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E. C. ANDERSON
Director

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Mica Deposits of the Petaca District Rio Arriba County, New Mexico

WITH BRIEF DESCRIPTIONS OF THE OJO CALIENTE DISTRICT, RIO ARRIBA COUNTY, AND THE ELK MOUNTAIN DISTRICT, SAN MIGUEL COUNTY

By
RICHARD H. JAHNS

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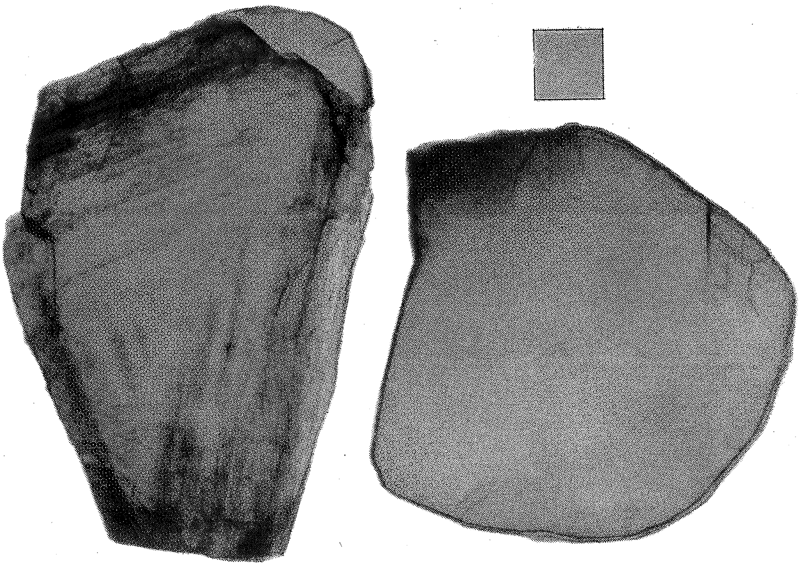
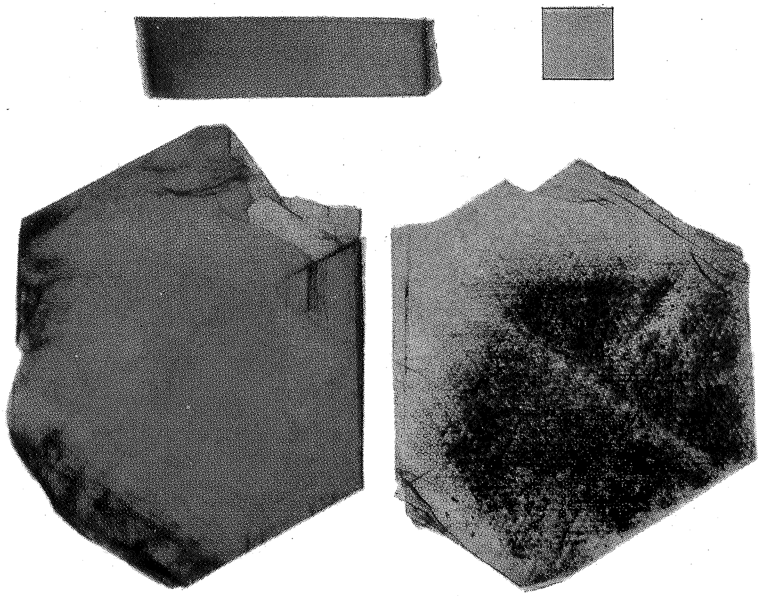


Pale green to yellowish olive mica. "Flat-A" sheet from Globe deposit, flat sheet with slightly stained corner from Kiawa deposit.



Sheets and ribbon of yellowish olive to brown mica, Cribbenville deposit. Note trigonal lattice pattern of stain in piece at left. All pieces were split from the same book.

TYPICAL SHEET MUSCOVITE FROM THE PETACA DISTRICT.
ONE-INCH SQUARE GIVES SCALE

CONTENTS

PLATES

FIGURES

THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

The New Mexico Bureau of Mines and Mineral Resources, designated as "a department of the New Mexico School of Mines and under the direction of its Board of Regents," was established by the New Mexico Legislature of 1927. Its chief functions are to compile and distribute information regarding mineral industries in the State, through field studies and collections, laboratory and library research, and the publication of the results of such investigations. A full list of the publications of the New Mexico Bureau of Mines and Mineral Resources is given on the last pages of this Bulletin.

BOARD OF REGENTS

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INTRODUCTION

GENERAL STATEMENT

Wartime increases in demand for mica of strategic quality, beryllium, tantalum, columbium, tin, lithium, and uranium have focused attention on pegmatite deposits more sharply during recent years than ever before. Not only have numerous technical developments of the past few decades involved new uses for these commodities, but during the recent period of emergency these and other uses were greatly expanded. The attendant rapid increases in demand and a heavy dependence on foreign sources of supply soon confirmed the need for a careful appraisal of domestic resources of the minor pegmatite minerals. This need had been foreseen prior to 1939, when the Federal Geological Survey began a program of pegmatite investigations that attained nation-wide scope by the spring of 1942.

Pegmatite deposits in the Petaca district of northern New Mexico have been sources of commercial mica since the seventeenth century, and some of the mines may well represent the oldest systematic operations for sheet mica in this country. Although an irregular but appreciable production of sheet, punch, and scrap mica has been maintained to the present time, little has been recorded concerning the geology of these deposits, the distribution and richness of mica concentrations within them, or their potentialities for future production of mica and other pegmatite minerals. A helpful background of general geology has been provided for the district by Just,[1] and several of the mines were briefly examined and described by Holmes[2] in 1899,

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[1] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, pp. 9-14, 40-50, 1937.

[2] Holmes, J. A., Mica deposits in the United States: U. S. Geol. Survey, 20th Ann. Rept., pp. 706-707, 1899.

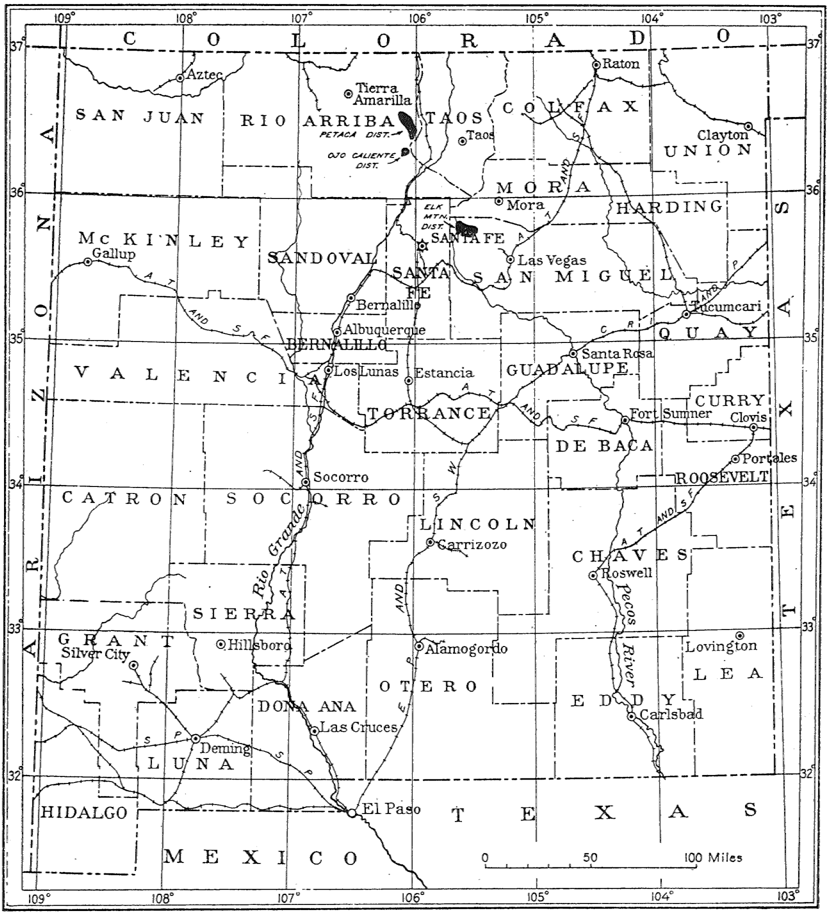

FIGURE 1. Index map of New Mexico showing locations of Petaca, Ojo Caliente, and Elk Mountain districts.

by Sterrett[3] in 1923, and by Just[4] in 1937. At no time, however, have all the more promising deposits been examined, and no geologic map of any mine in the district has been available heretofore.

The attention of the Geological Survey was turned toward the Petaca district in the fall of 1943, when a comprehensive program of pegmatite mapping and examination was begun. Detailed mapping, structural correlation, and mineralogic study demonstrate that the occurrence of mica and other minor constituents in the pegmatites follows certain rules and that a working knowledge of these rules can be applied to prospecting, evaluating, developing, and mining the deposits.

The Petaca pegmatites are remarkably consistent in their physical and mineralogical features, and appear to have a common origin. This is in accord with recent findings elsewhere in this country and in South America by members of the Geological Survey and others; their work has shown that most pegmatites, though erratic and unpredictable in detail, obey certain rules and within a given district or area can be analyzed and classified in much the same manner as many other mineral deposits. Although such classifications are basically empirical, they appear to be sound from both theoretical and practical standpoints, and tend to confirm the objections of some geologists to strong emphasis on the irregularity of pegmatite deposits with little or no recognition of broad consistencies that might be present.

FIELD WORK AND ACKNOWLEDGMENTS

The study of the Petaca and Elk Mountain districts was made intermittently during the period August 1943 to June 1944, and supplementary investigations were made in the Petaca and Ojo Caliente districts during the period September-November 1944. One hundred and seven deposits were studied in detail, of which 43 were mapped. Mapping generally was done on scales of 20 feet and 50 feet to the inch, but a few deposits were mapped on scales of 40 feet and 100 feet to the inch. Surface control was established with plane table and telescopic alidade. Underground control in large mines was established with sight alidade, tape, and hand level; in small mines with compass and tape. A transit was used in a few places where superior accuracy was needed.

Throughout the studies emphasis was placed upon subdivision of the pegmatites into mappable units of differing texture and mineralogy, and upon the recognition and interpretation of structural features, both in the pegmatites and in adjacent coun-

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[3] Sterrett, D. B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, pp. 158-164, 1923.

[4] Just, Evan, *op. cit.*, pp. 63-69, 1937.

try rock. In general, each pegmatite or pegmatite group and the immediately adjacent area were mapped, and detailed maps of several larger areas were prepared to show the structure of the country rock and the relations of other pegmatites and quartz veins to deposits of commercial interest. Field studies were supplemented by analyses of production records and mining costs for the few deposits where such data were available. Laboratory studies of feldspars and accessory minerals were made in offices at Petaca, New Mexico, and Asheville, North Carolina. Four hundred sixty-five crushed samples of material and 11 thin sections were examined.

The writer was assisted by E. Wm. Heinrich during the period August-December 1943, by L. A. Wright from October 1943 to June 1944, and by W. P. Irwin during the periods August-December 1943 and June-July and September-November 1944. These men participated in the instrument work, mapping, and examination of deposits. Immediate responsibility for the representation of geology and topography is indicated on each map published in this report, although final responsibility for all maps must be assumed by the writer. Irwin collaborated in the preparation of most of the illustrations, and Heinrich drafted the map and section of the Alma deposit and much of the three-dimensional diagram of the Lonesome deposit. Those descriptions of deposits to which Heinrich, Wright, or Irwin were primary contributors are appropriately designated in the text.

The recent studies of domestic mica deposits have been conducted in close coöperation with the Colonial Mica Corporation, agents for the Metals Reserve Company. E. J. Wemlinger, district manager assigned to the Santa Fe office, furnished much important information concerning production, quality, and processing of New Mexico mica, and his many personal kindnesses are gratefully acknowledged. H. M. Bannerman, W. T. Schaller, and James Gilluly of the Geological Survey, who visited the area during the fall of 1943, discussed many of the problems and contributed helpful ideas and suggestions. C. H. Johnson and R. J. Holmquist of the Federal Bureau of Mines were most generous with information they had obtained during their previous studies in the district, and their friendly coöperation during the course of Bureau of Mines exploration at the Apache and Elk Mountain deposits is greatly appreciated. Professor Ian Campbell of the California Institute of Technology made available the laboratory equipment that was used in the Petaca office.

The mine owners and operators in the district have provided production data and have facilitated the investigations in many other ways. The writer is especially grateful to Gabino Alire and Joseph Veseley of Petaca; Charles Besre of Tesuque; Frank Gallegos, Manuel Griego, Juan Trujillo, and Alberto Trujillo of La Madera; Elwood Romney and R. L. Schneider of Santa Fe;

Philip S. Hoyt of Van Horn, Texas; Joseph M. Maestas of Vallecitos; U. Leon Guy and Jay Stearn of Las Vegas; and Joseph A. Stanko and Joe Thompson of Los Angeles, California. It is also a pleasure to acknowledge the many personal kindnesses of Messrs. Romney and Schneider.

The active coöperation of John M. Kelly, formerly Director of the State Bureau of Mines and Mineral Resources, and A. D. Hahn and E. C. Anderson, his successors, aided considerably in the preparation of the report and expedited its publication. The manuscript was examined and criticized by E. N. Cameron, A. H. McNair, and J. B. Mertie, Jr., of the Geological Survey, and the general discussion of mica was critically reviewed by Bradley Johnson and W. J. Alexander of the Colonial Mica Corporation, Asheville, North Carolina. The writer is further indebted to Ida M. Morgan and Frances H. Jahns for able assistance in the preparation of the manuscript.

BIBLIOGRAPHY

The reports and papers listed below are those that contain specific mention of the Petaca district or some mine or deposit within it. Publications less directly concerned with the district are recognized in footnote form within the text.

1899. HOLMES, J. A., Mica deposits in the United States: U. S. Geol. Survey, 20th Ann. Rept., pp. 691-707. Discusses geology of mica deposits and properties of mica, and briefly describes the Cribben (Old Cribbenville) mine and others in the Cribbenville district.

1904. JONES, F. A., New Mexico mines and minerals (World's Fair Edition): Santa Fe, New Mexico, 349 pp. Includes a brief summary account of geology and ore deposits of New Mexico, a list of New Mexico minerals, and a historical account of mica occurrences and production in Mora, Rio Arriba, and Santa Fe counties (pp. 260-261).

1910. LINDGREN, WALDEMAR, The hot springs at Ojo Caliente and their deposits: Econ. Geol., vol. 5, pp. 22-27. Describes hot-spring deposits in the Ojo Caliente-La Madera area.

1913. STERRETT, D. B., Mica in Rio Arriba County, New Mexico: U. S. Geol. Survey Bull. 530, pp. 383-388. Describes several mica deposits in the Petaca and Ojo Caliente districts.

1923. STERRETT, D. B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, 342 pp. Includes a general discussion of geology, mineralogy, and mining of mica deposits, as well as a description of the Cribbenville, American (Coats), Globe, and Antonio Joseph deposits, Rio Arriba County (pp. 158-164).

1925. HESS, F. L., The natural history of the pegmatites: Eng. and Min. Jour., vol. 120, pp. 289-298. Briefly discusses mineral paragenesis of some Petaca pegmatites.

1930. HESS, F. L., and WELLS, R. C., Samarskite from Petaca, New Mexico: Amer. Jour. Sci., 5th ser., vol. 19, pp. 17-26. Describes the physical and chemical properties of samarskite from the Fridlund mine and discusses possible interpretations.

1933. **Hess**, F. L., The pegmatites of the western states, in *Ore deposits of the western states* (Lindgren volume): Amer. Inst. Min. and Met. Eng., New York, pp. 526-536. Discusses pegmatite genesis and mentions Petaca pegmatites in this connection.

1937. **Talmage**, S. B., and **Wootton**, T. P., The non-metallic mineral resources of New Mexico and their economic features: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 12, pp. 113-117. Briefly discusses the general features and uses of mica and describes several mica deposits in the Petaca, Ojo Caliente, and other districts.

1937. **Just**, **Evan**, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, 73 pp. Describes the general geology and many of the pegmatite deposits of the Petaca and Ojo Caliente districts. An areal geologic map and sections are included.

1942. **Northrop**, S. A., Minerals of New Mexico: Univ. of N. Mex. Bull., Geol. Ser., vol. 6, no. 1, 387 pp. Records occurrences of mica and other pegmatite minerals in New Mexico; includes bibliography.

1946. **Heinrich**, E. **Wm.**, and **Jahns**, R. H., The accessory minerals of the Petaca pegmatites, Rio Arriba County, New Mexico: in preparation. Describes the accessory mineral suite of the Petaca pegmatites and discusses its general significance.

1946. **Wright**, L. A., The Globe pegmatite, Rio Arriba County, New Mexico: in preparation. Describes the mineralogy and structure of a typical large pegmatite of the Petaca district.

PHYSICAL FEATURES

The Petaca district lies west of the Rio Grande near the eastern edge of Rio Arriba County, and is approximately 55 airline miles north of Santa Fe, 25 miles west of Taos, and 35 miles south of the Colorado-New Mexico state line. It occupies a part of the pre-Cambrian mass that lies between basalt-capped table-land to the east and higher plateau country underlain by sedimentary rocks to the west. The area of pre-Cambrian rocks is a rugged southward continuation of the San Juan Mountains of Colorado, and consists of a deeply dissected plateau surmounted by prominent mountain masses. The chief remnant of the old plateau surface is Jarita Mesa, which extends south-southeast from Kiawa Mountain between the Rio Vallecitos and the Tusas River (see Plate 1). This surface, which is at altitudes between 8,200 and 9,100 feet, slopes gently to the southeast and appears to be in accord with the general surface of the mesa land that lies to the east and southeast. Beneath these surfaces is a wide variety of rocks whose structure is locally very complex.

The pegmatite district occupies an area of about 60 square miles. It extends 15 miles north-south and an average of 4 miles east-west. It is bounded on the east by the Tusas River and on the west by the steep east slope of the Rio Vallecitos Valley.

These streams flow southward and southeastward to join at La Madera, whence the drainage (Caliente River) is southward into the Rio Grande via the Chama. The drainage pattern in the Petaca district is markedly asymmetric, with tributaries of the Tusas extending west and northwest far into the upland to form a broken country of rather deep canyons, steep slopes, and local high-level flats. It is in this rough terrain that most of the mica deposits occur. A somewhat lower, more gently rolling area, in which the older rocks are thinly and irregularly veneered by Tertiary volcanic rocks and sediments rich in volcanic material, lies immediately west of the Tusas River. This area increases in width from a mile or less north of the village of Petaca to 2½ miles between Petaca and La Madera. The altitude of Kiawa Mountain, the highest point in the district, is more than 9,500 feet, and still higher country lies outside the district to the northwest. Other prominences near the district are the Ortega Mountains, which are west of the Rio Vallecitos, and La Madera Mountain, which is south-southeast of La Madera. The lowest point in the district, the Caliente River at La Madera, is 6,400 feet above sea level.

The Tusas and Vallecitos Rivers, and segments of their principal tributaries, are perennial streams; all others are dry through most of the year. Kiawa and South Kiawa lakes occupy shallow natural depressions on Jarita Mesa, and several springs also are reliable sources of water in the otherwise dry upland country. The flow of some intermittent streams is stored in earth-dammed tanks for the use of cattle and sheep. Most of the precipitation, which probably is less than 25 inches per year, occurs as thunder storms in the late summer and as snow in winter. The depth of snow at altitudes above 8,000 feet is a foot or more for several weeks during most winters. The summer climate is generally mild, with warm days and cool nights; winter temperatures are seldom extreme, although sub-zero readings are common in the mountains. The lower parts of the district are covered with a thick growth of piñon, scrub oak, and many desert plants. Cottonwoods flourish along the streams. Above 7,300 feet the precipitation is great enough to support large open stands of yellow pine and spruce. Aspen is also common above 8,500 feet.

The entire district, which is very sparsely settled, lies within the Carson National Forest, but there are several small, irregular land-grant areas that are not under Forest Service jurisdiction. These grants lie along the narrow valley bottoms, and most of their fertile but stony soil is tilled for corn and other field crops by the Spanish-American inhabitants. The villages of Las Tablas, Petaca, Servilleta Plaza, La Madera, Ancones, and Vallecitos are little more than local concentrations of farmhouses, although some were once centers of mining and lumbering. The town of Cribbensville, a busy mining settlement 50 years ago, has been deserted for years and its buildings were long ago dismantled. Grazing, lumbering, and mining are permitted within the National Forest; the former two activities are closely supervised. One sawmill is now in operation.

A narrow-gauge branch line of the Denver and Rio Grande Western Railroad once served the district at La Madera, where it connected with lumber railroads from the Ortega Mountains and the valley of the Rio Vallecitos. After this branch was abandoned in 1931, a 15-mile truck or wagon haul from La Madera to Taos Junction, or a 13-mile haul from Petaca to Tres Piedras, was necessary to reach the Alamosa-Santa Fe narrow-gauge line of the same railroad. This line was abandoned in 1941, so that the nearest railroads are now the Denver and Rio Grande Western standard-gauge line at Antonito, Colorado, and the Santa Fe Railway at Santa Fe. The truck haul from La Madera to Antonito is 68 miles over State Route 110 and U. S. 285, both gravelled roads, with an additional 11 miles for goods originating at Petaca. The Forest Service plans to improve the Petaca-Las Tablas-Agua Canyon road (see Plate 1), however, so that it will be possible to haul from Petaca directly to Tres Piedras and Antonito, thus shortening the Antonito-La Madera distance to 56 miles and the Antonito-Petaca distance to 45 miles. The southern rail outlet, at Santa Fe, can be reached from La Madera over 26 miles of State Route 110 and U. S. 285 (both gravelled roads) and 34 miles of the paved U. S. 84.

Until recently vehicular transportation within the Petaca district was not reliable, particularly during or immediately after periods of wet weather. A graded and gravelled road to connect Petaca with La Madera was started by the Civilian Conservation Corps and completed by the Forest Service in 1943; this is State Route 111. Subsequent completion of all-weather roads to several mines now permits ready access to many parts of the district. Numerous ungraded roads, some irregularly maintained and others nearly impassable, serve most of the remaining mines. These routes of travel are shown in Plate 1, where an attempt has been made to draw practical distinctions between roads of different characteristics.

GEOLOGY

PRE-CAMBRIAN ROCKS

QUARTZITE AND QUARTZ-MICA SCHIST

Quartzite and quartz-mica schist constitute the most widely exposed geologic units in the Petaca district. These rocks underlie Jarita Mesa and much of the rough country to the east, and are also prominent to the north and west. Within the district they form such eminences as Kiawa Mountain, Big Rock, and Persimmon Peak (Plate 1). The most readily recognizable rock is white to bluish-gray quartzite that is nearly pure and commonly is massively bedded. This is the Ortega quartzite of Just,[5] who named it from excellent exposures in the Ortega Mountains. It is also well exposed on Kiawa Mountain, locally on the tableland east of the Kiawa mine, and in the vicinity of Ancones. Much more common in the Petaca district are gray to buff-colored micaceous quartzite and quartz-mica schist. These rocks, which range from thin-bedded nearly pure quartzite to fine-grained thinly foliated mica schist, have been termed the Petaca schist phase of the Ortega quartzite by Just.[6] Much of the micaceous rock is platy to slabby, and forms irregular outcrops on Jarita Mesa and in the areas east and southeast of the mesa.

The Ortega quartzite is vitreous and hard where relatively pure, but local feldspathic phases are sugary. It is rich in coarse magnetite where exposed in cliffs along the Tusas River Canyon 4 miles south of Petaca. Several other mineralogic variations have been noted, but these appear to be the effects of igneous activity and hence are discussed in the section on pegmatites. The lithology of the Petaca schist varies according to its mica content. With increase in the proportion of mica, most of which occurs as thin flakes $^1/_{16}$ to ¼ inch in diameter, the rock tends to be more thinly and strongly foliated, and silvery to greenish gray in color. Some layers are very feldspathic, and local conglomeratic horizons are present. Just[7] reports conglomerate at several localities and mentions pebbles consisting of white quartz, jasper, and black chert. Several thin lenses of conglomerate are exposed along the Apache Canyon road 1.2 miles west-southwest of Petaca, where they contain pebbles of red and white quartz and rhyolite.

Individual beds and thick groups of beds commonly grade along their strike from vitreous quartzite to mica-rich schist; such relations are especially clear in the rough country immedi-

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[5] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, p. 43, 1937.

[6] Just, Evan, *idem*, 1937.

[7] Just, Evan, *idem*, 1937.

ately west of Petaca and in the vicinity of the Kiawa mine. According to Just,[8] "The fact that the schist is restricted to the pegmatite area near the Tusas granite and the abrupt transition along the strike of a considerable thickness into typical Ortega quartzite suggest that the entire schistose phase owes its development to the granite intrusion, the granite having provided the materials and possibly the physical conditions that permitted the formation of schist. In the vicinity of the granite a more definitely recognizable contact zone is apparent. . . The Petaca schist should not be regarded as a separate member of the Ortega quartzite for purposes of correlation with other areas." The writer agrees with this conclusion and interprets most of the feldspar and mica as products of solutions related to nearby masses of granite and pegmatite. There was no opportunity during the present investigation to check the evidence for widespread introduction of these materials into the quartzite, but rather compelling evidence has been obtained around each pegmatite or group of pegmatite bodies.

The schistosity of the quartzite and related rocks is generally easy to recognize, especially on weathered surfaces. It strikes north-northwest to northwest, and dips west-southwest to southwest at low to moderately high angles through most of the area, although local variations are common. Broad structural variations appear to occur in several areas, notably between Las Tablas and Kiawa Mountain. Just[9] tentatively interprets the structure of the entire area as a series of large-scale, relatively tight folds that trend roughly east, but he also points out that detailed study would be necessary to test this intepretation adequately. No evidence incompatible with Just's interpretation was seen during the course of the present investigations.

Fracture cleavage, tightly compressed drag folds, and relics of cross-bedding are present in many exposures, and serve as clues to the orientation of the beds. They are not sufficiently common, however, for a reliable determination of the large-scale structure. Most of the minor structures in the area between the Apache and La Jarita mines (Plate 1) suggest a large-scale overturning of the beds, but their interpretation is beyond the scope of this report. Bedding is commonly conformable with the schistosity, though it is cut by the schistosity at small but distinct angles in many places where both structures are clearly discernible. Marked discordance is evident wherever the crests or troughs of folds can be seen. The apparent thickness of the quartzite sequence is reported as between 4 and 5 miles,[10] but estimates of true thickness must await a more satisfactory structural diagnosis.

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[8] Just, Evan, *idem*, 1937.
[9] Just, Evan, *op. cit.*, pp. 40-42, 1937.
[10] Just, Evan, *op. cit.*, p. 43, 1937.

AMPHIBOLE SCHIST

Dark greenish-gray to black amphibole schist is interlayered with the quartzite and quartzitic schist in many places, and composes much of the pre-Cambrian terrane northwest of the Petaca district. Schists rich in amphibole are present at the Kiawa mine, a mile west of the Kiawa mine, between the Alma and Lone Wolf deposits, west of the Cribbenville area, in a structurally complex area 1.5 miles northeast of La Madera, and elsewhere. Such rocks, whose outcrops range from 1 foot to 230 feet in breadth, are conformable with the adjacent quartzitic rocks and should be helpful in deciphering the structure of the pre-Cambrian rocks. These schists probably represent metamorphosed flows of andesite or basalt, and Just[11] notes recognizable remnants of amygdules and phenocrysts. The rocks are composed chiefly of dark-green hornblende, much of which has been altered to chlorite. Plagioclase, epidote, and magnetite are common accessory minerals.

