GRANITES AND SYENITES
OF THE PLINY RANGE
NEW HAMPSHIRE

by

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Granites and Syenites of the Pliny Range, New Hampshire

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Submitted to the Department of Earth and Planetary Sciences in partial fulfillment of the requirement for the degrees of Bachelor of Science and Master of Science.

The Pliny Range in the White Mountains, N.H. contains two bodies of syenite and a younger sequence of ring dikes and stocks of the White Mountain Plutonic Series intrusive into Oliverian gneiss. Age relationships of all units are known from field work.

White Mountain Plutonic Series rocks clearly show a trend of fractionation from diorite through granite characterized by decreasing albite content. Fractionation proceeded toward a minimum melting composition indicative of shallow depth and slight water undersaturation. Temperatures of crystallization decrease with age throughout the series.

The two syenites are similar in composition, and do not show a fractionation trend. They are characterized by large perthite and less abundant plagioclase phenocrysts set in a granitic groundmass. Unlike the younger granites there is no evidence of a vapor phase. Relationships among quartz, feldspar, and the mafic minerals suggest that the parent magma formed by partial melting under high pressure and relatively low water pressure, rose through the crust as a crystallizing mush, and finally fractionated toward granitic compositions during crystallization of the matrix under low pressure, water saturated conditions.

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INTRODUCTION

The Pliny Range is an area of low, densely wooded mountains that form a semicircular ridge and occupy the northern third of the Mt. Washington Quadrangle, New Hampshire. The mountains and much of the surrounding lowlands are underlain by igneous rocks which control the topography. The high arcuate ridges are upheld by resistant ring dikes of the White Mountain Plutonic Series. The lower slopes, and the large basin to the east of the range are underlain by a less resistant, older syenite. Farther to the east, an outlying ring dike supports the Crescent Range. The entire complex of syenites and granites intrudes an Oliverian dome of plutonic rocks and metavolcanics.

Relief in the area is considerable, as much as 2500 feet, but unfortunately outcrops are poor. Exposures are primarily confined to the crest of the range and the radial ridges. Nevertheless, the area is of great interest because of the variety of igneous rocks with a known sequence of intrusion.

R.W. Chapman mapped the Pliny complex during 1939 and 1940. In addition to a geologic map, his work (Chapman, R.W., 1942) produced a detailed description of the mineralogy of the units. Since that time, logging activity has made new exposures of bedrock. The present author spent two months in the Pliny Range in the summer of 1970, and remapped the area using Chapman's map and stratigraphy as a guide. Two new rock units were found: the porphyritic quartz monzonite comprising a ring dike west of the range, and the medium

Figure 1. Intrusive complexes of the White Mountain Plutonic Series (White, 1968).

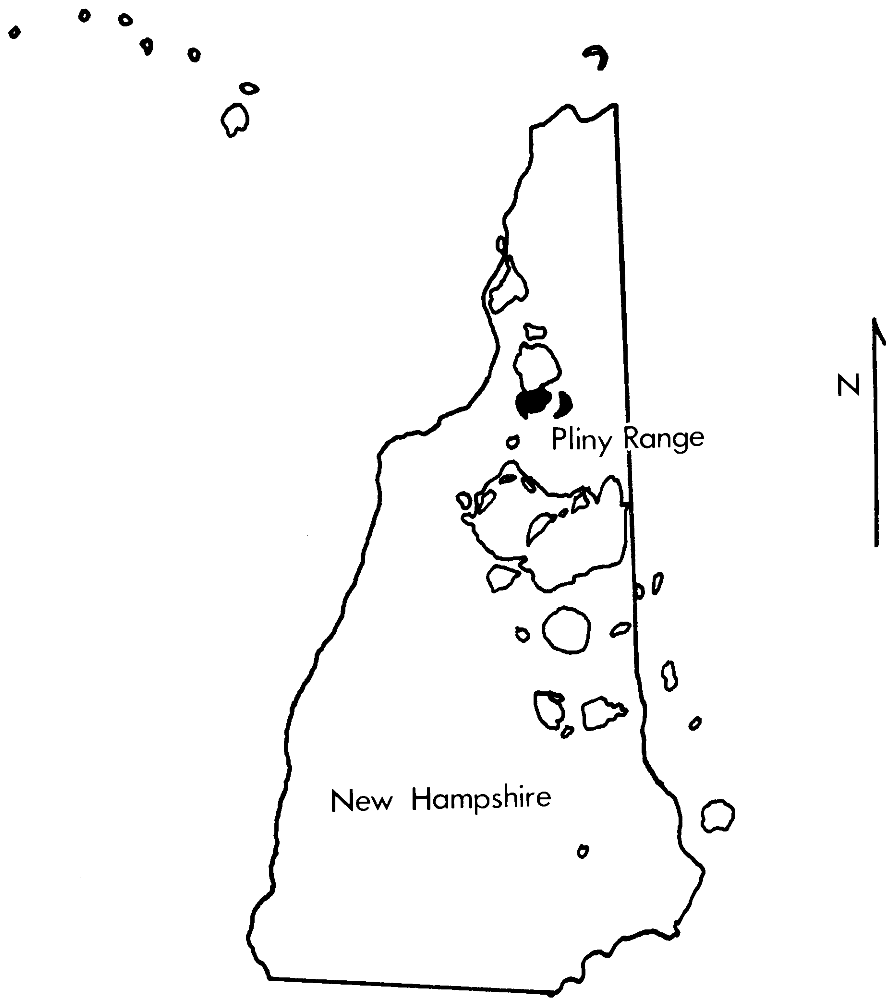
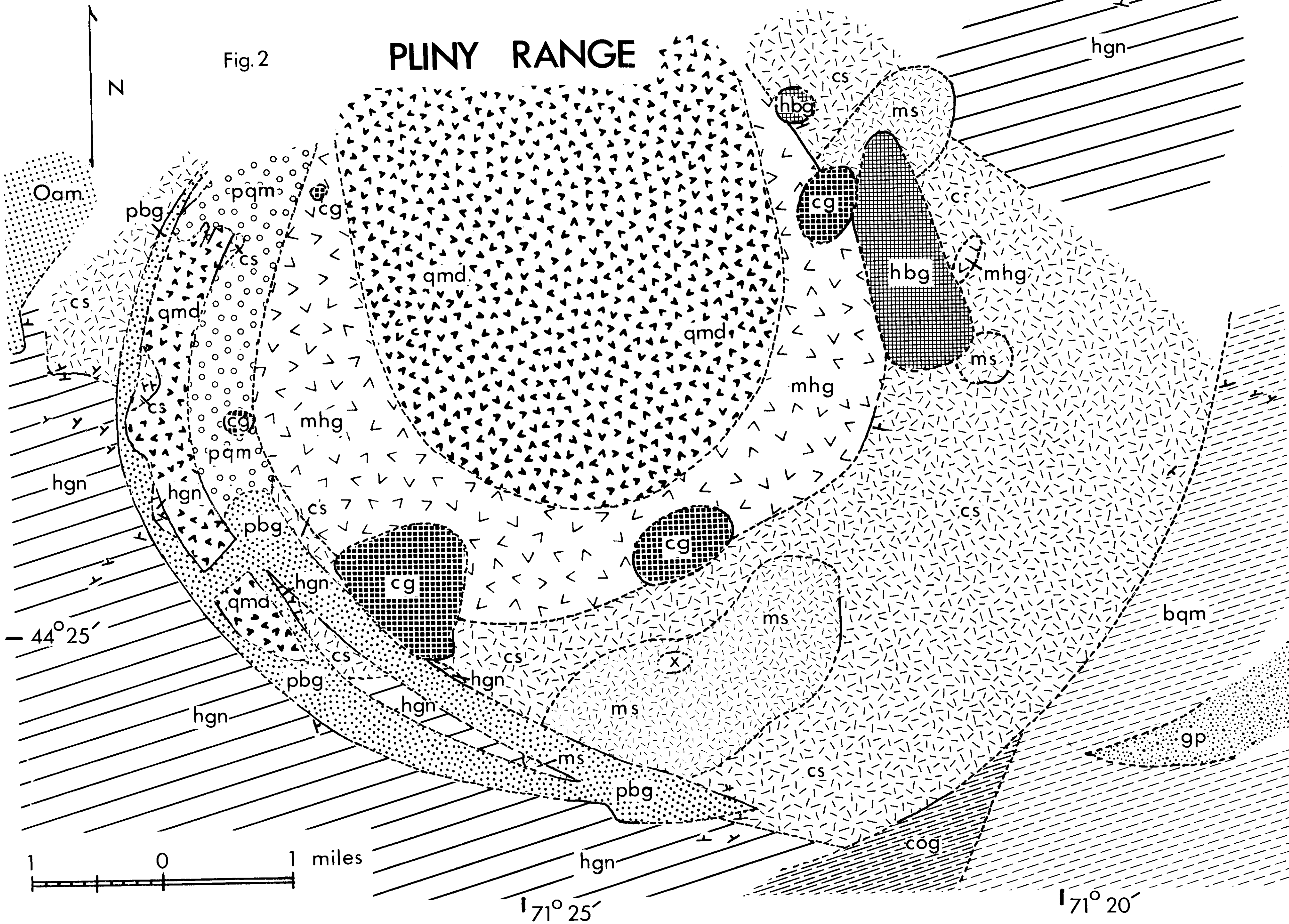


Fig. 1

Figure 2. Geologic map of the Pliny Range.

