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Pegmatites of Granite Peak Mountain Tooele County, Utah*

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ABSTRACT.—Pegmatites constitute 10% to 15% of Granite Peak Mountain. They occur mostly as tabular dikes enclosed in leucogranite and biotite granite-gneiss country rock. Three main zones are seen in many pegmatites: 1) a borderwall zone, 2) an intermediate zone, and 3) a core. The most common minerals present are microcline, quartz, plagioclase, and muscovite. Beryl, tourmaline, garnet, and hematite are found in varying lesser amounts. Other minerals are rare. Origin of the pegmatites is considered to be the result of Precambrian magmatic action and/or granitization.

Economic importance of the pegmatites and areas of metallization in the country rock is not considered to be great.

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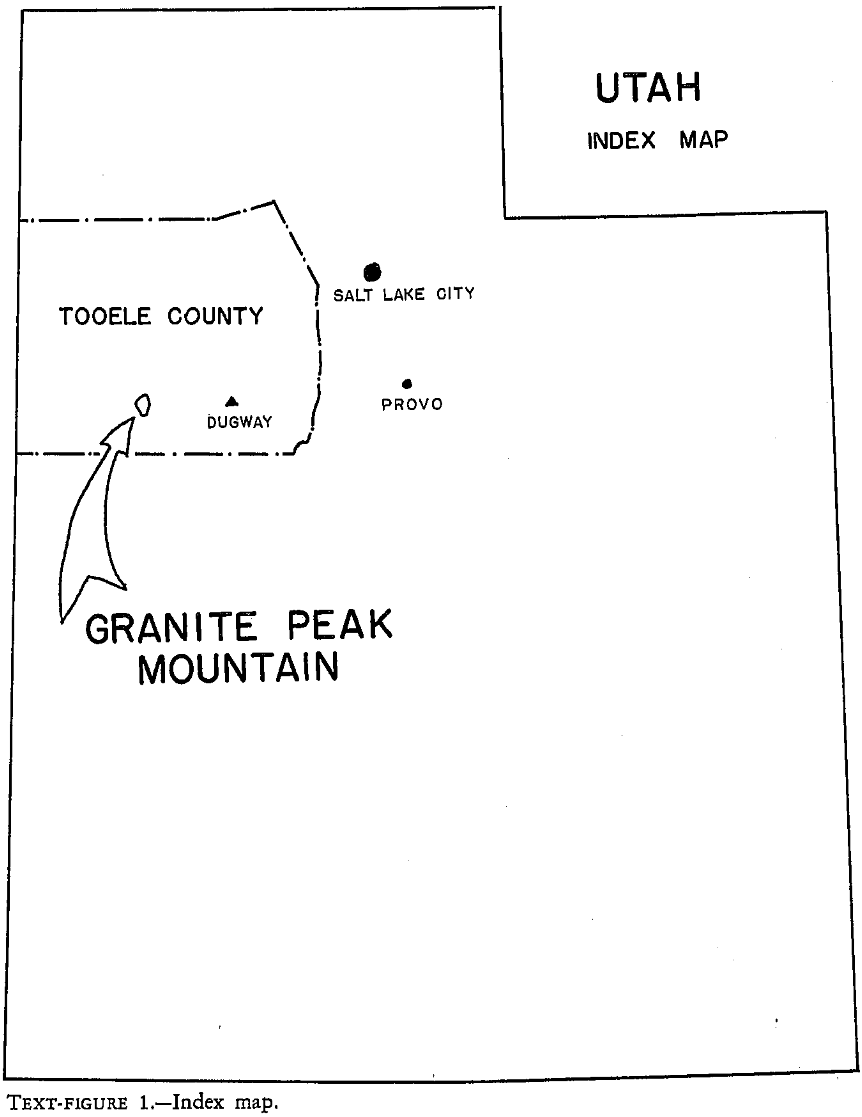
TEXT

*A thesis submitted to the faculty of the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, May 4, 1964.

INTRODUCTION

Location and Description

Granite Peak Mountain is located approximately 30 miles due west of Dugway, Utah, on the Dugway Proving Grounds military reservation. The mountain is elongate, trending generally north-south, and is widest near the northern end, being approximately eight miles long and six miles wide. It covers a total area of about 35 square miles. It rises from a playa valley floor at an elevation of 4,300 feet to a maximum elevation of 7,068 feet above sea level. Refer to text-figure 4 for an index to the topographic maps available of the area.



TEXT-FIGURE 1.—Index map.

A paved road connects Dugway to the northern end of Granite Peak Mountain, and the mountain is encircled by dirt roads maintained by the U.S. Army. There are, however, no good access roads into the interior of the mountain, and access can be made only by foot and to a limited extent by four-wheel drive vehicles. Travel in the entire area is restricted by military authorities and the author was allowed into the area only upon special permission and supervision by U.S. Army officials.

The slopes of Granite Peak Mountain are steep and rugged. Lake Bonneville terraces are visible on the mountain. The most prominent level is at about the 4,800-foot elevation, which marks the Provo Level of the ancient lake. This level is characterized by a beach conglomerate and travertine deposits.

Vegetation is sparse with a few cedar trees, grass, and bushes growing on slopes and valley floors. The climate is arid. One small spring near the northern end of Granite Peak Mountain is the only spring in the area.

Acknowledgments

The author wishes to express appreciation to the great many individuals who contributed technical advice and who extended valuable assistance in this study. Appreciation is given to Lt. Colonel John D. Servis, deputy post commander of the U.S. Army proving ground facility at Dugway, Utah, for allowing the author access to the Granite Peak Mountain area. Thanks are also given to Mr. A. M. Salisbury who coordinated field trips to Granite Peak Mountain and who contributed important information about mining activities of the area. The author wishes to thank Dugway Proving Ground personnel who were asked to give their valuable time as guides and as jeep drivers while research was being conducted. Valuable assistance was rendered by the Dugway Proving Ground Logistical Services who supplied aerial photo-maps and by the post public information officer who supplied various land photographs of Granite Peak Mountain.

Special appreciation is extended to Dr. K. C. Bullock, thesis chairman, who offered helpful suggestions and aided in research; and to Dr. L. F. Hintze who offered constructive criticism in preparation of the manuscript. Thanks are also extended to Mr. DeForrest Smouse and others who accompanied the author on various field trips to Granite Peak Mountain for their assistance.

Previous Work

Little information has been published concerning Granite Peak Mountain. Butler (1920) visited the mountain in 1913 and made general observations concerning the geology and mining. He supplemented his own findings with unpublished notes by Ellsworth Dagget who visited the area in 1898. Ives (1946, 1949) has also published some information about Granite Peak Mountain.

The pegmatites of Granite Peak Mountain were first investigated as such by Harry W. Parker on August 18, 1938 (Hanley, 1950), and were first prospected for various rare minerals during the same year. The pegmatites were examined once again for mica and beryllium minerals on April 6, 1943 by J. B. Hanley and G. A. Kennedy whose investigations were part of an appraisal by the U.S. Geological Survey of domestic resources of beryllium, tantalum, mica, lithia, and other common pegmatite materials (Hanley, 1950). Beyond these brief examinations no intensive investigations including petrographic examination were ever made of the pegmatites.

The U.S. Army in the early 1950's employed geologists to ascertain the value of mining claims on Granite Peak Mountain so that the area could be condemned and taken over for military testing purposes. Eventually court action brought all of Granite Peak Mountain and surrounding area into U.S. Army ownership. Settlements for mining claims were based upon the estimates of the geologists who made a fairly complete economic study of the area. Details of this study have not been made available.

Methods of Investigation

After securing permission for entry to the Dugway Proving Grounds from U.S. Army officials, field work was conducted in the area with the understanding that a member of the Dugway staff would accompany the field party.

Field work consisted of observing field relationships of the pegmatites and associated rocks, and collecting representative rock samples. Emphasis was placed upon examination of the pegmatite dikes. Thin sections made from the collected samples were examined petrographically to determine structures, textures, and mineralogy. Plagioclase composition was determined by use of the universal stage.

Aerial photo maps obtained from the Dugway Proving Ground Logistical Services proved to be very useful in observing regional relationships and sizes of the pegmatite dikes. Individual aerial photos were unavailable, however, and detailed mapping was impossible to perform.

Various samples of granite, gneiss, and samarskite were submitted to Professor James Whelan of the Mineralogy Department of the University of Utah in Salt Lake City, Utah, for age dating.