OTHER SCHISTS

Other schistose rocks, distinguished chiefly by their relatively high content of alumina, are interbedded with the quartzite and quartz-mica schist. Most are brown to gray thinly foliated schists that contain andalusite and staurolite. They appear locally on Jarita Mesa, north of Goodge Sawmill, and in the vicinity of La Madera, but are poorly exposed and constitute a very small part of the section.

META-RHYOLITE

Interlayered with other pre-Cambrian rocks are several thick units of flesh-colored to deep-red rocks to which Just[12] has given the name Vallecitos rhyolites. They are well exposed immediately southwest of the Cribbenville area, along the upper part of the steep east slope of the Rio Vallecitos Canyon, and at several places on Jarita Mesa. These rocks, which consist of volcanics and interbedded sediments, are schistose and locally difficult to distinguish from members of the quartzite sequence. According to Just[13] their classification as rhyolite (with subordinate trachyte) is based chiefly on their flow-banded structure, aphanitic ground-mass, phenocrysts of quartz and orthoclase, and interlayering with the other pre-Cambrian rocks on both large and small scales. The maximum apparent thickness of the meta-rhyolites is about 3,500 feet.

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[11] Just, Evan, *op. cit.*, p. 44, 1937.
[12] Just, Evan, *idem*, 1937.
[13] Just, Evan, *idem*, 1937.

GRANITE

A fine- to medium-grained pre-Cambrian granite, called the Tusas granite,[14] is exposed in the vicinity of Las Tablas, where it forms steep cliffs along the west side of the Tusas River. It is a part of a large intrusive mass that is irregularly exposed northwest of Kiawa Mountain, as well as at Tres Piedras to the northeast, but is mostly covered by younger rocks. The granite varies widely in mineralogy and texture, but in the Petaca district it is consistently gray to pink and nonporphyritic. It consists chiefly of quartz and microcline, with subordinate amounts of plagioclase and biotite, and locally a little magnetite. A sugary texture is common. Faint planar structures in the granite are due to the alignment of biotite flakes and a barely perceptible interlayering of biotite-bearing and biotite-free laminae. These structures are parallel to the surface trace of the granite-country rock contact, and in general are conformable with the foliation of the adjacent country rock.

The intrusive contact zone is well exposed. It trends north to north-northwest, is at least 1,500 feet wide, and shows a broad transition from massive-bedded faintly foliated slightly feldspathic quartzite to granite whose color, texture, and structure are not markedly different from that of the quartzite. The grains of quartz and feldspar in the granite are distorted, sheared, and locally corroded. Within the contact zone, layers of granite and giant inclusions or septa of altered quartzite commonly alternate. Much of the country rock has been impregnated with feldspar and locally with biotite, and all of the granite appears to be contaminated with country-rock material. Numerous partially digested inclusions are oriented parallel with the contact and with the foliation in the granite. These range from a few inches to many tens of feet in width, and the largest are at least 2,000 feet long. The unusual width of the contact zone may well be due to the gentle westward dip of the contact. As suggested by Just,[15] this would bring the granite to shallow depths beneath the country rock as well as to the east of it at the surface.

The relations in the Las Tablas area indicate that the granite tore off fragments of country rock in some places, insinuated itself between easily split masses in others, and developed an intricate composite of country rock and intrusive material throughout the contact zone. Partial to complete digestion of the invaded rock further confused these relations. Immediately west of the contact zone the quartzite has been impregnated with feldspar. Introduction of mica, on the other hand, took place at a considerable distance from the contact zone. As the distribution of mica is more immediately related to that of quartz veins and pegmatites, it is discussed in a later section.

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[14] Just, Evan, *op. cit.*, pp. 44-46, 1937.

[15] Just, Evan, *op. cit.*, p. 45, 1937.

PEGMATITES AND VEINS

Pegmatite bodies and quartz veins can be seen in almost all areas where pre-Cambrian rocks are exposed. Their relative abundance between the latitudes of Las Tablas and Ancones is reflected by the distribution of mica mines (Plate 1). Pegmatites are rare north and northwest of the Kiawa mine and are uncommon between La Madera and the Ojo Caliente district to the south. Both pegmatites and veins are present in the granite and in the quartzite and associated metamorphic rocks, but are structurally different in the two rock environments.

The Petaca pegmatites can be divided as follows into three general groups, each of which is structurally distinct from the others.

1. *Pegmatite bodies in granite.*
   These pegmatites are small, irregular, and discontinuous. They commonly are homogeneous and mineralogically simple, and in general are of no commercial importance.

2. *Sills and strike dikes in the metamorphic rocks.*
   Pegmatite bodies that lie parallel to the trace of the foliation in the metamorphic rocks may be wholly conformable in three dimensions (sills) or they may cut the foliation of the country rock in section (strike dikes). They tend to be continuous, but are irregular in detail. Their length is characteristically many times their width. Most are simple and homogeneous, but some contain distinct concentrations of minerals. A few have been mined for mica.

3. *Other crosscutting bodies in the metamorphic rocks.*
   Most of the larger pegmatite bodies cut across the structure of the enclosing rocks. The average ratio of the length of these bodies to their width is high, but not so high as for the strike dikes. The masses are cigar-shaped, trough-shaped, lath-shaped, and funnel-shaped, and a few show combinations of these shapes. Their common structural characteristics are a west-northwest to west-southwest strike, a steep northerly or southerly dip, and a westerly plunge. Parts of the more irregular masses may be conformable with the country-rock structure. The constituent minerals commonly occur in units of contrasting composition and texture. Mica and other desirable minerals are sufficiently concentrated to be recovered commercially from many deposits, and these crosscutting pegmatite masses include most of the deposits that have been mined.

The quartz veins are more difficult to classify. In the granite, where they occur as thin continuous fracture fillings, one set trends west to west-southwest and dips steeply north, and another, which is apparently younger, trends north to north-northwest and dips east at moderate angles. In the foliated rocks the quartz veins commonly occur as swarms of thin elongate lenses or thicker individual veins that tend to be conformable with the structure of the country rock; i.e., they strike north to north-northwest and dip gently to steeply west to west-southwest. Some, however, conform in strike but dip at an angle to the country-rock foliation. The quartz veins range in thickness from a fraction of an inch to 35 feet or more, with an average of about 2 feet. Some are short pods, but others are traceable for hundreds of feet.

Quartz is the dominant constituent of all the veins and the only constituent of many, but a wide variety of other minerals nevertheless is present in some of them. Most of the veins do not connect with pegmatites, but some—as traced along their strike—become feldspathic near their walls and merge into pegmatites or cut through the outer parts of pegmatites and merge with their quartzose cores. In addition to feldspars, common accessory constituents of the veins are ilmenite and magnetite, which occur chiefly as thin tabular crystals. Local concentrations of kyanite and dumortierite, associated in some deposits with hematite, are scattered through the rocks. Such minerals presumably were formed through contamination of the veins with country-rock material. In the western and northern parts of the district there are veins in which small quantities of pyrite, chalcopyrite, and molybdenite are disseminated. Quartz veins with carbonates, chlorite, and sulfides have been reported from the extreme northwest corner of the district.

The pegmatites and veins are thought to be genetically related to the Tusas granite. They form a broad fringe in the country rock around the granite and are distinctly less common in the areas farther away. Moreover, the general composition of the pegmatite bodies is markedly similar to that of the granite. It is believed that pegmatites began to form after much of the granite had consolidated, and the veins appear to have been formed still later. Both pegmatites and veins are known to be younger than the folding and metamorphism of the pre-Cambrian rocks and younger than some of the faulting. The emplacement of many pegmatites was controlled by folds in the country rock, and the shape and orientation of most of them is related to minor structures.

As shown in the vicinity of the Kiawa mine, where a thick layer of amphibole schist serves as an excellent marker, several faults in the metamorphic rocks are clearly transected by large masses of pegmatite, and other faults are occupied by quartz veins. Moreover, the corrosion and replacement of metamorphic minerals in the country rock by pegmatitic minerals shows that the pegmatites are younger than the regional metamorphism. Minor renewals of movement along some of the old faults have locally affected pegmatites and veins, and other younger faults show displacements amounting to tens of feet or more. The Globe and Capitan pegmatites have been offset in this way (see Plates 19 and 22).

Evidence for the pre-Cambrian age of the pegmatites and the rocks in which they occur must be taken from areas to the south and others in Colorado to the north. In such areas all Paleozoic rocks are relatively little metamorphosed and have undergone much less deformation. Pegmatites have been observed that are overlain by Paleozoic rocks with an intervening erosional unconformity. In the relatively few places in New Mexico and Colorado where younger pegmatites are known, they are much smaller, are simpler in structure and mineralogy, and can be clearly correlated with intrusive rocks of Paleozoic or younger age.

TERTIARY ROCKS

OLDER SEDIMENTARY AND VOLCANIC ROCKS

No Paleozoic or Mesozoic rocks are exposed in the Petaca area, though a thick section of Mesozoic sedimentary beds is present about 10 miles to the west. The oldest Tertiary rocks are beds of conglomerate and sandstone that lie on an irregular surface developed on pre-Cambrian rocks. They are best exposed in the vicinity of Las Tablas, where they form bold cliffs and benches along the lower slopes of the Tusas River Valley. The conglomerate, most of which lies near the base of the section, consists of cobbles and boulders cemented by a light gray sandy to pebbly matrix. The coarse clastics are composed of quartzite, granite, schist, volcanic rocks of probable Tertiary age, and chert that may have been derived from Paleozoic beds.[16] The conglomerate beds are overlain by gray to buff coarse friable sandstone, much of which is tuffaceous. These bedded rocks, which have been termed the Carson conglomerate,[17] appear at progressively higher levels to the north and west, and the surface on which they were deposited slopes in general to the southeast.

Overlying the Carson conglomerate in the Las Tablas area are volcanic rocks and sedimentary rocks rich in volcanic material. These can be traced southward along and immediately west of the Tusas River to points north of La Madera near the mouth of Alamos Canyon. Where exposed in the southern part

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[16] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba Counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull 13, pp. 16, 49, 1937.

[17] Just, Evan, *op. cit.*, p. 48, 1937.

of the Petaca district, these rocks have been assigned by Smith[18] to the Abiquiu tuff. They consist chiefly of red to purple andesite, andesitic tuff, and flow breccia; buff to red rhyolite; fine-grained, dark gray basalt; tuffaceous sandstone; agglomerate; and conglomerate and breccia with abundant fragments of volcanic rocks. The lavas and flow breccias are prominent at and near the base of the section. South of the Las Tablas area they lap against the pre-Cambrian rocks. Islands of the older rocks project through the thin cover of these Tertiary volcanics in the area south and southeast of the La Paloma mine (Plate 1). The contacts indicate that the volcanic rocks flowed around and against the older metamorphics, but at a few localities these relations have been complicated by subsequent faulting. Flows and sediments have been preserved as thin remnants at several places on Jarita Mesa, as well as in the rough country to the east.

No section of the older Tertiary rocks is more than a few hundred feet thick in the Petaca district, and no broad areas of such rocks are present. From relations in adjoining regions, the Carson conglomerate is regarded as early or middle Tertiary and the younger volcanic sequence as Miocene in age.[19]

SANTA FE FORMATION

The Santa Fe formation is present in the southern part of the Petaca district in a belt that extends north and northeast from La Madera. It also underlies Petaca Mesa and much of Turkey Mesa, where its edges are covered by landslides and talus from overlying basalt flows. This formation is thought to have been formed by streams draining highland areas and flowing into the Rio Grande Valley during late Miocene and Pliocene time.[20] The rocks consist of poorly to well consolidated sandstone, siltstone, conglomerate, and volcanic ash, much of which is rich in volcanic material. The beds, which are flat to gently dipping, have locally been eroded into badlands.

The Santa Fe formation overlies volcanic rocks along the

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[18] Smith, H. T. U., Tertiary geology of the Abiquiu quadrangle, New Mexico: Jour. Geol., vol. 46, pp. 944-952, 1938.

[19] For more complete descriptions of these and related rocks, see:
Bryan, Kirk, and McCann, F. T., The Ceja del Rio Puerco, a border feature of the Basin and Range province in New Mexico: Jour. Geol., vol. 45, pp. 801-828, 1937, pp. 1-16, 1938.
Smith, H. T. U., *op. cit.*, 1938.
Denny, C. S., Tertiary geology of the San Acacia area, New Mexico: Jour. Geol., vol. 48, pp. 73-106, 1940.
Stearns, C. E., The Galisteo formation of north-central New Mexico: Jour. Geol., vol. 51, pp. 301-319, 1943.
Wright, H. E., Cerro Colorado, an isolated non-basaltic volcano in central New Mexico: Amer. Jour. Sci., vol. 241, pp. 43-56, 1943.

[20] For detailed discussion of this formation, see:
Bryan, Kirk, Geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico: Regional Planning, Part VI: Rio Grande joint investigation in the Upper Rio Grande Basin (Washington, Nat. Res. Comm., 1938), vol. 1, Pt. II, sec. 1, pp. 209-215, 1938.
Cabot, E. C., Fault border of the Sangre de Cristo mountains north of Santa Fe, New Mexico: Jour. Geol., vol. 46, pp. 88-105, 1938.
Smith, H. T. U., *op. cit.*, pp. 953-960, 1938.
Denny, C. S., Santa Fe formation in the Espanola Valley, New Mexico: Geol. Soc. America, Bull., vol. 51, pp. 677-693, 1940.

east side of the Tusas River Valley and is faulted against older rocks in most other areas. The area immediately northeast of the lowermost part of Alamos Canyon is a complex structural mosaic of pre-Cambrian and volcanic rocks with local fault blocks of Santa Fe beds. In this area and elsewhere such beds are locally strongly deformed, but no pronounced large-scale flexures are present. These rocks are cut and offset by many faults. They have been mineralized by hot springs along fissures in the valley of the Rio Vallecitos south of La Madera and at several places northeast of La Madera.

QUATERNARY DEPOSITS

BASALT FLOWS

Flows of dark-gray fine-grained basalt cap Petaca Mesa, Turkey Mesa, and a part of Jarita Mesa. They appear to be remnants of an extensive basaltic flow that was poured out on a surface of low relief. This surface, which must have sloped gently to the southeast, was developed over areas underlain by a variety of rocks. Thus, the basalt overlies the Santa Fe formation, older volcanic rocks, and pre-Cambrian rocks in the Petaca district. The flows, which form a cover that ranges in thickness from a few feet to 40 feet or more, consist of olivine basalt that is dense to highly vesicular.

SEDIMENTARY DEPOSITS

The basalt-capped mesa lands east of the Tusas River Valley are veneered by unconsolidated water-laid sands and gravels, and by a broad series of low, elongate dunes. The form of the latter is so subdued that many are not easily recognized. Thin veneers of gravels—many merely concentrations of loose boulders—are present on several terrace-like remnants of old erosion surfaces between Jarita Mesa and the Tusas River.

Alluvium has been deposited to form relatively flat valley bottoms along the Tusas River north of Petaca, for a mile northeast from La Madera, in the vicinity of Servilleta Plaza, and along the Rio Vallecitos in the vicinity of Vallecitos, Ancones, and La Madera. Elsewhere the streams follow gorges and relatively narrow, winding canyons.

PEGMATITES

DISTRIBUTION AND OCCURRENCE

The pegmatites in the Petaca district occur in a broadly curving belt that extends from Kiawa Mountain southeast and south to La Madera. This belt is 1 to 4½ miles wide and about 15 miles long. The deposits that have been worked for mica occur in five rather distinct groups. These are shown in Plate 1 and are designated as follows.

A. *Kiawa group.*

The Kiawa group occupies a small area near the northwest corner of the district. The deposits are north of Kiawa Canyon and east-southeast of Kiawa Mountain at altitudes of 8,300 to 8,600 feet. They can be reached over a wagon road that extends from Las Tablas up the canyons of the Tusas River and Kiawa Creek, or over a poor automobile road that reaches Kiawa Canyon from the Jarita Mesa road via South Kiawa Lake.

B. *Persimmon Peak-Las Tablas group.*

The Persimmon Peak-Las Tablas group occupies a long narrow area that extends from a point west of Las Tablas to a point south-southwest of Persimmon Peak, a distance of almost 2 miles. The pegmatites are in rough country at altitudes of 8,000 to 8,400 feet. The area is crossed by the Las Tablas-Vallecitos trail and by the Hoyt wagon road, a winding, circuitous route. A poor road that is passable for automobiles reaches a few of the deposits from the Jarita Mesa road via Poso Spring.

C. *La Jarita-Apache group.*

The La Jarita-Apache group occupies the largest and least sharply defined area in the district. It extends from a point a mile south of Persimmon Peak southward and southwestward for 3 miles to a point west-southwest of Petaca, and includes an area of about 3 square miles. The deposits are at altitudes ranging from 7,450 to 8,350 feet. A graded and gravelled automobile road from Petaca to Goodge Sawmill gives direct access to several mines. Other deposits can be reached over branch roads that extend north to the rim of La Jarita Canyon and south to the rim of Apache Canyon. A poor automobile road also connects the Apache Canyon mines with Petaca.

D. *Cribbenville group.*

The Cribbenville group includes the oldest mines in the district. The deposits are rather closely spaced in a small area, once thickly populated, southwest of South Petaca, and lie between Gabalon Canyon and the rim of Abrevadero Canyon a mile to the south. They are at altitudes of 7,600 to 8,150 feet. Most are served by a good gravelled road that connects with State Route 111 at a point a mile south of South Petaca. Passable side roads reach all but two or three of the remaining deposits.

E. *Alamos group.*

The Alamos group, which includes several large mines, occupies a long narrow area that extends from the Little Julia deposits (south of Abrevadero Canyon) to the Guadalupe deposits in Alamos Canyon, 2½ miles south-southeast. The altitudes of the deposits range from 7,200 to 8,050 feet. The north end of the area can be reached over a poor automobile road that branches from State Route 111 at a point a mile south of Abrevadero Canyon. Other parts of the area are served by a good gravelled road to the Globe mine and by several poor branch roads.

A few outlying deposits cannot be conveniently included in the above groups, and hence are treated separately. Several pegmatites are present north of Jarita Canyon and southeast of the Persimmon Peak-Las Tablas group. The La Paloma and El Floto deposits lie east of the Alamos group and can be reached over a branch from the Little Julia road or over poor roads via the Globe mine or Paloma Canyon. The Hidden Treasure area, a mile south of the Alamos group, is served by a poor road that leaves State Route 111 at a point a mile northeast of La Madera. Other deposits are scattered on both sides of the La Madera-Petaca road between La Madera and a point a mile south of the Little Julia turn-off.

The pegmatites of chief interest occur in the metamorphic rocks west of their contact with the Tusas granite. Those in the granite are small and irregular and hold little or no commercial promise. The pegmatite bodies in metamorphic rocks, on the other hand, are strikingly consistent in many elements of their structure and mineralogy. They can be divided into two groups on the basis of their conformity or lack of conformity with the foliation of the enclosing rock; and they can be further classified on the basis of their own form, attitude, and internal structure.

Most of the deposits are well exposed despite a rather thick cover of vegetation. The pegmatite appears to be more resistant to erosion than much of the country rock, and thus commonly forms knobs and low ridges. The constituent minerals are not

TABLE 1. GENERAL STRUCTURAL RELATIONS OF PEGMATITE BODIES IN THE PETACA DISTRICT

General form of body	*Name*	*Shown in*	*Length on present surface (to nearest 5 feet)*	*Maximum outcrop breadth (feet)*	*Mean strike and dip* [c]	*Approx. mean plunge of body and/or structures within it*	*Mean strike and dip of country-rock foliation or schistosity*	*Plunge of minor structures in country rock*	*Type of pegmatite bodies*	*Remarks*
I. Dike, sill, pipe, or elongate pod	Bonanza	Plate 18	195	40	E.-W. Steep N.	Mod. W.	N. 30° W. 45° WSW.	Mod. W.; Gentle SSE.	Sharp	———
	Coyote	———	250	27	N. 85° W. Steep N.	Mod. W.	N. 40° W. 55° SW.	Mod. W.	Sharp	Tadpole-shaped in plan
	El Floto	Figure 24	680+	90 [a]	N. 70° W. V. steep NNE.	Mod.-gentle WNW.	N. 45° E 30° N.[d]	———	Sharp	One large east-trending branch
	Kiawa (N. dike)	———	1240+	38	N. 75° E. Steep-V. steep S.	Mod.-steep SW.	N. 60° E. 55° SSE.	Mod. SW.	Mod. sharp to sharp	Much mica in adjacent country rock
	La Paloma	Plate 23	260+	32	N. 65° W. Steep-mod. NNE.	Mod. NW.	N. 35° W. 60° SW.	Mod. NW.; Gentle SSE.	Sharp to gradational; many inclusions	Ends of dike covered by younger rocks
	Little Julia	Figure 21	800+	42	N. 75° E. V. steep N.	Gentle WSW.	N. 60° W. 25° SSW.	Gentle WSW.	Sharp	Thickness rather uniform
	Little Julia No. 1	Figure 20	955	25	N. 85° E. Steep N., var.	Mod. W.	N. 10° W. 35° W., var.	Mod.-gentle W. to WNW.	Sharp	Outcrop of dike slightly sinuous
	Lonesome	Plate 9 and Figure 12	165	19	N. 80° E. Steep-V. steep N.	Mod.-steep W.	N. 20° W. Var. WSW.	Mod.-steep W.	Mod. sharp	———
	North Cribbenville (W. dike)	Plate 18	225	30	N. 75° W. V. steep N. and S.	Gentle W.	N. 35° W. 45° SW.	Gentle SSE.; Gentle WNW.	Sharp	Small bulge near W. end of dike
	Silver Plate	———	200+	25[a]	N. 65° E. Steep NNW.[a]	Mod. W. (?)	N. 35° W. 55° SW.	Mod. W.	Mod. sharp to sharp	———
	Silver Spur (N. body)	———	210+	25[a]	N. 35° W. Mod. SW.	Gentle NW.	N. 35° W. 40° SW.	Gentle NW.; Mod. S.	Mod. sharp	Ends of sill not well exposed
	Silver Spur (S. body)	———	450+	36	N. 20°-40° W. Steep-V. steep WSW.-ENE.	Gentle NW.-NNW.	N. 40° W. 40° SW.	Gentle NW.	Sharp	Several small dikes branch from main body
	White	Plate 20	220 [a]	50+	N. 80° E. V. steep N., var.	Gentle-mod. W.	N. 15° W. 40° W.	Mod. W.	Mod. sharp; many inclusions	Crest and keel of dike are very blunt

TABLE 1. GENERAL STRUCTURAL RELATIONS OF PEGMATITE BODIES IN THE PETACA DISTRICT (CONTINUED)

General form of body	*Name*	*Shown in*	*Length on present surface (to nearest 5 feet)*	*Maximum outcrop breadth (feet)*	*Mean strike and dip* [c]	*Approx. mean plunge of body and/or structures within it*	*Mean strike and dip of country-rock foliation or schistosity*	*Plunge of minor structures in country rock*	*Type of pegmatite bodies*	*Remarks*
II. Dike, sill, pipe, or pod with bends, protuberances, or other irregularities *(concluded)*	La Jarita (N. dike)	Plate 8	275	13	N. 75° E. V. steep N.	Mod. W.	N. 25° W. 45° WSW., var.	Mod. W.	Sharp	Two quartz veins branch from dike near its east end
	La Jarita (middle dike)	Plate 8	165	12	N. 70° E. Steep-V. steep NNW.	Mod. W.	N. 25° W. 45° WSW., var.	Mod. W.	Sharp	Dike conformable with prominent set of joints
	La Jarita (S. dike)	Plate 8	155	31	N. 45° E. Steep NW.	Mod. W.-WSW.	N. 25° W. 45° WSW., var.	Mod. WSW.	Sharp	Large bulge at each end of dike
	Nambe	Figure 19	280+	54	N. 85° W. V. steep, var.	Mod. W.	N. 30° W. 50° WSW.	?	Sharp	Quartz vein extends northwest from dike
	Navajo	———	225	56	N. 85° W. Steep S.	Mod. W.	N. 40° W. 55° SW.	Mod. SSE.; Mod. W.	Sharp	Tadpole-shaped in plan, with three quartz branches
	North Cribbenville (main dike)	Plate 18	220 [a]	43	N. 65° W. Steep NNE., var.	Mod.-gentle NW.-WNW.	N. 35° W. 45° SW.	Gentle SSE.; Gentle WNW.	Sharp	Prominent northward bulge near east end of dike
	North Star	Plate 10	525	64	N. 65° W. Steep NNE.-steep SSW.	Mod.-gentle NW.-W.	N. 45° W. 50° SW.	?	Sharp	Large bulge at west end of dike
	Pavo (N. dike)	Plate 18	350+	30+	N. 70° W. Steep SSW.	?	N. 45° W. 40° SW.	Mod. S.; Mod. W.	Sharp	———
	Pavo (middle dike)	Plate 18	625	50 [a]	N. 75° W. Mod.-V. steep S.	Var. W.-SW.	N. 50° W. 40° SW.	Mod. WSW	Mod. sharp to sharp	Splits into two gently-dipping prongs at east end
	Pavo (S. dike)	Plate 18	510	105+	N. 80° W. Mod. S.-steep N.	Mod.-gentle W.-WSW.	N. 45° W. 40° SW., var.	Mod. S.; Mod. W.	Mod. sharp to sharp, with many inclusions	Splits into irregular projections at both ends
	Pinos Altos	Plate 15	350+	26+	N. 45° E. Steep NW.	Mod. W.-WSW.	N. 15° W. 40° W.	Mod. W.	Sharp to gradational	Very sinuous dike
	Prince	———	405	30	N. 60° W. Steep SSW.	?	N. 35° W. 45° SW.	Mod. W.	Mod. sharp to sharp	Very sinuous dike; splits into two short prongs at east end

TABLE 1. GENERAL STRUCTURAL RELATIONS OF PEGMATITE BODIES IN THE PETACA DISTRICT (CONTINUED)