Fig. 2



PLINY RANGE
N
Oam
pbg
pqm
cg
cs
qmd
mhg
hbg
ms
hgn
bqm
gp
cog
x
44° 25′
71° 25′
71° 20′
1
0
1
miles

White Mountain Plutonic Series

cg	Conway granite
hbg	hornblende biotite granite
gp	granite porphyry
pbg	pink biotite granite
pqm	porphyritic quartz monzonite
mhg	medium grained hastingsite granite
qmd	quartz monzodiorite

Syenites

ms	medium grained syenite
cs	coarse syenite

Oliverian Plutonic Series

cog	coarse granite
bqm	biotite quartz monzonite
hgn	hornblende gneiss

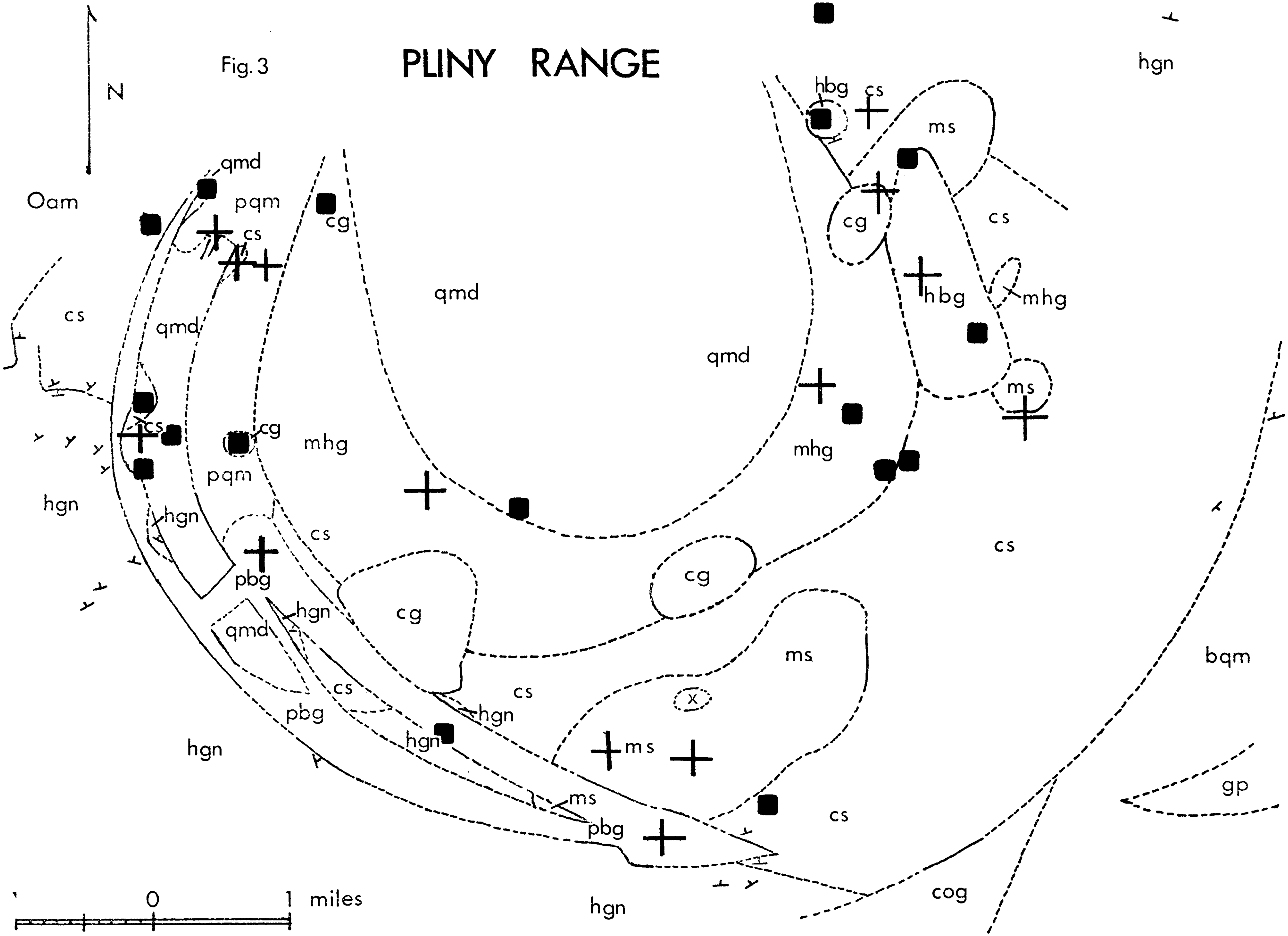
Ordovician

Oam	Ammonoosuc volcanics

Figure 3. Map of sample localities. Crosses indicate samples from which modes and compositions of alkali and plagioclase feldspar were obtained. Squares indicate samples from which modes and plagioclase feldspar compositions were obtained. All samples and results are listed in Table 2.

Fig. 3

PLINY RANGE



grained syenite which intrudes the coarse syenite south and east of the range.

From the samples collected, a study was made of the feldspars, biotites, and hornblendes. The compositions of these phases and the bulk compositions of the rocks were found to change regularly with age.

FIELD AND LABORATORY PROCEDURES

Mapping was done on a scale of 1:62,500. Most positions were pinpointed by use of an altimeter, as slopes are steep enough to produce good accuracy with this method.

Due to the scarcity of good outcrops, the sampling procedure was limited to taking rocks where possible. About 200 samples were collected and of these the freshest and most representative were used for modal analysis (Fig. 3). Extinction angle measurement of plagioclase was performed on a universal stage using the same samples as for the modal data. Finally, the most representative of these were ground and the alkali feldspar separated with heavy liquid to an estimated purity of 95%. The feldspar was then homogenized at 850°C, 1/2 kilobar for five days. The $\bar{2}01$ reflection was used to determine composition (Wright, 1968).

STRATIGRAPHY

The rocks of the Pliny Range fall into four groups: the Ammonoosuc Volcanics, the Oliverian Plutonic Series, the syenites, and the White Mountain Plutonic Series. The question

TABLE 1

NOMENCLATURE

Symbol	Unit name, this paper	Symbol	Unit name, Chapman (1942)
cg	Conway granite	cg	Conway granite
hbg	hornblende biotite granite	hbg	hornblende biotite granite
gp	granite porphyry	gp	granite porphyry
pbg	pink biotite granite	pbg	pink biotite granite
pqm	porphyritic quartz monzonite	-	no equivalent
mhg	medium grained hastingsite granite	hqs	hastingsite quartz syenite
qmd	quartz monzodiorite	qm	quartz monzodiorite and quartz monzonite
ms	medium grained syenite	-	no equivalent
cs	coarse syenite	cs	coarse syenite
cog	coarse granite	cog	coarse granite
bqm	biotite quartz monzonite	bqm	biotite quartz monzonite
hgn	hornblende gneiss	hqm	hornblende quartz monzonite
Oam	Ammonoosuc volcanics	Oam	Ammonoosuc volcanics

of whether the syenites belong to either of the other magma series will be discussed later. This paper deals primarily with the syenites and the White Mountain Plutonic Series. Ammonoosuc Volcanics occur in only a tiny patch on the northwest corner of the area. Oliverian rocks are mostly outside the Pliny complex, and were studied only in areas adjacent to the younger rocks.

Table 1 shows unit names used by the author and the names used by Chapman for equivalent rocks.

Ammonoosuc Volcanics

The Ammonoosuc Volcanics are represented by a light gray, fine grained biotite gneiss with large pink megacrysts of alkali feldspar. The megacrysts have grown along foliation planes and appear similar to the megacrysts of the adjacent Oliverian hornblende gneiss. Foliation is concordant with Oliverian rocks.

Oliverian Plutonic Series

The Oliverian rocks of the area comprise a dome (Chapman, Billings, Chapman, 1944) in a belt of gneiss domes stretching along the western border of New Hampshire. The basis of correlation with the Oliverian Series is lithology and structure. No radiometric age is available. Similar gneisses found in the Mascoma dome to the south, and which belong to the same series, have been interpreted as volcanics and dated as Ordovician (Naylor, 1969). The domes commonly contain granite or quartz monzonite intrusives which are also Ordovician (Naylor, 1969).

All Oliverian units in the area mapped are highly foliated and lineated and show a regional strike of N15°E with a northward dip. While they are in places brecciated by ring dike intrusions, they do not appear to have been deformed. Foliation is not deflected by the later intrusions.

Hornblende Gneiss

This is a highly variable unit, but usually quite distinctive. It is always highly foliated and usually lineated, but varies in the amount of layering, the thickness of layers, and the abundance of perthite megacrysts. Layers average about 1/4" but can be considerably thicker or thinner. The ground mass is black and white to pinkish white, with hornblende and oriented biotite forming the dark layers, and plagioclase, quartz, and alkali feldspar the light layers. When there is a high density of megacrysts the rock is similar in appearance to the coarse syenite, but can be distinguished by its better foliation, the presence of lineation, higher quartz content, inhomogeneity in hand specimen, and usually the presence of tiny garnets. Elongate, oriented inclusions of fine grain biotite gneiss are common, and these may be fragments of Ammonoosuc Volcanics. Aplite dikes are also common. Megacryst content does not appear to increase toward contacts with younger rocks.

Most varieties of the unit weather easily and so outcrops are poor, except for a rather hard phase on the western, lower slopes of the range.

Biotite Quartz Monzonite

This unit covers a large area around the Crescent Range and borders the east side of the coarse syenite. However, this contact is entirely concealed. The rock is very hard, forming impressive cliffs along passes in the Crescent Range. It is pink or occasionally gray, medium grained and equigranular. The biotite shows moderate to good parallel orientation. Major minerals appearing in hand specimen are alkali feldspar, quartz, plagioclase, and biotite. The rock is distinguished from the syenites by its better foliation, higher quartz content, and the presence of garnets. As in the hornblende gneiss, there are rounded and oriented inclusions of fine grained gray biotite gneiss.

Coarse Granite

The west end of the Crescent Range is underlain by coarse granite. Its most distinctive feature is that it is the coarsest granite in the area. The alkali feldspars are a moderate orange pink to moderate reddish orange. Quartz is smoky. Mafic content is low, the most abundant mafic phase being biotite. Hornblende and magnetite are also present. Lineation appears as elongated quartz grains.

Syenites

The two syenites together cover about a third of the area mapped. The younger unit, medium grained syenite, supports the main mass of Pliny Mtn., the only major summit not on the crest of the main ridge. Hence, this body is well exposed both horizontally and vertically.

