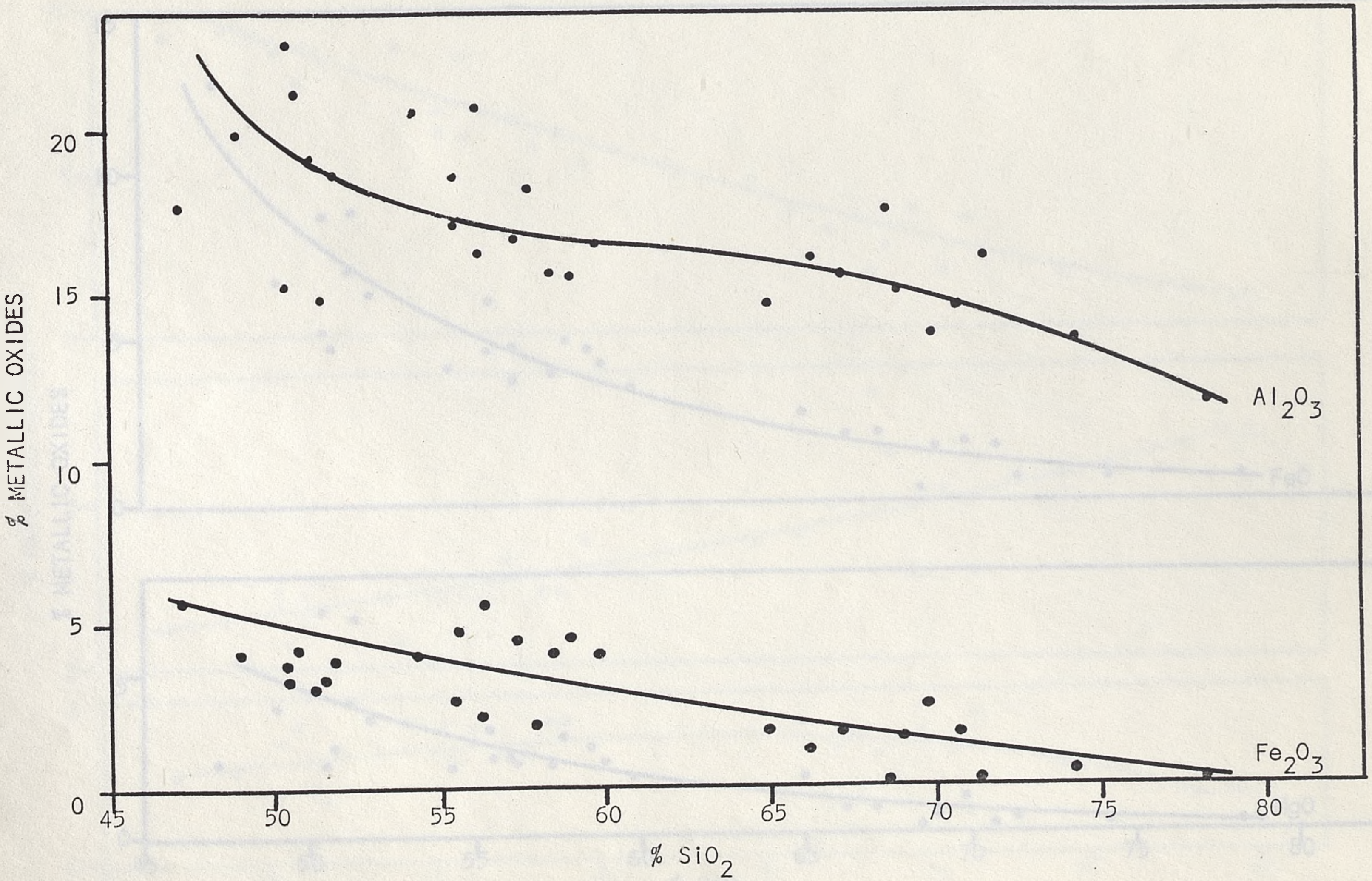

FIGURE (4). Variation diagram showing the variation of Al_2O_3 and Fe_2O_3 with the variation of SiO_2.

