American Journal of Science

NOVEMBER 1948

THE GLOBE PEGMATITE, RIO ARRIBA COUNTY, NEW MEXICO*

LAUREN A. WRIGHT

ABSTRACT. The Globe pegmatite, in the Petaca district of northern New Mexico, is a steeply dipping, tadpole-shaped dike about 650 feet long. Exposures developed during extensive mining of mica shoots above the 100-foot level reveal a symmetrical internal structure outlined by four microcline-quartz zones, and by a quartz core that is exposed near one end of the dike. In general the grain size and the proportion of quartz in the pegmatite increase from the walls inward.

Albite and associated green muscovite vein and corrode microcline, quartz, green fluorite, and beryl of the zones, and are concentrated in replacement units that are best developed between the walls of the dike and its innermost zones.

Spheroidal aggregates of radially oriented cleavelandite tablets are abundant, and featherlike clusters of columbite and monazite occur in many of them. Purple fluorite, spessartite, and sericite also are associated with the cleavelandite, but such minor late constituents as samarskite, sulfide minerals, bismutite, some purple fluorite, and lepidolite seemingly are unrelated to it.

The following paragenesis is indicated by rather clear-cut megascopic relations: (1) early development of quartz, microcline, green fluorite, and beryl, (2) formation of albite, green muscovite, and associated accessory minerals, chiefly along fractures in the earlier minerals, and (3) continued deposition of fracture-filling quartz, in part associated with earlier accessory minerals and in part with distinctly later and rarer minerals.

INTRODUCTION

THE Globe pegmatite is one of a group of closely related mica-bearing dikes exposed in the Petaca district of Rio Arriba County, New Mexico. Many of these dikes have been mined from time to time, chiefly for sheet, punch, and scrap muscovite, and several of the mines have been operated since early Spanish times. The output from the district since 1900 has amounted to about 0.5 percent of the total United States production during the same period. A substantial proportion of this output, however, has been obtained from only one mine, the Globe, which has been the chief source of mica in the district since 1936. The attention of the U. S. Geological Survey

* Published by permission of the Director, U. S. Geological Survey.

was focused on the deposits of the Petaca district during the period 1943-1944, owing chiefly to unusual wartime demands for sheet mica of superior quality, and many of the pegmatites were mapped and studied in detail. The data herein presented were obtained during these investigations.

The mine lies at an altitude of about 7400 feet in gentle rolling terrain midway between the villages of La Madera and

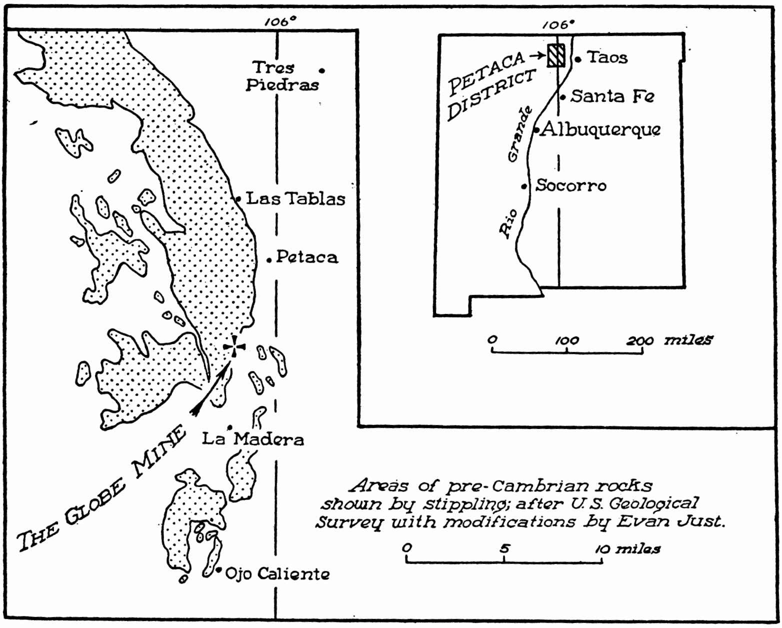


Fig. 1. Index map of the Petaca district showing location of the Globe mine. Insert shows location of the Petaca district in New Mexico.

Petaca (Text Fig. 1). It is in the NE ¼ NE ¼ sec. 36, T. 26 N., R. 8 E., and is easily accessible from State Highway 111 over a gravel-surfaced access road completed by the U. S. Forest Service in 1944. The pegmatite and mine are on a patented claim owned by the Western Non-Metallics Company of Los Angeles, California, and intermittent operations for scrap and by-product sheet mica have been carried on since 1935 under the direction of Joseph A. Stanko, President. The mine was idle when last visited in July 1946.

The deposit was opened in 1875, mainly by means of shallow cuts sunk in the extensive outcrops of mica-bearing pegmatite.[1] It was worked on a very small scale until about 1900, when a shaft and two inclines were sunk on a rich mica concentration. Many other openings were made in succeeding years, and a very irregular and complex series of drifts, stopes, winzes, and cross-cuts was developed. Most of these are still accessible, and provide an unusually complete three-dimensional exposure of a large part of the pegmatite.

The dike is typical of the larger pegmatite bodies in the district in general attitude, composition, and internal structure. On the other hand, it contains exceptionally rich mica concentrations and unusually abundant accessory minerals, some of which are remarkable in occurrence and habit. The paragenetic sequence of most of the minerals can be established with some assurance, and it also is possible to determine the order of development of the lithologic units of which the pegmatite is composed.

Mica deposits in the Globe pegmatite were mentioned by Holmes[2] and Just,[3] and some of the early mine workings were briefly described by Sterrett.[4] A more detailed report was recently published by Jahns,[5] and some features of the accessory minerals in the deposit were noted by Heinrich and Jahns[6].

Field Work and Acknowledgments

The Globe pegmatite was mapped on a scale of 20 feet to the inch by R. H. Jahns and the writer during the period November 1943 – November 1944. The property was visited on numerous occasions, and about four weeks were spent in actual mapping and detailed field examination. Some laboratory investigations also were made, but the data and discussions in this paper are based almost wholly upon the field studies.

[1] Jahns, R. H., Mica deposits of the Petaca district, Rio Arriba County, New Mexico: New Mexico School of Mines, State Bur. Mines and Min. Res., Bull. 25, p. 233, 1946.

[2] Holmes, J. A., Mica deposits in the United States: U. S. Geol. Survey, Twentieth Ann. Rept., pt. 6—cont., p. 706, 1899.

[3] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: New Mexico School of Mines, State Bur. Mines and Min. Res., Bull. 13, pp. 64-65, 1937.

[4] Sterrett, D. B., Mica deposits of the United States: U. S. Geol. Survey, Bull. 740, pp. 162-163, 1923.

[5] Jahns, R. H., op. cit., pp. 233-242, 1946.

[6] Heinrich, E. W., and Jahns, R. H., Accessory minerals of the Petaca pegmatites, Rio Arriba County, New Mexico: In preparation.