The coarse syenite occupies the outer slopes and the basin east of the range, and so is generally not well exposed. Large areas, particularly in the basin, are completely concealed.

Microscopic texture of the two units is nearly identical. Their compositions are also very similar, and distinct from all other units.

Both units show little or no foliation.

Coarse Syenite

The coarse syenite is a highly distinctive rock varying in texture from coarse to very coarse grained. In all varieties, the most striking and abundant feature is the large pink perthite phenocrysts. These commonly exhibit carlsbad twins and magnetite inclusions. They are usually accompanied by smaller and less abundant plagioclase phenocrysts.

The matrix is speckled or gray and medium to fine grained. Major constituents of the matrix are quartz, plagioclase, perthite, hornblende, biotite, and magnetite. In most samples a large percentage of the hydrous mafic minerals have altered to sphene and magnetite or to chlorite. The amount, color, and coarseness of the matrix varies considerably, but a large portion of the rock is always made up of phenocrysts. No systematic variations in the unit are discernible.

In thin section, the contrast between phenocrysts and matrix shows up clearly. The phenocrysts are rounded and share an irregular boundary with the matrix. A few perthite phenocrysts have cores of plagioclase, An_{50}. Plagioclase phenocrysts are weakly zoned, amounting to a difference in anorthite content between rim and core of a few percent. Perthite is less commonly zoned. The matrix is granitic in composition and equigranular. The plagioclase in the matrix gives slightly lower anorthite values than the phenocrysts, and often has a myrmekite texture. Quartz is intersticial in the matrix. The matrix surrounds each large grain in a thin film, and occurs as veinlets in the phenocrysts.

Crystallization apparently began with the growth of plagioclase and perthite phenocrysts. Later, precipitation of plagioclase ceased (p. 46), but growth of the alkali feldspars continued. Matrix minerals formed last, with the two feldspars preceding quartz.

The rock weathers easily, primarily by alteration of the mafic minerals. This leads to disintegration of the matrix, leaving a very coarse pink sand of alkali feldspar. This sand can be seen in the streambeds in the basin east of the range.

The coarse syenite exhibits a sharp contact with the hornblende gneiss that clearly truncates the foliation of the gneiss. Contacts with other older units are not exposed. Rounded inclusions of a fine grained biotite gneiss and more angular inclusions of hornblende gneiss were observed. These are sometimes but not always oriented.

Medium Grained Syenite

The medium grained syenite is a much more erosion resistant rock than the coarse syenite. The unit forms low cliffs on the south side of Pliny Mtn. Its resistance to weathering is probably due to its smaller grain size and lower mafic content. That, and its greater homogeneity, are the main distinctions between it and the coarse syenite.

In hand specimen the rock appears to consist entirely of alkali feldspar, except for scattered blotches of fine grained mafic minerals. Phenocrysts are present in abundance but are not visually evident. The rock is a pale pink, approaching a pale red purple, about the same as the coarse syenite but solidly colored.

Under the microscope, one can see that the textures of the two syenites are identical. Hence, the order of crystallization was the same. However, the different types of plagioclase in a given sample of the younger syenite show greater disequilibrium.

Medium grained hastingsite granite is very similar in gross appearance to the medium grained syenite, but the former weathers to a distinctive rusty pink, always has more quartz, and has sharply defined hornblende and magnetite grains, rather than blotches of fine mafics. In addition, the granite usually shows miarolitic cavities and seams while the syenite does not. In thin section the distinction is easily made.

Near the north end of the central stock of medium grained syenite, at about 2900 feet elevation, there is a spectacular igneous breccia involving desk-sized blocks of typical coarse syenite. These are suspended and disoriented in medium grained syenite. Elsewhere, in the saddle just west of Pond Hill and southward, large boulders of coarse syenite contain dikes of medium grained syenite. South of the summit of Pliny Mtn. the syenite contains a very large xenolith or roof pendant of a fine grained mafic material with perthite megacrysts.

The two minor stocks to the northeast of the central body are poorly exposed, and their shape only vaguely known. They differ mainly in a lower anorthite content of plagioclase.

Place of the Syenites in the Stratigraphy

The syenites are not related to the White Mountain Plutonic Series, as they lie well off the compositional trend of the younger rocks (p. 38 and Fig. 5).

Chapman, Billings, and Chapman (1944) also concluded that the coarse syenite is not part of the White Mountain Plutonic Series, and suggested the unit belongs to the Oliverian Plutonic Series. This was based on the similarity of megacrysts in the hornblende gneiss and the phenocrysts in the syenite, and on the belief that the syenite was similarly foliated. Subsequent mapping has revealed that the hornblende gneiss-coarse syenite contact is sharp, with the syenite truncating the foliation of the gneiss. The author believes that the coarse syenite is a smaller body than earlier mapping showed, and that some of the foliated areas of coarse syenite on the earlier map are a porphyritic phase of the hornblende gneiss. The problem remains ambiguous, for while the redefined coarse syenite body is nowhere highly foliated and never lineated, there are areas of weak foliation roughly aligned with the regional Oliverian trend. If the syenites are Oliverian, they are an unusual composition for the "unstratified core rocks" (Naylor, 1969) of the Oliverian domes, and might be related to the coarse granite (Chapman, Billings, and Chapman, 1944). Page (1968) has suggested that there was a late Devonian, post tectonic period of igneous activity in New England. Like the syenites, these plutons lack the metamorphic textures of the Oliverian and New Hampshire Plutonic Series but are older than the White Mountain Plutonic Series. The syenites may belong to this group, although the late Devonian intrusives generally show a series of mafic through granitic rocks rather than a single type.

In summary, because of the similarity of the two syenites in texture and composition, the author believes these units are part of the same igneous pulse. Because they show sharply discordant contacts and little foliation, they are apparently separate from and later than the Oliverian Plutonic Series. Because they lie well off the trend of the White Mountain Plutonic Series, they must be distinct from that activity also.

White Mountain Plutonic Series

The Pliny Range has one of many White Mountain Plutonic Series ring dike and stock complexes in New Hampshire (Fig. 1). These lie in a belt extending north from the Pawtuckaway Mtns. in southeastern New Hampshire to the Canadian border and probably including the Monteregian Hills of Quebec. The Pliny Range itself is truncated to the north by the younger Percy Complex (Chapman, R.W., 1948). Conway granite from some of the complexes has been dated by Foland, Quinn, and Giletti (1971), showing a spread of 100 million years for the different areas. The Percy Complex gives a median age of 172 million years, which places a lower limit on the age of igneous activity in the Pliny Range.

Quartz Monzodiorite

This unit occurs as both a ring dike and a central stock. It is by far the darkest of the non-foliated rocks, being about one third mafic minerals. In hand specimen its appearance is quite uniform throughout the area, except for minor variation in grain size from medium to coarse. Contrast between dark and light minerals always gives the rock a speckled appearance. The only significant visible variation occurs at the west rim of the ring dike where the mafic phase is coarse biotite, producing a very friable rock. The central stock was not as extensively sampled as the ring dike, but appears to be lacking in quartz and alkali feldspar and hence is a true diorite. This difference is not easily detected in hand specimen.

Plagioclase is always the predominant mineral, and in thin section its smooth zoning is apparent. Anorthite content in the cores varies, but averages around An_{50}. The rims are in equilibrium at An_{23}. The predominant mafic mineral occurrence is a pyroxene core, a rim of hornblende, and sometimes an outer rim of biotite.

For the mafic minerals, then, the order of crystallization was pyroxene, then hornblende, followed by biotite, probably as late stage alteration. Plagioclase occurs as inclusions in both hornblende and biotite, and so began to precipitate before or during the hornblende. Alkali feldspar and quartz were the last phases to form, as they are clearly intersticial. Sometime during crystallization, the ring dike became saturated with vapor, as miarolitic cavities containing quartz crystals are commonly found in that unit.

At the north end of the ring dike, a few small inclusions of coarse syenite were observed. And a quarter mile west of the ring dike, a one-foot wide dike of quartz monzodiorite, striking radially to the main dike, cuts both the hornblende gneiss and the coarse syenite. The presence of the older coarse syenite between the ring dike and the central stock shows that the ring dike is a separate structure and not a fragment of the stock that became detached by later intrusions or by faulting.

Medium Grained Hastingsite Granite

This unit, the largest and most resistant granite body, is primarily responsible for the existence of the Pliny Range. It underlies the main crest of the range, and appears as impressive 30 foot cliffs and 20 foot high boulders on the eastern slopes. The rock is very homogeneous throughout the 9 mile length of its ring dike. It is generally a moderate orange pink, the color of its predominant constituent, perthite. Weathering of mafic minerals gives it a rusty tint. Quartz crystals are clear and prominent. Hornblende is sharp and well defined. Unlike the later granites, biotite is rare or absent. Quartz is less abundant than in the younger granites, and is confined to the interstices. Except for magnetite, most grains are anhedral.

Under the microscope plagioclase inclusions in the alkali feldspar are evident. Hornblende grains contain some feldspar inclusions. Apparently hornblende and plagioclase were the first to form, later joined by alkali feldspar and finally by quartz. Magnetite is abundant but biotite is lacking, probably because of low activity of orthoclase (X_{Or} in perthite is .54).

Prominent features of the rock are abundant miarolitic cavities and seams containing quartz crystals and some euhedral magnetite. These are especially common near the summit of Mt. Starr King but are less frequently seen lower in the body. Around the summits of Mts. Waumbek and Weeks, near the contact of the central quartz monzodiorite stock and the medium grained hastingsite granite, the quartz monzodiorite contains numerous small granite dikes. These were interpreted as offshoots of the medium grained hastingsite granite. East of the main ridge, a huge boulder of the granite was found to contain a xenolith of hornblende gneiss. Other than this occurrence, the unit is remarkably free of inclusions.

Porphyritic Quartz Monzonite

This unit occupies most of the area adjacent to the concave side of the quartz monzodiorite ring dike and truncates the latter at its north end. The unit is largely concealed by material slumping off the crest of the range and is well exposed in only a few places near the north end of its ring dike. There, on the ridge east of Gore School, it forms a few low cliffs.