General form of body	*Name*	*Shown in*	*Length on present surface (to nearest 5 feet)*	*Maximum outcrop breadth (feet)*	*Mean strike and dip* [c]	*Approx. mean plunge of body and/or structures within it*	*Mean strike and dip of country-rock foliation or schistosity*	*Plunge of minor structures in country rock*	*Type of pegmatite bodies*	*Remarks*
II. Dike, sill, pipe, or pod with bends, protuberances, or other irregularities	Alamos (E. segment)	Plate 21	170	57	N. 65° E. Steep NNW.	Mod. W.	N. 10° W. 50° W.	Mod. W.	Mod. sharp	Connected with west body by thin neck
	Alamos (W. segment)	Plate 21	355	36	N. 85° W. Steep N.	Mod. W.-WNW.	N. 10° W. 50° W.	Mod. W.	Sharp	Thin sill branches from east end of body
	Alma	Plate 7 and Figure 10	560	30 [a]	N. 20° W. 35° WSW.	Mod.-gentle WSW.	N. 20° W. 40° WSW.	Mod. WSW.; Mod. SSW	Mod. sharp	South two-fifths of body is a long sill-like tail 2 to 3 feet thick
	Bluebird	Figure 16	280+	24	N.-S. Mod. W.	Mod. SW.	N. 20° W. 40° WSW.	Mod. SW.	Mod. sharp to gradational	Much impregnation of country rock with small thick books of mica
	Capitan-Blanca	Plate 18	880	70	N. 85° E. Mod.-steep N.	Mod. WNW.-W.	N. 40° W. 55° SW.	Mod. WSW.-W.	Sharp	Offset 40-45 feet along fault 200 feet from east end of body
	Cribbenville (main body)	Plates 18 and 19	795	115	N. 85° W. Steep N.	Mod.-gentle W.	N. 45° W. 50° SW., var.	Mod. SSE.; Mod. W.	Sharp, with many inclusions	Connected at depth with dike to southeast
	Cribbenville (S. body)	Plate 18	490	46	N. 75° W. Steep N.	Mod.-gentle WNW.	N. 50° W. 55° SW., var.	Mod. SSE.; Mod. W.	Sharp	Prominent bulge at west end of dike
	Etter	Figure 13	700	30 [a]	N. 85° W. Mod.-V. steep S.	Mod. WSW.	N. 50° W. 50° SW.	Gentle SE.; Mod. W.	Sharp	Prominent bulges near east end of dike
	Globe	Plate 22	645	60 [a]	N. 85° W. Steep, var.	Mod. W.	N. 20° W. 40° WSW.	Mod. W.	Mod. sharp to sharp	Faulted off at west end
	Hidden Treasure	Plate 24	390	42	E.-W. Mod.-steep N.	Mod. W.-WNW.	N. 35° W. 45° SW.	Mod. W.-WNW.	Mod. sharp	Two quartz branches project from dike near its east end
	Kiawa (main body)	Plate 6	1430	275	N. 75° E. Steep S., var.	Mod. SW.-gentle WSW.	N. 60° E. 55° SSE.	Mod. SW.	Sharp to gradational	Most of body contains many septa and inclusions of country rock

TABLE 1. GENERAL STRUCTURAL RELATIONS OF PEGMATITE BODIES IN THE PETACA DISTRICT (CONTINUED)

General form of body	*Name*	*Shown in*	*Length on present surface (to nearest 5 feet)*	*Maximum outcrop breadth (feet)*	*Mean strike and dip* [c]	*Approx. mean plunge of body and/or structures within it*	*Mean strike and dip of country-rock foliation or schistosity*	*Plunge of minor structures in country rock*	*Type of pegmatite bodies*	*Remarks*
III. Trough-shaped body, with or without complicating branches	Bonanza Extension	Plate 18	130	55 [a]	N. 60° W. Steep SSW.; E.-W. Steep N.	Mod. W.	N. 30° W. 45° WSW.	Mod. W.; Gentle SSE.	Sharp	Slightly asymmetric, with north flank longer and thicker
	Coats	Plate 17	380	35	N. 30° W. Mod. WSW.; N. 85° W. Steep N., Mod.-steep S.	Mod. WNW.	N. 45° W. 50° SW., var.	Mod. SW.; Mod.-gentle WNW.	Mod. sharp to sharp	Walls of body very irregular in detail
	Conquistador	Plate 11	210 [a]	30+	N. 70° W. Steep-V. steep SSW.; N. 60° W. Steep SSW.-NNE., var.	Mod. W.	N. 40° W. 45° SW.	Mod.-gentle W.	Sharp to gradational, with many inclusions	Main arms of body nearly join to form elliptical outcrop plan
	Fridlund	Figure 17	210	20 [a]	E.-W. Steep-V. steep S.; N. 15° E. V. steep W.	Mod.-steep SW.	N. 40° W. 60° SW., var.	Mod. SW.-WSW.	Mod. sharp to gradational	Distinctly asymmetric; southeast arm is relatively thin and short
	Pino Verde	Figure 18	170+	40 [a]	N. 70° W. Steep-V. steep SSW.; N. 85° E. V. steep N.	Mod. W.	N. 35° W. 50° SW.	Mod. W.	Sharp	Body fishhook-shaped in outcrop plan, with small "fishhooks" projecting from its keel
	Queen	Plate 16	465	47	N. 25° W. Mod. WSW.; N. 85° E. Mod.-steep N.	Mod. W.	N. 35° W. 45° SW.	Mod. W.	Sharp	Thickest part of body is on southwest limb
	South Kiawa	Figure 8	180 [a]	30+	N. 25° E. Mod.-steep WNW.; N. 5° W. Steep W.	Mod. SW.	Pegmatite body in trough of large syncline that plunges moderately southwest		Sharp	Trough overturned to ESE.
	Werner	Figure 14	640 [a]	60+	N. 70° W. Mod. SSW.; N. 85° E. Steep N.	Mod. W.	N. 25° W. 35° WSW.	Gentle S.; Mod.-gentle W.	Sharp	Large branch extends ESE. from trough

TABLE 1. GENERAL STRUCTURAL RELATIONS OF PEGMATITE BODIES IN THE PETACA DISTRICT (CONTINUED)

General form of body	*Name*	*Shown in*	*Length on present surface (to nearest 5 feet)*	*Maximum outcrop breadth (feet)*	*Mean strike and dip* [c]	*Approx. mean plunge of body and/or structures within it*	*Mean strike and dip of country-rock foliation or schistosity*	*Plunge of minor structures in country rock*	*Type of pegmatite bodies*	*Remarks*
IV. Inverted trough-shaped body	Apache	Plate 14 and Figure 15	490+	27	N. 70° E. Mod. NNW.; N. 60° W. Mod. SSW.	Mod. W.	N. 40° W. 50° SW., var.	Mod. SSW., var.; Mod. W.	Sharp	Most of south limb removed by erosion; may have been much shorter and thinner than north limb
	Green Peak	———	500+	45 [a]	E.-W. V. steep N.; N. 85° W. Steep S., var.	Mod.-steep WSW.	Crest of pegmatite body in small fold that plunges mod.-steep WSW.		Sharp	Trough is symmetric
	Keystone-Western	Plate 12	415	35	N. 85° E. Steep-V. steep N.; N. 25° E. Steep WNW.	Mod.-steep NW.	N. 15° W. 50° W.	Mod. NW.	Sharp to gradational	Asymmetric, with east limb longer and more straight
V. Body not assignable to Classes I-IV	Eureka	Figure 9	75 [a]	38	N. 70° E. Steep SSE. to steep-mod. NNW.	Steep-mod. WSW.	N. 40° W. 45° SW., var.	?	Mod. sharp to gradational	Body is wedge-shaped in outcrop plan, with minor projections
	Red	Figures 22 and 23	250+	65+	N. 70° E. Mod.-V. steep NNW., var.	Mod.-steep N.; Mod. W.-WNW.	N. 30° W. 55° WSW.	Mod. W.-WNW.	Mod. sharp	Steeply plunging inverted-trough structure at west end of body
	Sandoval (S. body)	Plate 13	320	55	Asymmetric inverted trough, plunging mod.-steep W.-WNW.; large funnel-like structure on NE. limb plunges mod. NW.		N. 50° W. 55° SW., var.	Mod. S.; Mod. W.	Sharp	Ovoid in outcrop plan, with SW. limb of trough appearing as a thin branch
	Sandoval (W. body)	Plate 13	125+	49	N. 75° W. Steep N.	Mod. WNW.	N. 50° W. 55° SW., var.	Mod. S.; Mod. W.	Sharp	Extremely irregular body, probably connected with S. body at levels above present surface
	Sandoval Extension	———	300+	55 [a]	N. 70° E. Mod.-gentle, var.	?	N. 50° W. 55° SW., var.	Mod. S.; Mod. W.	Sharp	Extremely irregular body

[a] Approximate.

[b] Length represents horizontal distance between ends of pegmatite body, as measured along a line approximately midway between the walls.

[c] Absolute dip values, to the nearest 5°, are as follows:

Gentle	—	10° to 25°	V. steep	—	75° to 90°
Mod.	—	30° to 45°	var.	—	markedly variable.
Steep	—	50° to 70°			

Separate strike and dip values are given for each limb of trough-shaped bodies.

[d] Disturbed, presumably owing to intrusion of several large pegmatite bodies.

weathered to great depths. The freshness and relatively complete exposure of the pegmatites combine to furnish an excellent two-dimensional picture of their structure and mineralogy; in addition, mine workings are still accessible in many deposits. The descriptions and discussions in the following sections are based on a detailed three-dimensional study of the deposits.

GENERAL STRUCTURAL FEATURES

FORM, SIZE, AND ATTITUDE

The pegmatite bodies vary widely in shape and size. Most are dikes, sills, pipes, or pods, but others have more irregular shapes. A general division into five classes can be made on the basis of form, as follows.

Class I. Dikes, sills, pipes, and elongate pods.

Class II. Dikes, sills, pipes, and pods with bends, protuberances, or other irregularities.

Class III. Trough- or scoop-shaped bodies, with or without complicating branches.

Class IV. Bodies with the form of an inverted trough or scoop.

Class V. Other bodies. These include some that are combinations of the above forms, and others so complex in three dimensions that they cannot be classified. Neither type is common.

Though most contacts between pegmatite and country rock are not continuously exposed, enough outcrops are present to show the size and attitude of the bodies. Most are clearly terminated along their strike in both directions. The ends of many are smooth and rounded, but others are marked by long narrow spines or broader less regular projections. The average length, or horizontal distance between the ends at the present surface, is 410 feet for 52 representative bodies that have been worked for mica (see Table 1). The maximum and minimum values are 1,430 feet and 75 feet, respectively. The average maximum breadth of outcrop is 49 feet, and the average breadth is 30 to 35 feet. Slightly less is the average thickness of the bodies, which ranges from a few inches in some stringers to 250 feet or more in the largest bodies. Ratios of length to breadth, which range from little more than 2 to 1 to about 70 to 1, reflect a wide variety of forms, from thick stubby pod-like bodies to thin dikes a thousand feet or more long.

Sills and sill-like bodies, which are most common in the Persimmon Peak-Las Tablas group, strike north to northwest and dip gently to moderately west and southwest. The dikes and

TABLE 1. GENERAL STRUCTURAL RELATIONS OF PEGMATITE BODIES IN THE PETACA DISTRICT (CONTINUED)

General form of body	*Name*	*Shown in*	*Length on present surface (to nearest 5 feet)*	*Maximum outcrop breadth (feet)*	*Mean strike and dip* [c]	*Approx. mean plunge of body and/or structures within it*	*Mean strike and dip of country-rock foliation or schistosity*	*Plunge of minor structures in country rock*	*Type of pegmatite bodies*	*Remarks*
I. Trough-shaped body, with or without complicating branches	Bonanza Extension	Plate 18	130	55 [a]	N. 60° W. Steep SSW.; E.-W. Steep N.	Mod. W.	N. 30° W. 45° WSW.	Mod. W.; Gentle SSE.	Sharp	Slightly asymmetric, with north flank longer and thicker
	Coats	Plate 17	380	35	N. 30° W. Mod. WSW.; N. 85° W. Steep N., Mod.-steep S.	Mod. WNW.	N. 45° W. 50° SW., var.	Mod. SW.; Mod.-gentle WNW.	Mod. sharp to sharp	Walls of body very irregular in detail
	Conquistador	Plate 11	210 [a]	30+	N. 70° W. Steep-V. steep SSW.; N. 60° W. Steep SSW.-NNE., var.	Mod. W.	N. 40° W. 45° SW.	Mod.-gentle W.	Sharp to gradational, with many inclusions	Main arms of body nearly join to form elliptical outcrop plan
	Fridlund	Figure 17	210	20 [a]	E.-W. Steep-V. steep S.; N. 15° E. V. steep W.	Mod.-steep SW.	N. 40° W. 60° SW., var.	Mod. SW.-WSW.	Mod. sharp to gradational	Distinctly asymmetric; southeast arm is relatively thin and short
	Pino Verde	Figure 18	170+	40 [a]	N. 70° W. Steep-V. steep SSW.; N. 85° E. V. steep N.	Mod. W.	N. 35° W. 50° SW.	Mod. W.	Sharp	Body fishhook-shaped in outcrop plan, with small "fishhooks" projecting from its keel
	Queen	Plate 16	465	47	N. 25° W. Mod. WSW.; N. 85° E. Mod.-steep N.	Mod. W.	N. 35° W. 45° SW.	Mod. W.	Sharp	Thickest part of body is on southwest limb
	South Kiawa	Figure 8	180 [a]	30+	N. 25° E. Mod.-steep WNW.; N. 5° W. Steep W.	Mod. SW.	Pegmatite body in trough of large syncline that plunges moderately southwest		Sharp	Trough overturned to ESE.
	Werner	Figure 14	640 [a]	60+	N. 70° W. Mod. SSW.; N. 85° E. Steep N.	Mod. W.	N. 25° W. 35° WSW.	Gentle S.; Mod.-gentle W.	Sharp	Large branch extends ESE. from trough

TABLE 1. GENERAL STRUCTURAL RELATIONS OF PEGMATITE BODIES IN THE PETACA DISTRICT (CONTINUED)

eneral form of body	*Name*	*Shown in*	*Length on present surface (to nearest 5 feet)*	*Maximum outcrop breadth (feet)*	*Mean strike and dip* [c]	*Approx. mean plunge of body and/or structures within it*	*Mean strike and dip of country-rock foliation or schistosity*	*Plunge of minor structures in country rock*	*Type of pegmatite bodies*	*Remarks*
. Inverted trough-shaped body	Apache	Plate 14 and Figure 15	490+	27	N. 70° E. Mod. NNW.; N. 60° W. Mod. SSW.	Mod. W.	N. 40° W. 50° SW., var.	Mod. SSW., var.; Mod. W.	Sharp	Most of south limb removed by erosion; may have been much shorter and thinner than north limb
	Green Peak	——	500+	45 [a]	E.-W. V. steep N.; N. 85° W. Steep S., var.	Mod.-steep WSW.	Crest of pegmatite body in small fold that plunges mod.-steep WSW.		Sharp	Trough is symmetric
	Keystone-Western	Plate 12	415	35	N. 85° E. Steep-V. steep N.; N. 25° E. Steep WNW.	Mod.-steep NW.	N. 15° W. 50° W.	Mod. NW.	Sharp to gradational	Asymmetric, with east limb longer and more straight
. Body not assignable to Classes I-IV	Eureka	Figure 9	75 [a]	38	N. 70° E. Steep SSE. to steep-mod. NNW.	Steep-mod. WSW.	N. 40° W. 45° SW., var.	?	Mod. sharp to gradational	Body is wedge-shaped in outcrop plan, with minor projections
	Red	Figures 22 and 23	250+	65+	N. 70° E. Mod.-V. steep NNW., var.	Mod.-steep N.; Mod. W.-WNW.	N. 30° W. 55° WSW.	Mod. W.-WNW.	Mod. sharp	Steeply plunging inverted-trough structure at west end of body
	Sandoval (S. body)	Plate 13	320	55	Asymmetric inverted trough, plunging mod.-steep W.-WNW.; large funnel-like structure on NE. limb plunges mod. NW.		N. 50° W. 55° SW., var.	Mod. S.; Mod. W.	Sharp	Ovoid in outcrop plan, with SW. limb of trough appearing as a thin branch
	Sandoval (W. body)	Plate 13	125+	49	N. 75° W. Steep N.	Mod. WNW.	N. 50° W. 55° SW., var.	Mod. S.; Mod. W.	Sharp	Extremely irregular body, probably connected with S. body at levels above present surface
	Sandoval Extension	——	300+	55 [a]	N. 70° E. Mod.-gentle, var.	?	N. 50° W. 55° SW., var.	Mod. S.; Mod. W.	Sharp	Extremely irregular body

[a] Approximate.

[b] Length represents horizontal distance between ends of pegmatite body, as measured along a line approximately midway between the walls.

[c] Absolute dip values, to the nearest 5°, are as follows:

Gentle	—	10° to 25°	V. steep	—	75° to 90°
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Steep	—	50° to 70°			

Separate strike and dip values are given for each limb of trough-shaped bodies.

[d] Disturbed, presumably owing to intrusion of several large pegmatite bodies.

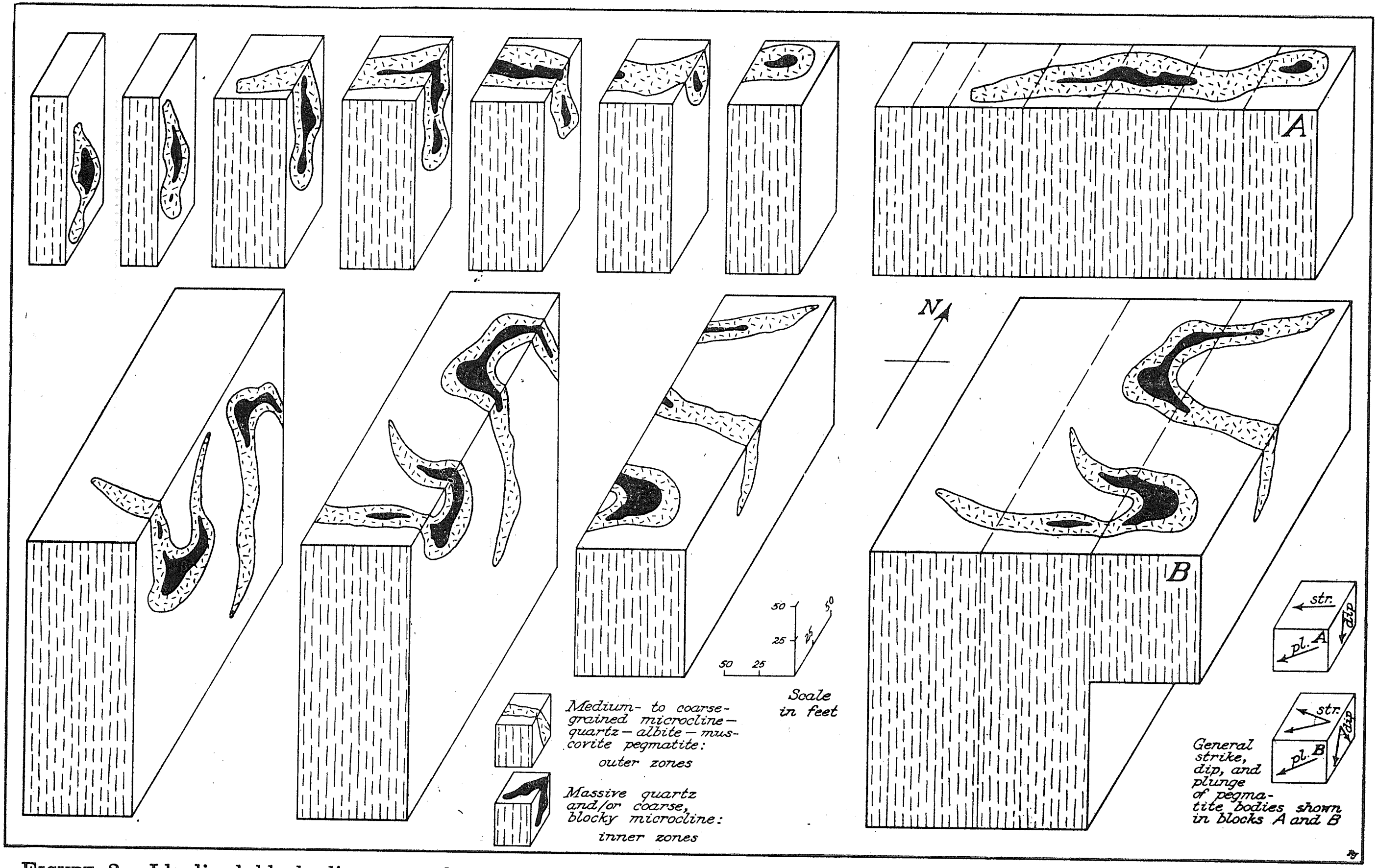

FIGURE 2. Idealized block diagrams showing three-dimensional relations of typical pegmatite bodies in the Petaca district.

only gap in our knowledge of the dimensions of the pegmatites. Erosion has removed large parts of some bodies, but has cut out only the tops of others, so that it is difficult to correlate their remaining down-plunge dimensions with present width or strike length. It seems probable, however, that the maximum original dimensions of most bodies were those measured along their plunges, and were several times the present strike lengths.

WALL-ROCK STRUCTURE

The planar structures in the pre-Cambrian quartzite and quartz-mica schist commonly strike north-northwest to northwest, and dip west-southwest to southwest at low to moderately high angles. The bedding in these rocks, where still recognizable, is essentially conformable with the foliation and schistosity, except along the crests or troughs of folds. These structures are much contorted adjacent to many pegmatite bodies, where they are generally restricted to narrow zones adjacent to the pegmatite contacts. Excellent examples occur at the Apache, La Paloma, and Lonesome deposits, though at others, such as the El Floto, Cribbenville, and Fridlund, the disturbance extends much farther from the pegmatite masses.

Many of the pegmatite bodies are remarkably uniform in attitude, and appear to have been injected into fractures or faults in the country rock. The evidences of original structural control of others have been partly or wholly obscured through alteration of the country rock by pegmatitic solutions. Many of the sills appear to have been emplaced along mechanically weak or otherwise susceptible beds. The strong distortion of the quartzite and schist adjacent to some pegmatites may be due either to the force of emplacement of those bodies or to earlier disturbance along fractures into which the pegmatites were subsequently injected. Little post-pegmatite movement is recognizable in most deposits; the pegmatite minerals are not markedly sheared and most contacts between pegmatite and country rock are undisturbed.

Many linear structures exist on bedding and foliation surfaces of quartzite and schist. These structures include minor closely spaced crenulations; streaks of minerals and aligned minerals of platy or elongate habit; lines of intersection of bedding and foliation planes, or of fracture cleavage and bedding planes; and the axes of drag folds. The crenulations, which are generally present in the more micaceous layers, tend to plunge south to southeast at moderate angles. Remnants of an apparently earlier set of crenulations, which can be recognized in some outcrops, plunge northwest to southwest. The aligned minerals and mineral streaks consist chiefly of biotite, fine-grained muscovite, chlorite, or amphibole. Like the crenulations, they generally plunge south to southeast.

Ripple marks and the intersections of planar structures generally plunge west-northwest to west-southwest, but too few observations are available for a general interpretation. Drag folds, which are relatively common, range from small discontinuous features that are little more than crenulations to large tightly compressed folds 10 feet or more from flank to flank. The axes of the folds pitch northwest to southwest at gentle to moderate angles.

At least two rather well-defined sets of pitching linear structures are evidently present in the district. One of these, which includes the axes of drag folds, an apparently early set of crenulations, and possibly other structures, is strikingly conformable with the plunge of pegmatite bodies and minor pegmatite structures in both direction and degree (Table 1). The chronologic relations between the two groups of structures in the country rock and between individual members of the groups are not fully understood.

INTERNAL STRUCTURE

GENERAL STATEMENT

The Petaca pegmatites are aggregates of microcline, quartz, plagioclase, and muscovite, named in their order of abundance. Some of these minerals occur in the interior of the pegmatites as crystals of giant size. The chief accessory constituents, in the approximate order of their abundance, are spessartite, green fluorite, columbite-tantalite, monazite, beryl, ilmenite and magnetite, bismutite and associated secondary bismuth minerals, purple fluorite, samarskite, sulfides, uraninite and secondary uranium minerals, pink muscovite, apatite, lepidolite, and tourmaline. These minerals form aggregates that range in texture from fine-grained (general grain size of less than 1 inch) through medium-grained (1 to 4 inches) and coarse-grained (4 to 12 inches) to giant (more than 12 inches). Many occur in well-defined rock units that are mineralogically or texturally distinct from adjacent units in the same pegmatite. The distribution of these units is definitely related to the over-all structures of the body and to minor structures within it and in the adjacent country rock.

The distribution of minerals within each unit also obeys certain general rules, although it is irregular in detail. This irregularity has caused some investigators to conclude that the deposits are so complex that no broadly consistent features are present. On the other hand, Just's tentative suggestion[21] that several of the pegmatite minerals occur in recognizable concentrations or "shoots" demonstrates his realization that many if not most of the irregularities are only superficial.

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[21] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba Counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, p. 47, 1937.

A general orderliness in the distribution of mineralogic and lithologic units in many pegmatites has been long recognized. References to segregations, veins, lenses, layers, bands, streaks, and ribs of massive quartz are common in reports written 20 to 40 years ago. Moreover, it has been recognized that cavities, concentrations of many unusual minerals, and concentrations of economically desirable minerals tend to occur at specific positions within a given deposit. For years, however, the attention of geologists was focused more upon the mineralogy of such units than upon their structure. More recent investigators have placed increasing emphasis upon the detailed mapping and structural interpretation of individual parts of pegmatites and have demonstrated the economic value of such studies in exploration, development, and mining.[22] That concentrations of economically desirable pegmatite minerals tend to occur in rock units distinct from adjacent barren units has been repeatedly confirmed by careful studies in many areas. On the other hand, few homogeneous pegmatite deposits are known to contain such minerals in concentrations rich enough to permit profitable mining operations under present economic conditions. The concept of pegmatite units provides a convenient means for classifying and systematically analysing the concentrations of useful pegmatite minerals. Thus, deposits of a given structural type can be compared with those of other types, not only as to size, shape, and richness, but on the basis of mining and extraction costs, quality of production, and other economic factors.

Detailed mapping and study of individual deposits in the Petaca district have raised many questions concerning the nature, significance, recognition, and nomenclature of structural and petrologic units in pegmatites. Some must remain unanswered until more complete basic data become available, but tentative answers to others can be given. The general concepts upon

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[22] See, for example:

Smith, W. C., and Page, L. R., Tin-bearing pegmatites of the Tinton district, Lawrence County, South Dakota: U. S. Geol. Survey Bull. 922-T, 35 pp., 1941.

Olson, J. C., Mica-bearing pegmatites of New Hampshire: U. S. Geol. Survey Bull. 931-P, pp. 373-376, 1942.

Bannerman, H. M., Structural and economic features of some New Hampshire pegmatites: New Hampshire State Planning and Dev. Comm., Min. Res. Survey, Part VII, 22 pp., 1943.

Page, L. R., Hanley, J. B., and Heinrich, E. Wm., Structural and mineralogical features of beryl pegmatites (abstract): Econ. Geol., vol. 38, pp. 86-87, 1943.

Cameron, E. N., Larrabee, D. M., McNair, A. H., and Stewart, G. W., Characteristics of some New England mica-bearing pegmatites (abstract): Econ. Geol., vol. 39, p. 89, 1944.

Jahns, R. H., and Wright, L. A., The Harding beryllium-tantalum-lithium pegmatites, Taos County, New Mexico (abstract): Econ. Geol., vol. 39, pp. 96-97, 1944.

Olson, J. C., Parker, J. M. III, and Page, J. J., Mica distribution in western North Carolina pegmatites (abstract): Econ. Geol. vol. 39, p. 101, 1944.

de Almeida, S. C., Johnston, W. D., Jr., Leonardoes, O. H., and Scorza, E. P., The beryl-tantalite-cassiterite pegmatites of Paraiba and Rio Grande do Norte, northeastern Brazil: Econ. Geol., vol. 39, pp. 206-223, 1944.