R. H. Jahns, who proposed and showed a continuing interest in the present paper, collaborated in much of the field work, made numerous helpful suggestions and criticisms, and furnished illustrative material. The writer also is indebted to W. Porter Irwin, who assisted effectively in the field work. Mr. Alberto Trujillo of La Madera, foreman at the mine, was very coöperative throughout the investigations and supplied much helpful information concerning the history of mining operations and the positions of inaccessible workings. Dr. W. T. Schaller of the U. S. Geological Survey discussed several problems in the field, and also contributed data on some of the accessory minerals. Critical review of the manuscript by Ian Campbell and R. H. Jahns of the California Institute of Technology, and by L. R. Page of the U. S. Geological Survey is gratefully acknowledged.

Structural Features

GENERAL STATEMENT

Exposures of pegmatite in the Petaca district are most abundant in an elongate, broadly curving belt that embraces a part of La Jarita Mesa and the rough country to the east. The area of this belt is about 25 square miles. La Jarita Mesa, underlain mainly by pre-Cambrian metasedimentary and metavolcanic rocks, is a gently undulating upland surface that is the narrow, southeasterly termination of the San Juan Mountains of Colorado. A granitic intrusive mass, named the Tusas granite by Just,[7] is exposed in areas north and east of the mesa. It also is pre-Cambrian in age. Both the granitic and metamorphic rocks rise with moderate relief above a discontinuous but locally thick blanket of Tertiary and Quaternary volcanic rocks and land-laid sediments.

Two southward-flowing streams, Tusas Creek on the east and the Rio Vallecitos on the west, have developed headward along the flanks of the mesa (Text Fig. 1), and several major tributaries of Tusas Creek flow eastward and southeastward through steep-walled canyons cut into the mesa surface. The southernmost of these, Alamos Canyon, extends through an area in which many pegmatites are exposed. One of these is the "Globe," which lies east of the canyon and immediately west

[7] Just, Evan, op. cit., p. 44, 1937.

of the general boundary between the pre-Cambrian rocks and the overlapping Tertiary volcanics (Text Fig. 1).

GENERAL STRUCTURE

The Globe dike is approximately 650 feet long, and is roughly tadpole-shaped in plan (Pl. 1). It trends west and in general dips steeply north. Its maximum outcrop breadth, near the west end, is about 60 feet. A sinuous tail tapers eastward to a width of six feet or less, but ends in a bulge 20 feet wide. A moderate westerly plunge of the entire dike is indicated by the plunge of its thickest part, the plunge of minor bulges, constrictions, and other irregularities in the pegmatite-wall rock contacts, and by the general distribution of clearly recognizable lithologic units within the pegmatite.

The dike splits westward into three prongs. The northern prong trends west-northwest and grades into a large quartz vein. The other two prongs are cut off by a fault that trends northwest and dips steeply southwest. No pegmatite is exposed west of this fault. The amount of displacement is not evident, but thickening of the dike with depth suggests that the western faulted-off portion lies wholly beneath the present surface. These three prongs are surface indications of a complex westward fingering that underground exploration in the dike has not yet clearly outlined. One thick branch that is not exposed at the surface trends west-northwest from the main dike, and has been extensively worked for mica during recent underground operations.

The country rock is a greenish gray micaceous quartzite in which closely spaced foliation planes strike north-northwest and dip 25° to 65° west-southwest. Veins and pods of quartz are scattered irregularly through this rock, and commonly transect the foliation in detail. They range from less than an inch to 100 feet or more in long dimension, and their widths are as great as 15 feet (Pl. 1). Much of the country rock in the vicinity of these quartz masses is thoroughly impregnated with fine-grained muscovite and has a highly crenulated foliation. This altered rock is exposed near many of the pegmatite contacts and in schistose inclusions within the pegmatite body, where it commonly contains much introduced feldspar. The quartzite is warped and in places severely contorted along the walls of the main pegmatite dike.

Two sets of joints and shear zones show evidence of both pre- and post-pegmatite deformation, as well as some deformation between the periods of deposition of the earliest and latest pegmatite minerals. One set trends northwest and dips steeply southwest, and the other parallels the strike of the dike, but dips steeply south. Some joints in the country rock have been filled with quartz and pegmatitic material, and some within the dike have been filled with late-stage pegmatite minerals. Post-pegmatite movement along several oblique faults has displaced the dike 20 feet or more, and other strong shearing has been localized along parts of both walls, particularly near the north end of the dike.

The pegmatite-country rock contacts are sharp and well defined, both where they coincide with shear planes and where they are unaffected by movement. The wall rock immediately adjacent to the normal, unsheared contacts is feldspathic and very rich in small muscovite flakes, but elsewhere it is typical nonfeldspathic quartzite with local micaceous partings. In places where shearing was especially pronounced, slivers and plates of pegmatite, feldspathic and mica-rich wall rock, and unaltered country rock are interlayered. They range in thickness from less than an inch to four feet or more.

Crumpling of the wall-rock foliation is particularly pronounced at the western end of the dike, and hence along its crest. This contortion appears to have accompanied the initial introduction of pegmatitic material. A mechanical shouldering aside of country rock evidently was accomplished by forces that acted both vertically and laterally, and the local deformation of the foliation indicates that emplacement of the dike postdated regional metamorphism. The magnitude of this deformation, as shown in present exposures, is not sufficient to account for the total volume of pegmatite that was introduced, so that processes other than simple pressure must have been operative.

There is no evidence of large-scale replacement of country rock by pegmatite, although the maximum extent of country-rock digestion is difficult to determine. The relatively unaltered nature of many country-rock inclusions within the dike, however, suggests that this process was of no great importance here, and that stoping or some other form of mechanical injection was much more effective. These inclusions have sharp and highly angular outlines, and the contorted foliation within them is orientated at random rather than parallel with the foliation is orientated at random rather than parallel with the foliation of the country rock in general. Some inclusions are thoroughly impregnated with pegmatitic material, to be sure, but they have retained their schistosity as a structure quite distinct from that of the surrounding pegmatite. These features, though not wholly diagnostic, indicate that the inclusions probably are not residua of country rock partly replaced *in situ*, but actually represent blocks that have been broken from the contorted walls. The emplacement of pegmatite, therefore, appears to have been largely mechanical accompanied by some impregnation of wall rock by mica, feldspar, and other pegmatite minerals.

MINE WORKINGS

During a period of more than 70 years of intermittent development and mining, much of the central and nearly all of the western part of the dike above the 75-foot level have been honeycombed with very irregular workings. The eastern half of the deposit, which has yielded little mica, has been prospected by means of eleven shallow pits and cuts. At least five unevenly spaced groups of cuts, shafts, and inclines have been developed in mica shoots originally exposed in the westernmost 200 feet of the dike. From east to west these have been designated as (1) the long cut and east shaft, (2) the lower pit an old incline, (3) the new incline, (4) the upper pit and main shaft, and (5) the air shaft or "breakthrough" (Pl. 1).