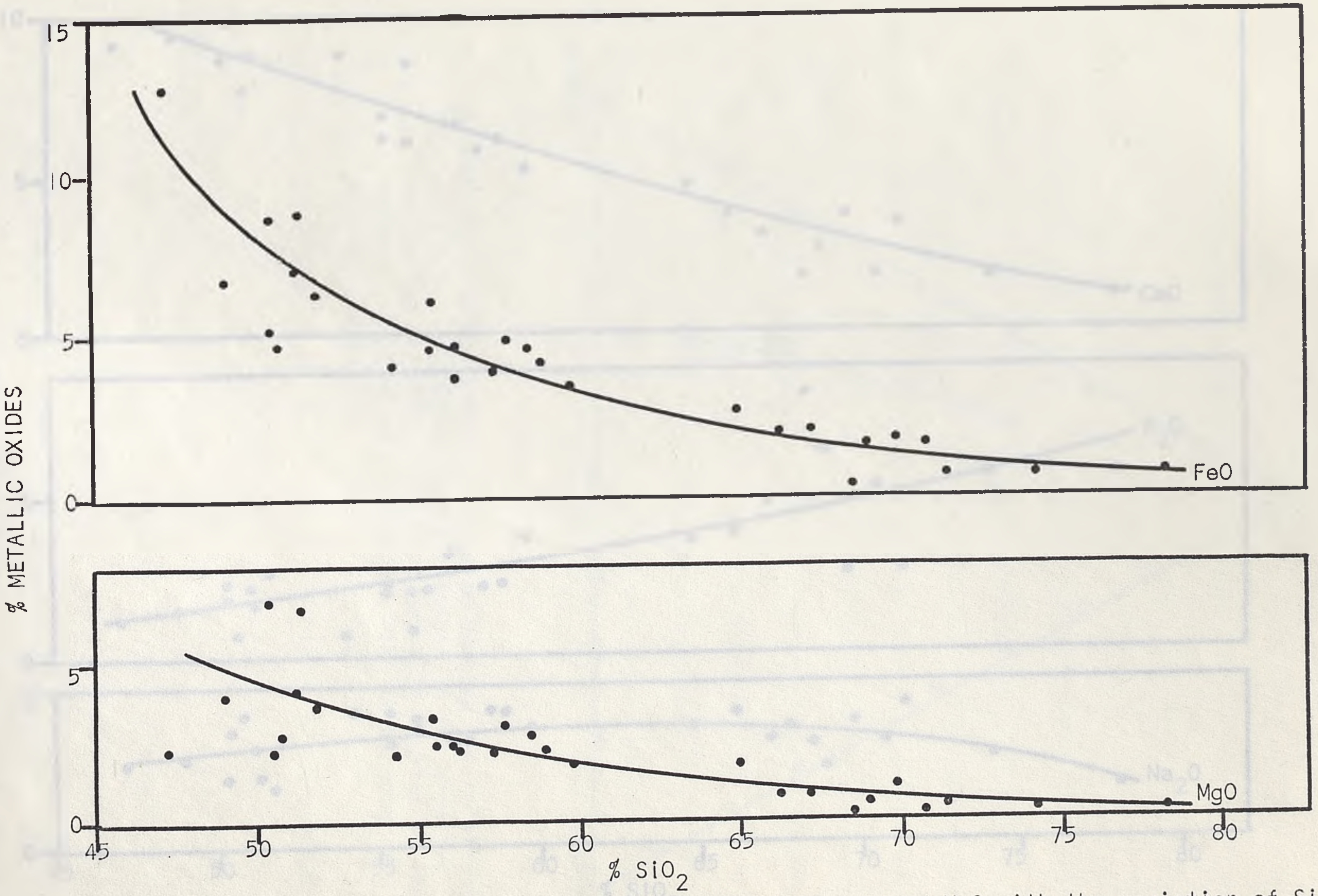

FIGURE (5). Variation diagram showing the variation of FeO and MgO with the variation of SiO_2.