Because of its large pink phenocrysts, it is similar to the coarse syenite in appearance, but its alkali feldspar is a more intense pink, and there is abundant quartz in small shattered aggregates. As in the syenites, mafic minerals are fine grained and occur in clots. Phenocrysts are perthite and less frequently plagioclase. Unlike other units, the perthite sometimes shows the microcline grid. Texture and composition vary little throughout the body.

In thin section, inclusions of alkali feldspar are found in hornblende, and plagioclase inclusions in alkali feldspar. Early crystals were plagioclase phenocrysts, later joined by alkali feldspar. This was followed by the matrix of feldspar and quartz. Hornblende may have grown during the entire sequence or it may have been late.

A major dike of prophyritic quartz monzonite, 100 yards wide, intrudes the north end of the quartz monzodiorite ring dike. Their contact is exposed on a low cliff, a few yards south of the col that lies between the minor summit one mile east of Gore School and the main ridge. This in fact was the only place in the Pliny Range where the dip of a contact was observed. The contact is sharp and straight. The dip is 60° inward, toward the center of the Pliny complex, and the strike is parallel to the other ring dike contacts. This indicates a cone sheet, if gross extrapolation is permitted. The contact also exhibits a chill zone about a foot wide through which the porphyritic quartz monzonite changes from coarse to fine grained where it contacts the quartz monzodiorite. The mafic mineral content increases across this zone toward the quartz monzodiorite. Stringers of porphyritic quartz monzonite intrude the quartz monzodiorite in a few places.

Pink Biotite Granite

The nature of the pink biotite granite ring dike is strikingly different from the other dikes. Through most of its length, the granite occurs as the matrix of an igneous breccia. The only exposure observed having more matrix than inclusions is at the eastern termiantion of the dike on Pliny Mtn.

Despite its high xenolithic content, the granite itself is quite homogeneous, although less so than the other ring dikes. It is a crisp-looking rock, strongly pink with dots of white plagioclase, clear quartz, and flecks of biotite. It is always medium grained and usually equigranular. One porphyritic specimen was found, and it is identical in texture and composition to the granite porphyry (see below).

In thin section quartz is intergranular and does not appear as distinct grains. Euhedral hornblende crystals are sometimes seen. The texture implies that quartz was the last phase to appear, and probably hornblende was the first. There is no evidence to indicate which feldspar formed first.

Miarolitic cavities are common. These contain quartz and biotite crystals and are associated with pegmatite areas. The pegmatites do not occur as dikes but as blotches grading into the surrounding rock. They consist largely of intergrown perthite and quartz with crystals ranging up to two inches in size.

Xenoliths found in this unit are fragments of Ammonoosuc Volcanics, hornblende gneiss, coarse syenite, quartz monzodiorite, and porphyritic quartz monzonite. Ammonoosuc Volcanics and hornblende gneiss inclusions are highly angular. Quartz monzodiorite inclusions are rounded. Other inclusions vary from rounded to subangular. In some areas only one type of xenolith occurs. In the southwest portion of the ring dike the xenolithic material is entirely hornblende gneiss. Southwest of Mt. Starr King and east of the screen the inclusions are all coarse syenite. Slightly farther southwest, where the granite truncates the quartz monzodiorite ring dike, the inclusions are quartz monzodiorite. But along the thin dike that circles the west rim of the range there is a jumble of hornblende gneiss, coarse syenite, and quartz monzodiorite to the south and coarse syenite, quartz monzodiorite, and a little porphyritic quartz monzonite to the north. Thus, if one disregarded the matrix and mapped the xenoliths as bedrock, the map pattern would not be changed except for the removal of the pink biotite granite unit. This and the angularity of much of the material indicates that the inclusions were not transported very far but rather were shattered in place and then engulfed in the rising granite magma. The concept is implied by Chapman's (1942) term for the structure: "shatter zone."

Granite Porphyry

This unit forms an outlying ring dike and was not studied extensively. Compositionally it is very similar to the pink biotite granite, and appears to occupy the same fracture zone. A search was made to find connecting dikes or faults, but only good, undisturbed outcrops of the intervening Oliverian coarse granite were found.

The rock is grayish orange pink, the subdued tone given by the finely divided mafic minerals in the ground mass. The texture of the rock is different from the pink biotite granite in that while the latter is usually equigranular, this rock is exceptionally porphyritic. Except for rare occurrences in the pink biotite granite, it is the only unit containing quartz phenocrysts, and it exhibits a very fine ground mass.

Phenocrysts are plagioclase, perthite, and quartz with a ground mass of similar composition except for a more albite-rich plagioclase. Inclusions of plagioclase occur in the alkali feldspar phenocrysts and vice versa, implying contemporaneous growth. The quartz phenocrysts are remarkably free of inclusions. Apparently the liquid had reached the cotectic line in the system quartz-albite-orthoclase-anorthite and was crystallizing quartz, alkali feldspar, and plagioclase of decreasing anorthite content when it was injected into the arcuate fracture.

The isolation of this ring dike from the other units of the complex hinders assigning it a place in the stratigraphy. However, one can guess from its compositional similarity to the pink biotite granite that it was derived from the same magma and so must have been emplaced after the porphyritic quartz monzonite.

Hornblende Biotite Granite

The hornblende biotite granite forms a small stock on the eastern slopes of the range. Like the neighboring medium grained syenite stocks, it is poorly exposed and cannot be mapped in detail. The small body to the northeast of the stock is identical in texture and composition.

In texture it is subporphyritic and varies from medium to coarse grained. The most abundant mineral and largest grains are perthite. These occasionally contain plagioclase cores and sometimes are rimmed by plagioclase. Plagioclase is always abundant, usually as grains somewhat smaller than the perthite. Quartz is also abundant, smoky, and intersticial. Biotite is prominent and so generally is hornblende. Both occur intersticially, but one biotite grain, pseudomorphous after hornblende, was found.

Plagioclase was the first feldspar phase to crystallize and was later joined by alkali feldspar. The place of biotite is unclear, but it appears to have been partially replaced by alkali feldspar during late stage crystallization. Some biotite formed by alteration of early hornblende. Quartz was the last phase to appear.

In the map pattern the hornblende biotite granite stock intrudes the outer rim of the medium grained hastingsite granite dike and so is thought to be younger. Isolation from other units of the series prevents establishment of direct age relations. Two factors suggest that it is younger than the pink biotite granite: (1) Its overall appearance is similar to the Conway granite which seems to cut off the edge of the pink biotite granite ring dike (exposures are also poor in that area) and which elsewhere in New Hampshire is the youngest unit of the White Mountain Plutonic Series. (2) The style of intrusion, like the Conway granite, is as a stock rather than as a ring dike. Perhaps caldera subsidence and ring dike formation had ceased and resurgence with the emplacement of stocks followed (Smith and Bailey, 1968).

Conway Granite

Conway granite occurs in five small stocks surrounding the crest of the range, and probably in smaller ones that escaped observation. Except for the stock east of Mt. Weeks, none are well exposed. Outcrops are low, rounded benches. More often there are no outcrops, only a jumble of Conway granite boulders emerging from the slope. Such is the case in the pass between Pliny Mtn. and Mt. Waumbek.

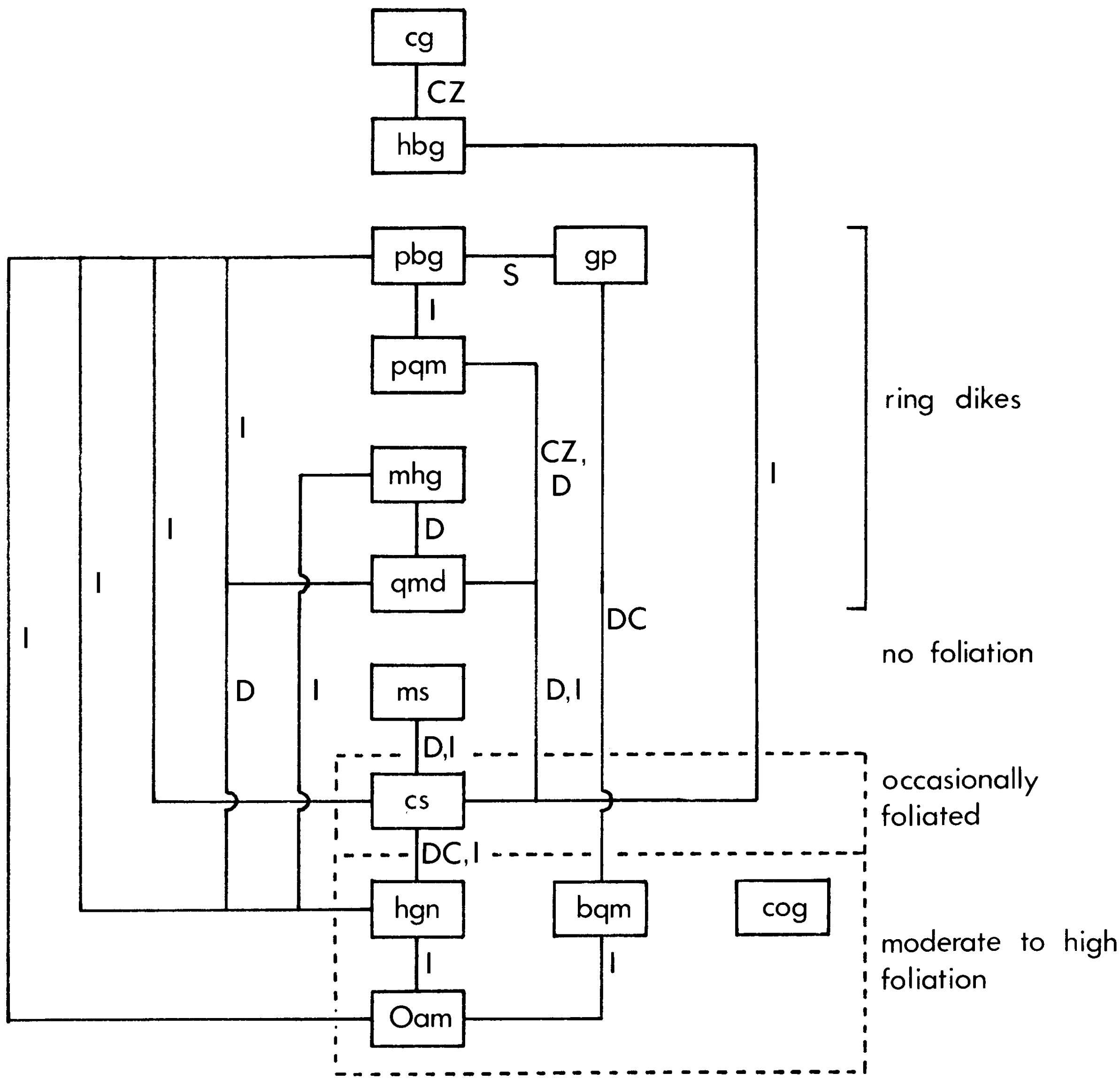
As was stated above, the Conway granite is similar to the hornblende biotite granite. The rock is a pale pink with flecks of biotite or hornblende. It is more likely to be coarse grained than the hornblende biotite granite, and is higher in quartz and alkali feldspar, and lower in plagioclase. Of these differences, the higher quartz content is most easily recognized. Quartz grains do not have the intersticial appearance of the quartz in hornblende biotite granite. Rather, they appear roughly spherical, protruding as domes from a fractured surface. This texture is consistent throughout the various stocks and is present in both medium and coarse grained varieties.