The east and main shafts are now caved or filled, but most of the underground workings are still accessible through the old and new inclines and the air shaft. All of these openings slope irregularly westward. Together with their appended workings, they are crudely en echelon in longitudinal section, and in several places either are connected, or are separated by only a few feet of pegmatite.

The irregularity of the Globe mine workings does not entirely reflect a corresponding irregularity in the distribution of mica. Most of the mica has been removed from two main groups of shoots that flank a central unit of massive quartz with giant masses of blocky microcline. These shoots have been encountered from various directions at several levels.

INTERNAL STRUCTURE

Quartz, microcline, albite, and muscovite are the major constituents in the Globe pegmatite. The chief accessory mineral is fluorite, which occurs as large masses of the green variety and as small pods and veinlets of the lavender to purple variety. Columbite, monazite, sericite, and spessartite are minor but wide-spread constituents, and lavender to pink muscovite, samarskite, beryl, bismutite and other secondary bismuth minerals, apatite, lepidolite, ilmenite, and sulfide minerals are rare or very rare accessories.

The major minerals occur in distinct lithologic units within the pegmatite body. These units are designated as zones, replacement bodies, and fracture fillings, in accordance with a terminology suggested by the U. S. Geological Survey.[8] Quartz and microcline are the principal constituents of the pegmatite zones, three of which are indicated on the accompanying map (Pl. 1). A fourth zone, exposed only in the underground workings, is composed of very coarse-grained granitoid pegmatite, and a fifth, relatively fine-grained outermost zone is so thin and poorly developed that it cannot be conveniently shown on a map of this scale. The "albite-rich pegmatite" unit of Plate 1 is not a zone, as it consists chiefly of muscovite and albite that appear to have been formed by replacement of preexisting microcline-rich pegmatite. This unit contains most of the commercial muscovite concentrations, as well as the bulk of the albite and accessory minerals in the pegmatite body. Fracture fillings, though too small to be shown on the map, are very abundant (Text Figs. 2, 3, and 4). These units contain quartz, albite, muscovite, and a large representation of accessory minerals in various proportions.

Four general types of zones can be differentiated on the basis of their distribution within the Globe pegmatite, and each is distinguished by textural differences or by differences in proportions of microcline and quartz, the chief mineral constituents. The thin, discontinuous border zone consists of microcline-quartz pegmatite with an average grain size of about one quarter of an inch. It is much finer grained than the remainder of the pegmatite, and is irregularly developed. It ranges in thickness from a knife edge to five inches, but in most places is an inch or less in thickness.

The wall zone, next inside the border zone, is much more continuous and considerably thicker. It consists of medium- to coarse-grained microcline-quartz pegmatite, and appears

[8] Cameron, E. N., Jahns, R. H., McNair, A. H., and Page, L. R., Internal structure of granitic pegmatites: In preparation.

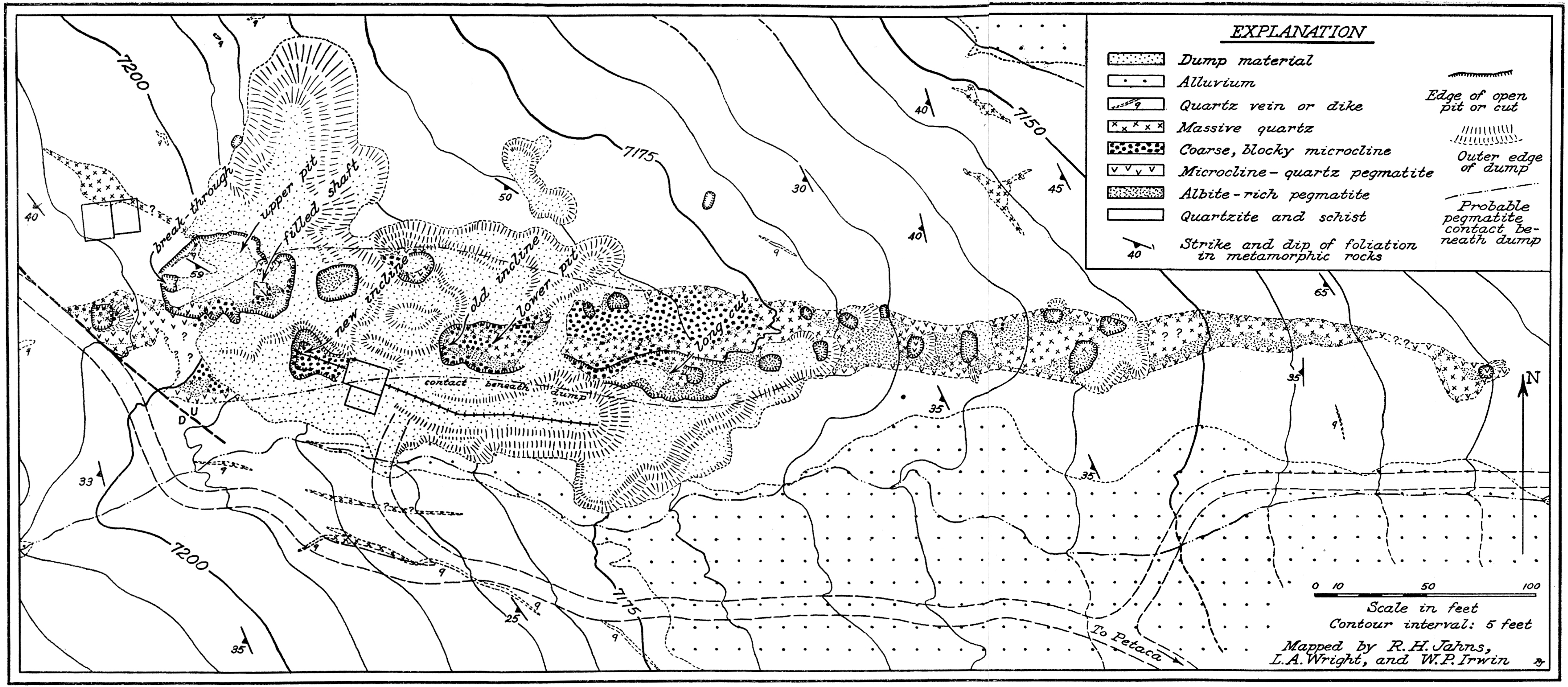


Plate 1. Geologic map of the Globe pegmatite dike, Rio Arriba County, New Mexico.

to have been well developed in all parts of the dike except within the northern and central prongs at the west end. Much of the wall-zone pegmatite appears to have been attacked and partly replaced by albite, muscovite, and other minerals. Where relatively little affected by these late-stage replacing solutions, it has an average thickness of about three feet. Microcline and quartz, the original wall-zone constituents, evidently were present in approximately equal proportions. Individual mineral masses range from a fraction of an inch to several inches in diameter, and are largest in that part of the wall zone nearest the center of the pegmatite body.