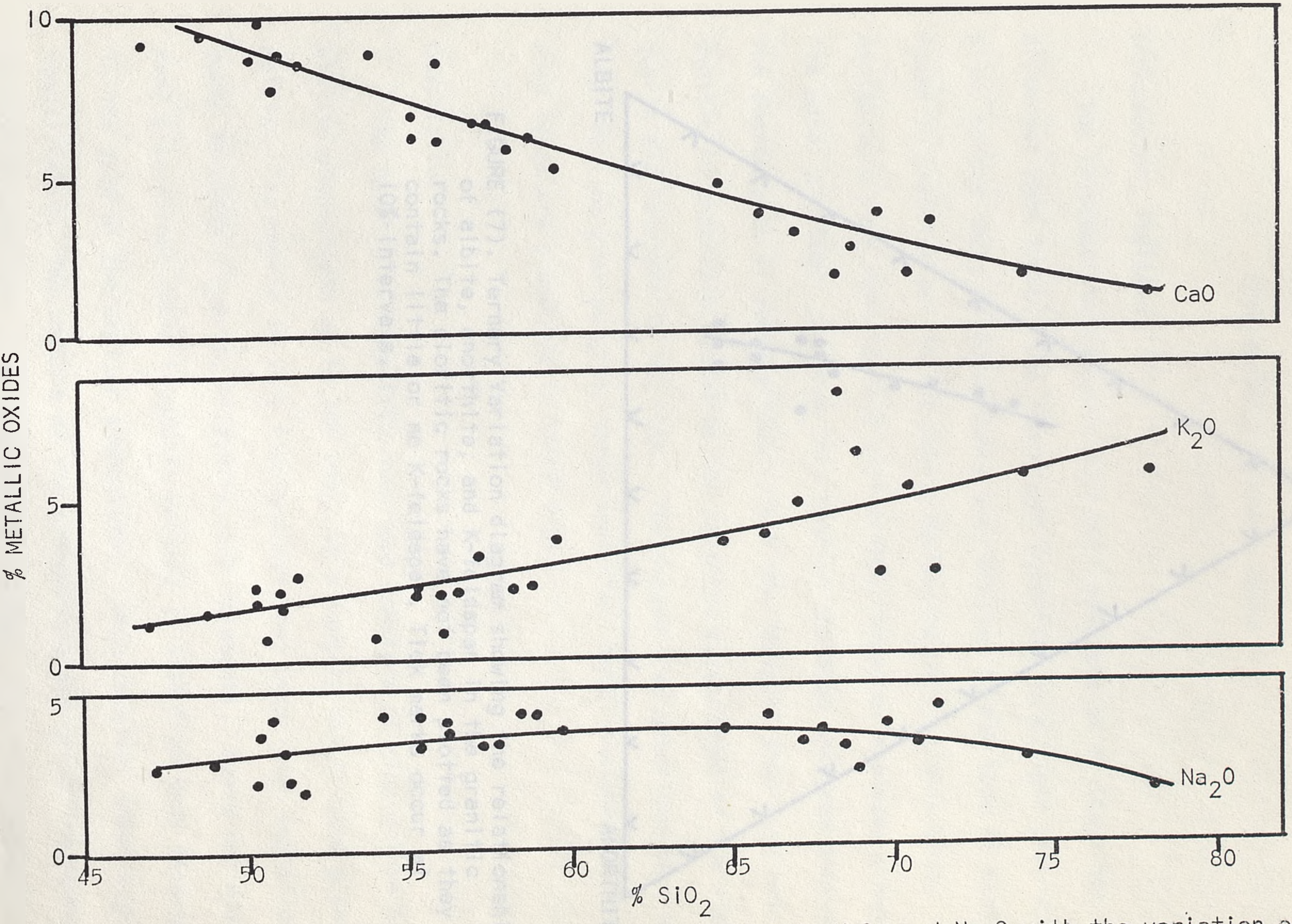

FIGURE (6). Variation diagram showing the variation of CaO, K_2O, and Na_2O with the variation of SiO_2.