Johnston, W. D., Jr., Beryl-tantalite pegmatites of northeastern Brazil: Bull. Geol. Soc. America, vol. 56, pp. 1015-1070, 1945.

Cameron, E. N., Larrabee, D. M., McNair, A. H., Page, J. J., Shainin, V. E., and Stewart, G. W., Structural and economic characteristics of New England mica deposits: Econ. Geol., vol. 40, pp. 369-393, 1945.

which these answers are founded are outgrowths of studies in the Petaca district, but they were developed more fully during discussions with E. N. Cameron, A. H. McNair, L. R. Page, and others who have been considering similar problems in other pegmatite districts. They therefore represent the combined efforts of many men. A fuller treatment of pegmatite units and the internal structure of pegmatites is to be published elsewhere,[23] but the following extract is presented as a background for specific analysis of the Petaca deposits.

The lithologic and structural units that can be recognized in many pegmatite bodies comprise (1) fracture fillings, generally tabular bodies that fill fractures in previously consolidated pegmatite, (2) replacement bodies, formed at the expense of preexisting pegmatite with or without obvious structural control, and (3) zones, which are successive layers or shells, complete or incomplete, that commonly have boundaries roughly parallel to those of the main body. All these units are distinguishable on the basis of contrasting composition or texture, or both. Contacts between units range from knife-edge sharpness to broad gradation amounting to 5 feet or more. Some are straight or uniformly curving, whereas others are very irregular.

The zones of a pegmatite, in ideal development, are successive shells concentric about an innermost zone or core. Some concentric or partly concentric units, however, are not zones, but result from fracture filling or replacement. The configuration of true zones reflects the shape of the pegmatite body, as shown in Figure 3A. In contrast, some of the zones are incomplete or discontinuous, and all gradations exist between complete zones and those that are developed only along one side or at one end of a body. These incomplete units occur in a wide variety of forms, of which lenses, layers, and pods are the most common (Figure 3). Zones generally appear to result from development of the pegmatite in successive stages inward from its walls. Inner zones, or apophyses from these zones, commonly transect outer zones; the reverse relation is unknown.

Zones are the earliest units to be formed within a pegmatite body. In the Petaca district they do not appear to have been formed by the wholesale replacement or metasomatism of preexisting pegmatite; but the possibility must be recognized of primary reactions, in which freshly formed zones were attacked and partially or wholly obliterated by solutions with which they were no longer in equilibrium. Distinction between such primary reactions and the later-stage replacement of fully or almost fully formed pegmatite by hydrothermal solutions is not always easily made, although the two processes are of fundamentally different significance.

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[23] Cameron, E. N., Jahns, R. H., McNair, A. H., and Page, L. R., The internal structure of granitic pegmatites: in preparation, 1946.

As most pegmatites are not completely exposed in three dimensions, incomplete zones may escape detection, either through lack of exposure or through removal by erosion. Moreover, zoned pegmatites appear unzoned if only one unit is exposed. As minable concentrations of desirable pegmatite minerals occur in specific parts of zoned bodies, the possible presence of undetected zones beneath the surface may be of considerable economic importance.

Structural units other than zones are formed in pre-existing pegmatite, commonly with clearly recognizable structural control. In this sense they are secondary features. Fracture fillings that are formed by the simple filling of fractures without replacement of the walls are similar in many respects to non-pegmatitic ores that were formed in open spaces. Fracture-controlled replacement bodies are formed dominantly by replacement of the walls of single fractures or groups of fractures. The form of such bodies is commonly similar to that of the openings from which it grew, although only the vaguest traces of primary control may remain. Both fracture fillings and replacement bodies may form at any stage after the consolidation of any part of a zoned or unzoned pegmatite. They may cut across one or more zones, generally those nearest the walls of the pegmatite. These later bodies tend to transect the entire sequence of zones or the entire pegmatite mass if it is unzoned. They then become increasingly difficult to distinguish structurally from dikes formed independently of the containing pegmatite.

Selective replacement, partial or complete, of a zone or group of zones yields partial or complete zonal pseudomorphs. Many such replacements are controlled by fractures, and units formed in this way are merely special types of fracture-controlled replacement bodies. Perfect pseudomorphs, in which zone boundaries are not transected by the replacement, are rare, but for practical purposes the overlap into adjacent zones ordinarily can be disregarded. Another source of irregularity is the partial replacement of zones. A partial zonal pseudomorph, as well as typical fracture fillings and fracture-controlled replacement bodies, is shown in Figure 3B.

ZONES

CLASSIFICATION

A classification of zones has been proposed by members of the Geological Survey[24] as follows:

1. Border zones
2. Wall zones
3. Intermediate zones
4. Innermost zones or cores.

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[24] Cameron, E. N., Jahns, R. H., McNair, A. H., and Page, L. R., *op. cit.*, 1946.

Figure 3 shows a somewhat idealized plan of these zones in a pegmatite body.

The border zones are fine-grained selvages that in most pegmatites are not more than a few inches thick. Most are of little significance in the mining or quarrying of pegmatites, and hence in the industry are not distinguished from adjoining zones. Wall zones, next inside the border zones, are coarser and much thicker. Although they are actually the zones second from the margins of pegmatite bodies, the designation "wall zone" has been retained in recognition of a terminology firmly established in pegmatite mining. Since border zones rarely are economic or mappable units, the term "wall zone", though strictly a misnomer, is nevertheless useful and widely understood.

The core or innermost zone generally occurs at or near the center of the pegmatite. Any zone between the core and the wall zone is an intermediate zone. Any number of intermediate zones may exist, but few pegmatites contain more than three. The innermost zone of a pegmatite cannot always be identified, for not every core can be seen or even predicted with reasonable assurance. Thus, a central unit identified as a core at one level may prove to be an intermediate zone when the top of the true core is exposed by subsequent mining (see Figure 12).

All units that can be distinguished on the basis of their mineralogy or texture were mapped during the Petaca investigations. Zones are identified in several of the maps and sections. Owing to lack of space, however, zones and and mappable components of zones are not distinguished in most of the maps.

BORDER ZONES

The border zones of pegmatites in the Petaca district range widely in thickness and grain size. Some are sharply defined and others fade into the country rock, the adjacent wall zones, or both. Some cannot be designated on maps because they are thin rinds, others because it is impossible to draw a line between them and adjacent units.

Most of the border zones are fine- to medium-grained aggregates of microcline, quartz, and small amounts of mica, with or without garnet, fluorite, and beryl. Such zones have sharp contacts with the country rock and may have been formed through rapid initial cooling of the pegmatite. They range in thickness from a fraction of an inch to several feet, and are well developed in the Cribbenville, Kiawa, Little Julia, Pinos Altos, and Queen deposits, where they are readily distinguishable from adjacent coarse-grained wall-zone pegmatite of nearly identical composition. Elsewhere, as in the Pino Verde, Silver Spur, and El Floto deposits, this type of border zone is represented by a very thin selvage that lies between coarse, microcline-rich pegmatite and the country rock.

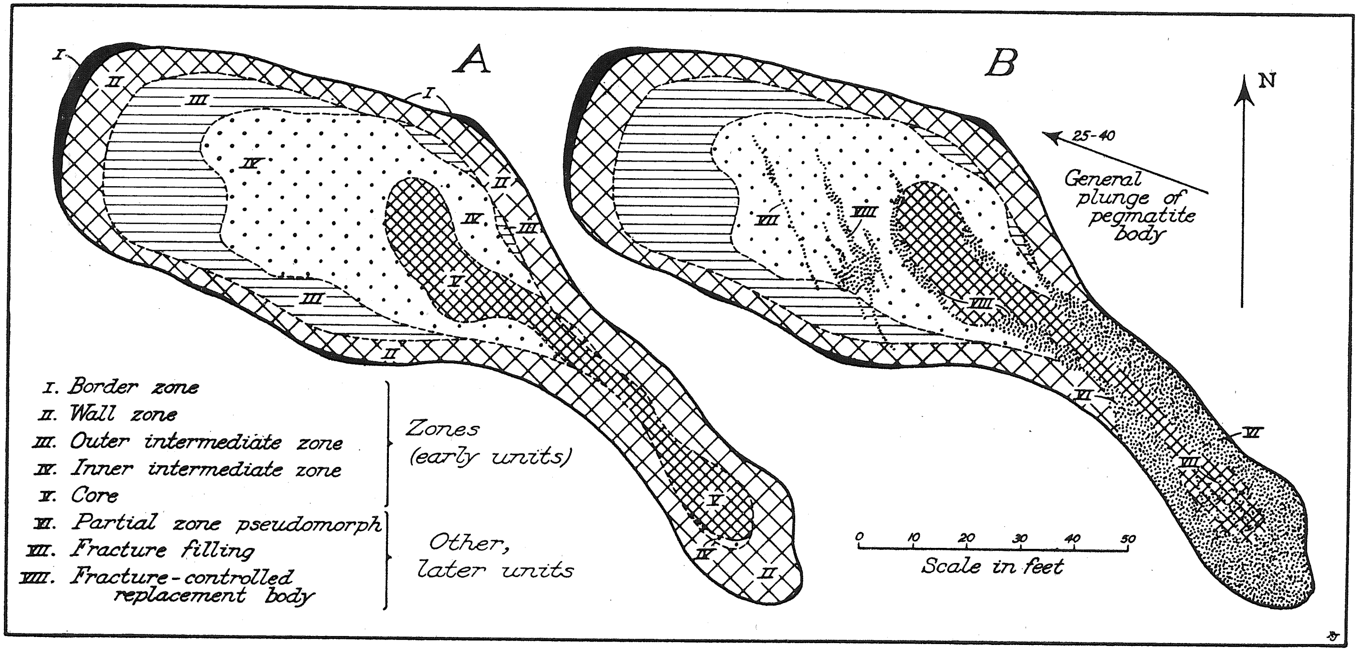

FIGURE 3. Idealized plans of pegmatite body showing distribution of zones (A) and other units superimposed on zones (B).

A second type is a relatively thin mica-rich rind between the country rock and the interior portions of the pegmatite. Such border zones generally represent strong reaction with the country rock and accompanying digestion of schistose material. They are well shown in the Hidden Treasure and locally in the White and Alamos deposits.

The broadest border zones occur in deposits around which the country rock has been soaked with pegmatitic material, as in the La Paloma, Conquistador, Eureka, Fridlund, Bluebird No. 2, and parts of the Kiawa. Zones of this type are irregular in detail and consist of medium to coarse aggregates of microcline, quartz, and small flakes of pale green mica. Some are also rich in albite-oligoclase feldspar. The mica flakes commonly are oriented parallel with the foliation of the adjoining schist and quartzite, and in many places this orientation is a relict of the country-rock structure.

WALL ZONES

Most wall zones are well defined. They range in thickness from a knife edge to several tens of feet, and generally consist of coarse microcline and quartz, with minor quantities of mica, garnet, fluorite, and beryl. Locally the quartz appears as irregular rods and spindles in the microcline to form rude graphic granite. Where the zoning is not distinct, the coarse wall-zone material commonly grades inward into pegmatite of nearly identical composition but extremely coarse texture. Giant crystals of microcline, some with well developed faces, form a mosaic in quartz, and locally the quartz is present as relatively pure masses several feet or more in diameter. Where zoning is more distinct the interior units tend to differ markedly from the wall zones in both composition and texture.

Some wall zones are so well developed that they form complete or nearly complete envelopes around the interior portions of pegmatites (Figure 3). Such zones are present in the Silver Spur, Alma, North Star, and Pinos Altos deposits. Others are incomplete, either because they were never fully formed or because they were formed but partly removed through reaction with solutions during original consolidation of the pegmatites. These generally appear as lenses, layers, or trough-like hoods. Excellent examples of such partial wall zones are present in the White, La Jarita (middle and south dikes), and Nambe deposits. Still others were complete or nearly complete, but have been partially obliterated through the action of late-stage replacing solutions.

INTERMEDIATE ZONES

The intermediate zones are probably the least regular of the zonal units. They are not present in some deposits, but as many as three occur in others. Such zones are rarely complete. They occur most commonly as hood-like units in the western (or upper) parts of the plunging dikes, sills, pods, and inverted troughs. Limbs of these hoods taper out along the sides of the bodies—eastward in plan and downward in section (see Figures 3 and 4). Intermediate zones generally occur on the flanks of normal trough-shaped bodies, as well as near their keels. Even where incomplete, they wrap partly around the innermost zones or cores.

The thickness of intermediate zones ranges even more widely than that of wall zones. Where they are uniformly developed as hood-like units, their thickness increases progressively from flanks to crest. In many other places their form is simpler, though not necessarily more regular. They occur, for example, as thin lenses, thick pod-like masses, layers of relatively uniform thickness, or large, irregular masses without consistent form. Thin lenses are most common, and generally extend beyond the tapering ends of hoods (Figure 3).

The composition of these zones likewise has a wide range. The most common rock types are (a) coarse blocky microcline, (b) coarse graphic granite, and (c) massive quartz with scattered microcline crystals 6 inches to 12 feet or more in diameter. Where all three types are present in a west-plunging pegmatite body, they can be traced on the surface as intermediate zones in the order (b) - (a) - (c) from west to east. In cross section they follow the same order from top to bottom. This sequence is strikingly consistent, whether all three or only two of these rock types are present, and only a few minor exceptions are known. Typical intermediate zones occur in many Petaca pegmatites, and are unusually well developed in the North Star, Lonesome, Alamos, Globe, Nambe, and White deposits.

CORES

Cores or innermost zones occur near the keels of the pegmatite, and hence appear near the east ends of their surface exposures (Figures 3 and 4). They generally consist of massive quartz, with or without scattered large crystals of microcline. The cores of a few zoned deposits are coarse-grained microcline-quartz pegmatite, with or without graphic granite. Like the outer zones, cores commonly have the shape of the adjacent walls of the pegmatite. They generally appear in the thickest part of the body. The core may be a single body, or it may be discontinuous and appear as a centrally located chain of thin lenses or thicker pod-like masses. Single cores range from long thin spines to thick ellipsoidal or pipe-like masses. They seem to represent the last zone to form in all the deposits.

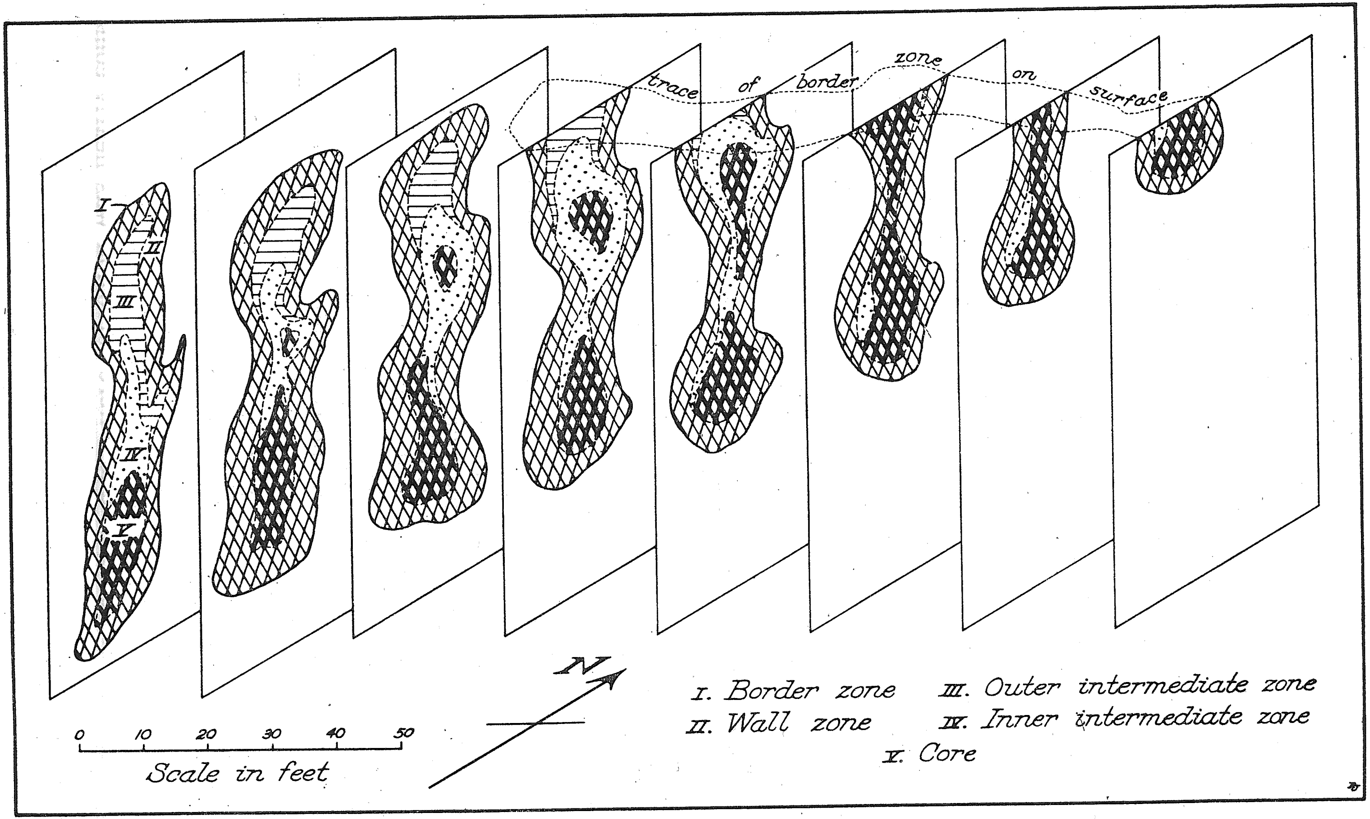

Figure 4. Idealized series of sections showing characteristic three-dimensional distribution of zones in a dike-like pegmatite body, Petaca district.

OTHER STRUCTURAL UNITS

FRACTURE FILLINGS

Most fracture fillings in the pegmatite bodies consist of quartz, with or without albite, samarskite, fine-grained mica, sulfides, and bismuth minerals. These quartz veins range in thickness from a fraction of an inch to a foot or more. Some cut across entire pegmatite bodies, transecting all zones and zonal boundaries. Other, earlier veins cut one or more outer zones but merge into a quartzose portion of an intermediate zone or the core. Most of the fracture-filling quartz is clear and colorless to milky white or light gray, but some of the latest veins consist of light to dark smoky quartz that commonly contains scattered small masses of samarskite.

Veinlets of coarse platy albite (cleavelandite) occur in the massive quartz, blocky microcline, and coarse microcline-quartz pegmatite of many deposits. They follow irregular fractures in quartz, and cleavage-controlled fractures in the potash feldspar. Where abundant, they form rectangular to irregularly anastomosing networks. Some appear merely to have filled open spaces, but most have partly replaced the fracture walls. Fracture-filling veinlets of late-stage microcline are rare, but are present in the Lone Wolf deposit, where they cut graphic granite, and in the Cribbenville deposit, where they cut microcline and quartz. The feldspar veins are markedly less continuous than the quartz veins. Fracture fillings occur in nearly all the pegmatites, but they are especially well exposed in the Apache, Kiawa, Cribbenville, Globe, La Jarita, Alamos, Coats, Sandoval, and Keystone-Western deposits.

Some of the veins consist of layers that are generally ¼ inch or less in thickness and are conformable with the fracture walls. Many seem to have been formed by repeated fracturing and subsequent deposition of material having the same or different compositions. The origin of other layers is obscure. The wall-to-core sequence in the layered veins generally is quartz—smoky quartz, feldspar—quartz, or feldspar—quartz—smoky quartz. Quartz, albite, and smoky quartz, deposited in the order named, occur in the north incline of the Globe mine and in the footwall stopes of the White mine.

REPLACEMENT BODIES

Albite and muscovite are the chief constituents of the fracture-controlled replacement bodies in the Petaca pegmatites. Some of these bodies are fracture fillings that have corroded the fracture walls. Further corrosion has produced irregular veinlets or groups of veinlets; and where corrosion was nearly complete, only remnants of the original material are left. These remnants may represent the cores of original fracture blocks. Thus all gradations in the replacement of quartz by cleavelandite can be seen in the cores of the Globe and Cribbenville pegmatites. The pattern of veinlets and larger, less regular masses of the replacing material is a characteristic result of partial replacement of a fractured homogeneous material.

Where the original material in these pegmatites was heterogeneous, most of the replacement was distributed in greater detail throughout the rock, chiefly because the controlling fractures were more closely spaced. Fractures in the typical wall-zone pegmatite, a coarse-grained microcline-quartz rock, extended not only through the constituent minerals but also along contacts between minerals. Thus fractures and grain boundaries combined to furnish many avenues of access for the replacing solutions, and the resulting albitization was widespread, regardless of its degree. An appreciable amount of fracture-controlled albite and mica is present in the wall zone of every pegmatite in the district, and many of these zones have been almost completely replaced. The albite, generally accompanied by muscovite, contains scattered crystals of beryl, bismuth minerals, columbite-tantalite, fluorite, garnet, monazite, samarskite, sericite, and sulfides.

Although the origin and control of these small masses of albite are evident from careful inspection of outcrops, mine workings, and dump specimens, the origin of other, somewhat larger bodies is not so plain. Such bodies generally appear as rosettes, "pillows", "bursts", or masses without distinctive shape (Figure 3B). A few that evidently were only partially formed indicate an original control by fractures, and the others probably represent fracture-controlled replacement bodies in which little or no trace of the primary fractures remains. They are present in all types of pegmatite, are common along contacts between zones, and are particularly abundant along the margins of quartz cores. Their size and number seem to be in direct proportion with the relative abundance of albite.

Individual rosettes or "bursts" of albite range in diameter from a few inches to more than 11 feet, and cleavelandite crystals within them are ½ inch to 5 inches long. The long dimensions of the crystals lie normal to the outer surface of the body in which they occur. Layered structures are common. The outer 2 to 6 inches of a series of large rosettes exposed in the No. 1 adit and adjacent stopes of the Apache mine consist of alternating layers of smoky quartz and cleavelandite, ranging in thickness from ⅛ inch to 1 inch. This structure is interpreted as a result of diffusion,[25] possibly involving reaction with the adjacent

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[25] For discussions of diffusion and diffusion layering, see:

Liesegang, R. E., Geologische diffusionen, Dresden and Leipzig, 1913.

Knopf, Adolph, Geology of the Seward Peninsula tin deposits: U. S. Geol. Survey Bull. 358, pp. 45-49, 1908.

Whitman, A. R., Diffusion in ore genesis: Econ. Geol., vol. 23, pp. 473-488, 1928.

Lindgren, Waldemar, *Mineral deposits,* pp. 176-177, New York, 1933.

Jahns, R. H., "Ribbon rock", an unusual beryllium-bearing tactite: Econ. Geol., vol. 39, pp. 186-189, 203-204, 1944.

rock, which is chiefly massive quartz. Many individual "bursts" and cauliflower-like aggregates of such masses are fringed with layers of small pale-green mica books ½ inch to 6 inches thick. These generally occur where the bounding material is microcline or microcline-rich pegmatite, and they may well represent reaction between the replacing solutions and the potash feldspar. An unusual type of layering is present at the margins of a broad aggregate of albite "bursts" in one of the pegmatites of the Alto group. The outer surfaces of the "bursts" are marked by a concentration of small yellow mica books, well-formed tabular garnet crystals as much as ½ inch in maximum dimension, and scattered tiny masses of samarskite, columbite, and monazite. Inside this layer is a 1- to 1½-inch layer of cleavelandite, followed locally by a very thin layer that contains many small masses of garnet and columbite. The remainder of each "burst" is cleavelandite.

Zone pseudomorphs have been formed where replacement of zones has been complete or nearly so. The wall zone of the Hidden Treasure deposit, for example, has been so thoroughly impregnated with albite and mica that it has lost its identity. Small residual mineral masses are the sole evidence that it was originally a coarse-grained microcline-quartz rock with small quantities of garnet, fluorite, and beryl. More commonly the replacement is less complete. The line of distinction between zones and partial zonal pseudomorphs in such deposits is necessarily arbitrary, even where the relations themselves are clear.

Partial pseudomorphs of zones generally occur as lenses or hood-like sheaths along the keels of pegmatite bodies, and hence appear at or near the eastern ends of their outcrops. They have commonly been formed at the expense of wall zones, although they tend to transect the boundaries between wall zones and adjacent cores or intermediate zones. Such secondary units are well exposed in the North Star deposit, where the east half of the wall zone has been thoroughly albitized, and in the Alamos deposit, where similar replacement has occurred in the eastern portion of the wall zone in each pegmatite body. Such partial pseudomorphs taper out upward and westward along the inner margins of the wall zones, as shown in the Pino Verde, Nambe, Fridlund, and White deposits. Their positions appear to have been governed by fractures along such margins.

Where albitization has been particularly extensive, the entire core has been replaced, and the resulting unit thus comprises a pseudomorph of the core and partial pseudomorphs of the border zone, wall zone, and possibly even an intermediate zone. The keel of the main Cribbenville body has been thus affected, and only remnants of the zones remain. Similar composite pseudomorphs of zones occur in the Silver Plate deposit, and probably in the Red deposit. Just as the Petaca pegmatites show all degrees of albitization, they also illustrate all stages in the progressive development of composite zonal pseudomorphs.

Another type of imperfect pseudomorph involves the selective replacement of certain minerals in a zone to form partial or complete mineral pseudomorphs but only a partial zone pseudomorph. Thus, many of the giant microcline crystals in the inner intermediate zone of the main Cribbenville dike have been replaced by sugary albite, but the surrounding massive quartz has not been affected. Similar replacement is less complete in the Freetland, Globe, Apache, and many other deposits.

RELATIONS BETWEEN PEGMATITES AND QUARTZ VEINS

Detailed maps of several areas in the Petaca district (see Plates 7, 8, 13, 16, 17, 18) and supplemental detailed observations in other areas demonstrate that few of the quartz veins are connected with pegmatite bodies at the present surface. Moreover, it seems likely that few are connected at depth, although a close genetic relationship is suggested. A few veins are sensibly later than the primary pegmatites, for they cut across entire dikes. Others are later than some parts of the pegmatites and essentially contemporaneous with other parts, as they cut some of the outer zones and merge with the intermediate zones or cores. Well-exposed examples occur in the La Jarita (north dike), Hidden Treasure, and Navajo deposits.

Many of the veins have been fractured and partly albitized in the same manner as the neighboring pegmatites. The similarity is more marked where quartz veins actually grade into pegmatite. Some veins can be traced for tens or even hundreds of feet as bodies of apparently pure quartz or quartz with only small and scattered quantities of albite. As traced farther, however, they become markedly pegmatitic, chiefly through the addition of microcline along their walls. As the amount of microcline increases, thin but well-defined wall zones can be recognized and the massive quartz becomes a pegmatite core. Such gradations can be traced along the strike of many veins, although these veins constitute a very small proportion of the total. Unusually clear-cut examples include the Maulsby (east end), Cribbenville (east end of south body), Keystone-Western (end of south limb), Kiawa (many veins on both sides of main pegmatite), and Coyote deposits.