An outer intermediate zone of very coarse-grained granitoid microcline-quartz pegmatite crops out in the central part of the central-western prong of the dike. It is much more extensively exposed underground than at the surface, and occurs typically as irregular masses that grade outward into the finer-grained wall-zoned pegmatite. The gradation ordinarily is accomplished within a distance of 18 inches. In most places this intermediate zone consists of quartz and subordinate microcline. The feldspar occurs chiefly as individual subhedral and anhedral crystals or crystal aggregates that reach a maximum diameter of about four feet, and is irregularly scattered through a coarse, granitoid aggregate of microcline and quartz. So little of this unit is exposed at the surface that it is not distinguished from the unreplaced remnants of the wall zone in Plate 1.

The coarse-grained outer intermediate zone merges inward into a unit of quartz and giant microcline that occupies the central part of the dike. This inner intermediate zone consists essentially of irregular masses of quartz, with scattered crystals of microcline so large that they can be mapped conveniently as individual lithologic units. The unit as a whole occupies a central position in the western part of the dike. The largest exposed mass of microcline lies north of the east shaft and the long cut, and is elongated parallel with the walls of the pegmatite body (Pl. 1). It is 100 feet long and 25 feet in maximum width. Other, smaller masses of microcline are irregularly distributed in the central part of the pegmatite body west of the long cut, and some grade into crystals that are recognizable constituents of the outer intermediate zone. In many places the contact between the two intermediate zones cannot be certainly assigned within limits of as much as three feet.

Massive quartz forms the core of the dike. It is exposed in and east of the long cut as a series of large, elongate lenses that are very irregular in detail. It may well have been a single continuous mass, or at least comprised a relatively few masses of considerable length, but evidently it has been partly replaced by albite since its original development. Substantial quantities of other late-stage minerals appear to have been introduced along irregular fractures. Dike- or vein-like masses of quartz occur on both sides of the central-western prong of the dike. The south mass may be a later quartz vein injected along the pegmatite-wall rock contact, and the other may be a part of the inner intermediate zone, here faulted against quartz—mica schist.

The textural relationships and general concentric distribution of zones in the Globe pegmatite suggest development of the constituent minerals from the walls of the dike inward. The grain size increases progressively in this direction, and local age relationships are indicated by apophyses of the core segments and intermediate zones. These apophyses transect zones that lie nearer the walls of the dike than do the core segments or intermediate zones in question. Transection of units by apophyses from zones nearer the walls has not been observed, despite careful search. Moreover, detailed examination of the zone boundaries indicates that each of these units veins and corrodes the zone adjacent on the outside (or toward the wall), but that it is itself veined or corroded by the zone adjacent on the inside.

Like many complex pegmatites in other areas, the Globe dike shows evidence of considerable late-stage reaction characterized chiefly by the introduction of albite, muscovite, and numerous accessory minerals. This late material is not scattered evenly throughout the dike, but is concentrated in irregular masses, or as distinctly tabular bodies along fractures. These concentrations are largest and contain the highest proportions of accessory minerals where they lie between the walls of the dike and the two innermost zones. In the western part of the dike, the original microcline in much of the wall zone has been obliterated over areas as large as six square feet. Fracture-controlled stockworks of albite in this zone cut across both microcline and quartz. Some of the albite-rich masses also transect the boundaries of zones, and thus form a structural pattern clearly

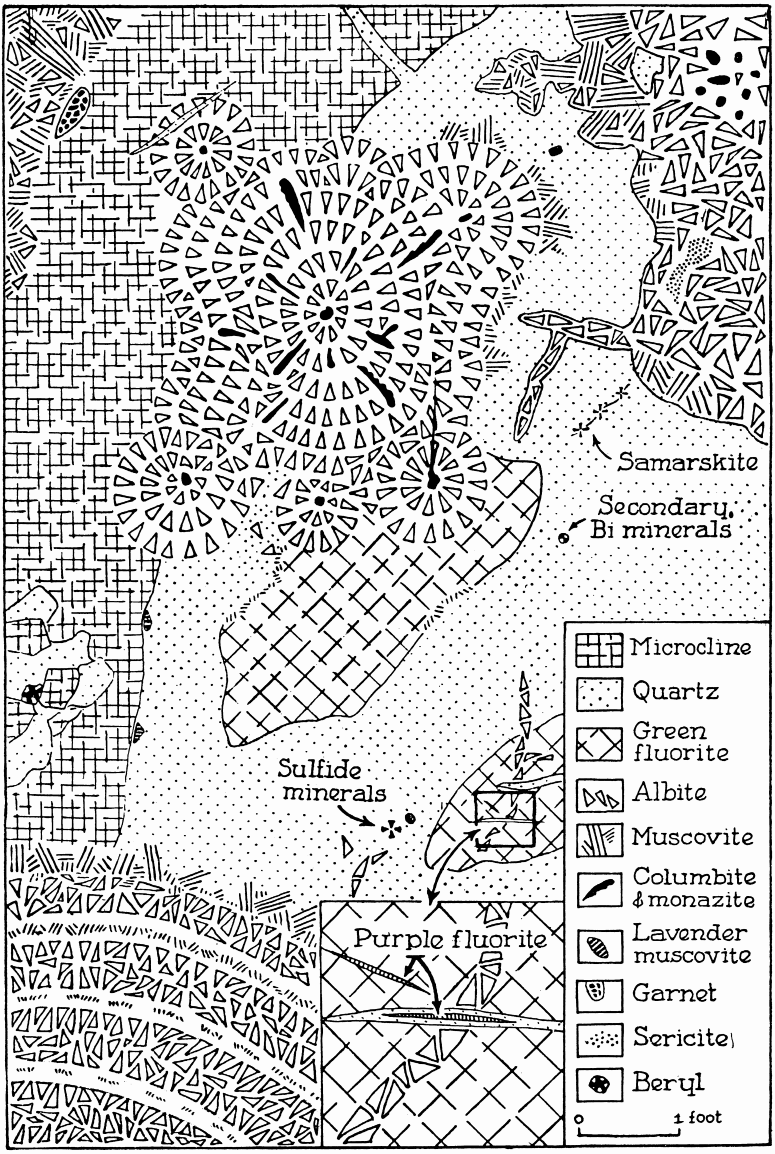


Fig. 2. Idealized diagrammatic sketch showing typical relations of the minerals of the Globe pegmatite.

discordant from the more regularly concentric pattern of the earlier zones. In places the albitization has extended so far inward from the wall zone of the dike that the entire inner sequence can be mapped as "albite-rich pegmatite" (Pl. 1).