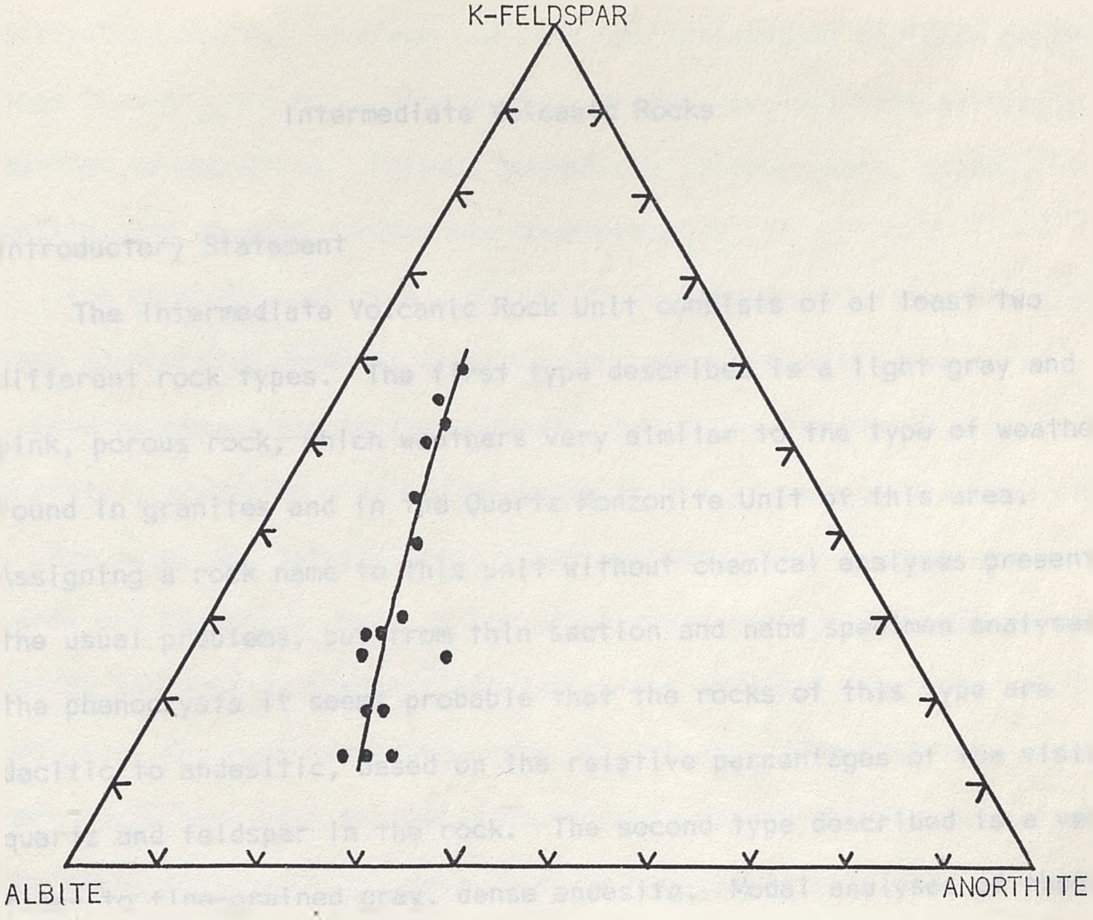

FIGURE (7). Ternary Variation diagram showing the relationships of albite, anorthite, and K-feldspar in the granitic rocks. The dioritic rocks have not been plotted as they contain little or no K-feldspar. Tick marks occur at 10% intervals.

VOLCANIC ROCKS

Intermediate Volcanic Rocks

Introductory Statement

The Intermediate Volcanic Rock Unit consists of at least two different rock types. The first type described is a light gray and pink, porous rock, which weathers very similar to the type of weathering found in granites and in the Quartz Monzonite Unit of this area. Assigning a rock name to this unit without chemical analyses presents the usual problems, but from thin section and hand specimen analyses of the phenocrysts it seems probable that the rocks of this type are dacitic to andesitic, based on the relative percentages of the visible quartz and feldspar in the rock. The second type described is a very fine- to fine-grained gray, dense andesite. Modal analyses of these rock types are presented in TABLE (10).