Thin sections reveal that plagioclase began to crystallize before alkali feldspar, as plagioclase occurs as cores in the perthite. Other relationships are not clear.

Mapping indicated that the Conway granite intruded all the other White Mountain Plutonic Series granites and the two syenites, but only one actual contact was found. This is between the Conway granite and the hornblende biotite granite, with the former chilled against the latter.

Figure 4. Age relationships among units mapped.

Fig. 4



CZ	chill zone at contact
D	dike
DC	discordant contact
I	inclusions
S	similar texture & composition

Figure 5. Bulk compositions of units in the systems $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2 and $NaAlSi_3O_8$-$KAlSi_3O_8$-$CaAl_2Si_2O_8$. Solid circles represent bulk compositions in weight fraction. Tie lines connect coexisting feldspars. Open circles show minimum melting compositions for water saturation at pressures shown (Tuttle and Bowen, 1958; and Luth, Jahns, and Tuttle, 1964).

Fig. 5

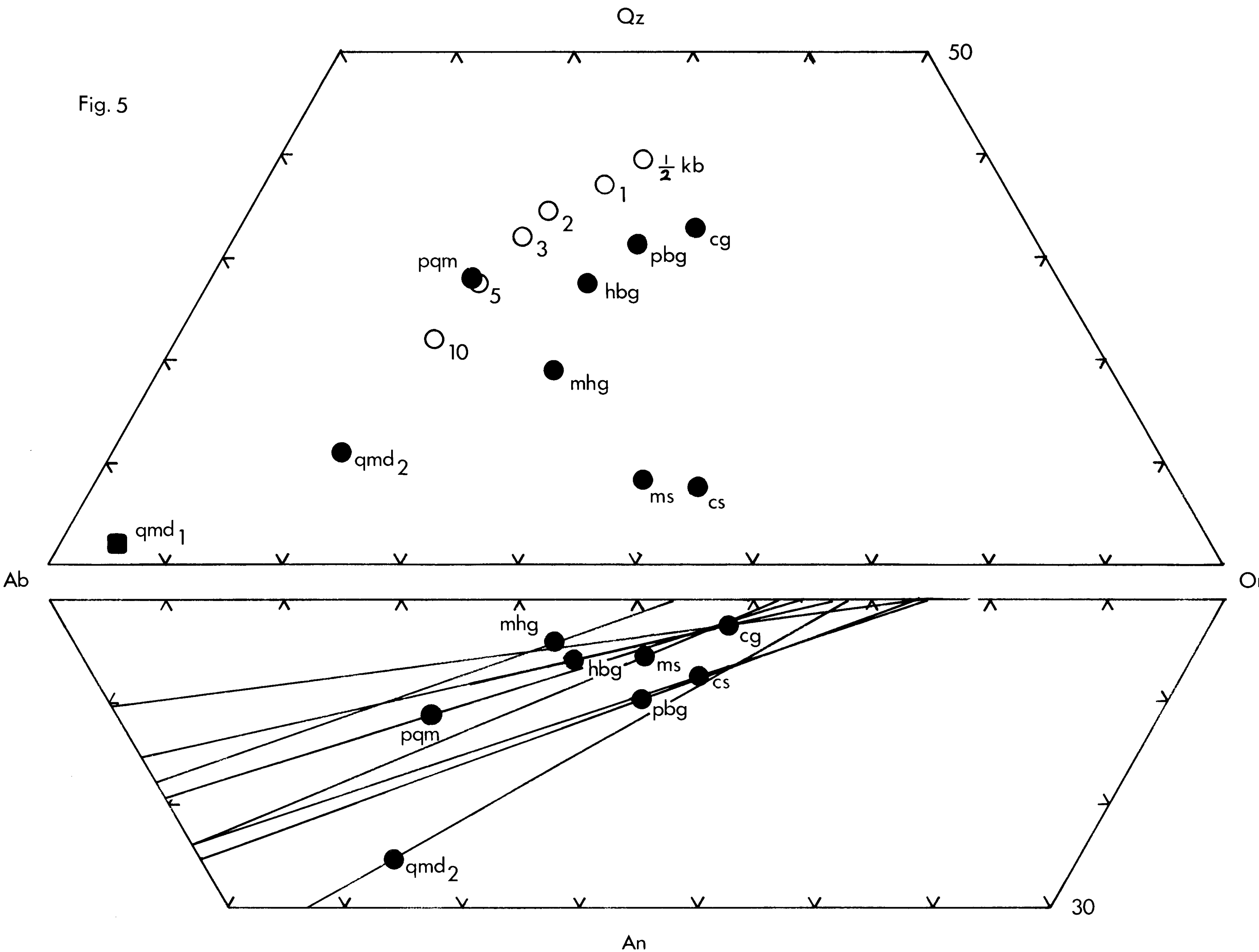

Qz
50
1/2 kb
1
2
3
cg
pbg
pqm
5
hbg
10
mhg
qmd 2
ms
cs
qmd 1
Ab
Or
mhg
cg
hbg
ms
cs
pbg
pqm
qmd 2
30
An

Figure 6. Compositions of feldspars and biotites from the units. Plagioclase compositions are from extinction angle measurements on a universal stage. Alkali feldspar compositions were determined by X-ray diffraction (Wright, 1968). Biotite compositions were obtained from refractive indices using the data of Wones (1963) for biotites on the phlogopite-annite join.

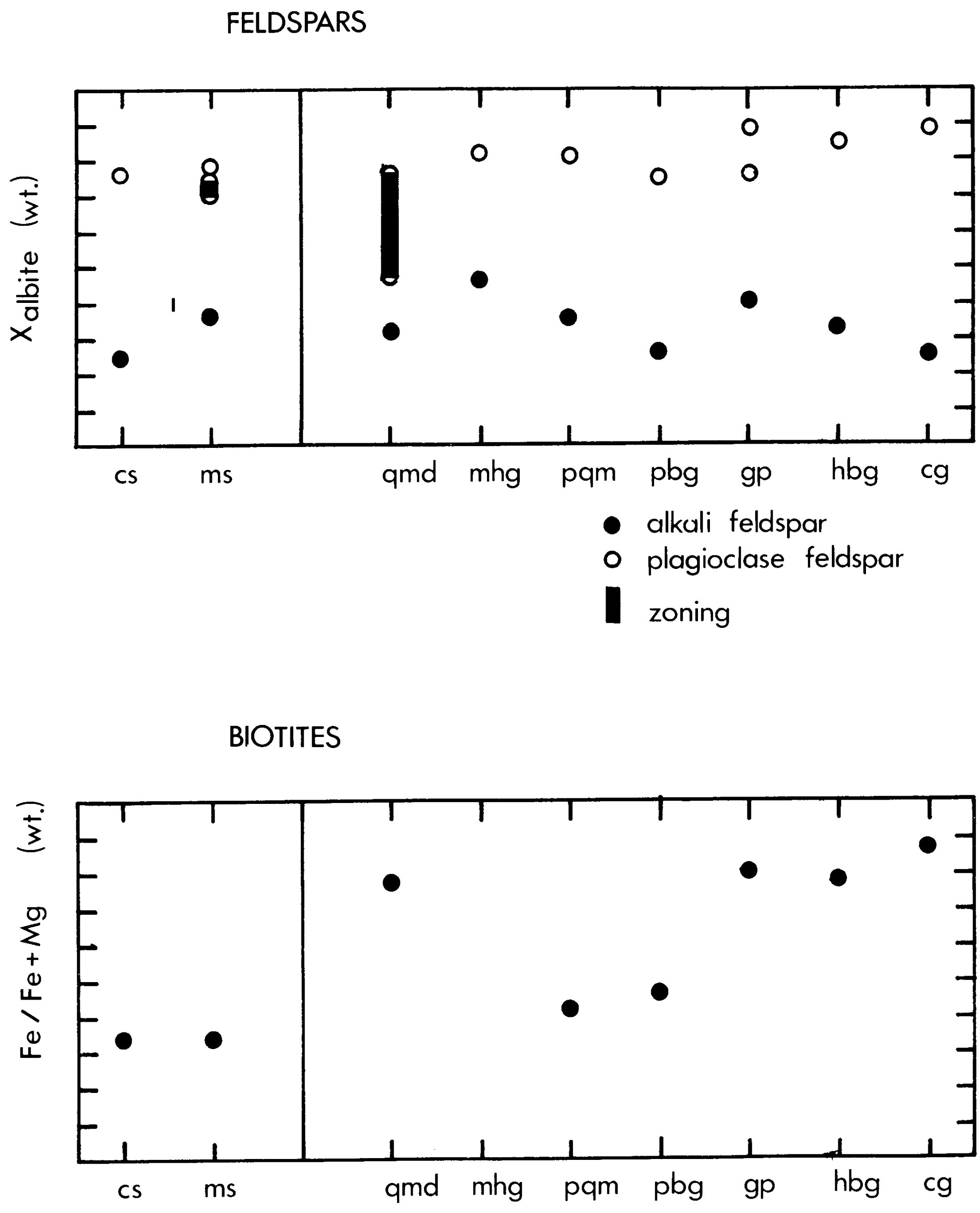

FELDSPARS
Xalbite (wt.)
cs
ms
qmd
mhg
pqm
pbg
gp
hbg
cg
alkali feldspar
plagioclase feldspar
zoning
BIOTITES
Fe / Fe + Mg (wt.)
cs
ms
qmd
mhg
pqm
pbg
gp
hbg
cg

Fig. 6

Summary of Data

A summary of observations concerning age relations is presented in Figure 4. Results of point counts, extinction angle measurements, X-ray diffraction, and oil immersion for individual samples are compiled in Table 2 and plotted in Figures 5 and 6.