The quartz cores of several deposits can be traced into crosscutting quartz veins that extend out to the walls of the containing bodies and thence along the walls. Such features superficially resemble quartzose border zones but actually are later fracture-fillings that are essentially contemporaneous with the innermost zones or cores. They may be mistaken for border zones where later albitization has obscured relationships. Such quartz veins also occur along zone contacts, where they may be easily mistaken for partially developed wall or intermediate zones. The critical crosscutting portions have commonly been masked by later replacement, or are not exposed, so that the interpretation of many of these features is doubtful. Quartz bodies of questionable age are present in the Little Julia, Triple EEE-A, and Alamos deposits.

Throughout the district the quartz veins appear to be contemporaneous with or slightly later than the nearby pegmatites. This tentative generalization is based upon the structural relations as outlined above and upon similarities in the sequence of deformation and late-stage mineralization in each type of deposit.

WALL-ROCK ALTERATION

The emplacement of many of the Petaca pegmatite bodies appears to have been controlled by fractures in the pre-Cambrian quartzite and schist, but for some the evidence of structural control is lacking. The distribution and orientation of the fractures must have been governed in turn by other widespread and uni-

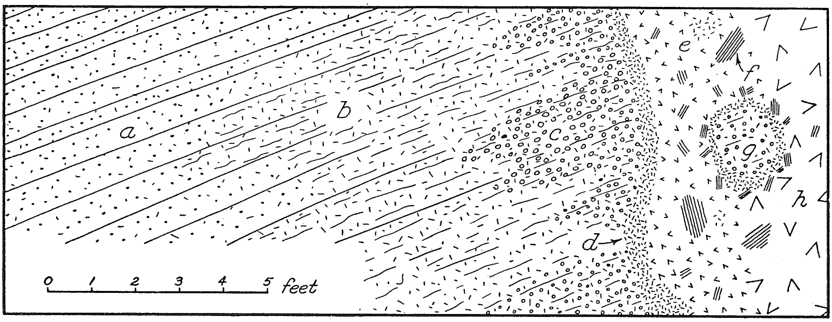

FIGURE 5. Diagrammatic sketch showing typical gradational contact relations between pegmatite and country rock in parts of the Petaca district.

a—slabby micaceous quartzite.
b—quartzite with muscovite-rich partings and disseminated small flakes of muscovite.
c—mica-impregnated quartzite with metacrysts of microcline and albite-oligoclase.
d—fine-grained mica-rich contact zone of pegmatite.
e—medium-grained microcline—quartz—albite-oligoclase—albite—muscovite pegmatite.
f—large book of muscovite.
g—inclusion of altered quartzite (lithologically similar to that in unit c).
h—coarse-grained microcline-quartz pegmatite.

form controls, as shown by the essential concordance of many structural features in both the pegmatites and the country rock. Some of the pegmatite bodies were confined between the walls of the fractures into which they were injected, and the adjacent country rock has been little affected by them. Others broke through the fracture walls to send out many small branches or apophyses, and still others literally soaked through the walls both before and during their consolidation. The latter type of pegmatite has produced the most profound alteration of the country rock.

A characteristic sequence of alteration is illustrated in Figure 5. The poorly defined pegmatite contact is marked by a distinct concentration of fine-grained pale-green muscovite. The adjacent country rock is also rich in mica, is thinly foliated, and has been impregnated with rudely formed metacrysts of microcline, albite-oligoclase, or both. These metacrysts are $1/8$ to $1/2$ inch in diameter, and decrease in number away from the contact. Beyond the zone of metacrysts the country rock has been impregnated with fine-grained feldspar and mica. The mica is not only uniformly disseminated through the foliated rock, but also forms numerous pale-green partings $1/32$ to $1/4$ inch thick. Farther from the contact this quartz-mica schist grades into the normal slabby, slightly to moderately micaceous quartzite. Most of the crenulated micaceous layers disappear entirely, but a few continue into the quartzite as much thinner and more uniform partings. Sequences of this type can be followed at many deposits. At some they are complete within a few feet, as at the Pinos Altos and La Jarita; at others within a few tens of feet, as at the La Paloma and Cribbenville; or at still others they may extend for many tens of feet, as in parts of the Kiawa area.

Some pegmatites are even less clearly defined than that shown in the sketch (Figure 5). Some broad border zones appear to consist almost wholly of pegmatitic material, but in them the orientation of mica flakes and small feldspar masses is plainly a relict structure of impregnated and replaced quartzite and schist. The line between such rocks and the adjacent country rock is not easily drawn. Bodies of hybrid border-zone material several feet or more thick are present in the La Paloma and Keystone-Western deposits, and locally in the Coats deposit. They are most numerous along the footwalls of the pegmatites.

An intricate series of branching pegmatite stringers, exposed in an open cut at the Vestegard deposit, illustrates some typical contact relations on a small scale. The stringers are $1/4$ inch to 15 inches thick, and consist of coarse microcline with minor quantities of quartz, albite, and mica. The potash feldspar is smoky gray, white, and blue green. The branching network is further marked by irregular protuberances and long narrow branches that extend into the country rock, a thinly foliated schist. This schist has been so thoroughly impregnated with pale-green mica and fine-grained, blue-green microcline that it is distinctly colored by these minerals. It also contains larger lenses and "knots" of blue-green microcline, with or without mica and albite. Away from the pegmatite stringers the schist progressively loses its blue-green color as the amount of feldspar diminishes, becoming a faintly greenish gray.

At several deposits the quartzite has not been converted to mica-rich schist, but instead has been permeated with fine-grained feldspar and small thick books of muscovite. This type of alteration, which is widespread on the slopes immediately west and northwest of Petaca, is especially clear at the Bluebird deposit. Here slabby to thick-bedded quartzite has been impregnated with sugary microcline and albite-oligoclase in poorly defined belts that flank the thin pegmatite (see Figure 16); and books of muscovite ⅛ inch in average diameter and ¼ inch in average thickness are scattered through the rock without visible orientation. Weathered surfaces of this altered country rock are buff to light brown, and feel spongy when struck with a hammer.

Less obviously related to pegmatite bodies are broad, remarkably continuous belts of micaceous country rock. Some are extremely rich in mica and have lost all resemblance to the quartzite from which they were formed. Their contacts with adjacent quartzite, although not sharp, are easily recognized. These micaceous belts follow bedding and foliation planes in detail, but in general trend across the country-rock structure at acute angles. They have been mapped in the Alma, Apache, Queen, and Kiawa areas. They are clearly related to the distribution of quartz veins and lenses in the Kiawa, Alma, and several other areas, but elsewhere they appear to be the result of impregnation along fracture or shear zones. Small-scale "soaking" of platy quartzite by mica at a prospect half a mile east-northeast of the Eureka deposit was guided not only by foliation planes but by fractures nearly conformable with the axial planes of small folds.

Where amphibole schist lies against pegmatite, as in the Green Peak deposit, it has been converted to a dense aggregate of biotite flakes whose average diameter is about ⅛ inch. Farther from the pegmatite contacts these flakes are somewhat larger but are widely scattered. Similar biotitization near the Alma pegmatite can possibly be ascribed to the alteration of thin amphibolite dikes and small pod-like intrusive masses, although no traces of the original material are now present.

MINERALOGY

ESSENTIAL MINERALS

FELDSPAR

Feldspar is a general term applied to a group of aluminum silicates and includes several mineral species. Orthoclase and microcline are the common potash feldspars; of these microcline ($KAlSi_3O_8$) is more abundant in the Petaca district. The plagioclase or soda-lime feldspars form a series ranging in composition from albite ($NaAlSi_3O_8$) to anorthite ($CaAl_2Si_2O_8$). This series is arbitrarily divided into six mineral species. Albite and oligoclase, the two most sodic members, are present in the Petaca pegmatites.

Microcline, the most abundant mineral in the pegmatites, ranges from fine-grained sugary crystalline aggregates to well-formed crystals 12 feet or more in diameter. It commonly occurs as irregular subhedral masses 6 inches to 5 feet in diameter. Most of these are equant, though many have been somewhat corroded by albite and other minerals. Microcline is the chief constituent of the wall zones and also occurs as an essential mineral in most border zones. In the interior zones it is generally present as large crystals in massive quartz or as nearly pure aggregates of coarse poorly formed crystals. The long dimensions of some of these aggregates are 30 feet or more. Most of the pegmatite that contains much microcline is hard and forms relatively continuous outcrops.

The potash feldspar is white, light to dark gray, flesh to deep brick red, and pale green to blue green. Flesh and deeper shades of red are most common. Many crystals are zoned, with gray cores and outer portions of blue green, green, or white; samples of such material can be seen on the dumps at the La Paloma, Vestegard, and St. Joseph deposits. Nearly all the microcline contains very thin platy to spindle-shaped subparallel lenses of sodic plagioclase in perthitic intergrowths. Such lenses are 0.01 inch or less in thickness. Their thickness, which tends to increase with the size of the microcline crystals, reaches a maximum of about 0.05 inch. Although the potash feldspar is really microcline perthite, it is termed microcline in this report.

Most of the albite in the Petaca pegmatite is extremely sodic (Ab_{96}--Ab_{99}). It occurs as fine-grained sugary crystalline aggregates and as groups of coarse platy crystals of the variety cleavelandite. These are ⅛ inch to 5 inches long, $^1/_{16}$ inch to 4 inches wide, and 0.01 inch to ⅛ inch thick. Their average dimensions are approximately 1 inch, ½ inch, and 0.05 inch, respectively. The ends of the crystals are characteristically curved or warped, and in many deposits entire crystals are curved. This is one of the most reliable means for recognizing cleavelandite. Fine, closely spaced ruling of twin lamellae can be seen along the sides of some crystals.

TABLE 2. LIST OF MINERALS IN THE PRE-CAMBRIAN ROCKS OF THE PETACA DISTRICT

Mineral	Occurrence			
	Pegmatites	Quartz veins	Granite	Metamorphic rocks [a]
Albite	x	x	x	x
Andalusite		x		x
Apatite*	x		x	
Azurite*	x	x		
Beryl	x	x		x
Biotite	x		x	x
Bismuth*	x			
Bismuthinite*	x			
Bismutite and other secondary bismuth minerals	x			
Bornite *	x	x		
Calcite	x	x		x
Cassiterite* [b]	x			
Chalcedony	x	x		
Chalcocite	x	x		
Chalcopyrite	x	x		
Chlorite	x	x	x	x
Chrysocolla	x	x		
Clinozoisite			x	x
Columbite-tantalite	x	x		
Covellite*	x	x		
Cuprite*	x	x		
Dumortierite		x		x
Epidote		x	x	x
Fergusonite* [c]	x			
Fluorite	x	x	x	x
Gadolinite* [d]	x			
Galena	x	x		
Garnet (chiefly spessartite and almandite)	x		x	x
Gummite*	x			
Hematite	x	x	x	x
Hornblende (and other amphiboles)			x	x
Ilmenite	x	x	x	x
Kaolinite (and other clay minerals)	x	x	x	x
Kyanite		x		x
Lepidolite*	x			
Limonite	x	x	x	x
Magnetite	x	x	x	x
Malachite*	x	x		
Manganese oxides	x	x	x	x

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* Rare.

[a] Includes mineralized zones with or without pegmatite bodies or quartz veins.

[b] Reported by F. A. Jones in N. Mex. School of Mines, Min. Res. Survey Bull. 1, p. 74, 1915, and by S. A. Northrop, Univ. of N. Mex. Bull., Geol. Ser., vol. 6, no. 1, p. 102, 1942.

[c] Reported by Harry Berman in letter cited by S. A. Northrop, *op. cit.*, p. 140, 1942.

[d] Tentatively reported by F. L. Hess and R. C. Wells, Amer. Jour. Sci., 5th ser., vol. 19, p. 20, 1930.

TABLE 2 (Continued)

Mineral	Occurrence			
	Pegmatites	Quartz veins	Granite	Metamorphic rocks [a]
Microcline	x	x	x	x
Molybdenite		x		
Monazite	x			
Muscovite	x	x	x	x
Oligoclase	x		x	x
Phenakite* [e]	x			
Phlogopite *	x			x
Pyrite	x	x		x
Quartz	x	x	x	x
Roscoelite [f]	x			
Samarskite	x	x		
Scheelite*	x	x		
Sericite	x	x	x	x
Serpentine				x
Sillimanite				x
Sphene			x	
Staurolite				x
Talc				x
Topaz			x	x
Tourmaline	x			
Uraninite*	x			
Uranophane*	x			
Yttrotantalite [g]	x			
Zircon			x	

* Rare.

[e] Occurrences reported by several prospectors and miners. One sample, stated to be from the Petaca district, was tested and found to be phenakite.

[f] Reported by Just, Evan, in N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, p. 46, 1937.

[g] Tentatively reported by Harry Berman and Clifford Frondel in private communication cited by Charles Palache, Harry Berman, and Clifford Frondel, *Dana's System of Mineralogy*, seventh edition, vol. 1, p. 800, 1944.

Most of the albite is lustrous and white, but bluish, flesh, and brownish shades are common. Some aggregates of crystals are deep brick red, especially where they surround or lie against masses of monazite, purple fluorite, or tantalum minerals. Although some crystals and fine-grained crystalline aggregates are hard, most coarse masses are relatively soft and crumbly. This is particularly true of the brick-red material. The albite locally resembles microcline in color, but it can be distinguished megascopically by its crystal habit, twinning lamellae, curving or warping of its crystals, and lack of perthitic structure, and less reliably by its occurrence in fine-grained aggregates and its tendency to crumble when struck with a hammer.

Albite is present chiefly as (a) fine-grained pseudomorphs and partial pseudomorphs of crystals and irregular masses of microcline; (b) crosscutting veins and larger masses; (c) rosettes, "pillows", or "bursts"; and (d) scattered concentrations

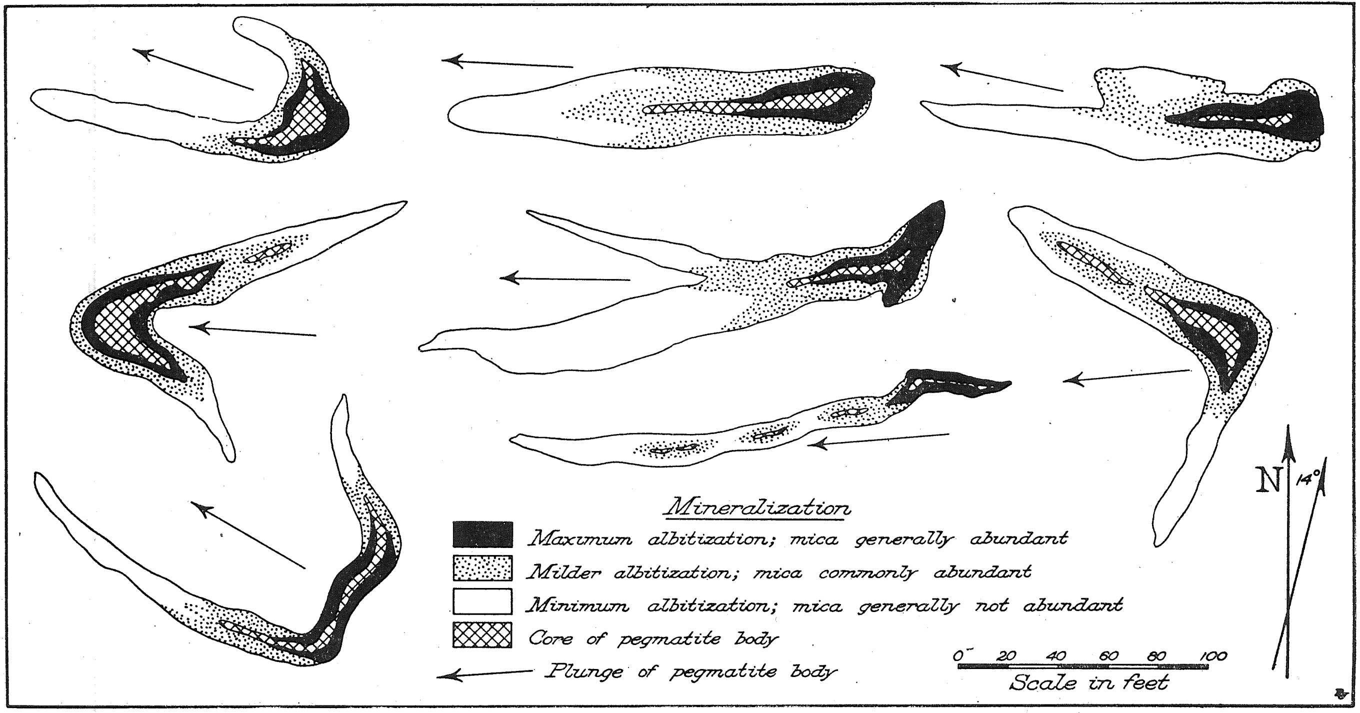

FIGURE 6. Idealized plans of typical Petaca pegmatite bodies showing plunges and characteristic distribution of mineralization.

that generally constitute a small proportion of the host rock. Cleavelandite appears to be more abundant than sugary albite, although there are all gradations between the two, both in grain size and crystal habit. Crystals of cleavelandite, particularly the larger ones, tend to be oriented with their broad surfaces normal to the contacts with other minerals. They commonly lie transverse to the fractures in which they were formed, so that subsequent fracturing has tended to shatter them and permit ready access of solutions from which later minerals were deposited. The tendency of the cleavelandite to be grouped in curving sheaflike aggregates is exemplified by rosettes and similar features in which the mineral forms concentric layers.

Albite-oligoclase feldspar ($Ab_{90}\pm$) is present in the border zones of several Petaca pegmatites, as well as in quartzite and schist that has been invaded by pegmatite. It occurs as small irregular masses and poorly formed crystals that are bluish to creamy gray in color and range in diameter from 1/8 inch to 1½ inches. Many of the cleavage surfaces are marked by polysynthetic twinning. The albite-oligoclase is distinct in appearance and mode of formation from the albite. It appears to have been formed slightly before, as well as during, the early crystallization of microcline. Many crystals have been transected and corroded by the potash feldspar and by the later-stage hydrothermal cleavelandite and sugary albite. These relations are especially clear in the border zone of the main Kiawa pegmatite, where albite-oligoclase is cut by thin irregular veinlets of microcline and both feldspars are partially replaced by cleavelandite.

QUARTZ

Quartz is almost as abundant in the pegmatites as microcline, and is even more widespread. It is present in those portions of the pegmatites that were first to consolidate, it occurs as late-stage veins that cut across all other units in the pegmatites, and it is present in most of the units formed during intermediate stages. Thus it seems to have been formed throughout the period of pegmatite activity. The quartz is generally milky white to light gray, although smoky and clear colorless varieties also occur. It is nearly everywhere massive, and commonly contains crystal impressions of other minerals that grew in it or around which it grew.

Quartz occurs chiefly as large masses in pegmatite cores or other zones, as quartz veins, and as an irregular interstitial filling in microcline-rich pegmatite (see pages 42-52). Small clear prismatic crystals of low-temperature quartz commonly occur in cavities in wall zones and albite-rich bodies, and are 1/16 to ½ inch in diameter and ¼ inch to 2 inches long. Average dimensions are about 1/8 inch and ½ inch, respectively. This late-stage well-crystallized quartz represents a negligible proportion of the total.

Quartz also occurs in graphic granite, in most of which it forms crude patterns. Such pegmatite consists of coarse gray, flesh-colored, or green microcline with scattered short thick spindles of white to smoky quartz. In the La Paloma, Vestegard, El Contento, Triple EEE-A, and Hillside deposits, the spindles are 1/8 inch to 1¼ inches in diameter (about 3/8 inch in average diameter). As the spindles are generally an inch or more apart, many hand specimens contain only one of them. Normal well-formed graphic granite is present in several other deposits, notably the Kiawa, Cribbenville, Pavo, Blanca, and Guadalupe, where the quartz forms striated tablets, spindles, and rods that are ovoid, rectangular, and L-shaped in section. Their average thickness is 1/8 inch, and they are spaced ¼ to ½ inch apart in subhedral microcline masses a foot or more in diameter. Some of the masses of feldspar are as large as 4 by 6 feet on an outcrop surface. The graphic granite generally occurs near the west and uppermost ends of the pegmatites, and grades westward into massive microcline and eastward into quartz or quartz-microcline pegmatite.

MICA

The mica group includes several mineral species, only one of which, muscovite, is abundant in the Petaca pegmatites. Muscovite, or potash mica, is a silicate of aluminum with potassium and hydroxyl, commonly $2H_2O.K_2O.3Al_2O_3.6SiO_2$ or $(OH)_4 K_2Al_4 (Si_6Al_2) O_{20}$. Its properties, on which its commercial classification directly depends, are discussed in detail on pages 76-79.

Fine-grained muscovite is a common constituent of the pegmatite border zones and of country rock that has been altered by pegmatitic solutions. It is also present as late-stage veneers and thin layers in fractures, and locally as almond- and turnip-shaped pods or "slugs". Coarse muscovite is commonest in the wall zones, particularly along contacts with cores or intermediate zones. It ranges in concentration from scattered small crystals, or books, to large masses that consist almost wholly of mica and attain a diameter of 25 feet. The mica of the Petaca district is consistently associated with albite, and this association is thought to be of genetic significance. It is also of economic importance.

ACCESSORY MINERALS

GENERAL FEATURES

Nearly fifty minerals have been recognized as minor constituents of the Petaca pegmatite deposits. Biotite, chalcedony, chlorite, hematite, kaolinite, limonite, manganese oxides, and sericite are widespread. Most of these are of secondary origin and replace pre-existing pegmatite minerals or inclusions of country rock. A few, notably the biotite of some border zones and the manganese and iron oxide inclusions in some mica books, are probably primary. Many other minerals occur rarely in a few deposits. These include apatite, azurite, bismuth, bismuthinite, bornite, cassiterite, covellite, cuprite, fergusonite, gadolinite, galena, gummite, lepidolite, phenakite, phlogopite, pyrite, roscoelite, scheelite, topaz, tourmaline, uraninite, and uranophane. Many of these are also present in quartz veins; sulfides, secondary copper and lead minerals, scheelite, and tourmaline are common in such deposits. Andalusite, calcite, dumortierite, epidote, kyanite, and molybdenite occur in quartz veins but not in the pegmatites.

The accessory minerals most characteristic of the Petaca pegmatites are spessartite garnet, fluorite, beryl, columbite-tantalite, samarskite, monazite, bismutite and other secondary bismuth minerals, ilmenite, magnetite, pink muscovite, copper sulfides, secondary copper minerals, and secondary uranium minerals. The first seven of these minerals occur in more than half of 69 deposits examined in detail, and most of the others are more widespread than heretofore supposed (see Table 3). This search was by no means exhaustive; hence it seems likely that these minerals are even more widespread than is shown by the figures in the table. Ilmenite, magnetite, secondary bismuth minerals, sulfides, and secondary copper minerals are also common in quartz veins, and beryl and fluorite occur in a few places with ilmenite and columbite in mica-rich schist.

The minerals listed in Table 3 constitute an accessory suite that is representative of the Petaca pegmatites but is not typical of pegmatites in other areas. They plainly show that beryllium, bismuth, columbium, copper, fluorine, manganese, the rare earths, tantalum, titanium, and uranium are the most abundant of the so-called rare constituents in these pegmatites. This accessory suite, together with the consistent structure and mineral composition, establish the Petaca deposits as a well-defined pegmatite province.[26] The most significant properties and megascopic relations of these accessory minerals are discussed in the following paragraphs. As several are of potential economic value, the discussions are aimed at facilitating their identification in the field.

GARNET

Spessartite, the manganese-aluminum garnet, occurs in nearly every pegmatite in the district and is the most abundant and widespread accessory mineral. It is commonest in wall zones, but is also present in many border zones and in some intermediate zones. Small euhedral crystals, ¼ inch or less in

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[26] Heinrich, E. W., and Jahns, R. H., The accessory minerals of the Petaca pegmatites, Rio Arriba County, New Mexico: in preparation, 1946.

TABLE 3. OCCURRENCE OF TYPICAL ACCESSORY MINERALS IN PETACA PEGMATITES

Mineral	Number of deposits in which mineral was observed	Percentage of all deposits examined (69) in which mineral was observed
Garnet	69	100
Green fluorite	63	91
Columbite-tantalite	60	87
Monazite	57	83
Bismutite, etc.	48	70
Beryl	46	67
Samarskite	40	58
Oxidized copper minerals	23	33
Ilmenite	16	23
Purple fluorite	14	20
Sulfide minerals	14	20
Magnetite	11	16
Secondary uranium minerals	11	16
Pink muscovite	8	12
Apatite	3	4
Uraninite	2	3
Lepidolite	1	1+
Tourmaline	1	1+

diameter, and rounded crystals and crystalline aggregates 2 feet or more in maximum diameter, are commonplace. Both large and small crystals are generally scattered evenly through the pegmatite. The garnet is lustrous and wine-red to cinnamon-colored where fresh, but dull and buff to tan where partially altered. Cores of unaltered material are present in many crystals and in crystal fragments bounded by fractures. Some crystals are rimmed with fine-grained pale-green chlorite. Most of the garnets whose diameter exceeds ½ inch are greatly fractured, and crumble easily to a fine-grained grit. This characteristic and the high specific gravity of the mineral identify it readily wherever the crystal form is not well developed. A small part of the garnet occurs as flattened relatively transparent crystals in books of mica. They are ⅛ to ¾ inch in diameter, and are generally less than ¼ inch thick.

FLUORITE

Two varieties of fluorite (calcium fluoride, CaF_2) are present in the Petaca district. Pale-green rounded equant masses and crudely formed crystals ¼ inch to 7 feet in diameter are common. Like garnet, this green fluorite occurs mainly in wall zones, but locally in border zones and intermediate zones, and rarely as flattened crystals in mica. Most of the larger masses have been shattered along cleavages and are crumbly. In some places the fluorite has been altered and partially or completely removed, leaving cavities lined or filled with compact reddish-brown clay or earthy yellowish-brown powder commonly containing gritty fragments of the fluorite. The green fluorite of the Petaca district has frequently been mistaken for beryl, but its softness, cleavage, color, and high specific gravity are distinctive.

The second variety of fluorite, which is relatively rare in the Petaca district, is light to deep purple. It generally occurs as small pods and thin veinlets in green fluorite, albite, or locally in microcline or quartz.

BERYL

Beryl (beryllium-aluminum silicate, $3BeO.Al_2O_3.6SiO_2$) is commonest in wall zones but exists in all zones. It also occurs in some crosscutting veinlets and fracture-controlled replacement bodies. The beryl ranges from milky white through shades of yellow-green and greenish-blue to rather deep blue. In the Sunnyside, Bluebird, Hidden Treasure, and Werner deposits it is well crystallized in elongate hexagonal prisms. More commonly, however, it appears as anhedral masses. The Alma, Lonesome, and Kiawa deposits contain irregular concentrations of such material. Most of the beryl individuals are ½ to 10 inches in maximum dimension, but several crystals 3 to 4½ feet long have been obtained from the Sunnyside deposit. Its hardness, crystal form, and poor cleavage distinguish the mineral from fluorite, and its color from most other minerals. Colorless beryl resembles quartz, but has a distinct greasy luster.