Albite that is recognizably later than the microcline and most of the quartz with which it is associated occurs in all parts of the pegmatite, so that the delineation of any such unit as "albite-rich pegmatite" must be somewhat arbitrary. Rock assigned to this category (see Pl. 1) contains 30 percent or more of late-stage plagioclase, and in general represents pegmatite in which replacement processes have been very active. Owing to its texture, structure, and mineralogy, as described above, this part of the dike is termed a replacement unit. The coarse muscovite in the dike is almost everywhere intimately associated with the albite, and hence nearly all of the commercial mica concentrations occur in the "albite-rich pegmatite." This distribution accounts for the position of most of the mine workings in the outer parts of the dike.

Fracture fillings are widespread, though quantitatively unimportant. They contain quartz, albite, muscovite, or combinations of these minerals, as well as an abundant suite of accessory species. They are discussed in some detail in connection with the description of minerals.

Mineralogy

Microcline

Microcline is the major constituent of all zones outside the quartz core. It ranges in average grain size from a fraction of an inch in the border zone to several feet in the inner intermediate zone, where some crystals eight feet or more in maximum dimension are exposed. Most of the microcline is anhedral in the granitoid pegmatite, but subhedral to euhedral forms are abundant in the intermediate zones, particularly in the inner intermediate zone.

The mineral ranges in color from white through tints of flesh and pink to a deep brick red. Most of the crystals contain clearly recognizable intergrowths of sodic plagioclase, and hence might well be more appropriately termed perthite. Perthitic structure is most coarsely developed in the largest crystals, which occur in the innermost zones of the dike. These crystals also have the deepest reddish color.

Microcline is plainly an early mineral in the Globe pegmatite. There is no indication that even small quantities of this feldspar postdate any other adjacent pegmatite material except a little quartz, and most of the other minerals either corrode the microcline masses or fill fractures in them (Text Fig. 2). It should be remembered, however, that the microcline of the inner zones is distinctly younger than that of the border and wall zones, which were formed earlier. Very little potash feldspar appears to have crystallized after development of the inner intermediate zone, and hence it appears to have been the first to cease formation during the consolidation of the pegmatite.

QUARTZ

Quartz, the second most abundant mineral in the dike, occurs in all the pegmatite units. Impressive masses of this mineral compose the core, or innermost zone, and are interstitial to the giant microcline crystals of the inner intermediate zone. Where the quartz of the core is adjacent to quartz of the inner intermediate zone, the boundary between the two zones is not easily drawn on a map. Many of the quartz-microcline contacts in Plate 1 thus actually lie within the inner intermediate zone. Large quantities of it are also closely associated with microcline of the outer units. In general the proportion of quartz decreases from the center of the dike outward, and hence is smallest in the oldest pegmatite units.

Some quartz veins extend into microcline crystals from the matrix of massive quartz that surrounds them. These veins, generally three inches or less in thickness, have straight or slightly sinuous walls, and commonly appear to be simple fracture fillings. Many of the walls, particularly those bounding veins of zigzag trend, are clearly matching. Other quartz veins transect the mosaics of quartz and microcline in the wall and outer intermediate zones. Still others transect albite—muscovite aggregates, and hence are late in the mineral sequence. Some of these are themselves transected by quartz veinlets that evidently represent very late stages in development of the pegmatite.

Most of the quartz in the zones is milky white to light gray, and has a massive to sugary appearance. The core segments are milky white, and in many places show considerable evidence of shattering and granulation. The quartz of the veinlets and other late-stage masses is clear and colorless to dark, smoky gray, and appears to be darkest in the youngest veinlets. Some irregular stringers of almost black quartz fill fractures that transect masses of albite and muscovite.

The deposition of quartz evidently extended from the earliest to the latest stages of pegmatite formation in the Globe dike. The greatest proportion was deposited during the latest stages of zone formation. Although quartz is abundant in many fracture fillings and replacement bodies, the total amount in this form is but a small proportion of the pegmatite as a whole.

ALBITE

Albite is the most abundant mineral in the replacement units, and also is widespread in fracture fillings and as small, scattered masses in the units designated as zones. It occurs chiefly as the lamellar variety, cleavelandite, but fine-grained, sugary albite also is common. A snowy white color is typical of both varieties of this feldspar, which thus is in sharp contrast with the deep pink to brick red microcline that is so common in the inner units of the pegmatite. Much of the potash feldspar is veined and corroded by the white albite, which forms clearly defined stockworks.

Most of the cleavelandite lamellae are curved, and have a brilliant, pearly luster. Much of the fine-grained, sugary variety occurs as irregular friable masses that generally are less than a foot in diameter. Locally the albite is deep brick red, and in this respect resembles much of the microcline. Moreover, a buff to pale reddish brown discoloration is characteristic of some aggregates of cleavelandite that contain clusters of columbite, monazite, and other accessory minerals (Pl. 2, Fig. 2).

Fracture fillings and fracture-controlled replacement masses of albite are prominent in the intermediate zones and core (Text Figs. 3 and 4). Most of the tabular masses thus formed have irregular walls, few of which are matching. Where cleavelandite appears to have been controlled by fractures, individual lamellae tend to occur at right angles to the individual fractures, and extend irregularly into the microcline-rich pegmatite that they have partly replaced. Where this corrosion has reached a more advanced stage, the albite-rich masses are no

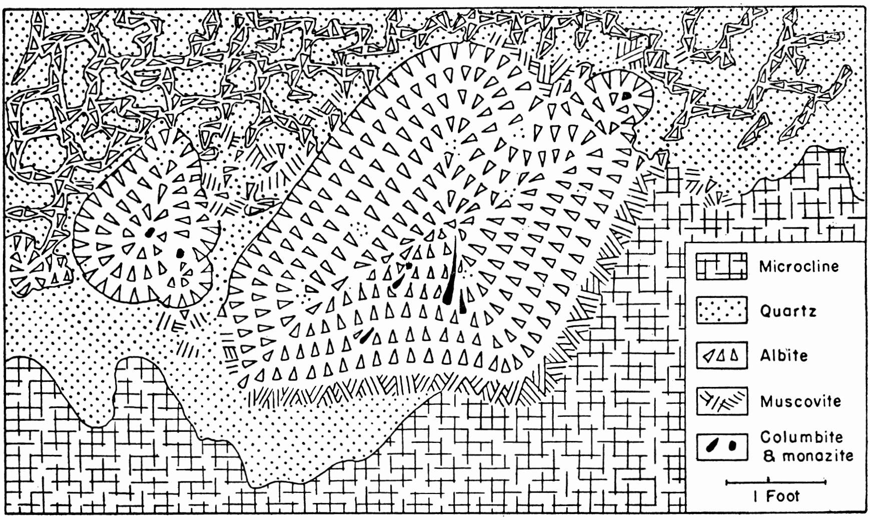


Fig. 3. Diagrammatic sketch of exposure in the old incline, showing albite veins in quartz. A large cleavelandite "burst" lies across a quartz-microcline contact.