GEOLOGY

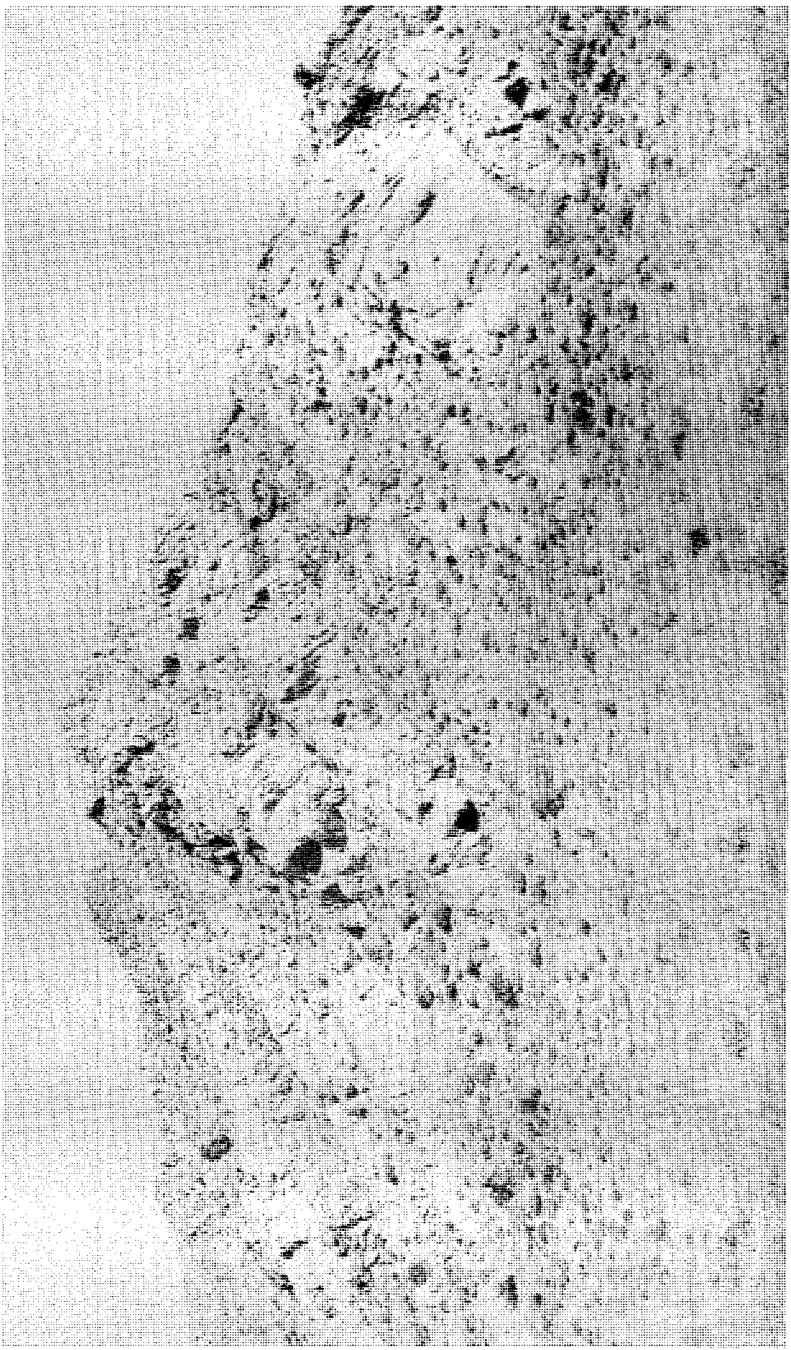
General Statement

Granite Peak Mountain consists of both intrusive and metamorphic rocks, although there is a possibility that the intrusive rocks are actually a product of granitization. For the purpose of this study, however, the "intrusive rocks" will be considered as being of igneous rather than of metamorphic origin. A detailed discussion of granitization is beyond the scope of this study but some evidences for it will be mentioned under "Metamorphic Rocks."

Butler (1920) described Granite Peak Mountain as consisting nearly entirely of granite with variation in composition from north to south. He described the northern area as consisting of a light colored granite with occasional lenses of mica and porphyritic material. The southern area is described as a granite perhaps approaching quartz monzonite in composition. In reality, the rock in the southern area is a biotite granite-gneiss which has the composition of a true granite with a gneissic structure.

Schists and phyllites are found on the extreme southern end of Granite Peak Mountain.

The rocks of Granite Peak Mountain are probably all of Precambrian age which differs from the state geologic map of Utah which lists them as both Tertiary and Precambrian (Stokes, 1961). The author believes that the state map is erroneous in this age determination.



EXPLANATION OF PLATE 1

Typical pegmatite dikes at the southeast end of Granite Peak Mountain. (Looking north)

U. S. ARMY PHOTOGRAPH

Explanation of Plate 2

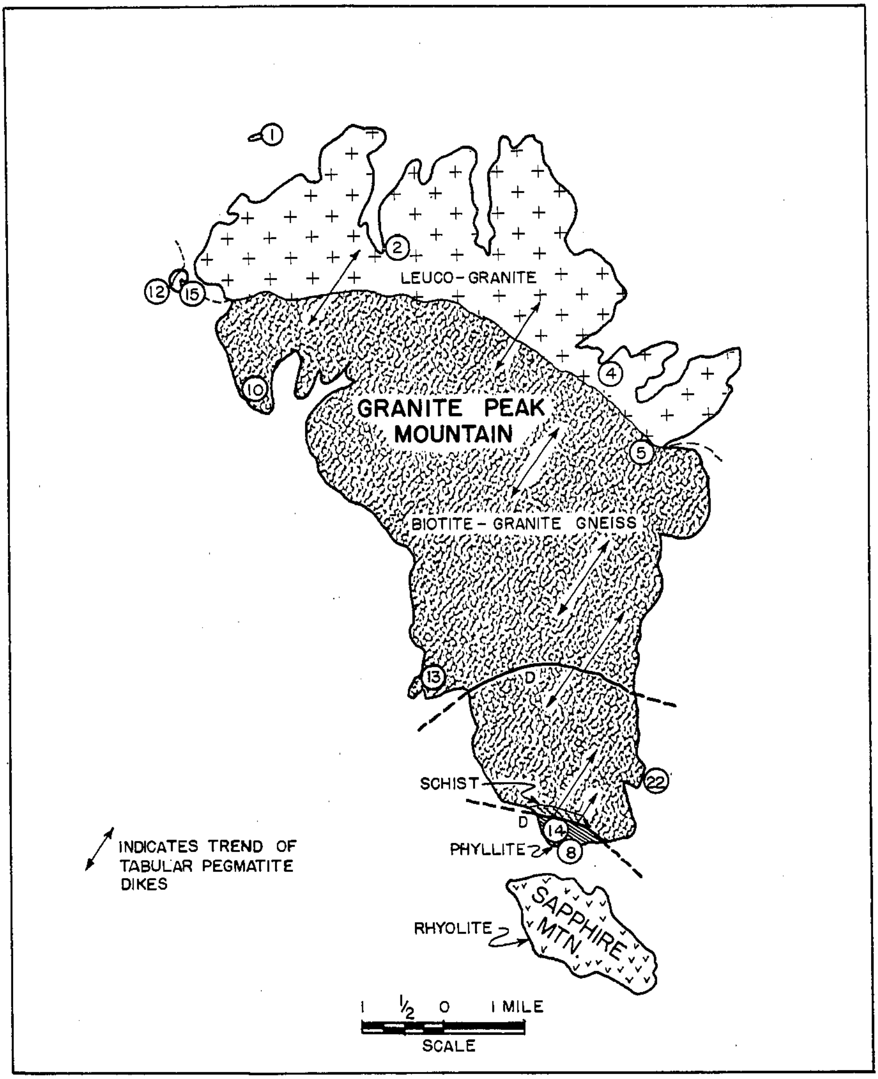
Stringers and irregular pegmatite body in biotite granite-gneiss country rock on the west side of Granite Peak Mountain.

U. S. ARMY PHOTOGRAPH

To the south of Granite Peak Mountain lies a body of extrusive rocks known as Sapphire Mountain but these are not genetically connected with Granite Peak Mountain.

Intrusive Rocks

The northern third of Granite Peak Mountain consists of a leucogranite intrusive which, from a distance, markedly contrasts with the darker metamorphic rocks to the south. The areal extent of this granite body is shown in text-figure 2.



TEXT-FIGURE 2.—Sketch map of Granite Peak Mountain showing geology and sample locations.

The main rock type is a white, medium grained, nearly equigranular granite, which varies slightly in composition to a slightly more calcic plagioclase as the intrusive-metamorphic contact is approached. Weathered surfaces exhibit a mottled brown desert varnish and some pitting.

Petrographic analysis shows the granite to be primarily composed of microcline, quartz, muscovite, albite, a little biotite, accessory minerals, and alteration products. The most common accessory minerals are zircon and apatite which occur as minor inclusions in microcline and quartz. An opaque mineral which is possibly an iron oxide also occurs. Alteration products are sericite, kaolinite, and calcite.. In some cases microcline and plagioclase have been extensively altered to sericite, whereas alteration to kaolinite and calcite has been minor. Biotite also shows slight alteration to chlorite. See Table I for an analysis of various representative granite samples.

Some dark inclusions, the largest approaching 50 feet in diameter occur in the granite. Microscopic examination reveal these to be diorite porphyry, consisting primarily of andesine and hornblende. See Table 3 for an analysis of representative samples.

Jointing is extensive throughout the granite but a study of patterns was not made. Some joints and faults appear to have been pathways for minor mineralizing solutions. Metallization was found to be present in several small veins, the most extensive of which is located in a fairly large canyon near the north-east end of Granite Peak Mountain. Butler (1920) describes this vein as being closely associated with a basic dike which outcrops prominently, strikes north, and dips steeply to the east. He states that the close association of dike and vein does not seem to indicate a genetic relationship but rather that the dike was a line of weakness along which mineralizating solutions passed. The author agrees with Butler's conclusions. All mineralization appears to be post-intrusion, perhaps of Tertiary age.

Other minor evidences of mineralization were found at the north-west end of Granite Peak Mountain in Cannon Tank Canyon near the spring. Here, limonite, some copper minerals, small amounts of fluorite, and amethystine quartz were found.

Numerous pegmatite dikes as well as some quartz veins cut through the intrusive with a general north-south trend. A more thorough discussion of these dikes will be found under "Pegmatites."

TABLE 1

Rosiwal Analysis of Leucogranite Samples from Granite Peak

Mineral	*Sample 1*	*Sample 2*	*Sample 4*	*Sample 5a*	*Sample 5b*
Microcline	39%	25%	44%	55%	34%
Quartz	45%	20%	37%	35%	42%
Muscovite	10%	11%	3%	2%	3%
Plagioclase	4%	43%	10%	6%	12%
Biotite	1%		5%	1%	8%
Accessories and Alteration Products	1%	1%	1%	1%	1%
Total	100%	100%	100%	100%	100%
Johannsen Classification	125P	117P	125P	125P	226P

See text-figure 2 for locations from which samples were taken. Sample 1 was taken from location 1, etc.