COLUMBITE-TANTALITE

The columbite-tantalite series, $(Fe,Mn)(Cb,Ta)_2O_6$, consists of columbate-tantalates of iron and manganese. The commonest mineral of the series is ferrocolumbite, in which the ratio of iron to manganese is greater than 3:1 and the ratio of columbium to tantalum is much greater than 1:1; but all species contain appreciable quantities of manganese. The tantalite at the Lonesome and Fridlund deposits is relatively low in columbium and high in tantalum. Both columbite and tantalite are black, with dull to lustrous surfaces, and have high specific gravities. They occur in four general forms:

1. Well-developed tabular to equant crystals ½ inch to 4 inches in maximum dimension (Lonesome, Keystone-Western, Silver Spur deposits).
2. Large "niggerheads" as much as 18 inches in diameter and weighing 20 pounds or more (Fridlund, Globe, Apache, North Cribbenville deposits).
3. Long thin feather-shaped crystals and crystal aggregates ¼ inch to 3½ inches wide, 2 to 22 inches long, and $^1/_{32}$ to ⅛ inch thick (Globe, Apache, Alamos deposits).

4. Intergrowths with samarskite, ilmenite, and rarely with magnetite (Sunnyside, Fridlund, Cribbenville, De Aragon, Eureka deposits).

The albite that surrounds most crystals and masses of columbite-tantalite is strongly discolored to shades of red and brown. Individual crystals generally show an irridescent tarnish and sharp lines of growth. The surfaces of the rounded masses, on the other hand, are characteristically dull and spongy in appearance, and are covered with impressions of cleavelandite crystals. The "feather columbite" consists of thinly tabular imbricated crystals. Some are arranged with step-like contacts resembling growth lines; others consist of distinct plates separated by thin films of albite. Small elongate crystals of monazite are commonly set in these columbite feathers, and are oriented parallel to their edges and to the edges of crystal plates. Crystallographically oriented intergrowths of samarskite and columbite occur in the Fridlund and Cribbenville deposits, and somewhat similar intergrowths of columbite in ilmenite and rarely in magnetite occur in many quartz veins and quartz-rich pegmatites. Some crystals of columbite project into ilmenite or magnetite, but more commonly small quantities of columbite are intergrown in apparently pure tabular crystals of ilmenite. The columbite occurs largely as small rods and blebs parallel to the crystal directions in the ilmenite.

Columbite-tantalite has no effect on the needle of a compass, but ilmenite affects a well-pivoted needle distinctly and magnetite strongly. The ilmenite-columbite intergrowths also affect a needle, but such mixed material is best tested by means of its specific gravity. If the specific gravity is less than 5, the amount of contained columbite is too small to permit commercial use of the material as columbium ore. The specific gravity of pure columbite-tantalite rises with increase in the tantalum-oxide content (Figure 7), but the relative amounts of iron and manganese appear to have little effect. Columbites from the Petaca deposits contain little tantalum and have specific gravities ranging from 5.1 to 5.7. The few tantalite specimens tested are within the range 6.5 to 6.8.

MONAZITE

Monazite is a phosphate of cerium and other elements of the rare earths. It generally contains variable percentages of thorium. In the Petaca district, monazite is a common minor constituent of those parts of the pegmatites that contain much albite. It occurs in three general forms:

1. Well-developed flattened crystals, averaging ¾ by ½ by ⅛ inch (Silver Spur, North Star, Freetland deposits).

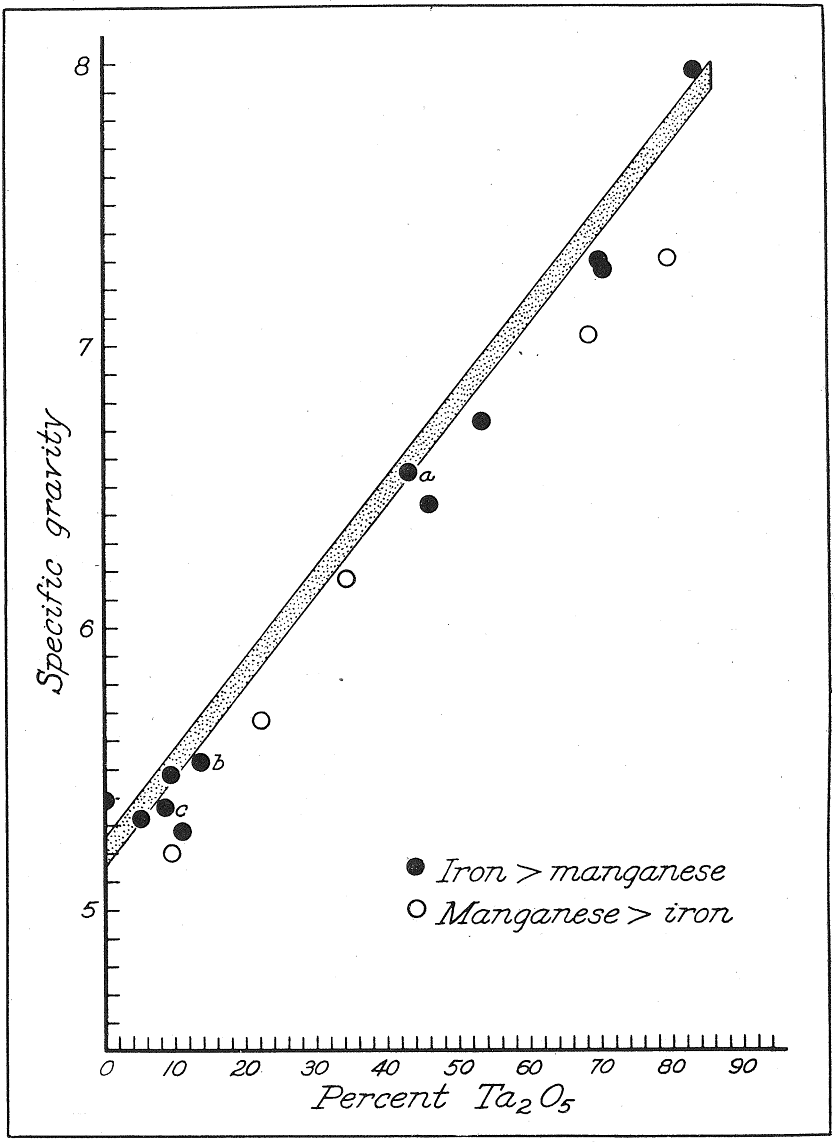

FIGURE 7. Relation between specific gravity and tantalum-oxide content in the columbite-tantalite series. Stippled area represents theoretical range of values based on assumption that the specific gravity of pure columbite is 5.20±0.05 and that for pure tantalite is 7.95±0.05.

a—composite sample of placer tantalite from Harding deposit, Taos County; analysis by Ledoux and Co., September 24, 1943.

b—columbite, Fridlund mine, Rio Arriba County; commercial assay.

c—columbite, Apache mine, Rio Arriba County; commercial assay.

All other points represent published analyses; see Palache, Charles, Berman Harry, and Frondel, Clifford, *The system of mineralogy of James Dwight Dana and Edward Salisbury Dana,* seventh edition, vol. 1, pp. 782-783, 1944.

2. Coarse crystals and equant masses as much as 5 inches in diameter and weighing ½ pound to 10 pounds or more (Coats, Fridlund, Pino Verde deposits).
3. Thinly tabular to elongate feathery crystals and crystal aggregates similar to the "feather columbite" and commonly associated with it (Globe, Alamos, Apache, Nambe, Capitan deposits).

The feldspar that surrounds monazite generally is stained yellowish-brown to deep brick red. Large masses of crumbly dark red cleavelandite contain monazite, spherical aggregates of columbite, and purple fluorite in the Globe, Fridlund, North Star, and several other deposits. The discoloration of the feldspar extends ½ inch to 15 inches or more beyond masses of monazite and columbite. The origin of this discoloration is not clear.

The monazite ranges from tan through yellowish and rusty brown to deep mahogany brown. The surfaces of large masses are marked by prominent growth ridges, and both crystals and fracture surfaces within crystals are commonly coated with thin scales and films of pale yellowish-green mica. The large crystals and fragments of monazite appear to be fresh, but some of the thin tabular to feathery crystals in the Apache, Alamos, and other deposits have been altered to a reddish-brown earthy powder. The Petaca monazite has been confused with garnet, but is heavier, more brownish, and more flattened in its crystal form. Moreover, the larger more equant crystals are not crumbly.

SAMARSKITE

Samarskite, a complex columbate-tantalate that contains calcium, iron, uranium, thorium, elements of the rare earths, and other constituents, is present as a late mineral in albite and quartz. It occurs chiefly as rough dull-black equant masses of pinhead to walnut size. Much larger aggregates of imperfect crystals and irregular closely spaced growths have been found in the Fridlund and Kiawa deposits, and a few well-formed prismatic crystals ½ to ¾ inch long have been obtained from the Lonesome mine. Samarskite is heavy and brittle, and is easily recognized by the deep reddish-brown to velvety-black color and splendent luster of its conchoidally fractured surfaces.

Cracks in samarskite specimens from the Fridlund deposit contain a black opaque mineral that may be gadolinite. According to Hess and Wells,[27] much of the Fridlund samarskite is an intergrowth of two minerals, one more radioactive than the other. They concluded that the more radioactive part is essentially yttrium pyrocolumbate and that the less radioactive part is

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[27] Hess, F. L., and Wells, R. C., Samarskite from Petaca, New Mexico: Amer. Jour. Sci., 5th ser., vol. 19, pp. 20-24, 1930.

nearer yttrium orthocolumbate. The general designation samarskite, however, was retained for the sake of convenience. According to Berman and Frondel,[28] X-ray powder pictures of ignited samples of this material show that the more radioactive mineral is similar to yttrotantalite and the weakly radioactive mineral is much like fergusonite. It is evident from the results of these investigations, which were made on a few specimens from one deposit, that detailed determinative work is needed on the radioactive tantalum-columbium minerals of the Petaca pegmatites. Much of the samarskite seen during the present investigation appears to be different from the material analyzed by Hess and Wells, and some appears to be homogeneous in polished section. At present, however, it seems desirable to follow Hess and Wells and retain the general designation samarskite for all this material.

ILMENITE AND MAGNETITE

Ilmenite (iron titanate, $FeTiO_3$) is common in the quartz veins and quartz-rich pegmatites. It occurs as tabular crystals that range from wafers less than $^1/_{64}$ inch thick and ½ inch to 4 inches in maximum diameter to large platy masses as much as ½ inch thick and 6 inches in diameter. It is black and heavy, though its specific gravity is less than that of columbite. It is sufficiently magnetic to influence the needle of a compass at distances of ¼ inch or less. Much of the ilmenite contains magnetite, which is intergrown as thin lamellae. Less commonly it contains smaller, irregular lenses of columbite.

Magnetite is locally present in the pegmatites and quartz veins as flattened crystals and equant masses the size of a man's fist. Much of it shows a well-developed octahedral parting. It is abundant in the country rock, both as detrital grains and as local concentrations of hydrothermal origin. Many small grains are also present in the pegmatites, as shown by the panning of crushed samples from several deposits.

OTHER MINERALS

Bismutite, a basic bismuth carbonate, is commonest in the quartz of intermediate zones, cores, and veins, where it occurs as veneers, irregular fracture-fillings, and pipe-like masses as much as 2 inches in diameter. It ranges from gray to bright canary yellow, but its luster is dull. The mineral is soft and very heavy. It is associated with other secondary bismuth minerals, most of which are thin films that range from gray or yellow through shades of orange and green to greenish brown. All these minerals appear to have been formed by the alteration of bismuth and bismuthinite. Several deeply striated prismatic masses of bismutite in the Fridlund deposit contain unaltered cores of

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[28] Berman, Harry, and Frondel, Clifford, private communication, 1941.

fibrous bismuthinite. Similar pseudomorphs are abundant in the Sandoval deposit, but rarely contain unreplaced cores.

Sulfide minerals occur sporadically. Chalcocite is present in the Cribbenville deposit as rounded pods the size of a walnut, and as somewhat smaller masses in the Kiawa, Alamos, Capitan, and other deposits. Chalcopyrite, bornite, covellite, galena, and other sulfides are rare. Oxidized copper minerals, chiefly malachite and chrysocolla, are widespread as veinlets and films formed in fractures. They also occur as ⅛- to ¼-inch veinlets in chalcocite in the Cribbenville deposit. Azurite and cuprite are rare.

Pink muscovite, in flat to gently curving blades $^1/_{16}$ to ⅝ inch in diameter, occurs in pods of fine-grained pale green mica in the Globe, Apache, Cribbenville, Fridlund, Kiawa, White, and Canary Bird deposits. It also occurs as waxy pod-like aggregates of fine flakes. The long dimension of such aggregates ranges from ½ inch to 9 inches. This pink mica appears to contain little or no lithium, and probably is similar to the pink muscovite from the Harding mine, Taos County, and from pegmatites near Pilare in the same county. Schaller and Henderson,[29] who described these micas, attributed their color to the presence of small quantities of trivalent manganese. Lepidolite, the lithium mica, occurs in pink muscovite at one deposit, the Globe, but it is rare. It forms waxy, translucent pods of very small flakes and is pink to deep lavender in color. It closely resembles the lepidolite of the Harding deposit.

Small heavy black crystals of uraninite occur in albite and late-stage quartz in the Fridlund and Pino Verde deposits. It is commonly surrounded by crusts of gray, yellow, brown, or orange alteration products, which distinguish it from samarskite. The secondary uranium minerals resemble bismutite and other secondary bismuth minerals, but are harder and have a bright luster. Apatite and tourmaline, which are common constituents of pegmatites in other districts, are rare in the Petaca district. Spodumene, amblygonite, and lithium phosphate minerals are absent.

PARAGENETIC SEQUENCE OF MINERALS

The minerals of the Petaca pegmatites were formed during an appreciable range in time.. Some of the earliest minerals grew by reaction with the country rocks, and others crystallized directly from pegmatitic liquids. As these minerals formed they were corroded by solutions with which they were no longer in equilibrium, or were surrounded by other minerals that crystallized from these solutions. In many places they were later fractured and new minerals were deposited in the fractures. Elsewhere they were partially or completely replaced by the minerals derived from later hydrothermal solutions that penetrated them

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[29] Schaller, W. T., and Henderson, E. P., Purple muscovite from New Mexico: Amer. Mineralogist, vol. 11, pp. 5-16, 1926.

along fractures and in other ways. The pegmatites are therefore clearly the result of a chain of events involving both the progressive development of new minerals and the local obliteration of minerals that were formed earlier. This chain of events was complex and differed from deposit to deposit, but the broad underlying pattern seems to have been uniform throughout the district.

The criteria for the recognition of mineral paragenesis in pegmatite deposits have been described by many geologists[30] and need no detailed review in this report. It suffices to say that only two features have been found to be dependable for indicating differences in the ages of minerals in the Petaca pegmatites:

1. Occurance of a mineral as a pseudomorph after an earlier mineral, where the identity of the earlier mineral can be clearly established by means of residual material, crystal form, or some other characteristic;
2. Occurrence of a mineral as a filling in fractures or cleavage cracks in an earlier mineral.

Other features, strongly suggestive but not conclusive, are helpful. These involve the occurrence of a given mineral:

1. In or consistently with another mineral whose age relations are known;
2. Along contacts between other earlier minerals;
3. As inclusions oriented in accord with cleavage directions in the host mineral;
4. In "bursts", rosettes, or other bodies generally formed by replacement processes;
5. As "embayments" or other forms that suggest the corrosion of an earlier mineral.

Still other features, such as irregular mineral boundaries and the occurrence of one mineral as well-formed crystals in another, have been of little value in the diagnosis of time relations. They generally permit two or more reasonable but contradictory interpretations.

The general age relations of the essential and the principal accessory minerals of the Petaca pegmatites are shown in Table 4. The range of hypogene-mineral development has been divided into four stages. The first includes the partial primary consolidation of the pegmatites, generally with the formation of border zones, wall zones, and hybrid border phases, the latter resulting

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[30] For an excellent general discussion see Bastin, E. S., Graton, L. C., Lindgren, Waldemar, Newhouse, W. H., Schwartz, G. M., and Short, M. N., Criteria of age relations of minerals, with especial reference to polished sections of ores: Econ. Geol., vol. 26, pp. 561-610, 1931.

TABLE 4. GENERAL AGE-ABUNDANCE RELATIONS OF ESSENTIAL MINERALS AND TYPICAL ACCESSORY MINERALS IN PETACA PEGMATITES

MINERAL	STAGES			
	Consolidation of outer zones of pegmatite bodies	Consolidation of inner zones of pegmatite bodies and formation of contemporary quartz veins	Crystallization of albite	Formation of quartz veins that transect all pegmatite zones
Essential minerals:				
Microcline	Very abundant	Very abundant	—	—
Quartz	Abundant	Very abundant	Abundant	Very abundant
Albite	—	Rare	Very abundant	Rare
Albite-oligoclase	Sparse	—	—	—
Muscovite	Sparse (?)	—	Very abundant	Sparse
Accessory minerals:				
Garnet	Abundant	Sparse	Sparse	—
Green fluorite	Abundant	Rare	Common	—
Beryl	Common	Sparse	Sparse	—
Columbite-tantalite	—	Rare	Abundant	Rare
Monazite	—	—	Abundant	Rare
Bismuth and bismuthinite [a]	—	Sparse	Common	Sparse
Other sulfide minerals [b]	—	Sparse	Common	Rare
Samarskite	—	—	Rare	Common
Purple fluorite	—	—	Common	Rare
Ilmenite	Rare	Common	Rare	—
Magnetite	Sparse	Common	Rare	—
Uraninite [c]	—	—	Rare	Common
Pink muscovite	—	—	Sparse	—

[a] Represented in most exposures by bismutite and other alteration products.
[b] Represented in most exposures by secondary iron and copper minerals.
[c] Represented in most exposures by uranophane, gummite, and other alteration products.

from the action of pegmatitic material on the country rock. The second stage represents the completion of primary consolidation, with the development of inner zones and the formation of contemporary quartz veins. This was followed by the crystallization of albite, both as fracture-filling material and as masses of replacement origin. The final stage was the formation of quartz veins that transect all pegmatite zones and the later-stage albite masses. These stages and the mineral products characteristic of each can be recognized in most pegmatites of the district, even though not all of them are clearly zoned.

The relative abundance of each mineral in Table 4 is expressed by the terms very abundant, abundant, common, sparse, and rare. The latest minerals, notably samarskite, uraninite, and dark smoky quartz, occur in veins that cut across zones and other pegmatite units. Albite, which plainly is later than microcline and much of the quartz, represents a stage during which many of the accessory minerals were developed. On the other hand, much of the garnet, green fluorite, and beryl, as well as some magnetite and ilmenite, were formed with microcline at an earlier stage, and subsequently were transected, corroded, and in places nearly obliterated, by albite. Albite-oligoclase and microcline were the earliest minerals to form, and neither appears to have developed after the primary crystallization of the pegmatites. A few microcline veinlets have been observed in graphic granite, but these appear to have been contemporaneous with adjacent microcline-bearing intermediate zones. Quartz was abundantly developed during all the stages. The earliest is white to light gray and the latest smoky and somewhat transparent.

These relations are in general agreement with the broad divisions outlined in the table. Thus, samarskite occurs as cross-cutting veinlets in columbite at the Lonesome deposit, purple fluorite in green fluorite at the Globe, Keystone-Western, Cribbenville, and other deposits, and bismutite in beryl and green fluorite at the Sandoval deposit. The relations between minerals developed during the same general stage are less consistent. Columbite occurs as inclusions in monazite in parts of the Globe and Alamos deposits, but cuts across monazite masses elsewhere in the same pegmatites. Though their significance is minor, such irregularities in the structural relations of nearly contemporaneous minerals tend to obscure the broad relatively simple paragenetic history.

At what stage or stages was mica developed in the Petaca deposits? A small proportion of this mineral was formed as fine-grained yellow flakes on the surfaces of late-stage fractures. A somewhat larger proportion occurs in the border zones and outer parts of the wall zones of many deposits as small books in microline—albite-oligoclase—quartz pegmatite. This material may have been formed at a much earlier stage. The great bulk of the mica, however, including all the large books, occurs with albite and appears to have formed during the albite stage. Mica is common in most deposits that are rich in albite and is rare in all deposits in which albite is a minor constituent. This association is one of the consistent features in the district, and in general the mica occurs in crosscutting relations to the potash feldspar. None of the commercial muscovite, therefore, appears to be strictly a primary constituent of the pegmatites. The range of mica formation did not correspond exactly in time to that of the albite development, but appears to have been distinctly shorter. That albite continued to form after the crystallization of mica is shown by the partial albitization of mica books in many deposits. Nearly perfect pseudomorphs of fine-grained cleavelandite after mica have been observed in the Globe, Hidden Treasure, Silver Dollar, and Alamos deposits (see Plate 3, top).

PEGMATITE GENESIS

The origin of pegmatite deposits has held the attention of geologists for many years, but no single explanation appears to have gained general acceptance. Kemp[31] has shown that most of the earlier hypotheses were based on the assumption that pegmatite formation involves simple injection and consolidation. The nature of the pegmatite-forming solutions and the mechanism of injection were the chief points of discussion. A different hypothesis, which emphasized the formation of pegmatites by more than one process, was introduced by Brögger[32] in 1890, but gained widest recognition when it was further developed by several geologists[33] during and after 1925. According to this concept, an original material of simple composition, commonly consisting essentially of potash feldspar with a small proportion of quartz and possibly small quantities of other minerals, is formed by crystallization from a cooling magma of similar composition. At a later stage this primary material is acted upon by hydrothermal solutions of complex composition and is partially or completely replaced by a new group of minerals. This two-process

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[31] Kemp, J. F., The pegmatites: Econ. Geol., vol. 19, pp. 697-723, 1924.

[32] Brögger, W. C., Die mineralien der syenitpegmatitgrange der sudnorwegishen augit und nephelinsyenite: Zeit. Kryst., Min. 16, pp. 215-235, 1890.

[33] See, for example:

Schaller, W. T., The genesis of lithium pegmatites: Amer. Jour. Sci., 5th ser., vol. 10, pp. 269-279, 1925.

Hess, F. L., The natural history of the pegmatites: Eng. and Min. Jour., vol. 120, pp. 289-298, 1925.

Landes, K. K., The paragenesis of the granite pegmatites of central Maine: Amer. Mineralogist, vol. 10, pp. 355-411, 1925.

Schaller, W. T., Mineral replacements in pegmatites: Amer. Mineralogist, vol. 12, pp. 59-63, 1927.

Schaller, W. T., Pegmatites: *Ore deposits of the Western States* (Lindgren volume), pp. 144-151, Amer. Inst. Min. Met. Eng., 1933.

Hess, F. L., The pegmatites of the Western States: *Ore deposits of the Western States* (Lindgren volume), pp. 526-536, Amer. Inst. Min. Met. Eng., 1933.

Landes, K. K., Origin and classification of pegmatites: Amer. Mineralogist, vol. 18, pp. 33-56, 95-103, 1933.

Hess, F. L., Pegmatites: Econ. Geol., vol. 28, pp. 447-462, 1933.

mechanism is thought to have led to the formation of many structurally and mineralogically complex deposits.

Many geologists have accepted most elements of the two-process theory and have applied it to pegmatite deposits in all parts of the world.[34] Others, however, have been reluctant to postulate two distinct mechanisms, but instead are inclined to view pegmatites as the result of a single crystallization process involving late-stage reactions between earlier-formed minerals and adjacent residual solutions, as well as the filling of open spaces created by fracturing during consolidation.[35] Many of those who have studied pegmatites admit that their conclusions are not based on sufficiently widespread observations to explain satisfactorily the origin of all deposits. As more and more pegmatites are investigated it becomes increasingly apparent that no single theory of origin can have general application. Each pegmatite or group of similar pegmatites should therefore be viewed individually so far as the determination of petrology, structure, or genesis is concerned.

Much discussion has arisen in the past from efforts to apply a single hypothesis of origin to all pegmatite deposits, even though the author may have restricted his views to a particular type of pegmatite. Many proponents of the two-process hypothesis may have intended that this interpretation should apply only to pegmatites of the potash-feldspar group,[36] in which primary plagioclase is a minor constituent. The mica-bearing sodic-plagioclase pegmatites so common in the Southeastern states and New England, the pegmatites of basic composition, and several

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[34] See, for example:

Andersen, Olaf, Discussion of certain phases of the genesis of pegmatites: Norsk. Geol. Tidsskr., vol. 10, pp. 116-205, 1928.

Derry, D. R., Genetic relations of pegmatites, aplites, and tin veins: Geol. Mag., vol. 68, pp. 454-475, 1931.

Landes, K. K., The Baringer Hill, Texas, pegmatite: Amer. Mineralogist, vol. 17, pp. 380-386, 1932.

Pegau, A. A., Pegmatite deposits of Virginia: Virginia Geol. Survey, Bull. 33, pp. 44-49, 1932.

Spence, H. S., Feldspar: Canada Dept. Mines and Geol. Bull. 731, pp. 1-4, 1932.

Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull 13, pp. 28-30, 46-48, 1937.

McLaughlin, T. G., Pegmatite dikes of the Bridger Mountains, Wyoming; Amer. Mineralogist, vol. 25, pp. 46-68, 1940.

Hess, F. L., Spodumene pegmatites of North Carolina: Econ. Geol., vol. 35, pp. 942-966, 1940.

[35] See, for example:

Fersmann, A., Uber die geochemisch-genetische klassification der granit-pegmatite: Mineral. und Petrog. Mitteil., vol. 41, p. 64. 1931.

Wright, J. F., Geology and mineral deposits of a part of southeastern Manitoba: Geol. Surv. Canada, Mem. 169, p. 103, 1932.

Stockwell, C. H., The genesis of pegmatites of southeast Manitoba: Roy. Soc., Canada, Trans., 3rd. ser., vol. 27, pp. 44-45, 1933.

Maurice, C. S., The pegmatites of the Spruce Pine district, North Carolina: Econ. Geol., vol. 35, pp. 179-185, 1940.

Uspensky, N. M., On the genesis of granite pegmatites: Amer. Mineralogist, vol. 28, pp. 437-447, 1943.

Quirke, T. T., and Kremers, H. E., Pegmatite crystallization: Amer. Mineralogist, vol. 28, pp. 571-580, 1943.

de Almeida, S. C., Johnston, W. D., Jr., Leonardoes, O. H., and Scorza, E. P., The beryl-tantalite-cassiterite pegmatites of Paraiba and Rio Grande do Norte, northeastern Brazil: Econ. Geol., vol. 39, pp. 206-223, 1944.

[36] Schaller, W. T., *op. cit.*, p. 279, 1925.
Hess, F. L., Pegmatites: Econ. Geol., vol. 28, p. 450, 1933.

other types, are excluded from this group. Maurice[37] has shown that many past disagreements might be ascribed as much to differences in the meaning of the terms "pegmatite" and "granite pegmatite" as to intrinsic differences in genetic interpretation.

The Petaca pegmatites can be treated genetically as a unit. Their primary minerals indicate that they may be classified as members of the potash-rich clan, which contains small amounts of soda in the form of early-stage albite-oligoclase crystals, crystalline masses, and perthitic intergrowths. The original microcline, albite-oligoclase, and quartz were distributed to form structural units or zones in most deposits, and were accompanied by garnet, green fluorite, beryl, mica, and small quantities of magnetite and ilmenite. These accessories appear to have formed during the primary consolidation of the pegmatite bodies, and are most common in the outer zones.