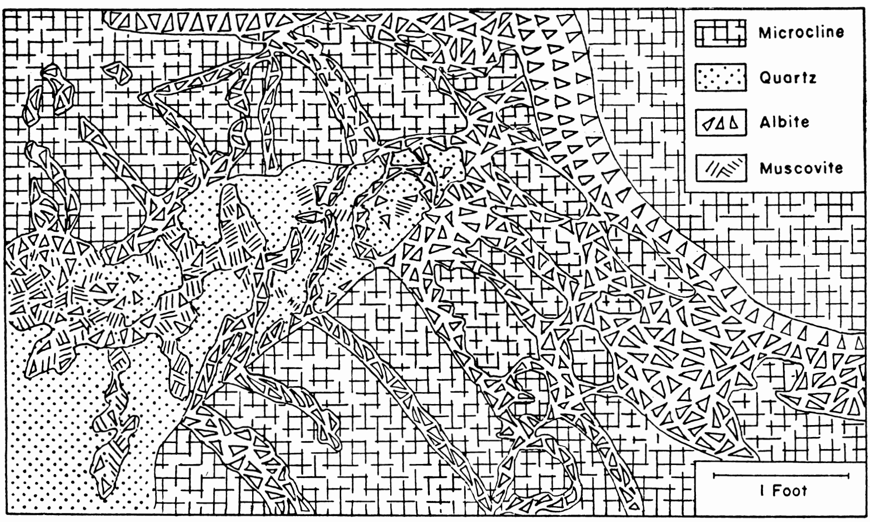


Fig. 4. Diagrammatic sketch of exposure near bottom of the "break-through." Here albite fills parallel fractures in the microcline and forms irregular veins in a septum of quartz. Mica occurs only with albite in the quartz, a local relationship.

longer veinlike, and there are all gradations between individual veins and large, irregular masses of no clearly assignable form, with intermediate stages represented by stockworks of albite in the host minerals.

In addition to fractures, cleavage planes in microcline and boundaries between crystals of microcline or between crystals of microcline and other minerals have served as avenues of access for albitizing solutions. Pseudomorphs of fine-grained albite after large microcline crystals are exposed in several of the mine openings in the interior parts of the dike. Many of these pseudomorphs retain very perfectly the original crystal form of the microcline, and in some of them an original perthitic structure can be recognized, chiefly by means of slight textural differences in the albite.

The most widespread concentrations of albite are those in the inner part of the granitoid wall zone of the pegmatite body. These consist almost wholly of albite and other late minerals, and in many of them specific evidence of structural control is not at hand. The lamellae of cleavelandite are not systematically oriented in many of the aggregates, but some small masses of coarse albite do show a radial structure.

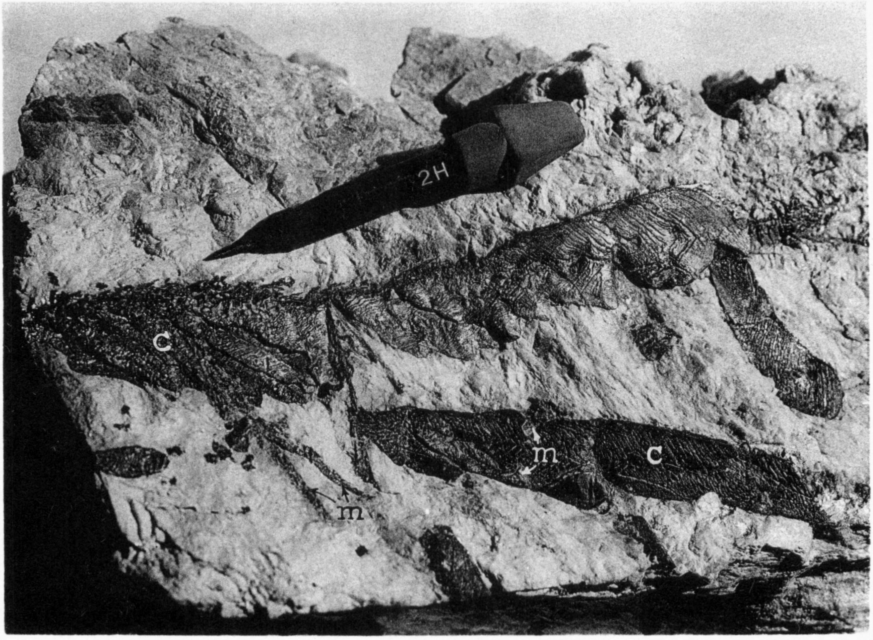
The most spectacular form of albite occurs in the inner parts of the wall zone and outer parts of the adjacent outer intermediate zone, where there are many spheroidal or cauliflower-like aggregates of coarse cleavelandite. These are two inches to eight feet or more in diameter, and have a concentric, shell-like structure. They consist of cleavelandite lamellae that are oriented radially, with the outer surface of each layer marked by the aligned terminations of individual lamellae. Concentrations of small muscovite books that were formed discontinuously along some of these surfaces accentuate the concentric structure. The outer margins of individual spheroids

---

EXPLANATION OF PLATE 2.

Fig. 1. Imbricate, featherlike aggregates of columbite (c) and monazite (m) in a cleavelandite matrix. In this specimen the monazite occurs as lighter colored inclusions in the columbite and as thin aggregates in the albite.

Fig. 2. Underground exposure near the entrance of the new incline showing a cluster of cleavelandite spheroids formed at the expense of earlier pegmatite minerals. The cluster is in contact with microcline along the upper left and lower left parts of its border, with quartz on both sides and with green fluorite along its lower right border.


2H
C
m
C
m

commonly are marked by richer concentrations of larger muscovite books.

The cleavelandite-rich spheroids occur singly or in clusters. Neither their distribution nor their internal structure appears to reflect any pegmatite structure that controlled their development, and many of them lie across contacts between earlier minerals. Even in detail there is no distortion or irregularity in the walls of the spheroids where they cross contacts between microcline and quartz, or between any other earlier-formed minerals.

Similar, though smaller, spheroidal aggregates of cleavelandite have been described from the Branchville, Connecticut, pegmatite by Shainin.[9] He attributes their spheroidal shape to the previous existence of radial fractures that grew outward from crystals of crytolite. These fractures are thought to have permitted the access of albite-forming solutions, with preservation of the cyrtolite in the center of the cleavelandite masses thus formed.

A comparable origin, based upon postulated fracturing about centrally disposed crystals of monazite or columbite, might be applicable to the Globe spheroids. Evidence to be described, however, indicates that the columbite and monazite were formed contemporaneously with and later than most of the associated cleavelandite. Moreover, none of the late-stage minerals in the Globe pegmatite are surrounded by zones of radial fracturing that are commensurate in size with even the smallest of the spheroids. Had such fracturing guided this albitization, the albite lamellae might reasonably be expected to have grown normal to individual fractures, rather than radially with respect to the centers of fracturing. Certainly this perpendicular orientation is typical of the fracture-filling cleavelandite in the pegmatite. Finally, many of the Globe spheroids evidently were developed in pegmatite so heterogeneous in mineralogy and texture that evenly disposed radial fracturing would be unexpected.