Descriptions

The dacitic to andesitic rock type consists of plagioclase and biotite phenocrysts up to 3mm long, in a largely devitrified glassy matrix. The matrix is very fine-grained, but under high magnification seems to contain quartz, tridymite, and feldspars. There are also many plagioclase grain fragments varying in size from very fine-grained to the size of the smaller phenocrysts. When observed under high magnification, the borders of the phenocrysts and grain fragments appear to be slightly replaced by the matrix. The six plagioclase grains studied in one thin section of this rock type have euhedral oscillatory zoning. Average compositions, determined on these grains, range from An_{38} to An_{58}. The biotite grains have all been partially replaced by magnetite. Primary magnetite, clinopyroxene, sphene, apatite, and rounded zircons are also present.

The andesite rock type consists of hornblende, biotite, and plagioclase phenocrysts, some as large as 3mm, set in a very fine- to fine-grained matrix of plagioclase, quartz, and small amounts of what is probably glass. The plagioclase laths in the groundmass are from .1mm to .2mm long, and between these laths are very fine-grained crystals of quartz and feldspar. Most of the plagioclase phenocrysts have normal zoning, and average compositions determined on eight grains in one thin section of the rock type range from An_{55} to An_{90}. Some of the hornblende phenocrysts have been partially replaced by magnetite while some are completely replaced. Euhedral hornblende crystals with rims of magnetite are present. The biotites have also been partially replaced by magnetite. Primary magnetite and some fine grains of orthopyroxene and clinopyroxene are present. There is a very definite alignment of the plagioclase grains in the groundmass, and a flow texture is apparent around the phenocrysts.

Age and Correlation

Ross (1961) has mapped these rocks as post-Esmeralda felsic volcanic rocks; however, elsewhere in the county he has described post-Esmeralda intermediate volcanic rocks. His description of these latter rocks corresponds very closely with the description of the intermediate volcanic rocks made in this study. The Esmeralda has been well dated on the basis of fossils, and has been assigned a late Miocene to early Pliocene age (Ross, 1961, p. 46). Elsewhere in the county, the intermediate volcanic rocks lie unconformably on the felsic volcanic rocks (Ross, 1961, p. 48), which would make the intermediate volcanic rocks late Pliocene or younger.

In the Black Mountain area, the intermediate volcanic rocks rest upon the metamorphic, dioritic, and granodioritic rocks; they include the dioritic rocks; and have been assigned a Tertiary age.

Petrogenetic Conclusions

The normal zoning of the plagioclase crystals of both rock types indicates a magmatic origin (Vance, 1962). The andesite rock type occurs only in small areas of outcrop, but its trachytic texture indicates that there was some movement of the rock during its final stages of crystallization. In the dacitic to andesitic rock type, the grains, as opposed to the groundmass, make up a fairly low percentage of the rock, vary widely in their size, and are highly fragmental. On this basis, this rock type has been classified as a crystal tuff.

Mafic Volcanic Unit

Introductory Statement

The Mafic Volcanic Unit consists of a hornblende andesite, darker and coarser grained than the andesite of the Intermediate Volcanic

Unit, with some basalt. Both rocks weather identically in the field, and it is only on a fresh surface that they can be differentiated. Both of these types are here mapped as one, but it is probable that further work in the area could result in the separation of the two rock types. These rocks do not commonly occur in outcrop, but occur as large talus slopes, rock streams, or what may be flow fronts. They cap the summit of Black Mountain and end abruptly 600 to 800 feet below the east side of the summit. The andesite is a gray-brown rock with a purplish hue, while the more oxidized portions of the rock are brownish-red. The basalt is a gray to black rock, but both rock types have a surface weathered to a dull brown. Modal analyses of these rock types are presented in TABLE (10).