A later stage—characterized by the widespread activity of hydrothermal solutions rich in soda, silica, and alumina, and containing appreciable quantities of columbium, tantalum, beryllium, thorium, uranium, the rare earths, fluorine, bismuth, copper, and other elements—is represented by the development of abundant albite, muscovite, and many accessory species. These minerals were formed through replacement of the primary pegmatitic constituents by solutions that were guided mainly by fractures. Mineral and zone pseudomorphs were formed in some places, and elsewhere replacing solutions penetrated the walls of joints, fissures, and other openings to attack the earlier minerals and form rosettes, tabular bodies, and less regular masses of new material. Not only were most of the later minerals plainly formed at the expense of pre-existing material, but their structural control demonstrates that this replaced material was sufficiently solid to fracture under stress. Additional beryl, garnet, and fluorite were developed during the hydrothermal or albitization stage; and the physical and chemical properties of each appear to differ somewhat from those of earlier-formed, primary masses of the same species. Relatively small quantities of the accessory minerals generally identified with the stage of albitization were probably also formed during the last stage of crystallization of the pegmatite zones.

During the final stage, which was characterized by fracturing and the formation of veins of smoky quartz, replacement processes appear to have become subordinate to simple open-space filling. Uranium-thorium minerals, muscovite, and some of the same accessories developed during the preceding albitization accompanied the vein quartz.

The Petaca pegmatites thus appear to have been formed by (1) the injection of primary magmatic solutions into the quartzite and schist, followed by (2) crystallization from these solu-

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[37] Maurice, C. S., *op. cit.*, pp. 182-183, 1940.

tions of lithologic units rich in potash feldspar and quartz, (3) a later attack and replacement of these minerals by hydrothermal solutions of complex composition, and (4) the final filling of open spaces by quartz and minor accessory minerals. In some broad aspects of their development they closely resemble the lithia pegmatites described by Schaller,[38] the pegmatites described from central Maine by Landes,[39] and those described from several districts by Hess.[40] Their formation can be traced through a range of falling temperature from a stage during which the pegmatitic solutions had sufficient force to shoulder aside the country rock, through a stage characterized by solutions of great mobility and penetrative power, to a closing stage of deposition by solutions confined to open spaces. The tracing of this development is of considerable economic significance. Its applications are discussed in the following section of this report.

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[38] Schaller, W. T., *op. cit.*, pp. 269-279, 1925.

[39] Landes, K. K., *op. cit.*, pp. 355-411, 1925.

[40] Hess, F. L., *op. cit.*, pp. 289-298, 1925.

ECONOMIC FEATURES OF THE PEGMATITE MINERALS

MICA: GENERAL FEATURES

PROPERTIES

The micas constitute a group of complex aluminum silicates whose outstanding characteristic is an almost perfect basal cleavage. The true mica minerals can be split along this cleavage into thin sheets or films that are tough, flexible, elastic, and possess extremely low electrical and heat conductivity. Four of these minerals occur in the Petaca district: muscovite, the potassium mica; biotite, the magnesium-iron mica; lepidolite, the lithium mica; and phlogopite, which contains magnesium and a little fluorine. Of these, only muscovite is sufficiently abundant to be of economic importance, and the discussions of "mica" in this report are therefore devoted to this mineral alone. Many properties of muscovite have been described in detail by Sterrett,[1] whose report also contains clear and effective illustrations of representative structural features.

Much commercial mica occurs in rough blocks or "books", some of which are partially or completely bounded by irregular crystal faces. The books are tabular to equant, generally with their shortest dimension perpendicular to the cleavage. Those with crystal faces tend to be hexagonal or rhombic in outline. Their outer surfaces are characteristically rough and pitted, and are commonly marked by impressions of adjacent crystals of mica or other minerals. The outer parts of some books are crushed or tangled and must be cut away before the remaining material can be split into thin sheets. Muscovite is transparent and nearly colorless when so split, but thick plates may be distinctly colored. The most common shades are gray, green, amber, brown, and pink. In contrast to the dull, rough surfaces of most books, freshly split mica sheets possess a hard, brilliant luster. The material itself is rather soft, however, and can be cut by a knife without difficulty.

Mica has many physical peculiarities that are of fundamental economic importance. Most are structural imperfections, presumably caused by stress during or after crystallization. The varieties of the mineral have been described as "A", "housetop", "wedge-A", "chub-A", "flat-A", "herringbone", "fishbone", "feather", "horsetail", "wedge", "ribbed", "rippled", "buckled", "warped", "creped", "cross-grained", "reeved", "hairlined", "haircracked", "pinholed", "ruled", "ribboned", "tanglesheet",

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[1] Sterrett, D. B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, pp. 11-19, 1923.

"locky", "gummy", "tied", and "bull" mica, and its colors as "rum", "ruby", "amber", "white", "black", "green", and other, intermediate shades. Variations in kind and distribution of inclusions have led to such designations as "specked", "spotted", "lined", "black", "clay stained", "sand pitted", "gritty", "air stained", and "vegetable stained".

"A" or housetop mica is distinguished by two series of lines, striations, or shallow corrugations that intersect at an angle of about 60°. The third series necessary to complete the "A" is not present, so that the structure actually resembles the letter "V". Much "A" structure is caused by the tapering-out of sheets along straight lines. The edges of some of these incomplete sheets are flanked by narrow ribbons or strips. Many of the corrugations in "A" structure are simple closely spaced folds or crenulations. Some "A" books in which the imperfections are not strongly developed can be split into sheets of commercial value, and in others the material that lies between the two bars of the "A" is flat and can be trimmed out for use. In still others the structure is present through only a part of the book. Much "A" mica, however, is so seriously marred that it must be classed as scrap.

Herringbone (fishbone, feather, horsetail) mica is marked by the same imperfections present in "A" structure, but their angle of intersection is about 120° rather than 60°. The lines and crenulations flank a central line or narrow strip to form a pattern resembling that of a feather or the skeleton of a fish. Herringbone books contain little or no flat material and hence are generally processed as scrap.

Wedge structure is caused by the interlayering of sheets of unequal size. Some extend entirely across the book, whereas others taper out at intermediate points. Books in which groups of incomplete laminae extend inward from all edges may be externally regular in shape, but owing to their complex wedge-like internal structure they rarely yield any sheet mica. Books in which a preponderance of incomplete laminae extends inward from one edge are themselves markedly wedge-shaped. Wedge structure is common in "A" and herringbone micas, but also occurs in mica not marked by such imperfections. "Wedge-A" books, especially the small, thickly wedged "chub-A" books, consist almost wholly of scrap; hence the distinction between "wedge-A" and "flat-A" mica is important from an economic standpoint.

Ribbed or rippled mica is marked by waves or ridges, generally broad and shallow, that are not assignable to "A" or herringbone structure. The terms "buckled" and "warped" have also been applied to such material. Sheets in which these imperfections are not too severe may have commercial value for some uses. Cross-grains or reeves are fine irregular striations or crenulations that result in breaks or tears when the mica is split.

Some are caused by an intergrowth of two books and some by an irregular intergrowth of two or more sheets in the same book. The origin of others is not clear. Hairlines or haircracks are generally so thin and fine that their presence may not show until the mica is split, when they cause separation of laminae. According to Sterrett,[2] crystals of "A" mica in which only one direction of striations is present are called "hair-lined".

One of the commonest structures in mica books is ruling, which consists of regular, sharply defined parting planes that lie at an angle of nearly 67° with the cleavage plane. Only one set of these partings is present in many books, but two or three sets occur in others. Their traces on cleavage surfaces intersect at angles of about 60°, and where three sets are present they commonly separate the sheets into triangular fragments. Many sheets ruled in two directions are separated into rhombic or diamond-shaped fragments. In strongly ruled books the structure generally continues through their entire thickness, but in other books it is confined to certain layers in which it may extend partly or completely across the cleavage faces. Where one set of ruling planes is well developed the mica is separated into strips or ribbons that commonly are less than an inch wide. Ribbons in some large books, however, are as much as 4 or 5 inches wide, and hence may be valuable if free from other defects. Ruling appears in much "A" and herringbone mica, in which it coincides in direction with the striations or corrugations, but it is more common in books that lack these features.

"Tanglesheet" is a term applied to mica that tears when split. Such material splits evenly and easily in some places, but yields ragged, cross-grained films in others. This tangling, "tying", or "locking" is generally due to a partial intergrowth of books or of sheets in a single book. The designation "tanglesheet" is also applied to coarse aggregates of irregularly intergrown books, which are commonly marked by "A", herringbone, or wedge structure, or combinations of these. Where such aggregates are several feet in maximum dimension they may be referred to as "bull" mica. Such material is useful only as scrap.

Magnetite and hematite are the most common inclusions in mica. They may occur as reddish, smoky brown, or black spots or tiny specks, or they may be grouped in triangular lattice-like patterns. Whether present as distinct spots, elongate aggregates of spots, or separate strips, such inclusions tend to be grouped or oriented in accordance with the crystal directions of the enclosing mica. The edges of many spots are so irregular that they create a tufted or dendritic appearance. According to Sterrett,[3]

> These tufts . . . are very thin and rarely penetrate far into a sheet of mica. The dark-brownish color of many of these spots

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[2] Sterrett, D. B., *op. cit.*, p. 16, 1923.

[3] Sterrett, D. B., *op. cit.*, p. 18, 1923.

> is due to the translucency of the thin films (of iron oxide). . . . Each spot owes its dendritic appearance to the arrangement in lines of small particles. . . From these lines of particles other particles branch off at more or less definite angles.

Many inclusions of magnetite have decomposed to yield yellow to reddish limonite, or hematite in shades of orange, red, and brown. Inclusions of hematite are commonly altered to limonite.

Flattened crystals of garnet occur in some plates of muscovite. Inclusions and intergrowths of biotite are common. Other included minerals are apatite, zircon, rutile, zoisite, quartz, tourmaline, albite, and manganese oxides. Quartz and albite may also be interlayered with mica plates to form composite masses of little or no economic value. The edges of other books are intergrown with these minerals, and must be removed by trimming before the remaining mica can be split. Books in which spindles of quartz are present are known as "gritty" or "sand pitted". Some mica is marked by a pale-green discoloration that is termed vegetable stain. The coloring material commonly is chlorite, organic matter, or material rich in ferrous iron. It may be evenly distributed as extremely thin, curdy aggregates or may occur as separate clumps. Air-stained mica contains flattened pockets, tiny bubbles, or groups of closely spaced bubbles that are filled with gas. Vegetable stain and air staining are considered serious defects only in mica of the highest qualities.

Most books that have been exposed to weathering and the action of downward-percolating surface waters are coated with limonite, manganese oxides, clay, silica, or other secondary minerals. Where these have been deposited by waters that penetrated between the laminae of the mica, the value of the books is materially reduced. The stained parts must be removed by careful trimming and splitting.

CLASSIFICATION

As taken from the mine, the mica crystals or books are designated as "mine-run", "run-of-mine", "book", or "block" mica. The term "block mica", however, is also applied to partially prepared stock that will yield sheet material, as well as to certain types of imported sheet material, and hence might well be dropped as an alternative for "book mica". For commercial purposes mica can be classified primarily as sheet, punch, or scrap, depending upon the type of material obtained from the mine-run books. Scrap includes books and flakes that are too small or too marred by imperfections to yield acceptable sheet or punch material, as well as the waste from those books that do yield such material. The scrap obtained as trimmings and discarded splittings in the preparation of sheet and punch goods is known as shop scrap or bench scrap in contrast to mine scrap, which ordinarily never reaches the trimming and rifting shops.

Sheet mica as generally understood is material that is relatively flat and sufficiently free from structural defects to be manufactured into certain shaped products that are used chiefly in electrical equipment. Such material is also known as "uncut sheet". Uncut sheet mica has been freed of obvious scrap, split or "rifted" into relatively thick plates, and trimmed by one of several means. If it is capable of yielding prepared sheets or "patterns" 1½ by 2 inches in minimum size it is known in the New England and Southeastern states as sheet or pattern mica, and in New Mexico and other Western states as "plate mica". That the general term "block mica" is more suitable for such material has been pointed out by Gwinn,[4] who defines it as prepared mica of "random thickness ⅛ inch to less than $^1/_{100}$ inch (125 to 10 mils), which contains a usable area of 1½ by 2 inches minimum." Uncut mica capable of yielding prepared material less than 1½ by 2 inches is sometimes known as "uncut punch" or "uncut circle", but more commonly as "punch" and "circle". The prepared material is generally referred to as "trimmed punch" or "small sheet".

Size designations for domestic sheet mica are based upon

TABLE 5. DOMESTIC AND INDIAN SIZE GROUPS FOR CLEAR SHEET MICA[a] (INCLUDING PUNCH AND SHEETS LARGER THAN PUNCH)

Usual domestic grades		Usable area in single rectangle (square inches)			Standard Indian grades
		Minimum		Maximum	
Small punch	Punch[b]	1	to	1½	No. 6 small
Punch		1½	to	2½	No. 6
Circle		2½	to	3	No. 5½
1½ by 2 inches		3	to	4	No. 5
2 by 2 inches		4	to	6	
2 by 3 inches		6	to	10	No. 4
3 by 3 inches		10	to	12	No. 3
3 by 4 inches		12	to	15	
3 by 5 inches		15	to	24	No. 2
4 by 6 inches		24	to	36	No. 1
		36	to	48	No. A-1
6 by 8 inches		48	to	64	Special
8 by 8 inches		64	to	80	Extra special grades
8 by 10 inches		80	to	96	

[a] Adapted from charts issued by the Colonial Mica Corporation, agent for Metals Reserve Company. Applies to sheets not less than 0.007 inch in thickness.

[b] This general term applies to mica yielding usable sheets not less than 1 inch in diameter.

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[4] Gwinn, G. R., Strategic mica: U. S. Bur. Mines Inf. Circ. 7258, p. 18, 1943.

the dimensions of the largest rectangle of a given quality that can be obtained from the block. The usable rectangle must be free from holes and cracks and must meet certain tolerances as to other flaws. The domestic and Indian size groups for sheet mica are summarized in Table 5. A more complete discussion of size grading, and typical grading tables and charts, are included in a report recently issued by the Federal Bureau of Mines.[5]

Quality designations for sheet mica vary according to the classification used. They are inexact, owing to inescapable differences in individual interpretations of the standards. Indian standard groups, beginning with the best quality, are clear, clear and slightly stained, slightly stained, fair-stained, good-stained, stained, heavy-stained, light-dotted, black-spotted, and black-stained. In 1938 the American Society for Testing Materials[6] set up Indian grading as the American standard and designated six principal qualities. These are clear, clear and slightly stained, fair-stained, good-stained, stained, and black-stained or spotted. Several of the groups are sometimes subdivided into more specific categories.

PREPARATION AND MANUFACTURE

The first rough separation of mica is generally made at the mine, either at the face or portal or on the dump. Obvious mine scrap is separated from the better books, from which adhering fragments of quartz, feldspar, and other foreign material are then cobbed. Some of this rough-cobbed or selected mine-run mica is sold as such to jobbers or manufacturers, but at many mines it is prepared further. The books are split or rifted by means of a 3-inch single- or double-edged blade into plates that are generally less than $^3/_{16}$ inch thick. Through skilled handling of the rifting knife defective laminae are removed with a minimum waste of higher-quality material, and the products obtained are block mica, punch and washer stock, and bench or shop scrap. In New Mexico much of the cobbed mica is split into plates somewhat thicker than $^3/_{16}$ inch, but both these and the thinner riftings are known there as "plate mica". As such they constitute a specially selected form of mine-run material. There appears to be little distinction between trimmed and untrimmed sheets in the New Mexico usage of the term "plate mica".

After rifting, the ragged and broken edges of many plates are removed by hand, a process known as "thumb trimming". This is an especially common practice in districts where much of the mica is badly ruled or marked by "A" structure. Thumb-trimmed material may be sold to manufacturers as such or it may be further trimmed with a knife. Most Indian mica is knife-

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[5] Gwinn, G. R., *op. cit.*, pp. 7-10, 1943.

[6] A.S.T.M., Grading and classification of natural mica: Amer. Soc. for Testing Mater., Release D-351-38, 1938.

trimmed or "sickle-trimmed" until free of cracks and flaws, but domestic procedure is somewhat different. Half-trimmed mica, for example, is cut on two adjacent sides, with no cracks, reeves, cross-grains, or ribs extending from those sides. Three-quarter-trimmed mica is cut on all sides, with no cracks or comparable flaws extending from two adjacent sides or into the final pattern area. Only full-trimmed mica is cut on all sides and contains none of the flaws noted above. Some mica is trimmed with shears, and during recent years attempts have been made to employ blades and saws.

A large proportion of sheet mica is consumed in the form of splittings. These are films 0.0007 to 0.001 inch thick that are generally cleaved from punch and the smaller sizes of sheet stock. Some also are derived from thin films or "skimmings" that are a by-product from the rifting of larger sheet material. Splittings are used in the manufacture of built-up mica board and other forms of electrical insulation. Although many mechanical devices have been tested for the preparation of these films, practically all films are still split outside the United States by hand methods, generally in places where labor costs are very low.

The cut mica blocks that represent punch, circle, and larger sheet stock are processed into discs, washers, and thin plates of various sizes and shapes. This generally involves additional splitting, followed by trimming, cutting, or stamping into more or less standardized patterns. Most of this material is then cut to final form, if necessary, by the manufacturers of the devices in which the mica is to be used. Composite forms can be built up to any desired thickness by the cementing of individual pieces with shellac or a similar bonding medium. In general, only a small proportion of the prepared block material is represented in the finished products. The bulk of such material is skimmed or cut away as waste, which is marketed as scrap of superior grade.

Most scrap mica, including material derived from non-pegmatitic sources, is processed by grinding. It is classified on the basis of its mechanical purity and the color of the ground product. About a third of the mica ground in this country is prepared by wet methods, which yield relatively fine-grained material. Most of the coarser, less expensive products are ground by dry methods. Reports published by the U. S. Bureau of Mines[7] give details of the problems and methods of mica grinding.

USES

The uses of mica are based upon its perfect cleavage, remarkably low conductivity of heat and electricity, non-inflammability, flexibility, elasticity, transparency, luster, lubricating properties, and the ease with which it can be worked into final

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[7] Myers, W. M., Mica: U. S. Bur. Mines Inf. Circ. 6205, pp. 7-8, 14-18, 1929. Horton, F. W., Mica: U. S. Bur. Mines Inf. Circ., 6822, 56 pp., 1935.

form.[8] A high proportion of all sheet mica is used as an electrical insulating material. Washers, discs, and other small trimmed or stamped forms are not only used as such, but can be built up into rods or tubes that are bonded with a suitable cementing material. Simple and composite pieces are used as tubes, sleeves, studs, washers, bushings, laminations, and thin perforated plates in condensers, transformers, small heating elements, rheostats, fuses, incandescent bulbs, radio and electronic tubes, various types of coils, and acoustic, X-ray, and other specialized equipment. Splittings are built up into mica board or applied as facing on paper, cloth, and other materials used in the manufacture of heater elements; commutators; boards, panels, and other mounting forms; parts of condensers; and many other electrical devices.

Most coarsely ground mica is used in the manufacture of roofing materials, although the demand for such mica as a refractory is constantly increasing. It is also used for decorative purposes as a coating on wall paper, as a constituent of certain stuccos, plasters, and cements, or alone as Christmas-tree snow. During recent years increasing quantities of roughly prepared mica have been used in foundry facings and in the insulation of buildings, or have been manufactured into molded electrical insulation. Very finely ground mica is used extensively in the manufacture of rubber, paints and other protective coatings, lubricants, textiles, and plastics. It is an effective filler and bonding medium, and commonly increases the resistance of the products to corrosion, heat, and fatigue.

STRATEGIC MICA

With the beginning of World War II, the problem of military mica requirements was thrown into sharp relief. According to Wayland,[9]

> Army equipment requires large amounts of muscovite mica splittings in the form of built-up mica commutator segments and coil insulation in motors and generators. Other military items using significant amounts of muscovite splittings are transformers, switchboards, and blasting apparatus. Flexible mica tape, made from bookform or loose-dusted splittings cemented to paper, linen, glass cloth, and other backing, is widely used in coil insulation in heavy electrical equipment and in aircraft generators. All mica splittings come from India, principally because of the enormous amount of hand labor required in their preparation. In this emergency, the need for them was anticipated and large industry and government stocks were on hand, while shipments have continued to come by sea in spite of war-time hazards. . . The mica problem in this war is unprecedented in many ways. Our big problem now is for radio and magneto condensers. . . Mica condensers

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[8] For uses of mica see Wierum, H. F., and others, The mica industry: U. S. Tariff Commission, Rept. 130, 2nd ser., pp. 11-26, 1938.

[9] Wayland, R. G., Mica in war: War Production Board, Mica-Graphite Div., Mica Release No. 10, pp. 1-2, 1944. (Paper presented before the meetings of the American Institute of Mining and Metallurgical Engineers, New York City, February 1944.)

> are particularly characterized by the constancy and excellence of their electrical properties under varying physical conditions, a most important factor in military radio.

The wartime demand for sheet mica, particularly for the superior qualities, was further intensified by sharp increases in the use of mica for aircraft spark plugs, radar condensers, vacuum tubes, and other electrical devices for combat equipment.

Strategic mica, as first defined during World War II by War Production Board Conservation Order M-101, is reasonably flat block and sheet mica, of heavy-stained quality or better, that is free from cracks and comparable imperfections. Excluded from this category are scrap mica, block mica that will yield a size less than 1 by 1 inch, and splittings used in making built-up mica. The definition of "strategic mica" is by no mean rigorous. Specifications are generally set up in terms of current needs and anticipated requirements, and are modified as conditions change. Nearly all strategic mica produced in New Mexico during the period of World War II, however, was sold under the general definition outlined above, and thus comprised material ordinarily referred to in this country as clear trimmed punch and sheet. This is the meaning of the terms "strategic mica" and "strategic-grade mica" as hereinafter used. Several discussions of such mica and some of the problems connected with increasing its production already have been published.[10]

To be acceptable for use in high-grade condensers mica must have a low power factor, which is a measure (expressed in percent) of the loss of electrical energy in a condenser in which the mica is the nonconducting substance. Excessive overheating and damage result from high power losses; hence good condenser mica must have a power factor of less than 0.04 percent. Tests have suggested that the power factors of almost all clear "ruby" or cinnamon brown micas are sufficiently low for condenser use, but that the factors of green and some brown micas may vary appreciably. The details of this variation are not known at present, nor are the reasons for it thoroughly understood.

To stimulate domestic production of strategic mica, the Metals Reserve Company, a subsidiary of the Reconstruction Finance Corporation, designated the Colonial Mica Corporation as its agent, with authority to purchase mica of certain types and to assist the operators of mines. Mining equipment was leased to operators at low rental rates, financial assistance was rendered in many instances, and consulting services for problems of min-

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[10] Wayland, R. G., *op. cit.*, pp. 1-8, 1944.

Burgess, B. C., Mica mining and preparation cost: Amer. Inst. Min. and Met. Eng., preprint of paper presented at New York meetings. February 1944, pp. 1-17, 1944.

Lintner, E. J., Mica, a war essential mineral: Rock Products, vol. 47, no. 5, pp. 48-50, 92-93; no. 6, pp. 74-76, 114-116, 1944.

Billings, M. H., and Montague, S. A., The wartime problem of mica supply: Eng. and Min. Jour., vol. 145, pp. 92-95, 1944.

See also War Production Board Mica Releases No. 1 and No. 2, July 6, 1942.

ing and preparation of the mica were made available. A market for mica of superior quality was assured at favorable prices and for specified periods.

PRICES

Prices for sheet mica not only fluctuate widely in response to variations in demand, but vary according to the size and quality of the material available at a given time. The general range for clear trimmed sheet mica in the 1½- by 2-inch size group has been $0.12 to $0.65 per pound over a period of about thirty years, whereas that for the 2- by 3-inch group has been $0.45 to $1.50 and that for the 4- by 6-inch group has been $1.60 to $3.75. Prices of $8.00 or more have been quoted for the 8- by 10-inch size from time to time; such large sheet material is not common in most deposits. The value of untrimmed small sheet or punch mica has ranged from 2½c to about 15c per pound.

The larger sizes of trimmed electric (stained sheet) mica are sold according to a sliding price scale, with values consistently lower than those for clear material of comparable size. Electric mica is also sold as thumb-trimmed block, generally at prices that vary according to the estimated proportion of waste. Many jobbers purchase selected mine-run material (either clear or stained), rift and trim it, and sell the prepared mica to manufacturers. Others purchase punch and washer stock from which they recover and trim sheet material, and still others have recovered sheet and punch mica from mine scrap.

Prices for most scrap mica range from $9.00 to $30.00 per ton, depending in part upon whether it is bought at the mine or at some more convenient distributing point. Bench scrap, which is reasonably free from quartz, feldspar, and other impurities, generally commands a higher price than mine scrap. The value of clear light-colored mica that yields a very white product when ground is also relatively high. Buyers and grinders of mica are listed in U. S. Bureau of Mines Information Circular 7258.[11]

Prices reach very high levels during war periods, when the demand for sheet mica is greatly increased and the problems of supply are often complex. The rising trend during the period December 1941-December 1944 is shown in Table 6. Through a part of 1942 strategic-grade mica was purchased by private individuals and organizations, and by the Colonial Mica Corporation as well. In November 1942 the Colonial Mica Corporation became the sole purchaser of such material, and the price scale was raised substantially. A standard price of $5.00 per pound for prepared sheet and punch mica was offered in May 1943, chiefly to stimulate production from deposits yielding a high proportion of mica in small sizes. Additional subsidies in the form of price increases were added later, until on January 1, 1945, private pur-

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[11] Gwinn, G. R., *op. cit.*, pp. 15-17, 1943.

TABLE 6. PRICE SCHEDULES FOR DOMESTIC CLEAR SHEET MICA DURING PERIOD DECEMBER 1941-DECEMBER 1944 [a]

SIZE (inches)	PRICES						
	Private Purchasers		Colonial Mica Corporation				
	December 1941	April-May 1942	June 1942 [b]	November 1942 [b]	May 1943 [c]	Feb. 1944 [c]	August 1944
Punch	.10- .15	.12- .16	.22	.30	5.00	6.00	6.00 [d]
1½x 2	.45- .65	.50- .65	1.10	2.40			
2 x 2	.60- .85	.95-1.10	1.75	3.52			6.00 [e] and 8.00 [d]
2 x 3	1.30-1.50	1.50-1.85	2.75	4.64			
3 x 3	1.90-2.05	2.00-2.35	3.50	5.12			
3 x 4	2.15-2.25	2.25-2.60	4.25	6.08			
3 x 5	2.60-2.75	2.75-3.00	5.00	7.04			
4 x 6	3.60-3.70	3.75-4.00	6.25	8.00			
6 x 8	5.25-5.50	5.50-6.00	8.00	9.12			

[a] Adapted in part from Billings and Montague, The wartime problem of mica supply: Eng. and Min. Jour., vol. 145, p. 94, 1944.