Much of the albite in the Globe pegmatite appears to have been introduced along fractures, microcline cleavage planes, and other planar discontinuities. In many places the number and spacing of fractures evidently determined the relative

[9] **Shainin, V. E., The Branchville, Connecticut, pegmatite: Amer. Mineral., vol. 31, pp. 336-338, 341-343, 1946.**

degree of albitization (Text Figs. 3 and 4), although this generalization does not apply as well to the spheroids described above as to other albite-rich parts of the dike. The structure and mineralogy of the spheroids themselves suggest that the tabular cleavelandite grew outward from single centers, with the radial structure developed as a normal reflection of such growth.

In general, the albite replacement appears to have shown no marked preference for any of the earlier minerals, and most of the controlling and localizing factors for albitization may well have been physical rather than chemical. Small, discontinuous fractures and grain boundaries in the medium- to coarse-grained granitoid wall-zone pegmatite appear to have been the most favorable loci for replacement.

MUSCOVITE

Pale green muscovite is the only mineral of current economic importance in the Globe pegmatite. Most of it occurs in rather well-defined concentrations or shoots composed of books ranging from less than an inch to more than five feet in diameter. Many of these books form irregularly intergrown aggregates, but individual books and fan-shaped aggregates of books are by no means rare. "A" structure, ruling, herringbone structure, and other imperfections are common, and only a small proportion of the material is suitable for sheet-mica uses. A substantial amount of muscovite occurs as small books that are disseminated sparsely through large quantities of pegmatite, or as somewhat larger books that are too widely scattered for profitable recovery.

The coarser muscovite is almost everywhere closely associated with albite. Many of the richest mica shoots occur along the margins of large, irregular masses of albite in which little or none of the original microcline-rich pegmatite remains. In this sense the relation between muscovite and the albite of the cleavelandite spheroids is repeated on a much larger scale. The most regular groups of mica concentrations occur along the inner margins of albitized masses of wall-zone pegmatite. The major concentrations lie immediately adjacent to the boundaries between the albite-rich masses and pegmatite of the adjacent outer intermediate zone or inner intermediate zone. These central zones are locally embayed or transected by replacement bodies of albite and muscovite, and in several places mica concentrations have been mined at or very near the center of the dike.

Although the muscovite is a characteristic associate of albite, the reverse relation is not everywhere the case. Much of the albite in the dike appears to have been developed later than the coarse muscovite, and there is widespread evidence for the partial replacement of muscovite books. This is particularly clear in the central parts of many mica shoots, where the books are corroded and transected by aggregates of fine-grained albite. Most of these aggregates appear to have been controlled by cleavage planes in the host mica books. This albitization need not indicate that the soda feldspar in general is later than all of the muscovite, but instead an age difference between the muscovite in the center of the replacement masses and much of that in the peripheral parts is suggested. The margins of each growing mass of replacement pegmatite may well have been marked by development of muscovite and albite, with the muscovite progressively replaced by additional albite, during subsequent growth of the mass. The albite that has corroded the centrally disposed books of muscovite therefore may have been contemporaneous with muscovite that lies nearer the edges of the replacement masses.

FLUORITE

Granular fluorite, though a widespread pegmatite accessory mineral in the Petaca district as a whole, probably is most abundant at the Globe mine, where it is confined chiefly to the western parts of the dike. It occurs in a variety of forms with widely different mineral associations.

An apple-green variety forms podlike masses that range from a fraction of an inch to more than six feet long (Text Fig. 2). The largest of these are irregularly distributed through the quartz—microcline mosaics in the intermediate zones. There is no evidence that the green fluorite is either earlier or later than the massive quartz and microcline, but certainly is earlier than much of the albite. All the albitization phenomena previously described with respect to microcline are also characteristic of most of the fluorite masses, and the albite is present in comparable abundance. The smaller green pods in the central parts of the dike generally are surrounded and veined by albite, and thus appear to be residua from larger masses of fluorite. Small green masses of fluorite also occur in the wall and border zones, where they form granitoid aggregates with quartz and microcline. The general relations of the green fluorite are markedly similar to those of the same species in the Baringer Hill, Texas, pegmatite.[10]

A purple variety of fluorite is present as small, irregular masses and in thin veinlets. It occurs only in albitized pegmatite. Many of the smaller green fluorite pods show areas of purple mottling, and there are all gradations between these and completely purple masses. The veinlets of purple fluorite commonly transect pods of green fluorite, but locally they cut across albite and other earlier minerals. The center of at least one veinlet of purple fluorite in albite is marked by a stringer of smoky quartz. A single small mass of brown fluorite with local deep purple mottling is associated with cleavelandite in a large specimen collected from the mine dump. Some of these occurrences probably indicate a late introduction of calcium fluoride, but others may well represent a discoloration of green fluorite in place, or the corrosion and solution of green fluorite followed by deposition of the purple variety.

COLUMBITE AND MONAZITE

Columbite and monazite in the Globe pegmatite are nearly identical in their crystal-habit and mineralogic relations. Both are abundant accessory constituents, but columbite is the more common. In simplest form, these minerals occur as equant anhedral to euhedral crystals an inch in average diameter. Many, however, are much larger, with maximum dimensions of four inches or more. Crystal faces ordinarily are well developed and twinning is common. The columbite of this general type has a submetallic to dull, earthy luster, and much of it appears to be altered to a semi-friable material. The monazite is mahogany red, with a subresinous luster.

Most of the equant crystals of columbite and monazite occur singly or as groups scattered through brick red albite. They are typically associated with deep purple fluorite. A few well-formed columbite crystals were observed in massive quartz, where they were associated with albite. Some crystals that

[10] Landes, K. K., The Baringer Hill, Texas, pegmatite: Amer. Mineral., vol. 17, pp. 387-389, 1932.

are surrounded by albite have irregular outlines owing to an interlayering of their marginal parts with cleavelandite lamellae. Columbite "niggerheads," some reported to have weighed as much as 60 pounds, were encountered during mining of the southern albitized border in the western part of the dike. None of these were observed by the writer, but evidently they were unusually large developments of the smaller crystals described above.

The columbite and monazite also are widespread in albite-rich parts of the dike as aggregates of thin, tabular plates arranged in delicate, feather-like patterns. As shown by X-ray patterns,[11] the dark-colored parts of these aggregates are columbite rather than tapiolite. They have a shiny metallic luster with local iridescent areas, whereas the associated monazite is yellowish brown and resinous. Individual plates rarely are more than one sixteenth of an inch thick and three quarters of an inch in diameter, but the feathery aggregates range in total length from an inch or less to at least 26 inches. Monazite, in contrast, was not observed in "feathers" more than eight inches long.