Descriptions

The hornblende andesite is composed of a felted mass of plagioclase crystals in a near aphanitic groundmass, with some phenocrysts of hornblende. The plagioclase, which varies in its percentage of the rock throughout the unit, has euhedral oscillatory zoning, and its average compositions, determined on sixteen grains in three thin sections of the rock, range from An_{40} to An_{80}. They range in size from very fine-grained in the groundmass up to 2 mm. The hornblende phenocrysts which range up to 7mm in length are partially to completely replaced by magnetite, and clinopyroxene grains are commonly present in rims around the altered hornblende crystals. Many of the plagioclase and hornblende crystals are euhedral. The clinopyroxene appears to be titaniferous augite, and some grains are as large as 2 mm. Orthopyroxene,

Specimen No.	Groundmass Percent	Plagioclase Percent	Hornblende Percent	Biotite Percent	Magnetite Percent	Clinopyroxene Percent	Orthopyroxene Percent
BM-1-66	45.0	40.0	2.0	---	8.0	4.0	1.0
BM-6-66	25.5	54.5	2.5	---	10.5	6.5	0.5
BM-136	33.5	51.0	2.5	1.0	5.5	5.5	1.0
Average	34.7	48.5	2.3	0.3	8.0	5.3	0.8
BM-312	50.0	34.0	1.5	---	7.0	7.5	---
BM-301	39.5	46.0	3.0	2.0	18.5	1.0	0.5
BM-299	77.0	15.0	3.0	2.0	1.0	2.0	---

TABLE (10). Modal analyses of the volcanic rocks, based on 200 point point-counts of each specimen. BM-1-66, BM-6-66, and BM-136 are the hornblende andesite rock type; BM-312 is the basalt rock type; BM-301 is the andesite rock type; and BM-299 is the dacitic to andesitic rock type.

apatite, and primary magnetite are also present. There may or may not be small amounts of glass, and there is little evidence of devitrification in the rock. A slight tendency toward a trachytic texture is present.

The basalt is similar to the andesite, but with distinctly more clinopyroxene. The plagioclase grains range in size up to .5mm, have euhedral oscillatory zoning, have an average composition of An_{60}, and have trachytic texture. The hornblende crystals are partially to completely replaced by magnetite, and are as large as 3mm. Primary magnetite and apatite are also present. The one hand specimen taken contains a quartz pod 20mm in diameter, possibly an amygdule or inclusion.

Age and Correlation

The mafic volcanic rocks have been mapped and described by Ross (1961, p. 49-51) as Tertiary and Quaternary mafic volcanic rocks. He notes that their occurrence as cap rocks, and the general preservation of their original textures, is consistent with assigning a Pleistocene age to these rocks. However, Gilbert (1941, p. 787-788) uses stratigraphic relationships to show that similar rocks southeast of the county are lower Pliocene.

In the Black Mountain area, the mafic volcanic rocks occur capping the summit of the mountain, and their original textures seem to have been preserved. They also overlie the Tertiary intermediate volcanics in the southern part of the area. On this basis, these rocks have been assigned a late Tertiary to early Quaternary age.

Petrogenetic Conclusions

Both rock types of the Mafic Volcanic Unit have normally zoned plagioclase, indicating a magmatic origin (Vance, 1962). The tendency toward a trachytic texture of the hornblende andesite, and the good trachytic texture of the basalt, indicate that there was some movement at the time the rock crystallized. The wide extent of the unit, and its presence capping the summit of the mountain, support the hypothesis that the mafic volcanics consist of one or more volcanic flows.

Other Volcanic Rocks

A red, poorly consolidated, rhyolitic tuff was found in the andesite talus above the Black Mountain Copper Mine. It contains fragments of quartz, biotite, and magnetite, in a very glassy, slightly devitrified matrix. The quartz has well-developed conchoidal fracture, and the biotites are partially replaced by magnetite. There are many crystal grains which appear to have been completely kaolinized, and their crystal outlines imply that they may have been feldspars. These kaolinized grains are commonly rimmed by fine-grained quartz crystals. It is difficult to assign this rock to a mapped rock type, as it may have been part of the mafic volcanics, or it may have been part of the intermediate volcanics and picked up by the later mafic volcanics.