Age of the leucogranite is tentatively regarded as Precambrian. This granite is similar to the granite intrusions of the Raft River Range in the northwestern corner of Utah (Stokes, 1961) which also are Precambrian.

Extrusive Rocks

Directly to the south of Granite Peak Mountain lies a smaller peak known as Sapphire Mountain which is a large horizontal rhyolite flow. It rises several hundred feet above the valley floor and is tear-drop shaped with its long axis lying in a northwest-southeast direction. It is surrounded by Quaternary lake sediments and covers an area of about six square miles.

Petrographic analysis of samples from Sapphire Mountain shows the flow to be a rhyolite porphyry with small phenocrysts of quartz and sanidine and a groundmass of very fine-grained material tentatively identified as quartz, plagioclase, sanidine, calcite, and a little glass. Hematite also occurs in considerable amounts giving a red cast to the flow. Sanidine in some cases has been wholly altered to calcite. A copper-colored phlogopite mica is disseminated in small amounts throughout the flow.

Age of this extrusive rock was not determined directly, but it is correlative with similar flows in ranges adjacent to Sapphire Mountain. Erickson (1963) and others have shown that the flows in the Thomas and Dugway Ranges to the south are Tertiary in age. The Sapphire Mountain flow must be of the same general age.

Metamorphic Rocks

The southern two-thirds of Granite Peak Mountain consists of metamorphic rocks which range from a biotite granite-gneiss in the north to a phyllite which occurs on the extreme southern end of the mountain. Outcrops of a biotite schist appear between the phyllites and the biotite granite-gneiss, however, exposures of schist are small.

The biotite granite-gneiss has an indistinct foliation and its texture is medium grained to porphyritic. It greatly resembles a dark granite and, in fact, could be classified with a Johannsen (1932) classification number of 226P, which is granite. Microcline, quartz, biotite, plagioclase (oligoclase) are most dominant. Hypersthene, sphene, garnet, zircon, apatite, some opaques, and alteration products are present in varying amounts. See Table II for analyses of representative samples.

Porphyritic (porphyroblastic?) material is widespread with the main exposures seen at the metamorphic-intrusive rock contact zone to the north and along the western slopes of Granite Peak Mountain. Composition of the phenocrysts, which are euhedral and which range up to two inches in size, was found to be microcline. Composition of the groundmass is generally quartz, microcline, biotite, and other minor minerals.

The phyllite exposed at the extreme southern end of Granite Peak Mountain ranges between a sericite schist and a phyllite. Petrographic analysis shows the composition of this rock to be primarily of quartz and sericite (muscovite) with some biotite and pyroxene present (see Table III for analysis). Foliation is well developed with the general trend striking approximately N. 60°W. and dipping between 55° and 65° south.

Jointing is rather extensive throughout the metamorphic rocks. Several faults are present at the southern end of Granite Peak Mountain, and these have been channelways for mineralizing solutions which deposited fluorite,

TABLE 2
Rosiwal Analysis of Biotite Granite-gneiss of Granite Peak

Mineral	*Sample 5c*	*Sample 12*	*Sample 10*	*Sample 13*
Microcline	50%	32%	32%	49%
Quartz	32%	29%	20%	33%
Biotite	15%	18%	21%	11%
Plagioclase	Tr.	14%	7%	3%
Hornblende	1%	Tr.	18%	Tr.
Hypersthene	..	5%	Tr.	Tr.
All others	2%	2%	2%	4%
Opaques	..	x	x	x
Sphene	x	x	x	x
Calcite	x	..	x	..
Garnet	x	x	x	x
Zircon	x	x	x	x
Apatite	x	x	x	x
Tourmaline	..	x	..	..
Sericite	x	x	x	x
Chlorite	x	x	x	x
Total	100%	100%	100%	100%

See text-figure 2 for locations from which samples were taken. Sample 5c was taken from location 5, ets.
x - indicates mineral is present in sample.

TABLE 3
Rosiwal Analysis of Miscellaneous Rock Samples from Granite Peak

Mineral	*Sample 8a Phyllite*	*Sample 14b Quartz Dike*	*Sample 15 Diorite*	*Sample 22 Aplite*
Quartz	42%	87%	20%	50%
Microcline	..	1%	Tr.	40%
Muscovite	43%	..	..	3%
Andesine	..	..	42%	..
Albite	..	..	..	7%
Biotite	14%	10%	Tr.	..
Hornblende	..	..	36%	..
Pyroxene	1%	1%	..	..
All Others	..	1%	2%	Tr.
Opaques	..	x	x	x
Sericite	..	..	x	x
Chlorite	..	x	..	..
Calcite	..	x	..	..
Zircon	..	..	x	x
Apatite	..	..	x	?
Total	100%	100%	100%	100%

See text-figure 2 for locations from which samples were taken. Sample 8a was taken from location 8, etc.
x indicates mineral is present in sample.

specular hematite, quartz, copper minerals, galena, gold, and other minerals which may have been present but were not exposed. The mineralization is considered to be Tertiary in age.

Many pegmatite dikes cut through the metamorphic rocks and are discussed below under "Pegmatites." A few aplite dikes also cut through the area especially toward the south. They are commonly several feet thick and are composed of quartz, microcline, albite, and minute grains of muscovite. The aplites are fine-grained with few phenocrysts of quartz and microcline.

A discussion of the origin of the metamorphic rocks is beyond the scope of this paper, however, the field relationships and high rank of metamorphism suggest the possibility of granitization. Thus the granite "intrusive" at the northern end of Granite Peak Mountain could be a product of granitization. Evidence for this is the absence of a true baked zone and the presence of a gradational contact between the leucogranite and the biotite granite-gneiss. Muscovite disappears and biotite appears at this contact zone but the microcline and quartz content remains basically the same in both bodies. Sphene and hornblende are absent in the leucogranite but appear in the biotite granite-gneiss (see tables I and II). These evidences, especially the biotite content and the appearance of sphene, suggest the "basic wave front" concept advocated by Reynolds (1947).

Age of the metamorphic rocks is tentatively determined to be Precambrian since the textural nature of these rocks is similar to Precambrian rocks in other parts of the Western U. S. especially in the Mojave Desert area of California (McCulloh, 1954).

Structure

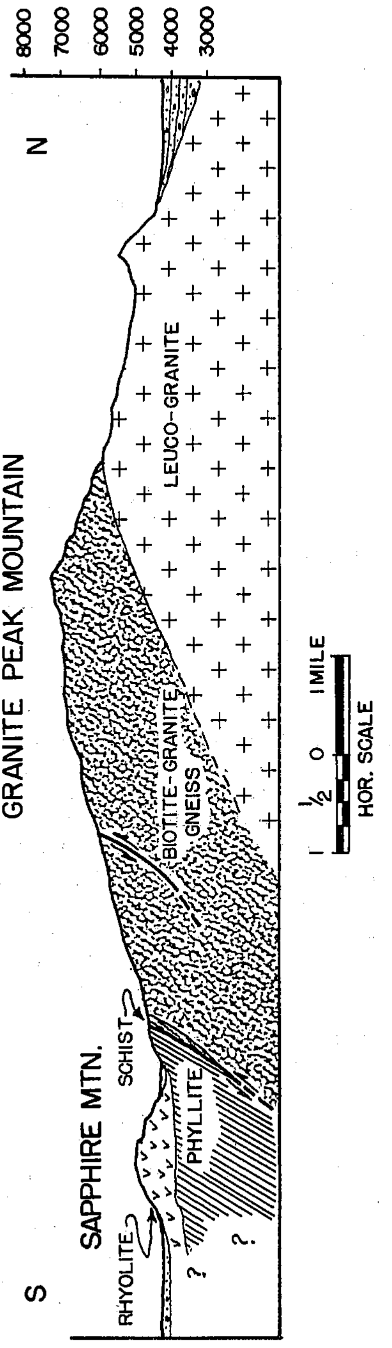
Granite Peak Mountain itself appears to be an uplifted block of granitic and metamorphic material that has subsequently been subjected to extensive erosion.

Many faults are present in the area especially on the south end of the mountain (see text-figure 2). Here several normal faults cut the area in a N. 70°W. direction then curve to about a N. 40°W. direction. They dip steeply to the south. Displacement of these faults must range from several tens of feet to several hundreds of feet. Other normal faults cut Granite Peak Mountain about two miles north of the southern end (see text-figure 2). Here three curving faults lying close together are seen displacing pegmatite bodies on the west side of the mountain. The largest lies just to the north of the other two and exhibits a displacement of at least 150 feet. Strike of these faults is parallel and trends in an east-west direction. Dip ranges from 35° to 70° south. Many other faults undoubtedly exist in the area but because of the homogeneous nature of the rock they are difficult to detect.

Evidence for faulting are brecciated zones, linear clefts in rocks (which suggest relatively recent faulting), extensive mineralization, and displacement of pegmatite bodies. Age of the faulting may be placed at after emplacement of pegmatites but cannot be determined with certainty. Much of the faulting may be associated with block faulting of the Basin and Range Province or perhaps with the Laramide orogeny.

None of the faults mentioned above are shown on the state geologic map of Utah or on any other geologic map of the area to the knowledge of the author.