Most of the "feathers" are composed of plates that lie in rows and fit closely against one another or even interpenetrate to form an imbricate pattern. The overlapping edges, as exposed on the "feather" surfaces, are curved and essentially parallel in plan. They characteristically appear as gently curving crenulations or scarplets (Pl. 2, Fig. 1). The "feathers" themselves have many different shapes. The smaller aggregates commonly are oval in plan, and the larger ones range from broad, heavily scalloped blades to narrow, spearlike types. Some "feathers" comprise plates that are separated from one another by cleavelandite lamellae, and in section appear like series of thin, overlapping sandwiches.

Many of the platy columbite aggregates occur singly, others as regular or irregular groups. In some closely spaced clusters smaller "feathers" extend from larger ones in dendrite-like arrangements (Pl. 2, Fig. 1). In such groups the columbite commonly is associated with monazite of similar habit, although the monazite is subordinate. Most of the "stems" are columbite, whereas columbite and monazite form the "branches." Monazite also occurs as inclusions within the columbite. In

[11] W. T. Schaller, personal communication, 1945.

some of the smaller clusters, however, these relations are reversed, with monazite forming the "stems" and columbite occurring within them as inclusions. Another systematic arrangement is shown by the "feathers" that are radially disposed with respect to the centers of cleavelandite spheroids (Pl. 2, Fig. 2). Single crystals commonly occupy the centers themselves.

Imbricate groups of tabular columbite crystals also were observed at the Alamos mine, about three quarters of a mile northwest of the Globe pegmatite, and at the Capitan and Apache mines, about two and one half miles north and three and three quarter miles north-northwest of the Globe, respectively. At the Capitan, the monazite is distinctly more abundant than the columbite. In all localities the "feathers" occur only within masses of cleavelandite.

The intimate structural and spatial relationship between cleavelandite and feathery columbite and monazite, as well as the occurrence of tabular columbite and monazite in albitized pegmatite only, suggest a close genetic association between the three minerals. There is no evidence that any large quantity of the columbite or monazite is pre-albite in age, but neither do these minerals fill throughgoing fractures in albite. The presence of a tabular or lamellar host mineral, such as cleavelandite, may well have controlled development of the "feather" structure. Individual plates composing the "feathers" tend to conform with the orientations of the adjacent cleavelandite lamellae, although they locally cut across these lamellae at acute angles. Some of the radiating "feathers" also transect the internal structure of the albite spheroids in which they occur (Pl. 2, Fig. 2). These relations seem to indicate that the platy aggregates of monazite and columbite were formed later than at least some of the albite, and hence that they were developed mainly during and after, rather than before albitization.

OTHER MINERALS

Wine red to yellowish brown spessartite is sparsely and irregularly distributed through the albite-rich pegmatite. It occurs chiefly as granular, friable, partly altered masses as much as eight inches in maximum dimension. These masses are most abundant near the inner margins of the albitized border zone. Small flattened euhedra of spessartite, generally a half inch or less in diameter, are present between the laminae of some green muscovite books. Both these and the larger, subhedral to anhedral masses evidently were formed during and after albitization.

Pale green sericite is abundant throughout the albite-rich

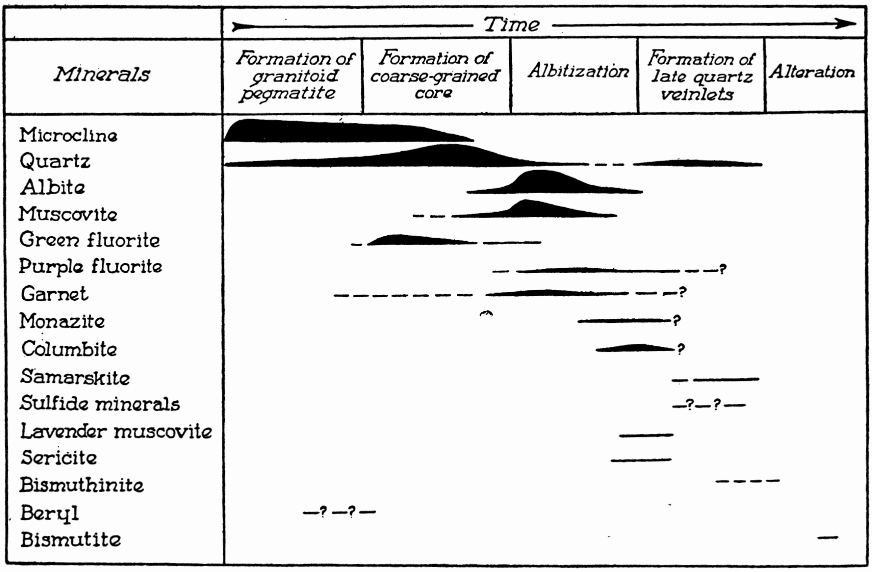


Fig. 5. Paragenetic sequence of the Globe pegmatite in minerals. Time divisions and vertical dimensions of the age figures are schematic, and do not represent true proportions.

pegmatite. It fills minute fractures in microcline and albite masses, and surrounds and veins many columbite and monazite crystals. The mineral also forms irregular, turnip-shaped masses as much as two feet in diameter. Such masses are waxy in appearance, and are compact aggregates of very small mica flakes. Most of them evidently were formed by replacement of microcline. Throughout the pegmatite the sericite appears to be a very late mineral.

Small aggregates of pale pink muscovite books were seen at several places in the new and north inclines. Most of the books are one thirty-second to one eighth of an inch in diameter, but locally are as much as five eighths of an inch in this dimension. They resemble the pink to purple muscovite described from the Harding mine and other localities to the east.[12] Aggregates of this mica fill irregular fractures in quartz and albite, and also occur in small concentrations along albite-quartz contacts. As indicated by its clearly defined post-albite relations, the pink muscovite is also one of the latest minerals in the Globe pegmatite.

Two small masses of extremely fine-grained lepidolite, one of which is near the center of a cluster of pink muscovite flakes, were found in the north incline. These represent the only known occurrence of lithium minerals in the entire Petaca district.

A few specks of dark brown to black samarskite occur in albite masses and in quartz veinlets that transect albite. They are typically associated with very late quartz, much of which is very dark in color.

Crudely tabular masses of yellow to gray bismutite as much as three inches in diameter occur in albitized quartz and in post-albite quartz veinlets in the new incline. At several other underground exposures fracture surfaces in quartz are coated with thin veneers of bismutite.

Minor quantities of pale green beryl occur as small anhedra in the quartz—microcline border zone. The relationships of this mineral are not wholly clear, but it appears to be part of the earliest granitoid pegmatite mosaic.

A small, lenticular mass of sulfide minerals was observed in partly albitized massive quartz near the collar of the air shaft, and grains of such sulfide also are scattered through the quartz of several veins. The principal species are pyrite, chalcopyrite, galena, and chalcocite, but all are rare.

CALIFORNIA DIVISION OF MINES,
SAN FRANCISCO, CALIF.

[12] Schaller, W. T., and Henderson, E. P., Purple muscovite from New Mexico: Amer. Mineral., vol. 11, pp. 5-15, 1926.