DISCUSSION OF RESULTS

Figure 5 shows the bulk compositions of the syenites and White Mountain Plutonic Series plotted as weight percent in the albite-orthoclase-quartz system and the ternary feldspar system. In both cases X_{albite} represents contributions from plagioclase and alkali feldspar.

The albite-orthoclase-quartz plot shows clearly the distinction between the White Mountain Plutonic Series and the syenites. The White Mountain Plutonic Series follows a trend from the albite corner of the field to the center, with successively younger units poorer in albite. The syenites, however, lie together near the middle of the albite-orthoclase sideline, well away from the trend of the younger rocks.

Comparison of the Syenites

There is no clear fractionation trend in the syenites. The average medium grained syenite is richer in albite and slightly richer in quartz than the coarse syenite. However, the scatter of individual coarse syenite samples, while relatively small, is sufficient to surround the medium grained syenite compositions. The slightly lower anorthite content of the medium grained syenite is due to the lower modal volume of plagioclase feldspar. The medium grained syenite is more homogeneous, and there is little variation in the unit on the 1500 vertical feet of mountainside over which it is exposed. However, it covers a much smaller area than the coarse syenite.

A consistent difference between the two syenites is that the exsolved plagioclase, matrix plagioclase, and plagioclase phenocrysts are more in equilibrium in the coarse syenite than in the medium grained syenite. For the coarse syenite this results in an unlikely amount of anorthite in the perthite phenocrysts and probably represents subsolidus equilibration. The coarse syenite, being older, has been reheated more times and hence has had greater opportunity to reach equilibrium.

Origin of the Syenites

There is no question that the syenites are of igneous origin and existed in at least a partially fluid state. Both units show sharp, discordant contacts with the country rock, and the medium grained syenite in particular contains large disoriented xenoliths.

Bowen (1928) suggested that certain syenites are cumulates, resulting from the settling of feldspars or feldspathoids. Such syenites, however, show vertical gradations with quartz content increasing upward and feldspar content increasing downward. This pattern does not appear in the 2000 feet of relief through which the Pliny Range syenites are exposed.

Contamination of the magma by carbonate-rich country rock has also been suggested in some cases for formation of syenites. However, the country rock in the Pliny Range is quartz-rich and furthermore the granites generally contain more xenoliths than the syenites.

Since, like the granites, the syenites are low in mafic content and are largely described by the components albite-orthoclase-quartz, the possibility must be considered that, like the granites (Chayes, 1951; Luth, Jahns, and Tuttle, 1964; and Tuttle and Bowen, 1958), they also represent a minimum melting composition. The conditions required for this situation and the lack of related igneous rocks in the area suggest partial melting rather than fractionation as the mechanism of origin.

The question that must be considered is what conditions or additional phases will shift the minimum melting composition toward the middle of the albite-orthoclase join. Two common components have a profound effect on the minimum. The work of Luth, Jahns, and Tuttle (1964) shows that with water saturation the minimum is shifted toward the albite corner with increasing pressure. The opposite effect is obtained by dissolving anorthite in the system (Winkler, 1967). Anorthite dissolves almost exclusively in albite, lowering the chemical potential of albite in plagioclase and thereby decreasing the fraction of albite in the melt. This can be seen graphically in the quaternary system albite-orthoclase-anorthite-quartz (Fig. 6). Planes of constant anorthite content intersect the cotectic line at points farther from the albite-anorthite sideline with increasing anorthite content. However, anorthite does not appear to be an important factor in the present case, since anorthite content for the syenites is no higher than the White Mountain Plutonic Series granites.

Another important effect on the minimum melting composition is that of total pressure in water undersaturated systems. Luth (1969) has shown that high total pressure shifts the eutectic minimum in the systems quartz-albite and quartz-orthoclase toward more feldspar. The trend is reversed in the quartz-albite system when albite breaks down to form jadeite and nepheline at 33 kilobars (Bell and Roseboom, 1969). High total pressure should shift the quaternary minimum (Fig. 7) for the albite-orthoclase-anorthite-quartz system toward the alkali feldspar sideline. At low water pressures the shift should be toward the middle of the sideline rather than the albite end. The effects of high total pressure and low water pressure are also reflected in the alkali-rich portion of the ternary feldspar system (Barth, 1969). The syenites do indeed seem drier than the White Mountain Plutonic Series, as the latter generally show miarolitic cavities and occasionally some pegmatitic areas and the syenites do not.

Assuming the syenite magma formed under these conditions, a possible course of crystallization is outlined in Figure 8. The pressure needed and the shallowness of the New England crust require that the source be the upper mantle. After partial melting occurred under high pressure in a dry environ-

Figure 7. Sketch of the system $NaAlSi_3O_8$-$KAlSi_3O_8$-$CaAl_2Si_2O_8$-SiO_2, showing changes with varying total pressure and water pressure. The syenite magma may have formed at high total pressure and low pressure, and completed crystallization at low pressure and water saturation.

Fig. 7

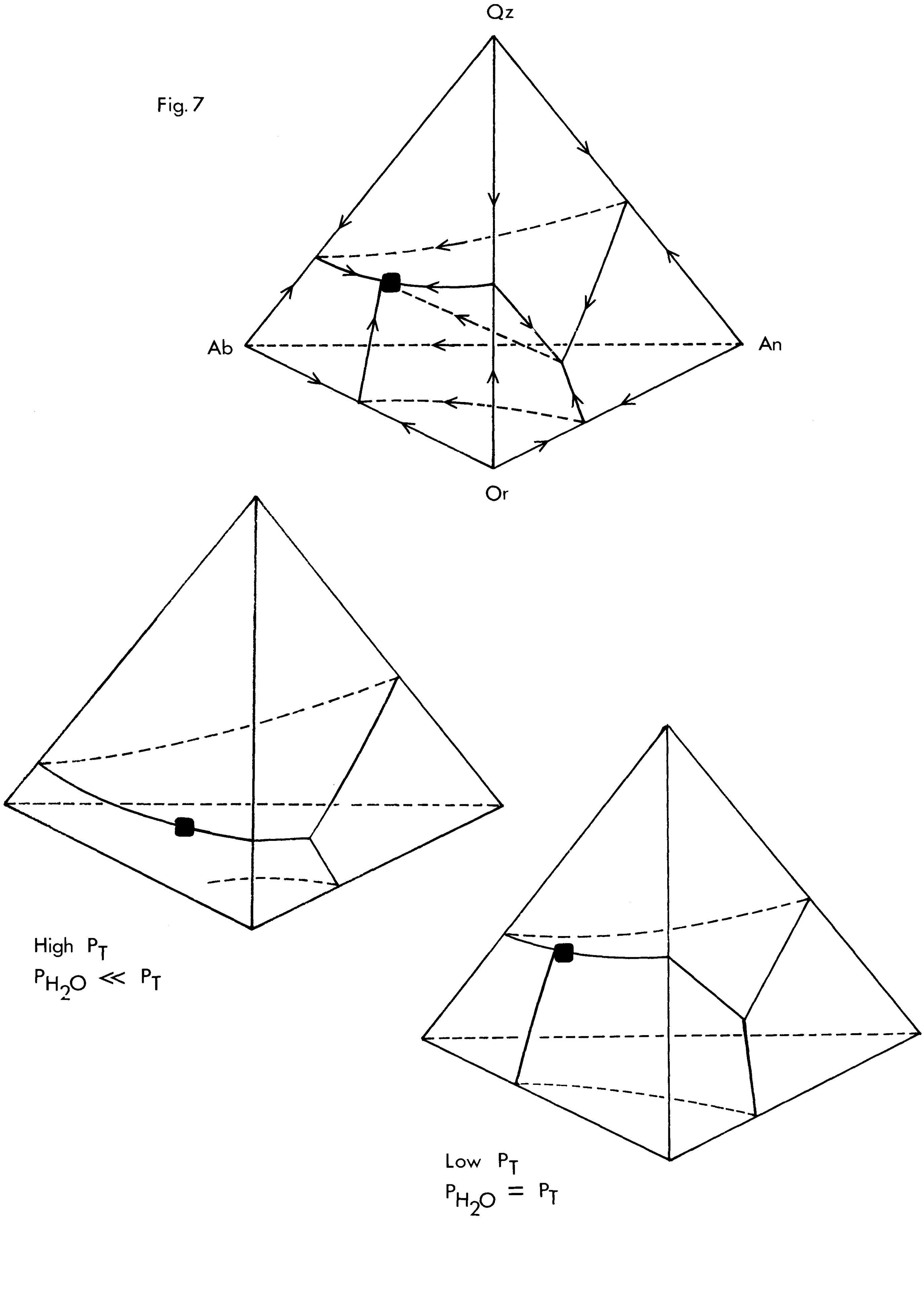


Figure 8. Course of crystallization of the syenites in the tetrahedron albite-orthoclase-anorthite-quartz. The heavy line (L) represents the course of the liquid. Lighter lines connect coexisting liquid and solid phases. The liquid formed in the interior of the tetrahedron near the middle of the alkali feldspar join and moved toward the center of the albite-orthoclase-quartz face.