Jointing is extensive throughout the metamorphic and intrusive rocks but their patterns were not determined in detail. As mentioned under "Pegmatites" below the pegmatite dikes have a definite structural trend of about N. 35°E. and a steep dip to the west indicating an early joint or fracture pattern that was filled with granite pegmatite solutions and/or influenced by granitization. These pegmatite dikes are nearly perpendicular to the foliation of the schists, and phyllites which occur at the southern end of Granite Peak Mountain. Foliation of the phyllites strikes about N. 60°W. and dips about 60° south.



TEXT-FIGURE 3.—Idealized North-South cross-section through Granite Peak Mountain.

The intrusive-metamorphic rock contact zone strikes nearly east-west and has a fairly shallow dip of about 15° to 20° south. This contact zone probably extends for some distance beneath the metamorphic rocks.

Attitude of the flows comprising Sapphire Mountain appears to be essentially horizontal.

Mining Activity

Published information concern mining activity in this area is limited with the most extensive information being found in U.S. Geological Survey Professional Papers 111 (Butler, 1920) and 227 (Hanley, 1950). The author was able to obtain small amounts of additional information by oral communication, personal correspondence, and by visual evidence of mining.

Butler (1920) quotes Ellsworth Dagget as saying that mining was active in the area around 1898 with about 22 tons of ore containing lead and small amounts of gold and silver being mined up to 1898. In 1914 when Butler visited the area personally no mining activity was reported although activity subsequently resumed to a small degree until the early 1950's when the U.S. Army closed down all mining operations.

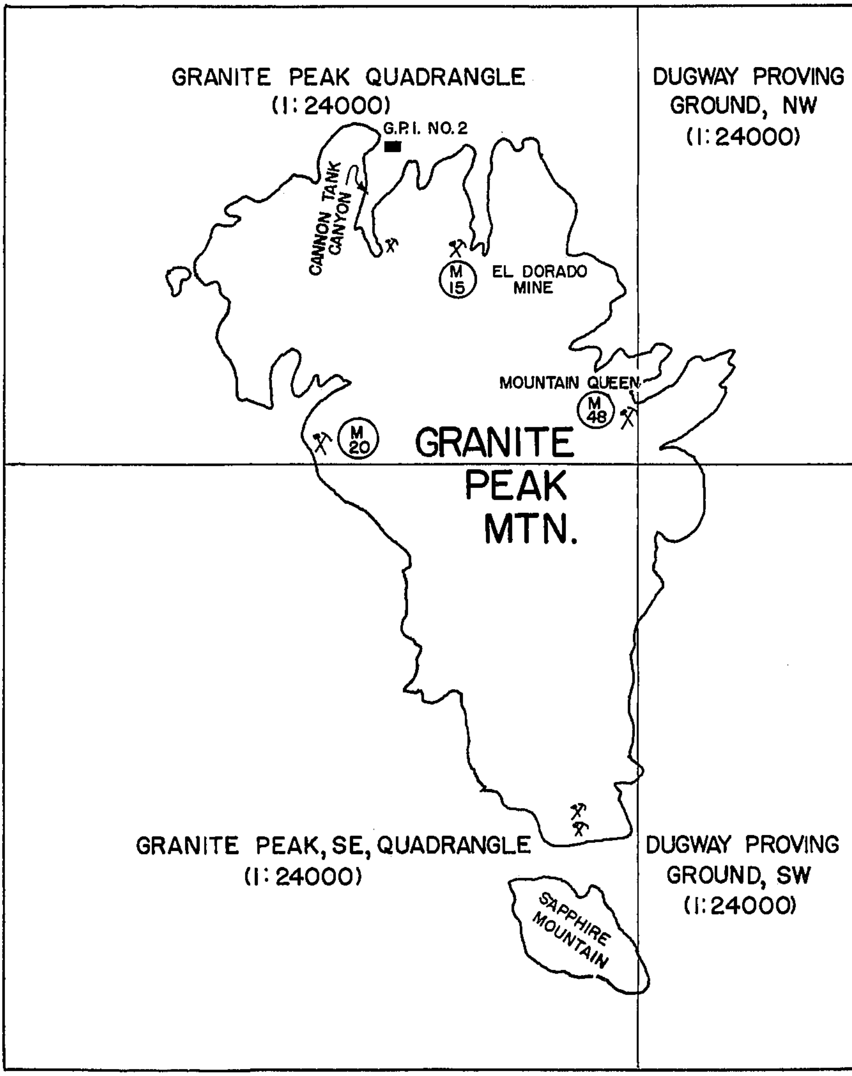
Many prospect pits and one fairly large shaft are located on Granite Peak Mountain at the points of heaviest mineralization (see text-figure 4). The large mine shaft is located in a canyon at the northeastern end of Granite Peak Mountain in the leucogranite, about one and one-half miles south-east of G.P.I. No. 2 (see text-figure 4). This mine was known as the El Dorado Mine and is probably the area where lead, gold, and silver mentioned earlier was mined (A. M. Salisbury, pers. communication). The author found only limonite, chalcopyrite, hematite, and malachite present in small amounts. These minerals were undoubtedly mined to a small extent also.

Approximately one mile due west of the El Dorado Mine, located in Cannon Tank Canyon, is a fairly large prospect pit also situated in the leucogranite. It apparently contained small amounts of flourite, amethyst quartz and limonite.

At the southern end of Granite Peak Mountain within the biotite granite-gneiss other prospect pits are found containing crystal quartz, amethyst quartz, specular hematite, limonite, galena, copper minerals, and a trace of gold. Other minerals may have been present but no extensive search was made to find them. One other mine is located on the east side of Granite Peak Mountain near the intrusive-metamorphic rock contact zone. This mine was known as the Mountain Queen and apparently contained the same assemblage of minerals as the El Dorado Mine but in smaller amounts.

All metallization is post faulting in age and is possibly associated with Tertiary volcanic activity although it could be of a different period. The presence of fluorite in mineralized areas of Granite Peak Mountain may be correlative to the fluorite deposits of Spors Mountain and other areas of the Thomas Range to the south of Granite Peak Mountain. These flourite deposits have been shown to be associated with or occur immediately after Tertiary volcanic activity (Staatz and Osterwald, 1959). Other fluorite deposits occur in Carboniferous rocks of the Wildcat Mountains to the north (Buranek, 1942).

An attempt had been made to mine muscovite, which occurs widely throughout the area, by the Mica Corporation of America mining company. This operation proved to be economically unfeasible. Beryl is present in many



TEXT-FIGURE 4.—Sketch map of Granite Peak Mountain showing location of prospect pits and mining claims, and index map to U.S.G.S. topographic maps of the area.

of the pegmatite bodies but as far as could be determined no attempt had been made to mine it. These beryl occurrences were observed in 1943 by Hanley (1950). The deposits were not studied in detail and Hanley regarded them to be too small to be mined economically at that time.

The following is a summary of all mining claims located on Granite Peak Mountain considered valid by court action when the area was condemned by the U. S. Army in 1964 (personal communication with A. M. Salisbury, 1964). Refer to text-figure 4 for location of claims.

Tract M-15: El Dorado No. 3 - No. 9 inclusive, El Dorado tunnel group, Ella no. 1 and Ella no. 2 lode mining claims. (W. H. Clover Estate) Ten valid claims.

Tract M-20: Desert Queen nos. 1-8 inclusive, all being validated and unpatented lode mining claims. (Mica Corporation of America)

Tract M-48: Mountain Queen nos. 1-3, Superior nos. 1 and 2, Velma nos. 1-3. (Perkins Estate) One valid claim.

Geologic History

Determination of the geologic history of Granite Peak Mountain is at best speculation. There are several possible sequences of events which could have led to formation of the metamorphic rocks and/or intrusive rocks of the mountain. Two of the most plausible series of sequences are as follows:

1. Sediments deposited during Precambrian times were subjected to orogeny and metamorphism which resulted in the formation of phyllites and schists and the intrusion of a biotite granite. Recurrent movements or shears developed a gneissic texture on the intrusion. Later, also in the Precambrian period, a leucogranite intrusion invaded the area. Pegmatites were emplaced as a late magmatic activity with aplites and quartz veinlets appearing slightly afterward.
2. Metamorphism occurring during the Precambrian period transformed sediments into phyllites and schists. It then increased in intensity causing granitization to take place. At the point of greatest influence granitization formed a leucogranite body which passes sharply into a slightly lower rank biotite granite-gneiss lying between the leucogranite and the schists. The contact zone between the leuco-granite and biotite granite-gneiss may be thought of as a basic wave "front" in which dark minerals move away from the center of granitization. (Reynolds, 1947). Pegmatites, aplites, and quartz veinlets were emplaced at a later stage of the granitization.

The author favors the first possibility. Angular blocks of biotite granite-gneiss found within the leucogranite at the contact zone would indicate magmatic action.

After this Precambrian activity the region then probably was covered with sediments and was later involved in Laramide regional folding and thrusting whose effects are not recorded in the immediate area. In Tertiary time Basin and Range block faulting raised the mountain and subjected it to erosive agents. Extensive faulting on Granite Peak Mountain probably took place during this period although some of it may have been associated with older Laramide activity. Post-faulting mineralization occurred when the faults became passageways for mineralizing solutions. Vulcanism was active during the Tertiary period and flooded the area to the south with flows.

The Quaternary period saw the development of Lake Bonneville which resulted in the deposition of lake sediments and the development of various shore-line features on both Granite Peak Mountain and Sapphire Mountain. The lake later retreated leaving lake playas and desert-like conditions which persist to present.