In the diorite, just below the small area of intermediate volcanics in the mafic volcanics, two very large angular boulders of a welded tuff were found. The welded tuff is a dark brown to black rock and has glass shards, bent biotite crystals, and fragments of plagioclase, biotite, magnetite, sphene, hornblende, quartz, orthopyroxene, clinopyroxene, zircon, and obsidian. Again there is no evidence of which unit the welded tuff was once a part.

FAULTS AND JOINTS

The most prominent faults in the Black Mountain area are the range front faults and the faults flanking the graben just west of the summit of the mountain. The range front faults have prominent, well-developed scarps which can be seen in the field as well as on the topographic maps and aerial photographs. The faulting which produced the graben near the summit of the mountain must have been quite recent, as it clearly cuts the Quaternary Mafic Volcanic Unit. The vertical distance from the bottom of the graben to the summit of the mountain is about 700 feet, and the distance from the bottom of the graben to the false summit to the west is about 400 feet, indicating that there is at least 500 feet of displacement on these faults.

The other less prominent faults shown on the map were generally observed as shearing in prospect pits and road cuts. The orientations of these faults are shown on the map, but their displacements are unknown.

The more prominent sets of joints in the area have been plotted on the map.

ECONOMIC GEOLOGY

Within the area of this study three mines were once in operation. The historical information on these mines is from Ross (1961, Table 6.3). The map area includes the entire Mountain View Mining District, The Mountain View and Granite areas, just north of the road leading to the Black Mountain Copper Mine in the western part of the area produced a small amount of gold and silver around 1909. The mining of these areas appears to have followed quartz veins in the Dioritic rocks.

The Black Mountain Copper Mine produced about $29,000 of copper during World War I. The mine is in the Felsic Metatuff Unit and some malachite, azurite, and pyrite are present on the dumps.

The Northern Lights Mine also produced some copper during World War I. The mine is in the Crystalline Limestone Unit, and the dumps contain some malachite, azurite, chalcocite, chalcopyrite and pyrite.

Small prospect pits are present throughout the area and are of two types. The first type includes small pits and adits which are in areas where some malachite and azurite is evident. The second type includes adits, shafts and pits in iron oxide stained quartz veins.

SUMMARY OF GEOLOGIC HISTORY

The metamorphic rocks, including the Felsic Metatuff Unit, the Fine-Grained Metadiorite Unit, and the Crystalline Limestone Unit, are thought to be the oldest rocks in the area. The close association of these three units in the field indicates that they are very close to the same pre-metamorphic age. They are here considered to be of questionable Middle Triassic age. The Felsic Metatuff Unit of of volcanic origin, the Fine-Grained Metadiorite Unit is a shallow intrusion, and the Crystalline Limestone Unit was deposited by a shallow sea. A period of burial followed their formation and some regional metamorphism may have begun. These three units were then intruded by Jurassic and Cretaceous rocks, were contact metamorphosed, and exist today as roof pendants.

The dioritic rocks are of questionable Jurassic age, and intruded the Triassic rocks. The dioritic rocks have been autometamorphosed. The diorite was intruded over a period of time, with later parts of the intrusion intruding and contact metamorphosing the previously consolidated parts.

During the Cretaceous the granitic rocks, including the Black Mountain Granodiorite, the White Mountain Granodiorite, and the Quartz Monzonite Unit, were intruded in that order. They intruded the Triassic metamorphic rocks, and the Jurassic dioritic rocks and probably contributed to the metamorphism of both these rock types.

Following the intrusion of the granitic rocks, there was a period of uplift and erosion. In the Tertiary the intermediate volcanic rocks were extruded and now overlie the metamorphic, the dioritic, and the granitic rocks. During the Quaternary, the mafic volcanic rocks were extruded and now cap the summit of the mountain and overlie the Tertiary volcanics. Alluvium from the Walker River, Pleistocene lake beds, and outwash and slope wash from the higher ground form the unconsolidated valley fill.

Basin and range faulting took place chiefly during the Late Cenozoic, uplifting the Wassuck Range to its present position.

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