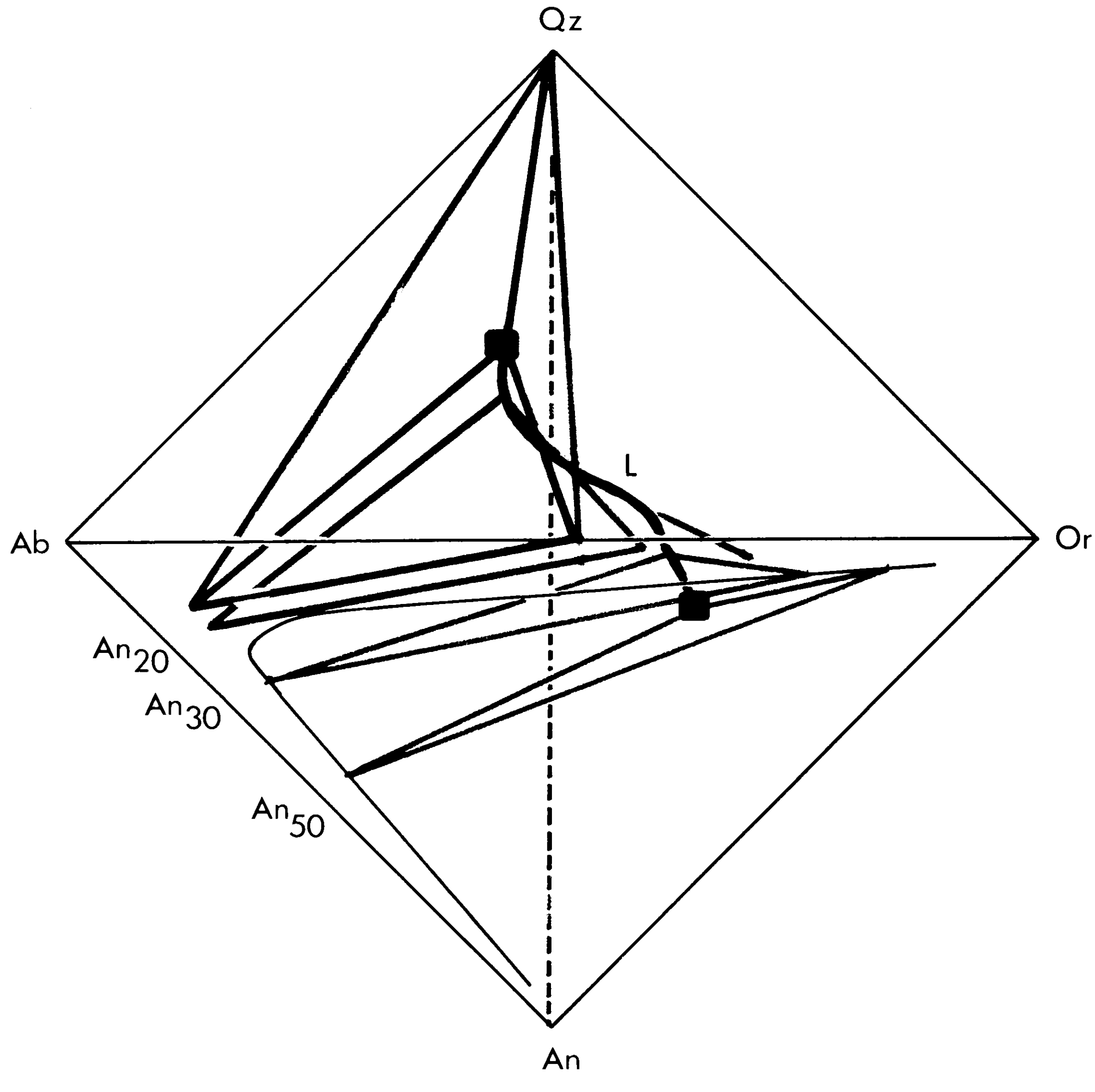


Fig.8

ment the liquid fraction began to rise. Heat required to maintain magmatic temperatures as cooler rock was encountered was supplied by the growth of phenocrysts. As discussed above, crystallization began with An_{50} plagioclase and alkali feldspar. The most abundant inclusions in these crystals are magnetite, as water pressure was insufficient to form biotite or hornblende. After a period of growth of both alkali feldspar and plagioclase phenocrysts, the liquid left the two feldspar field. This is indicated by the discontinuity between anorthite contents in the plagioclase phenocrysts and plagioclase in the matrix. As the magma and growing phenocrysts rose the total pressure correspondingly fell. Concurrently, water and other volatiles were concentrated in the liquid fraction, effectively increasing the activity of water in the magma. Falling P_T and rising P_{H_2O} together increased the solubility of quartz and albite in the melt at the expense of orthoclase. This encouraged the growth of potassic alkali feldspar phenocrysts while concentrating albite and quartz in the liquid, eventually producing a liquid fraction of granitic composition. After phenocryst growth was far advanced and the mushy mass approached its final position, water was sufficiently concentrated in the matrix liquid for the stability of hydrous mafic phases. Accordingly, biotite and hornblende were precipitated, rather than magnetite. Another effect of rising activity of water was that the two feldspar field was reentered and the matrix feldspars, sodic plagioclase and alkali feldspar, began to form. These were joined by quartz and crystallization was complete.

The events outlined are somewhat speculative but are an attempt to explain the following features of the syenites:

(1) The bulk composition of the syenites.

(2) The dryness of the magma.

(3) The granitic composition of the matrix.

(4) Texture:

- matrix surrounds each phenocryst;
- rounded, eroded nature of the phenocrysts.

(5) The absence of hydrous mafic phases as inclusions in the phenocrysts and their presence in the matrix.

An alternative hypothesis regarding the texture is that it is metamorphic in origin. As was mentioned before, the units were certainly magmas at one time. The phenocrysts themselves remained unaffected by any metamorphism, as they are relatively free of fracturing, granulation, or recrystallization and retain their zoning. Conceivably, the matrix could have been produced by granulation and recrystallization along the margins of the phenocrysts. However, it is unlikely that severe recrystallization of 20 percent of the rock could leave the phenocrysts relatively unaffected, the xenoliths sharp, fresh, and undeformed, and the contacts distinct and straight.

White Mountain Plutonic Series

As was mentioned earlier, White Mountain Plutonic Series rocks fall on a clear trend. The trend parallels the water saturated minima in the albite-orthoclase-quartz system, lying a short distance to the feldspar-rich side of the minima. From the arguments presented (p. 41), these compositions should represent the minima of systems slightly undersaturated in water. Alternatively, they could represent compositions on the cotectic line in the quaternary granite system at low but finite anorthite content, water saturation, and varying pressures. Anorthite content does not appear to be a controlling factor, as demonstrated by porphyritic quartz monzonite. This unit is the richest in anorthite of the post-quartz monzodiorite units, but is displaced off the trend in the orthoclase-poor direction on the albite-orthoclase-quartz projection. This is opposite to the shift in minimum melting compositions caused by dissolving anorthite in the melt (p. 40). A further possibility is that each unit composition represents contributions from a liquid on the water saturated minimum plus feldspar phenocrysts carried in that liquid during emplacement.

Such factors as assimilation or contamination do not appear to be important, at least at shallow levels, in the development of the White Mountain Plutonic Series. All the units are quite homogeneous and, except for the pink biotite granite, do not contain many xenoliths. Where xenoliths do occur, they are generally angular and fresh. They show evidence of neither melting nor much alteration. One exception is the quartz monzodiorite. Inclusions of coarse syenite in this unit are well rounded. This was undoubtedly the hottest intrusion and may have assimilated some foreign material, but there is no evidence for large scale melting of country rock.

Two lines of evidence indicate falling temperatures with younger intrusions. First is the change in partitioning of sodium between plagioclase and alkali feldspar. The temperature dependence of this variable is discussed by Barth (1969). The change in partitioning is shown by the fanning of tielines between coexisting feldspars (Fig. 5). At lower temperatures plagioclase absorbs proportionally more sodium than the alkali feldspar, and hence the angle between the tielines and the albite-orthoclase sideline decreases with younger units.

A second line of evidence concerning temperature is biotite composition. Several factors including temperature, water pressure, and oxygen fugacity affect the composition of biotite (Wones and Eugster, 1965). Total pressure at time of emplacement must obviously be the same for the units. Miarolitic cavities show that water pressure equalled total pressure at time of crystallization. Therefore, if oxygen fugacities were comparable and the biotites were in equilibrium during emplacement, lower temperatures would be required for the annite-rich biotites of later intrusions to be stable. If the magma was internally buffered, as is likely (Nash and Wilkinson, 1969), the enrichment of biotites with annite reflects both falling temperature and oxygen fugacity. The composition of biotite from the quartz monzodiorite is out of line with this trend (Fig. 6), but at least some and possibly all of this biotite is secondary and so does not represent conditions during crystallization.

Origin of the White Mountain Plutonic Series

If granites represent the "residua" or end point of fractionation for a differentiating magma, then their bulk composition should reflect the conditions and especially the depth at which they evolved. Granite magma may, however, move from its place of origin. The granitic rocks in question certainly show evidence of rapid upward movement into fracture zones and away from their place of origin. If after emplacement the magma remains partially fluid for a sufficient period for equilibrium to be reestablished, the bulk composition can no longer change, but the phases may change or at least change composition. In this light the feldspar and biotite compositions have been interpreted as indicators of conditions during emplacement. Implications of bulk compositions will now be considered.