PEGMATITES

General Statement

The pegmatites of Granite Peak Mountain are of the fine-to-coarse-grained granite pegmatite variety and are by far the most spectacular of all pegmatites found in the state of Utah. They constitute a very large percentage of the total rock volume of Granite Peak Mountain and in this respect they are unique. Hanley (1950) describes these pegmatites as being invariably small, isolated, extremely irregular podlike bodies that are oriented haphazardly with no structural control being evident. He also states that the largest pegmatites are only about 125 feet long, a few feet wide, and a few feet in depth. Although other observers also took this view, the present study reveals these observations to be erroneous. As will be shown below, many pegmatites on Granite Peak Mountain have a definite general trend, and attain great size and depth besides having other regular and predictable features.

Unfortunately, the pegmatites appear to be of little importance economically. Muscovite (scrap mica), beryl, and samarskite are the main minerals of economic value, but these are not present in any great quantity.

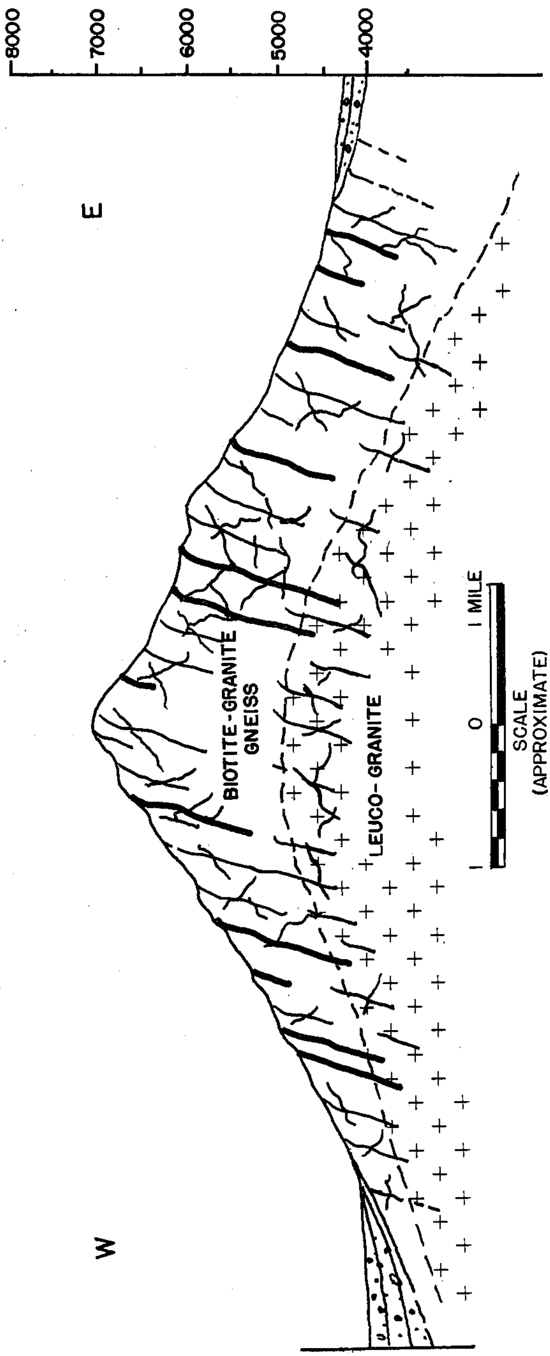
The age of the pegmatites is at present in doubt. However, it is the opinion of most geologists who have visited the area that the country rocks are characteristic of other Precambrian terranes of the Western United States. The pegmatites though slightly younger than the country rock and although unlike any other Precambrian pegmatite bodies in the state of Utah are probably of comparable age. They appear to be associated with the leucogranite intrusion. Other Precambrian pegmatites are found locally in the Beaver Dam Mountains in the south-western corner of Utah (Hintze, 1963, Butler, 1920, and Dobbin, 1939).

Occurrence and Regional Relationships

Pegmatite dikes are extremely numerous throughout the entire extent of Granite Peak Mountain and may form as much as 10% to 15% of the total rock volume. In places they may constitute as much as 50% of the outcrops. The dikes occur in both the leucogranite and the biotite granite-gneiss and appear to terminate against a fault zone near the extreme southern end of Granite Peak Mountain. Only a quartz vein, which appears to be of a diferent age, was seen to penetrate into the phyllites. The pegmatites appear to be fewer in number and smaller in size in the leucogranite. No dikes appear in the extrusive rocks.

Although there is a great deal of cross-cutting, the general strike of the larger pegmatite dikes, as determined by aerial photo-maps and field observations, is about N. 35° E. The general dip of the dikes ranges from about 55° to 70° to the west. The strike of the pegmatites appears to be nearly perpendicular to the foliation of the schists and phyllites at the south end of Granite Peak. The dikes also cross the general foliation of the biotite granite-gneiss at varying angles.

The pegmatites have about the same resistance to weathering as the country rock and so in most cases do not rise above their surroundings. They often have gradational contacts with the enclosing rock but no true relic structures were seen by the author within these dikes. This gradation may simply be a reaction of the pegmatite fluids with the country rock and/or it



TEXT-FIGURE 5.—Pegmatites. Idealized East-West cross-section through Granite Peak Mountain.

may be due to the process of granitization. All pegmatites appear to have been derived from the same source.

Form and Size

There are several different types of pegmatite bodies present on Granite Peak Mountain and these may be classified according to form.

First, there are stringers which range in thickness from a few inches to over one foot and generally connect with the larger dikes. Length ranges up to several hundred feet. Stringers are not zoned as a rule but their overall composition is about the same as that of zoned pegmatites. These are not to be confused with quartz veinlets which are of a later age and cut the pegmatites. Stringers are tabular and may be many feet wide. They occur in the leucogranite and biotite granite-gneiss.

Secondly, there are pegmatite bodies which resemble lenses or pods. These are extremely variable in size and are often zoned. They were seen to be connected in some, but not all cases, with other dikes by stringers. Widths vary from a few inches to about ten feet and lengths vary from several feet to about 40 or 50 feet. Occurrence of this type of pegmatite did not appear to be extensive and no attempt has been made to ascertain the number of these bodies.

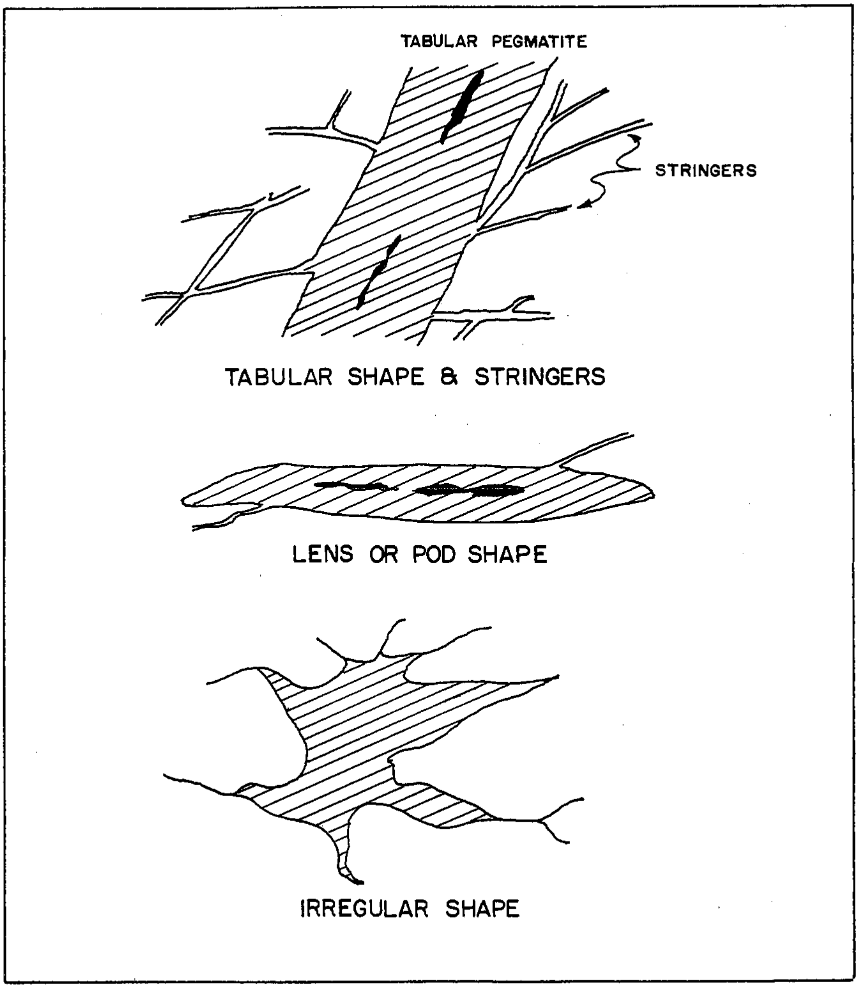
The third and probably the most important type of pegmatite is the tabular variety. These dikes range in width from a few inches to about 80 feet and in length from a few feet to over five thousand feet. Larger tabular dikes attain great depth as is shown by their continuity even through deep valleys. The rule that the depth of dikes may be reasonably estimated at one-half the length, if it may be applied here, would place the depth of these tabular dikes at as much as a half-mile below the surface.

In some instances dikes which have irregular form were observed. These may have been the result of replacement. They are invariably connected with a large number of stringers.

Zonation

Many dikes, especially the tabular and pod varities, show distinct zonation. Others appear to show a rather even distribution of minerals and grain size throughout. These may be thought of as homogeneous dikes while the zoned pegmatitie bodies may be thought of as heterogeneous dikes. Very fine-grained aplitic zones were found within some of the large pegmatities, as well as coarse-grained areas. Quartz cores appear to be absent in many pegmatites, though they may appear at depth.