As has already been mentioned, assimilation or contamination by shallow crustal material is not thought to be of importance in the origin of the series in question. Further, it is difficult to imagine that partial melting could produce such an extensive and ordered series. This leaves magmatic differentiation. The simplest form of differentiation is a body of magma at depth, slowly cooling and losing its high temperature phases by crystal settling or by mantling of crystals. Successive fractions are tapped off the top of the magma chamber or squeezed from a mush. Such a model could roughly account for this series if the separating phases are alkali feldspar, plagioclase, and mafic minerals. The fit is good for quartz monzodiorite through medium grained hastingsite granite. It is not so good for anorthite content in the latter portion of the series.

Another possibility is suggested by the parallel nature of the trends for the series and the water saturated minima (Fig. 5). The units may represent the end points of fractionation for successively lower pressures, tapped from a common parent magma as it rose through the crust. The same fracture system was repeatedly exploited. The driving mechanism may have been the over pressure of volatiles. When the parent magma reached a depth such that the pressure of volatiles exceeded the hydrostatic pressure by a critical value, the roof fractured and the granitic melt intruded upward and perhaps erupted as rhyolite along ring fracture zones. Toward the end of the series the parent magma itself may have been entirely granite, gradually rising, fractionating toward the minimum melting composition for less and less pressure, and tapped at intervals. Whether or not this hypothesis is valid, it is reasonable to conclude that the units of the series represent the fractionation of a parent magma toward a low pressure minimum melting composition.

The geometry and possible mechanics of intrusion are discussed by Chapman (1942). The analogy with modern calderas is obvious (Smith and Bailey, 1968). Caldera subsidence is commonly accompanied by volcanic eruptions. While the erosion level is too deep for volcanics to be found in the Pliny Range, they are associated with the White Mountain Plutonic series in the Moat Range and the Ossippe Mtns. (Noble and Billings, 1967).

FURTHER WORK

Since the syenites apparently belong to neither the White Mountain Plutonic Series nor the Oliverian Plutonic Series, their age is open to question and could fall anywhere within a 300 million year time span. By age dating it might be possible to relate them to other events in New England. The task would not be easy, however, since whole-rock Rb/Sr is very low and rarely close to 1.0. Mineral ages from biotite or hornblende are hindered by the generally advanced alteration of those minerals. Furthermore, the best sample localities are on the slopes of the range, close to younger intrusives.

A major element analysis of the Pliny Range syenites and White Mountain Plutonic Series rocks is in progress. A trace element study is the next logical step in testing models of origin. The variety of igneous rocks in the complex, their freshness, and the certainty with which the age relations can be demonstrated makes them ideal for such a study.

ACKNOWLEDGMENTS

I am indebted to Prof. David R. Wones for many ideas and suggestions concerning field work, the petrographic study, and preparation of the paper. Prof. Richard S. Naylor and Mr. Rudolf Hon also made many helpful suggestions. I am especially grateful to my nephew, Mr. Robert Mignard for accompanying me on the longer trips across the Pliny Range, and to my wife, Alice Eichelberger, who gave much help and encouragement. Support for the field work was provided by grants GA 1109 and GA 13092 of the National Science Foundation to Prof. Wones.

TABLE 2

SAMPLE	CS-59	CS-62	CS-79	CS-128	CS-147	CS-152	CS-156
quartz	2.7	1.3	4.4	6.9	0.8	9.6	14.7
alkali feldspar	63.8	79.8	67.7	57.9	67.0	56.6	47.3
plagioclase feldspar	27.9	11.7	14.5	25.8	20.3	23.8	34.6
biotite	1.6	4.0	0.8	5.7	10.9	4.3	1.3
hornblende	2.1	-	9.1	1.6	-	4.6	0.5
garnet	0.1	-	-	-	-	-	-
opaques	1.2	2.1	0.4	0.6	0.4	0.2	0.2
sphene	0.7	1.1	2.6	1.5	0.2	0.6	0.9
chlorite	-	-	0.5	-	0.5	0.3	-
X_{Or} - wt.% alkali fs.	-	-	74	74	-	-	-
X_{An} - mole% plagioclase -phenocryst	-	25*	-	29*	-	-	24
-matrix	23	26	24	26	22*	12	24
-exsolution	24	26	24	-	-	11	-
R.I. biotite	-	-	-	1.616	1.634	1.624	1.614
R.I. hornblende	1.672	-	1.712	1.688	-	1.684	1.681

Modes based on 1000 counts per thin section. One thin section per sample.

X_{An} is average of 2-3 determinations, except starred data are single determinations.

Refractive Index (R.I.) refers to γ.

SAMPLE	CS-178	MS-118	MS-138	MS'126	MS'168	MS'170
quartz	10.3	6.3	8.4	8.0	7.0	22.0
alkali feldspar	43.8	74.5	63.1	67.2	41.0	44.6
plagioclase feldspar	39.5	16.0	23.8	18.8	49.0	30.4
biotite	-	1.2	2.4	-	-	-
hornblende	3.4	0.3	-	-	-	-
garnet	-	-	-	-	-	-
opaques	0.9	1.6	1.2	2.0	0.6	1.3
sphene	0.7	0.2	1.0	trace	1.5	0.6
chlorite	1.4	0.8	0.1	4.0	0.9	1.2
X_{Or} - wt.% alkali fs.	76	63	62	-	-	-
X_{An} - mole% plagioclase						
-core	50	29	-	-	-	-
-phenocryst	26	25	-	-	15	15*
-matrix	23	20	23	-	11	8
-exsolution		16	17	-	7	8
R.I. biotite	-	1.623	1.619	-	-	-
R.I. hornblende	1.686	1.675	-	-	-	-

MS' refers to samples from satellite stocks.

SAMPLE	QMD_1-W	QMD_2-45	QMD_2-46	QMD_2-52	QMD_2-70
quartz	0.9	5.3	5.4	9.4	6.7
alkali feldspar	3.3	12.4	25.7	12.0	1.5
plagioclase feldspar	57.8	55.2	43.0	42.6	53.7
biotite	8.2	13.3	10.1	24.0	13.9
hornblende	12.9	6.5	12.0	10.1	19.8
pyroxene	5.7	0.8	-	0.9	-
garnet	-	-	-	0.1	-
opaques	3.5	1.0	3.3	0.6	4.4
sphene	0.3	-	-	-	0.5
chlorite	7.4	5.0	0.5	0.3	-
X_{Or} - wt.% alkali fs.	-	-	68	-	-
X_{An} - mole% plagioclase -core	54	48	45	62	47
-rim	23	23	24	21	23
R.I. biotite	1.658	1.670	1.677	1.682	-
R.I. horn-blende	1.671	1.694	1.723	1.696	-

QMD_1 refers to sample from central stock. QMD_2 refers to samples from ring dike.

SAMPLE	MHG-SK	MHG-148	MHG-163	MHG-164
quartz	20.1	15.4	16.3	17.7
alkali feldspar	51.9	64.6	57.5	73.7
plagioclase feldspar	24.9	16.0	22.3	2.4
biotite	-	0.2	0.2	0.1
hornblende	-	-	3.0	5.0
garnet	-	-	-	0.1
opaques	2.3	1.4	1.0	1.0
sphene	0.3	0.5	-	-
X_{Or} - wt.% alkali fs.	55	-	-	52
X_{An} - mole% plagioclase -core	-	17*	17*	27*
-rim or grn. w/o zoning	28	13	10	18*
-exsolution	10	13	8	7
R.I. hornblende	-	-	1.730	1.728

SAMPLE	PQM-78	PQM-81	PQM-85	PBG-94	PBG-106	PBG-114
quartz	24.2		24.9	42.8	11.1	30.5
alkali feldspar	27.2		34.9	27.7	58.7	43.3
plagioclase feldspar	41.4		36.6	24.5	26.7	23.7
biotite	1.2		2.3	3.6	0.8	0.4
hornblende	3.0		0.1	0.2	-	-
opaques	1.2		0.9	0.7	1.3	1.0
sphene	1.4		0.3	0.3	0.4	0.8
chlorite	-		-	0.3	0.4	0.3
X_{Or} - wt.% alkali fs.	-	68	59	80	-	68
X_{An} - mole% plagioclase						
-phenocryst	18*	-	18	none	none	none
-matrix	20*	-	18*	23	25	26
-exsolution	-	-	7	-	-	-
R.I. biotite	-	1.633	1.626	1.636	1.636	1.637
R.I. hornblende	-	1.669	-	1.663	-	-

SAMPLE	GP-34	HBG-166	HBG-169	HBG-174	HBG-175
quartz	(39.9)	20.9	31.7	16.1	31.6
alkali feldspar	(49.6)	56.7	36.6	45.0	42.8
plagioclase feldspar	(5.8)	18.1	26.2	34.7	21.6
biotite	0.8	2.4	4.7	2.8	3.5
hornblende	1.7	0.9	-	-	trace
opaques	0.9	0.9	0.5	1.1	0.2
sphene	-	0.1	0.3	0.3	0.3
chlorite	1.4	-	-	-	-
X_{Or} - wt.% alkali fs.	60	-	-	67	-
X_{An} - mole% plagioclase					
-core	27*	-	35*	-	-
-phenocryst	23	none	none	none	none
-matrix	10	10	25	13	11
-exsolution	-	9	-	7	-
R.I. biotite	1.675	1.676	-	1.670	1.672
R.I. hornblende	1.715	1.713	-	-	1.710

Parentheses indicate uncertain values due to fineness of grains.

SAMPLE	CG-43	CG-82	CG-171
quartz	30.2	33.2	31.7
alkali feldspar	47.9	61.3	47.3
plagioclase feldspar	21.5	4.8	18.7
biotite	0.1	trace	1.4
hornblende	-	1.1	0.3
opaques	0.3	-	0.3
sphene	-	-	0.1
X_{Or} - wt.% alkali fs.	-	-	74
X_{An} - mole% plagioclase -grain	9	12	10
-exsolution	9*	-	10*
R.I. biotite		1.684	1.684
R.I. hornblende		1.727	1.725

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The author is a member of Phi Lambda Upsilon, honorary chemical society. While at M.I.T. he was active in winter mountaineering with the M.I.T. Outing Club.

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