Texturally, the pegmatites themselves would fall under the fine to coarse-grained varieties using the pegmatite texture classification outlined by Cameron, *et. al.,* (1949): less than one inch - fine-grained, one to four inches - medium-grained, four to twelve inches - coarse-grained, more than twelve inches - extremely coarse-grained. Maximum size of individual crystals of any mineral found within the pegmatites varies from less than one inch to about twelve inches. Individual microcline crystals commonly reach four or five inches in length and sizes up to nine inches were not uncommon. Several beryl crystals attained a length of just over twelve inches but classifying the pegmatites as extremely coarse grained on the basis of these few crystals would be unjustified. This pegmatite textural usage should not be confused with texture terms used for normal rock descriptions.



TEXT-FIGURE 6.—Typical pegmatite shapes.

As a rule the pegmatites show some type of zonation, and, although indistinct in some cases, three main zones may be described as suggested by Cameron, *et. al.,* (1949). These are the border-wall zone, the intermediate zone, and the core. No sharp distinction is evident between the border zone and wall zone, although in rare cases a border zone of one inch or less thickness may be seen. In all other cases grain size is gradational moving from contact with the country rock into the pegmatite. For purposes of this study the border and wall zones have been combined into a single unit.

The border-wall zone forms the outermost portion of the pegmatite and is in contact with the country rock. It is fine-grained as a rule (less than one inch) and grain size varies from 0.01 to 0.5 inches. Some very fine-grained (0.01 to 0.05 inches), nearly sugary areas were seen occasionally but these were not confined to the outer zones. The border-wall zone is characterized by nearly equal proportions of quartz, microcline, and plagioclase near oligoclase in composition, Muscovite content is generally higher in this zone than in the inner zones. Books of muscovite occurring in this zone are also larger as a rule than in other zones. Width of the border-wall zone ranges from negligible thickness in small pegmatites to about a foot in the larger varieties. It is not always distinguishable as a unit. This zone is often gradational into the country rock.

The intermediate zone is by far the most extensive unit of the pegmatite and is found between the border-wall zones and the core. It is generally variable in grain size from fine-grained to coarse-grained (see-below). In most pegmatites the intermediate zone may be divided into three parts: an outer division, a middle division, and an inner division. The outer division of the intermediate zone is fine-grained with a grain size range of 0.01 to 1.0 inches. It has a fairly high percentage of quartz, and microcline percentage appears to decrease slightly from the border-wall zone. The muscovite and plagioclase content remain constant. Graphic intergrowths are common. The middle division of the intermediate zone is characterized by a rise in microcline content and by locally coarse textures. It is medium-grained on the average with a grain size range of 0.02 to 2.0 inches. The inner division is coarse-grained and is characterized by large subhedral crystals of microcline which range from one inch to over nine inches in length. Perthite is most common in this division but is present in other divisions of the intermediate zone. Most beryl and rare earths are also found in this area especially where it comes in contact with the core. Other minerals are relatively deficient.

The core zone generally forms the nucleus of the pegmatite and is characterized by large coarse-grained deposits of extensively fractured dense milky quartz. This nucleus is nearly symmetrical with the rest of the pegmatite. Grain size of quartz ranges from less than a millimeter to several inches. Beryl and microcline intergrown with quartz are commonly found in the core. Other minerals such as samarskite, fracture fillings of hematite and amethyst quartz, and a little muscovite may be present in the core. Some pyrite altering to limonite is also found as fracture fillings in this zone.

Composition of the homogeneous pegmatite dikes is identical with that of the intermediate zone of heterogeneous dikes. The homogeneous dikes often contain graphic intergrowths and perthite.

The very fine-grained areas within pegmatite dikes are of the same composition as the border-wall zone, with the exception of the microcline content which appears to be lower, and the plagioclase content which appears to be slightly higher. The plagioclase is generally lower in An composition (An_6 to An_7). Muscovite occurs as numerous minor flakes and no books were observed.

The mineral assemblages in the various zones of Granite Peak Mountain pegmatites correspond generally to the major mineral assemblages found in pegmatites of other parts of the United States. Of the eleven possible assemblages for pegmatites the Granite Peak Mountain pegmatites correspond to five. These are nos. 1 and 2 (plagioclase-quartz-muscovite) which correspond generally to the border-wall zone; no. 3, (quartz-perthite-plagioclase, with muscovite, without biotite) which corresponds to the outer and middle divisions of the intermediate zone; no. 4 (quartz-perthite) which corresponds to the inner intermediate zone; and no. 11 (quartz) which corresponds to the quartz core zone. Mineral assemblages 5-10 were not observed in the Granite Peak Mountain pegmatites. These zones, however, are not common in, any U.S. pegmatites except in the Black Hills region.

Mineralogy

Minerals occurring in pegmatites of Granite Peak Mountain may be divided into two main groups. These are the following:

1. Essential minerals which form the bulk of the pegmatite rock.
2. Accessory minerals which may or may not be present or which occur only as minute crystals.

Hematite, pyrite, and flourite, though listed as accessory minerals, are considered to be fracture fillings of a much later age. Alteration products are grouped with those minerals from which they were derived.

The following is a list of minerals found in the Granite Peak Mountain pegmatites by the author.

Essential Minerals

Quartz	Microcline
Muscovite	Plagioclase

Accessory Minerals

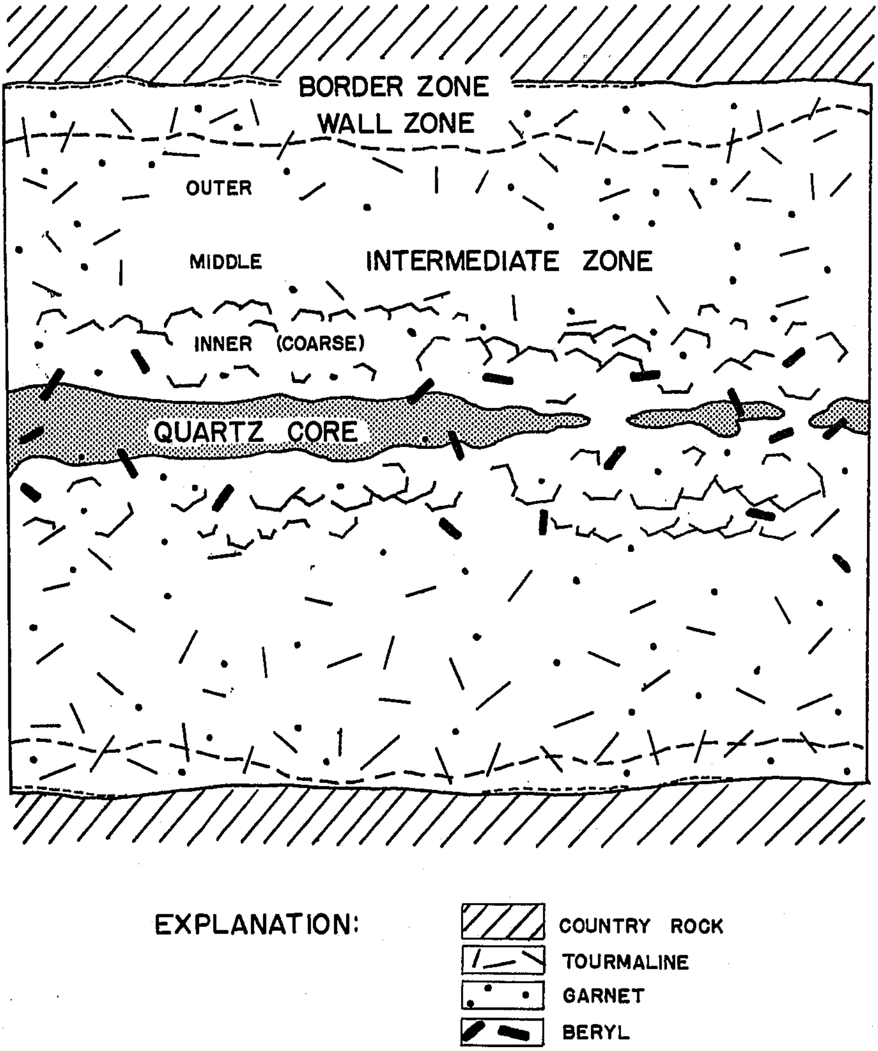
Garnet	Samarskite	Fluorite
Tourmaline	Hematite	Zircon
Beryl	Pyrite	Apatite

Quartz

Quartz is found in all zones of the pegmatite dikes. Its color ranges from gray and milky to purple (amethyst quartz) in mineralized areas. Some cores and mineralized areas contain vugs of quartz crystals which are generally small. Most quartz occurring in cores is of the massive milky or gray quartz variety. It is generally highly fractured. Extensive undulatory extinction, seen under the microscope, coupled with the apparent fracturing shows this quartz to be greatly strained (probably due to force of crystallization in the core). Quartz in other zones shows less strain. Grain size of quartz in cores revealed through petrographic examination ranges from very fine (0.01mm) to coarse (several inches) with a mosaic pattern being characteristic. Quartz in other zones is fine to medium grained (0.01 to 2.0 inches), and in all cases is anhedral. It is frequently intergrown with microcline to form graphic granite and with muscovite.

Microcline

Microcline commonly occurs as large subhedral crystals in the intermediate zone and as small anhedral aggregates in the other zones. It is not present in large amounts in the core, however. The largest microcline crystals attain a length of over nine inches and are generally perthitic. Most microcline ranges from two to five inches in size. The smaller crystals are less commonly perthitic. Microcline frequently displays poikilitic texture with

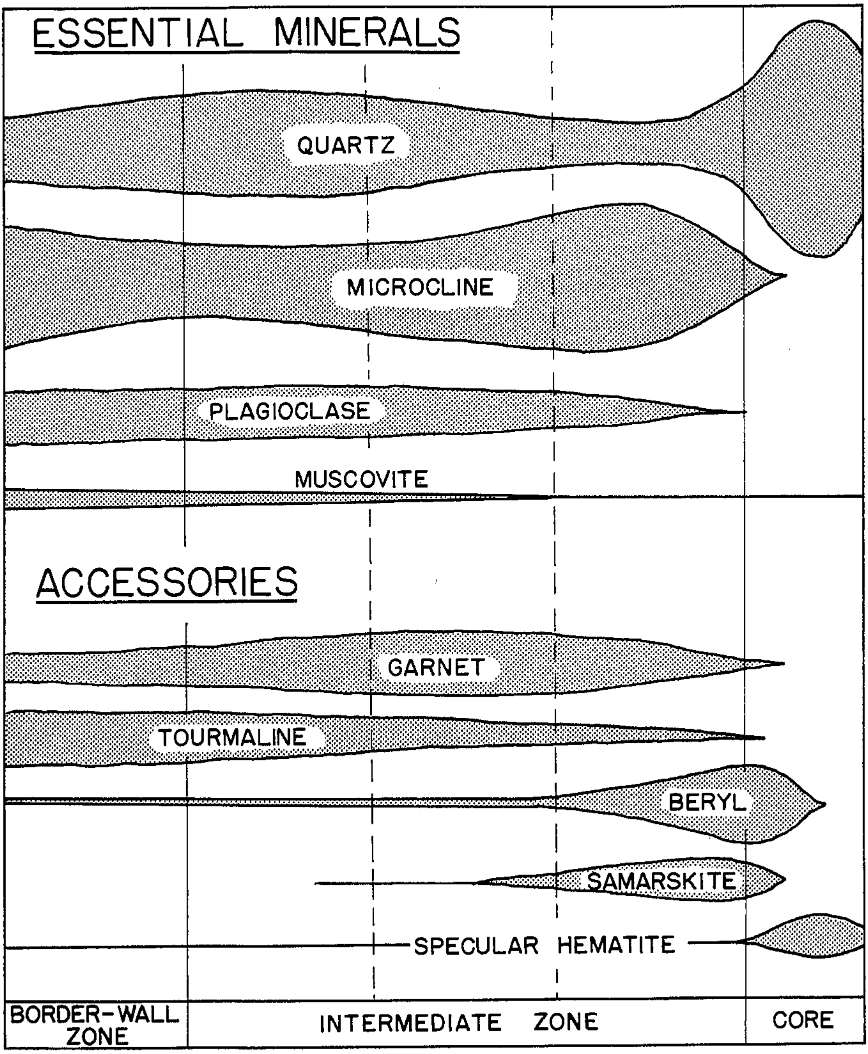


TEXT-FIGURE 7.—Zonation in typical pegmatites.

inclusions of plagioclase and quartz being common. It is also frequently intergrown with quartz to form graphic granite, especially in the middle and inner intermediate zones in association with larger microcline crystals. Microcline alters to sericite and kaolinite in most observed pegmatites. It is invariably white in color.

Plagioclase

Plagioclase is, in general, fine to medium grained and rarely occurs as large crystals. It is white in color and may be found intergrown with micro-



TEXT-FIGURE 8.—Zonal distribution of minerals in a typical pegmatite.

cline to form perthite. This intergrowth is of the replacement variety as shown by the ragged outline of the plagioclase. Plagioclase is also found as inclusions in microcline, and where the inclusions occur simultaneously with perthite in the same microcline crystal the An content of each was found to be different. The An content of perthite is generally higher. Overall anorthite composition in plagioclase ranges from An_{13} to An_3 in typical pegmatites examined by the author. The An content diminishes uniformly moving from the outer zones to the center. Plagioclase is found in all zones except the core.

Muscovite

Muscovite occurs throughout all zones including the core which it may penetrate extensively. It is found both as books and as single flakes. The books range in size from a diameter of four or five inches in pegmatites occurring in the leucogranite to about one and one-half inches maximum diameter in pegmatites occurring in the biotite granite-gneiss. Muscovite books are more commonly about one-half to one inch in diameter. They do not appear to have any real orientation within the pegmatites. The fine-grained variety of muscovite, sericite, is found as an alteration product of both mircocline and plagioclase. It is very common.

Graphic Granite

Graphic granite occurs most widely in the intermediate zone of the pegmatites and is found occasionally in the border-wall zone. Variations in intergrowths were noted ranging from irregular inclusions of quartz in microcline to a true graphic intergrowth in which crystallization appears to have been nearly simultaneous. The quartz in this case is seen as fluted rods in crystals of microcline. This feature is well developed megascopically in hand samples and may be seen under microscopic examination as micro-graphic texture. In this case the quartz intergrowths may be seen to become extinct simultaneously upon rotation of the microscope stage. Quartz shows very little, if any, strain in graphic granite.

Perthite

The most common perthite present is the replacement variety which occurs extensively in the middle and inner intermediate zones. The exsolution variety of perthite was rarely seen. Larger crystals of microcline were apparently most susceptible to replacement by plagioclase (along twin planes) while the smaller crystals were less commonly altered. Plagioclase outlines in perthite were generally very ragged and this criterion was used to suggest replacement. Composition of plagioclase in perthite ranged between Ab_{95} - An_5 and Ab_{88} - An_{12}.

Garnet

Garnet of the almandite variety is found in most pegmatities and through all zones including occasional occurrences in the core. The crystals are invariably blood-red in color and attain a miximum size of about one and one-half inches in diameter. The garnets are more commonly approximately one to two millimeters in diameter and are euhedral in outline. They are easily shattered and larger specimens are rarely well preserved.

Tourmaline

Tourmaline is of the black schorl variety. It is found disseminated through most pegmatites but less densely as the core is approached and rarely in the core itself. Tourmaline occurs most extensively in the outer zones. The average length of tourmaline crystals is about one-fourth to one-half an inch but some complex crystals resembling tree trunks attain a diameter of about one and one-half inches and a length of about five or six inches. The large tourmaline crystals were common in pegmatites occurring near the south end of Granite Peak Mountain. They are invariably highly weathered at the surface. Radiating clusters of tourmaline are also common.

Beryl

Beryl occurs in many but not all pegmatites and is found most extensively near and in the margins of the quartz core. Crystals are generally elongate and euhedral with an average diameter of about 1/8 inches (3mm). However, some crystals were observed to attain a diameter of about three inches and a length of over twelve inches. These were found in tabular pegmatite dikes of medium size (about ten feet wide). Colors of beryl crystals ranged from a light greenish blue to a pale blue. The green cast may be due to alteration in some beryl crystals. Most crystals are fractured or tend to fracture easily and upon weathering crumble into fragments. No crystals of gem grade were found. Crystals were tapered in most instances especially in the larger sizes and they were found to be commonly deformed or intergrown in clusters. Intergrowths of muscovite and quartz in beryl were common. In some instances beryl crystals are found sheathed with small flakes of muscovite and not uncommonly are found coated with flakes of specular hematite especially in the fractured cores. Beryl exposures though common were not extensive. Maximum concentration of beryl per square yard noted by the author was about 200 square inches. This is a concentration of about 1:6. Overall concentration of beryl in pegmatites containing large beryl exposures drops, however, as the pegmatite is traced through its entire extent and a concentration of less than 1:1000 would be more realistic. Only about 10% of all pegmatites contain exposures of beryl and the average concentration of beryl in these pegmatites is small. No attempt has been made to estimate total beryl reserves present on Granite Peak Mountain because of the great number of pegmatite bodies present.

Samarskite

Samples of samarskite were not seen in place by the author but were found as float near pegmatite exposures at the southern end of Granite Peak Mountain. The samarskite seen is subhedral in form and is brownish black in color. Some red color is present but this is due to oxidation of iron present. It apparently occurs in the intermediate zone near the quartz core. Samples found were radioactive.

Hematite

Hematite of the specular hematite variety was found in many quartz cores as fracture fillings. It commonly occurs in all parts of pegmatite bodies also as fracture fillings but seems to be more highly concentrated in the core. This hematite represents a later stage of mineral activity than that which emplaced the pegmatites. Specular hematite crystals were often well formed but rarely exceeded a length of one-fourth inch. Veinlets of specular hematite were commonly one-fourth inch thick.

Pyrite

Very little pyrite was found in pegmatites and its occurrence appears to be restricted to fractures in quartz cores. It is altered to limonite in most cases. Pyrite was probably deposited simultaneously with specular hematite.

Fluorite

Fluorite is found in some pegmatites where fracturing has occurred and fluorine solutions had been allowed to enter. Occurrence of fluorite is rare and

TABLE 4
Average Rosiwal Analyses of Typical Pegmatites of Granite Peak

Mineral	*Border-Wall Zone*	*Outer Intermed.*	*Middle Intermed.*	*Inner Intermed.*	*Core*
Microcline	39%	30%	48%	56%	2%
Quartz	33%	43%	27%	20%	97%
Plagioclase	21%	20%	21%	22%	Tr.
Muscovite	5%	6%	3%	1%	Tr.
Others	2%	1%	1%	1%	1%
Garnet	x	x	x	x	..
Beryl	x	x	x	x	x
Tourmaline	x	x	x	x	..
Samarskite	..	..	x	x	?
Hematite	x	x	x	x	x
Zircon	x	x	x	x	x
Apatite	x	x	x	x	?
Sericite	x	x	x	x	..
Total	100%	100%	100-%	100%	100%

Note: All minerals listed under "others" are variable from one pegmatite to another. Zircon and apatite, however, are universally present. Beryl and tourmaline do not occur together.
x indicates mineral was present.

was found by the author only in conjunction with amethyst quartz in the quartz core. Once again, this mineral was probably deposited about the same time as the hematite and pyrite and may be genetically related to fluorite deposits in the Thomas Range to the south and/or the Wildcat Mountains to the north.

Zircon

Zircon occurs as minute bluish colored crystals throughout all zones of most pegmatites (color was observed in thin section). It is less common in the quartz core zone. Crystals are generally euhedral but are found to be malformed in many instances. They are found as inclusions in other minerals, especially feldspars and quartz, but are not large or numerous enough to form any significant part of the rocks.

Apatite

Elongate, euhedral crystals of apatite are very common in all pegmatites. They range in size from very minute inclusions to long narrow crystals about 1/2mm in length. They appear to be colorless in thin sections and occur as inclusions in most minerals. Apatite is distinguished from zircon on the basis of birefringence (Kerr, 1950).

Origin

Since most pegmatites of Granite Peak Mountain are of the tabular dike variety and extend to some depth it must be assumed that their origin was from a source farther beneath the surface. They were presumably the result of injection of aqueous solutions into more-or-less parallel fractures or joints. The lenses and pods and irregular shaped pegmatites probably have been areas of local dilation or even replacement.

Examination of the anorthite content of normal plagioclase shows a decrease as the core is approached in most pegmatites. (See table 5) This fact coupled with excellent zonation exhibited by many pegmatites indicates a progressive crystallization sequence beginning at the walls and moving inward. Magmatic action and/or granitization may have been operative and influential in the formation of these pegmatites.

Evidence was lacking for extensive alteration or two cycles of deposition. It must be assumed that the pegmatites themselves were deposited in a single sequence within a closed system. An exception would be the replacement of microcline by plagioclase to form perthite. Positive replacement was indicated by the ragged borders of plagioclase in microcline. Average An content of perthite is about 8 although it was observed to range from 5 to 12 in representative samples. Normal plagioclase and perthite having different An compositions were observed in the same mircocline crystals indicating two periods of plagioclase emplacement.

A possible sequence of crystallization would be as follows: zircon and apatite crystallized initially since they are found in nearly all quartz and feldspars as euhedral crystals. Next followed crystallization of microcline, plagioclase approaching oligoclase in composition, muscovite, and quartz along with tourmaline and garnet. Muscovite was allowed to grow into larger books in the leucogranite country rocks where it may have been influenced by the muscovite content in the leucogranite. Less muscovite is found in pegmatites occurring in metamorphic rocks which lack muscovite. Microcline intergrowths and quartz began to crystallize simultaneously forming graphic intergrowths and this crystallization continued well into the intermediate zone. As the end of the intermediate period was approaching microcline began to crystallize into large crystals and predominates. The possible presence of mineralizing gases probably allowed crystals to grow to a greater size in most cases. Quartz, plagioclase, and muscovite occur in smaller amounts and as inclusions which are not extensive at this point. Beryl crystallized near the final period when residual quartz, now nearly alone, began to crystallize. The rare earths when present also began to crystallize during the late period. Finally the quartz was deposited in the remaining space in the center of the pegmatites. Some small miarolitic cavities containing small quartz crystals indicate areas where remaining space was not used up. These may have remained filled with mineralizing gases for a period of time, then later released along fractures. No inclusions of gases or bubbles were found, however. Force of crystallization during this late period caused fracturing in most quartz cores allowing later mineralizing solutions to deposit specular hematite, fluorite, and pyrite.

Late in the sequence of original crystallization microcline was partially altered to perthite.

TABLE 5

Average An (Anorthite) Concent in Typical Granite Peak Pegmatites

Zone	*An Range*	*Average*
Border-wall	7-13	9
Outer Intermediate	6-9	9
Middle Intermediate	6-8	7
Inner Intermediate	3-6	5
Core	--	--
Perthite (Intermediate)	5-12	8

Note: An Range indicates the anorthite content of plagioclase present in all pegmatite samples in the indicated zone.

Areas of aplitic or fine-grained material in pegmatites is interpreted as being the result of rapid crystallization caused by the absence or premature escape of mineralizing gases. The presence of these gases is considered to prolong crystallization causing extremely coarse crystals to appear.

SUMMARY AND CONCLUSIONS

The rocks of Granite Peak Mountain were formed by the action of metamorphism, intrusion, and/or granitization probably in the Precambrian period. Pegmatites were emplaced as a late stage of instrusion and/or granitization. Aplite dikes and quartz veins were formed about the same time.

Zonation of the pegmatites, decrease in anorthite (An) content of plagioclase toward the center of pegmatites, and the presence of small miarolitic cavities in some quartz cores suggest filling of open fractures by residual magmatic fluids or fluids supplied at the late stage of granitization. Crystallization proceeded from the walls inward forming nearly parallel zones of differing composition. The last material to crystallize was quartz which is found at the center of zoned pegmatites. Residual quartz elsewhere formed stringers in fractured country rock and pegmatites. Homogeneous pegmatites in the area are the result of nearly simultaneous crystallization of all minerals throughout the width of each pegmatite.

Hematite, pyrite, fluorite, and amethyst quartz found as fracture fillings in the pegmatites are apparently products of mineralization which the author considers to be of a later date than the emplacement of the pegmatites. This mineralization is very similar to that occurring in various joints and fault zones in the country rock and is probaly of the same age and source. Fluorite present in mineralized zones on Granite Peak Mountain may have been derived from the same source as those in the Thomas Range which are of Tertiary age.

The economic potential of the area presently does not appear to be great. The presence of muscovite, beryl, and samarskite in pegmatites warrants close scrutiny but their concentration is not considered to be sufficiently high to allow commercial extraction. Metallization in the country rock stimulated limited mining activity. Granite Peak Mountain has a small potential of low tenor ores of gold, copper, lead, and possibly silver, but mining and exploration in the area is not possible at present since the area has been condemned by the U.S. Army for use as a test site.

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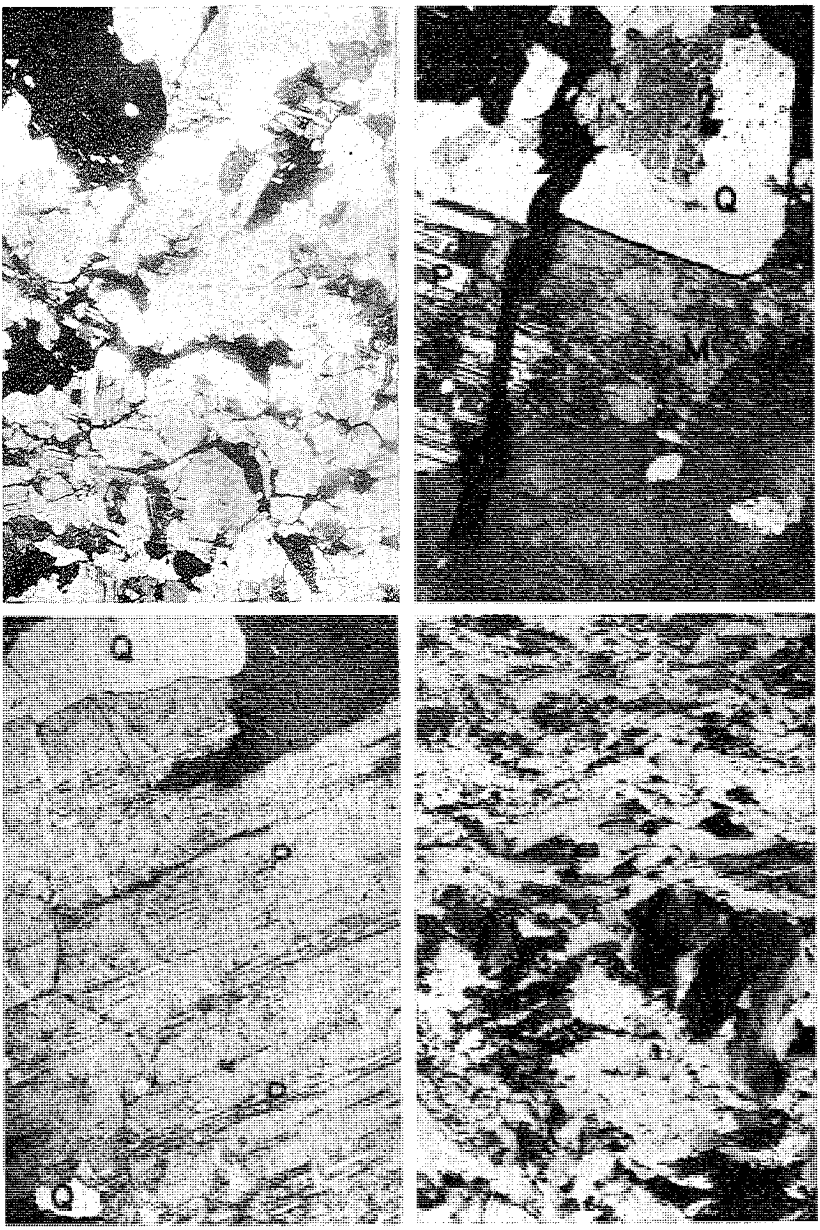

EXPLANATION OF PLATE 3

FIG. 1.—Micro-photograph of pegmatite sample showing grain size of minerals in a fine-grained border-wall zone. (30x)

FIG. 2.—Micro-photograph of pegmatite sample showing large graphic intergrowth of quartz (Q) in microcline (M). Perthite (P) is also present. Intermediate zone. (30x)

FIG. 3.—Micro-photograph of pegmatite sample showing perthite (P) and irregular quartz intergrowths (Q). Intermediate zone. (30x)

FIG. 4.—Micro-photograph of quartz in core zone of pegmatite. Undulatory extinction is extensive. (30x)