[b] Punch material required to yield 20% or more of trimmed pieces 1 by 1 inch or larger; price scale for larger mica based on No. 1 quality and half trim, with maximum bonuses of 30% and 40% for three-quarter trim and full trim respectively.

[c] Based on full-trimmed punch and three-quarter-trimmed sheet mica.

[d] Full-trimmed mica.

[e] Three-quarter-trimmed mica.

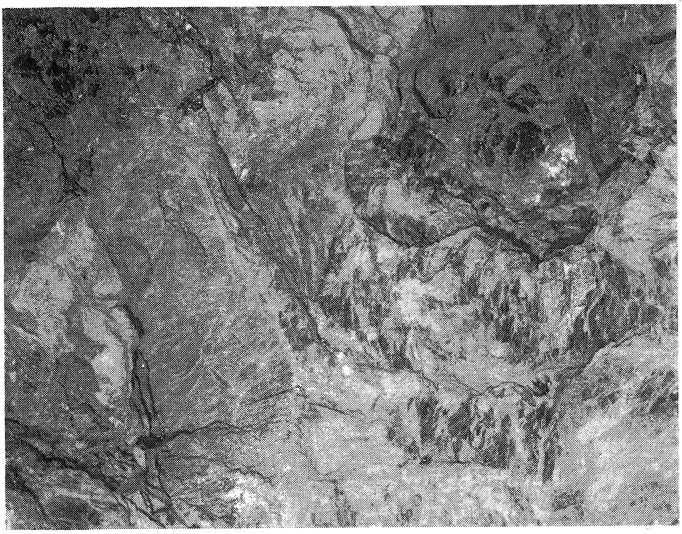
chases of strategic-grade mica were again permitted. At that time the Colonial Mica Corporation continued to buy sheet mica of "ruby" color only, and purchases of full-trimmed mica smaller than 1½ by 2 inches were discontinued. Prices for mica of superior quality were subsequently decreased further with the general trend toward a peacetime economy.

MICA IN THE PETACA DEPOSITS

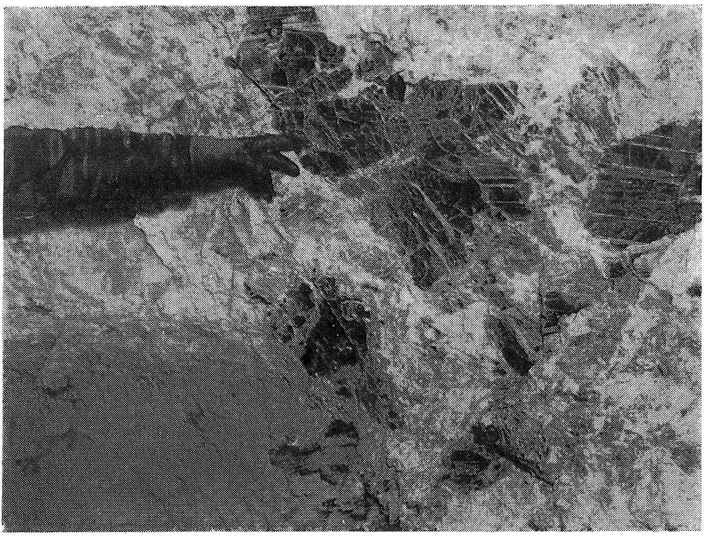
PROPERTIES

The mica in the Petaca district ranges from yellowish green through shades of very pale green, brownish green, and greenish brown to deep bottle green. It occurs in books that range in diameter from an inch or less to at least 7 feet. The largest books yield trimmed sheets 20 inches or more in diameter, but such material is very rare. The best mica concentrations are generally rich in tangled, intergrown books that are useful only as scrap. Most of the remaining mica is marked by "A" structure, though "flat-A" is much more common than wedge. Other common defects are ruling (Plate 3) and broad warping or rippling. Thus very little sheet mica from the Petaca pegmatites is perfectly flat, and a high proportion of the prepared material is in the small-sheet range. Herringbone structure, pinholes, and cross-grains are not common.

The mica in a few deposits is heavily stained, chiefly by



Partly albitized mica books, main incline, Globe mine. Large microcline crystal (gray, below hammer) is veined, fringed, and corroded by albite (white).



Severely ruled mica books in albite (white) and quartz (light gray), central mica shoot, Cribbenville mine.

RULED AND PARTLY ALBITIZED MICA BOOKS, GLOBE AND CRIBBENVILLE DEPOSITS hematite and magnetite in lattice-like patterns, and lightly specked material is encountered in other deposits. Most of the mica in the district, however, is clear. Vegetable and air stains are rare, but some books are marred by inclusions of garnet, fluorite, and quartz. Layers of silica deposited between cleavage laminae by surface waters seriously damage much otherwise excellent mica. In deposits where albitization has been unusually widespread, the edges of many books have been corroded and replaced by this feldspar, and in a few mica shoots some books have been almost completely replaced (see Plate 3, top).

The results of power-factor determinations made during the past 6 years on a few specimens from several deposits suggest that most Petaca sheet mica would be satisfactory for use in condensers and other devices in which material of superior electrical properties is required. Similar results were obtained when 60 pieces of clear sheet mica from the Globe, Cribbenville, and Kiawa deposits were tested in September 1945 by F. W. Lancaster of North Carolina State College. These tests were made in Asheville, North Carolina, with determination of the power-factor reciprocal by means of a Bell Telephone Laboratories Q-meter. All the specimens were found to be well within the E-1 group. More systematic and comprehensive tests are needed to permit comparisons of mica samples from different deposits and comparisons between Petaca mica and that from other districts.

OCCURRENCE

GENERAL RELATIONS

The association of muscovite with albite in the Petaca pegmatites is consistent. Little mica is present in deposits or parts of deposits that contain little albite, whereas all deposits rich in mica are also rich in albite. The amount of muscovite in a given pegmatite unit is generally proportional to the relative abundance of albite, but this relation does not necessarily hold where the pegmatite consists almost wholly of albite. Such rock units may contain the remnants of many books that appear to have been largely replaced by the plagioclase. Masses of completely or almost completely albitized pegmatite in which little mica is present are common in the Silver Dollar, Apache, Kiawa, Cribbenville, Globe, Alamos, and Hidden Treasure deposits.

No correlation between the size of the pegmatites and their mica content seems to exist. Both large and small deposits contain rich and extensive mica shoots, yet some of the largest pegmatites in the district are virtually barren of mica. Evidently the degree of late-stage albitization and the introduction of mica were dependent upon factors other than the size of the pegmatite.

STRUCTURAL DISTRIBUTION

Concentrations of albite and mica are present in deposits of all general forms. They are most abundant at the keels and along the lower flanks of plunging pegmatites, and hence appear near the eastern ends of such bodies at the surface. They are also common at and near the keels of plunging trough-like bodies, which are U-shaped, hook-shaped, or boomerang-shaped in plan. The mica is thus most abundant at and near the main bends, which generally constitute the most easterly exposed parts. On the other hand, the mica in plunging inverted trough-like bodies is most abundant near their westerly exposed portions, as it is concentrated near and along their crests. Concentrations of mica in other, less regular bodies commonly occur along bulges, indentations, or lines of junction with branching dikes or irregular apophyses.

The details of mica distribution within the pegmatite bodies are complex. The workable concentrations can be related to zones in a definite way, but they are not restricted to any one or any group of these units. They may transect zone boundaries at any angle. In this respect the Petaca deposits are fundamentally different from most of the mica pegmatites of New England and the Southeastern states, in which commercial concentrations of muscovite are largely restricted to specific zones.[12] The mica in such pegmatites is apparently a primary constituent of units that are rich in oligoclase and calcic to median albite, in striking contrast to the Petaca muscovite, which occurs with sodic albite in hydrothermal concentrations superimposed upon the original pattern of zoning in microcline-rich pegmatites. Such helpful descriptive terms as "intermediate-zone deposit" and "wall-zone deposit" are therefore not applicable to the Petaca deposits.

The following modes of occurrence are characteristic of the Petaca mica.

I. Pegmatite bodies in which zoning is not well developed.
   A. Disseminations throughout the pegmatite. The proportion of mica in these deposits generally decreases from east to west or from bottom to top in westerly plunging pegmatite bodies. Most of the mica books are small and few of the concentrations are rich enough to be of commercial interest.
   B. Well-defined concentrations along one or both borders of the pegmatite. These concentrations, which are gen-

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[12] Bannerman, H. M., Structural and economic features of some New Hampshire pegmatites: New Hampshire State Planning and Dev. Comm., Min. Res. Survey, Part VII, 1943.
Olson, J. C., Mica bearing pegmatites of New Hampshire: U. S. Geol. Survey Bull. 931-P, pp. 373-376, 1942.
Olson, J. C., Parker, J. M., III, and Page, J. J., Mica distribution in western North Carolina pegmatites (abstract): Econ. Geol., vol. 39, p. 101, 1944.
Cameron, E. N., Larrabee, D. M., McNair, A. H., Page, J. J., Shainin, V. E., and Stewart, G. W., Structural characteristics of New England mica deposits: Econ. Geol., vol. 40, pp. 369-393, 1945.

erally thin, decrease in richness and taper out from east to west in most deposits. The mica books are characteristically small and so scattered that they cannot be recovered commercially.

C. Concentrations at the margins of small pods and lenses of massive quartz. Many of these have been prospected, but in general they are too discontinuous and contain too little mica to be mined at a profit.

D. Irregular concentrations in small pod-like portions of the pegmatite that are relatively rich in interstitial quartz. No concentration of this type has supported operations beyond the prospecting stage.

E. Poorly defined fringes around partly digested inclusions of country rock. These contain mica in books of moderate size, but the material is commonly soft and severely tangled. Few concentrations are sufficiently extensive for scrap-mica operations.

II. Deposits in well-zoned pegmatite bodies.

A. Concentrations along the borders of the pegmatite and around the margins of inclusions; similar to types A and B above. Neither of these appears to be of economic importance.

B. Concentrations flanking cores, especially where the cores consist of massive quartz with or without giant crystals of microcline. Such deposits are commonly rich and contain many large books, especially near their keels or east ends. They are of considerable commercial importance.

C. Concentrations in wall zones, especially along their inner margins. These also tend to be richest near the easterly ends or keels of most pegmatite bodies. They may flank more than one inner zone and may extend irregularly into such zones. They are characteristically rich, especially where the wall zone is relatively thin, and hence are commercially important, although they contain a higher proportion of scrap material than the concentrations adjacent to cores.

D. Fringes at the margins of rosettes and "bursts" of cleavelandite. These concentrations, which contain soft mica of scrap grade only, are generally small and of little economic interest.

E. Concentrations along major fractures. These also contain soft tangled mica of scrap grade, and are so small that they can be worked only where they are adjacent to other, richer concentrations of mica.

F. Disseminations in massive quartz and quartz-rich pegmatite, generally formed through intensive replacement controlled by a network of closely spaced fractures. Such concentrations are present at or near the keels of plunging pegmatite bodies and are generally extremely rich. The mica occurs as books too small to yield sheet and punch material.

The well-zoned pegmatites thus contain more workable shoots of mica than those in which zonal structure is indistinct. In the westerly or microcline-rich parts of many zoned bodies, however, the occurrence of mica may be similar to that in poorly zoned deposits. The immediate control for mica mineralization was probably furnished by fractures or fracture groups. These appear to have led to development of rich concentrations along contacts between zones, particularly along contacts between wall zones and adjacent inner zones. Rolls, warps, and other irregularities in such contacts were particularly effective in localizing the mica-forming solutions. The distribution and elongation of the mica shoots plainly reflect the plunge structure of the pegmatite zones and of the bodies themselves. For this reason, structural analysis of the zoning in a given deposit is as helpful in determining its economic potentialities as it would be if the mica were a primary constituent of the zones.

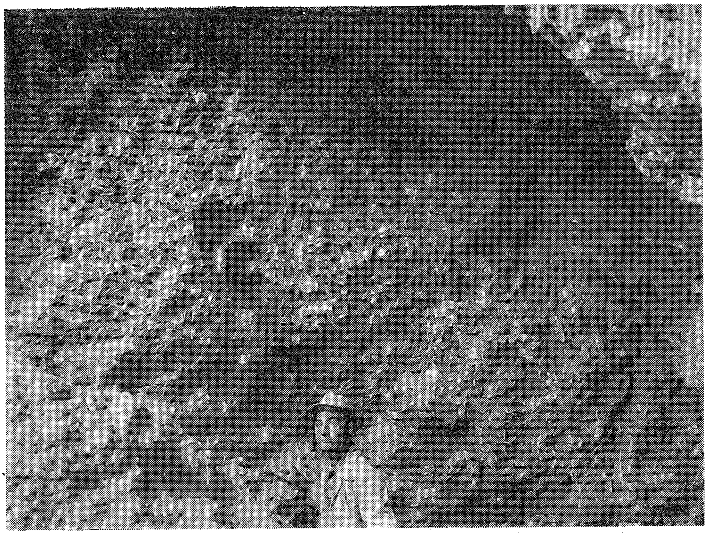
The largest books are generally found near or against cores of massive quartz and are characteristically marked by "A" structure. Much of the coarse mica in rich shoots not immediately adjacent to the cores occurs in tangled intergrowths that yield little sheet material. The proportion of high-quality mica is greatest in the rich shoots formed through nearly complete replacement of thin wall zones adjacent to cores of massive quartz. Mica near or along the footwall of a dike is commonly softer and more severely warped, ruled, and broken than that along the hanging wall, but there are numerous exceptions. Mica in deposits whose contacts with the country rock are markedly irregular and gradational is commonly relatively soft and occurs in tangled masses.

GUIDES FOR PROSPECTING

Prospecting in the Petaca district followed the discovery of mica concentrations at the surface. As mining progresses, fewer such concentrations remain and it becomes progressively more difficult to judge the potentialities of a given pegmatite solely on the basis of exposed mica. It becomes increasingly necessary to use all other available means of evaluation.

If a pegmatite body is more than a foot or two thick at the surface it may be worthy of attention, for it need not be large to

Mined-out part of rich core-margin mica shoot, looking southwest at No. 3 cut, Elk Mountain mine. Men are standing on massive quartz core, with coarse-grained microcline-rich wall zone above their heads. Zones and hanging wall of pegmatite body plunge gently southward at extreme left, progressively more westward to right.



Broad roll in footwall of massive quartz core, Red mine. Crest of roll is directly over man's head and plunges to right. Note remnants of many mica books and molds of others in the quartz.

STOPES IN RICH MICA SHOOTS, ELK MOUNTAIN AND RED DEPOSITS yield appreciable quantities of mica. Moreover, it may thicken with depth, just as large masses may thin rapidly with depth. If the deposit is rich in albite, particularly in the lustrous white curving plates of cleavelandite, concentrations of mica may be expected. On the other hand, if good outcrops are available and these contain little albite, the pegmatite may well be disregarded in favor of more promising deposits.

If albite and mica are noted in a deposit that is zoned, the possibilities for productive shoots are good, especially where a core of massive quartz, coarse blocky microcline, or a combination of the two is present. The approximate outcrop plan of such a deposit should then be determined, so that more detailed examination of outcrops and judgment of intervening covered areas can be confined to the most promising part of the body, which might be termed the focus of mineralization. As shown diagrammatically in Figure 6, such foci of mineralization tend to lie at or near the easterly ends of dikes and trough-like bodies that plunge in a westerly direction, and at or near the westerly ends of inverted trough-like bodies with a similar plunge. The mica tends to occur at some distance from the ends of deposits unusually rich in albite, as shown by the stippled areas in the diagrams. The distances from the foci of mineralization at which concentrations of mica are found tend to vary in proportion to the degree of albitization. The hanging-wall and footwall sides of cores and intermediate zones, as well as broad warps, indentations, and protuberances in the margins of zones or pegmatite bodies should be scrutinized for promising shoots.

The general procedure outlined above is suggested primarily to eliminate the expenditure of money, time, and effort on deposits or parts of deposits where little return can be foreseen on the basis of geologic analysis or past experience. On the other hand, this procedure is not an infallible means for finding workable mica deposits, though it should serve to narrow the search to the most promising parts of the most promising pegmatite bodies.

Two general techniques were involved in past operations in the Petaca deposits. Some miners closely followed mica shoots downward from their outcrops, whereas others attempted to intersect the productive portions of deposits at depth by means of planned adits or shafts. The former technique involved the selective mining of the richest portions of the mica shoots by means of tortuous "gopher-hole" workings, with the leaving of much mica in the ground. This method is wasteful, imposes serious limits on the depth to which a given shoot can be worked, and fails to uncover reserves in the form of adjacent shoots. Just[13]

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[13] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, p. 61, 1937.

records the oft-expressed opinion that such methods are excusable because pegmatites are small and characteristically irregular, shoots are discontinuous, and grade is uncertain. He reasonably concludes, however, that "While this judgment may be fair enough in a survey of past operations, there is no reason to believe that the mica industry is less susceptible to improvement than other mineral industries. In fact, the writer believes that the mining and processing of mica are particularly fertile fields for the application of modern technical knowledge."

The second technique, while much more farsighted, is necessarily somewhat uncertain. This uncertainty is great wherever the work is done without detailed consideration of the form and attitude of the pegmatite bodies, particularly those with a gentle plunge or abrupt and large-scale variations in dip. Experience has demonstrated that the general aiming of adits and shafts at down-dip extensions of known deposits is a risky procedure in the Petaca district. Several low-level adits that have been driven to intersect productive parts of pegmatite bodies have been disappointing because they passed beneath the keels of these bodies. Although they actually show the significance of the gentle to moderate plunges involved, such disappointments have been repeatedly cited in support of the thesis that pegmatite bodies are too irregular to be developed in advance of mining.

It is no accident that the mining of rich concentrations of mica downward from their outcrops in the Petaca district has led to development of inclines and inclined stopes that generally slope in a westerly direction. This down-slope or down-plunge direction of mica shoots and of the pegmatite bodies themselves should receive prime consideration in the planning of exploration and development. Plunge structures in a given area tend to be remarkably consistent, as pointed out in the discussions of structure and in descriptions of individual deposits. Minor fold axes in the country rock, elongation of pegmatites in outcrops and old workings, rake of bulges and corrugations in pegmatite contacts, and other structural features thus form a basis for estimating the direction and degree of plunge. In the absence of such features a guess based on the known preponderance of moderate westerly plunges in the district should involve little risk.

Many pegmatite outcrops virtually barren of mica have been prospected, apparently on the assumption that workable concentrations must be present at depth. The disappointing results of such operations show that this assumption is rarely justified. The distribution of mica within a pegmatite body is governed by processes whose activity ceased long before the present surface was formed, and hence bears no genetic relation to the present surface. Unless there is definite structural evidence for the existence of a mica shoot at a given point beneath the surface, exploration should not be directed toward that point on the mistaken assumption that the mica content of any pegmatite must increase with depth. Neither does the quality of mica tend to improve with depth, except for diminution and disappearance of such near-surface features as clay staining, some kinds of vegetable staining, softness induced by water soaking, and buckling and splitting caused by frost action. "A" structure, ruling, wedge structure, and other defects have been produced by processes that bear no significant relation to the present surface. This is equally true of spots and lattice-like intergrowths of magnetite and hematite. Although the irregular distribution of such stains is not fully understood, the average proportion of stained mica books in a given deposit is as likely to increase downward as to decrease.

QUANTITATIVE RELATIONS

Rough quantitative analyses of mica shoots have been made in those deposits that have been mined, although precise determinations of the richness of mica shoots, as well as the mica content of entire pegmatite bodies, are beyond the scope of present investigations. The average proportion of mica in each of fifty-two mined pegmatites ranges from less than 0.1 percent up to 8 percent, with an overall average of less than 2 percent. This low figure is scarcely surprising if the relatively barren western portions of most bodies are considered. The average mica content of those parts of the deposits in which mica shoots are present—generally the easterly half or third of a given body—is distinctly higher and probably amounts to 3½ or 4 percent. It seems plain that bulk operations aimed at working entire bodies for their mica alone would not be profitable ventures.

The richness of individual mica concentrations or shoots cannot be determined exactly. Reliable production records are obtainable for a few mines only; moreover, many of the older mine workings are no longer accessible. It has been possible, however, to estimate the mica content of many shoots on the basis of mica-rich material left on the walls and backs of workings, fragments of uncobbed material near mine portals, untrammed material in the workings, and the mica in the breasts themselves. Production records, whenever obtainable, have served as a basis for analysis by comparison with the volume of workings from which the mica was taken. Results from the two methods were in strikingly close agreement for the seven deposits that could be investigated in such detail.

The proportion of book mica in concentrations that have been worked ranges from less than 2 percent to 95 percent. Most of the better deposits contain between 9 and 12 percent mica. The richest concentrations are compact aggregates of books less than 1½ inches in diameter (parts of the Nambe, Capitan, and Red deposits), or tangled masses of coarsely intergrown "bull" mica (parts of the Globe and Kiawa deposits). The average proportion of mica in most productive shoots is 25 percent or less, and is generally 15 percent or less. Although the richness of a given mica shoot ranges widely from place to place, it tends to be uniform over distances of 25 feet or more, and the shoot itself is quite distinct from adjacent, relatively barren pegmatite.

The average proportion of trimmed sheet and punch material that can be obtained from Petaca mica is about 0.5 percent. This is considerably lower than the "average range" of 3 to 8 percent cited by Billings and Montague[14] for domestic deposits. Most workable deposits in North Carolina, the chief mica-producing state, yield mica from which an average of about 4 or 5 percent of trimmed block can be obtained. The writer's observations in New Mexico and elsewhere suggest that a low yield of sheet and punch stock may be a characteristic of mica that was formed in pegmatite at a late stage by hydrothermal replacement processes. The ratio of trimmed sheet to trimmed punch material obtained from Petaca mica during the recent wartime operations is about 1 to 2. This may well be somewhat lower than the average for domestic deposits, owing chiefly to severe ruling, warping, tangling, and "A" structure. Moreover, most of the sheet is in the small-size range (grades 4 and 5).

More detailed analyses of the quantity and quality of mica are included in the discussions of individual deposits.

MICA IN THE COUNTRY ROCK

The quartzite country rock has been impregnated with small flakes of pale green mica in many parts of the district. Such zones of impregnation tend to be rich where they include or lie adjacent to lenses and pods of pegmatite and vein quartz. At the Veseley deposit, for example, hundreds of pounds of almost pure mica were obtained by merely digging, breaking up, and screening the thoroughly altered quartzite. Mica-rich masses of this type are discontinuous, however, and hence are of limited economic interest. Less clearly related to pegmatites or quartz veins are remarkably continuous belts of mica-impregnated country rock. They range in width from a few feet to a hundred feet or more, and have been mapped in several areas (see Plates 13, 14, and 16). Some are extremely rich in mica, but any large-scale operations would necessarily involve milling to eliminate the quartz.

BERYL

GENERAL FEATURES

Beryl is used as a gem material and in ceramics, but most of it is converted to beryllium compounds, beryllium metal, and beryllium-bearing alloys. The oxide, carbonate, and silicate of

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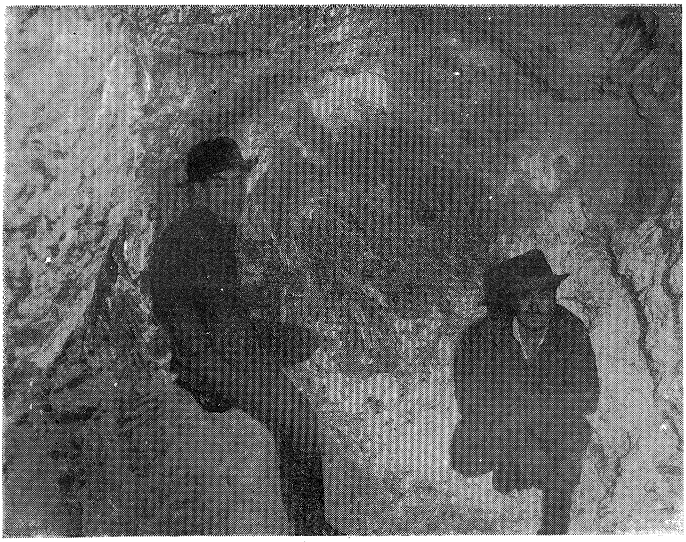
[14] Billings, M. H., and Montague, S. A., The wartime problem of mica supply: Eng. and Min. Jour., vol. 145, p. 95, 1944.



Rich mica concentration, heading of main incline, Globe mine, October, 1944.

Preparing Cribbenville mica, custom mica shop, Santa Fe.

RICH MICA CONCENTRATION, GLOBE DEPOSIT, AND PREPARATION
OF MICA IN SANTA FE

beryllium are used in ceramics, in the preparation of fluorescent lamps and screens, and in special processes of paint and textile manufacture. Beryllium metal is used in X-ray tubes and in the optical systems of specialized electrical instruments. It is alloyed with aluminum for some light-metal uses, and is a minor constituent of some nickel and iron alloys. The chief current demand, however, is for copper-base beryllium alloys, whose desirable properties include hardness and structural properties superior to those of pure copper, extraordinary resistance to fatigue and wear, good electrical conductivity, response to hardening treatments after being worked soft, and non-sparking qualities. These alloys are nonmagnetic. Beryllium-copper generally contains 2 to 4 percent beryllium; other special-purpose alloys are made by adding cobalt, chromium, silver, or nickel. Members of the beryllium-copper group of alloys are used in non-sparking tools and in springs, contact plates, bushings, shims, and corrosion-resistant parts in motors, precision instruments and machines, gauges, and other devices in which material with one or more of their unusual properties is desirable or essential. The use of beryllium alloys is a development of recent years, and has constantly increased with increase in demand for special-purpose metals and the growing knowledge of their potentialities through metallurgical research.

Prices for clean-cobbed domestic beryl were quoted at $30 to $35 a short ton (at the mine) for several years prior to 1941, but they gradually rose during succeeding years in response to wartime increases in demand and transportation difficulties in the importation of foreign beryl. By May 1943 a price of $120 per dry short ton was guaranteed by the Metals Reserve Company, a subsidiary of the Reconstruction Finance Corporation, for beryl ore containing 10 percent beryllium oxide (BeO). An additional $12 per ton was paid for each 1 percent above 10 percent, and a penalty of $12 per ton was assessed for each 1 percent under 10 percent, down to 8 percent, the minimum content for acceptable material. In June 1944 the price was raised to $145 per ton, with a bonus or penalty of $14.50 per ton unit for material containing more or less than 10 percent BeO, respectively. The Metals Reserve Company discontinued its beryl purchases on January 1, 1945, and subsequent open-market prices have been at distinctly lower levels.

DETERMINATION OF GRADE

The acceptability of beryllium concentrates and the prices paid for them are based upon their average content of beryllium oxide. The BeO content of pure beryl varies with the percentage of certain alkali constituents, notably sodium and caesium.[15] In general the BeO content ranges from less than 10 percent to a

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[15] Schaller, W. T., oral communication, April 1942.

theoretical maximum of about 14 percent. Most of the larger crystals and masses of beryl in the Petaca pegmatites can be cobbed relatively free from other minerals, but some are cut by veinlets and irregular crystalline aggregates of albite and quartz. Some crystals consist of concentric shells of quartz and beryl. The proportion of beryllium oxide in such composite material is appreciably lowered by the beryllium-free impurities.

Few reliable analyses of Petaca beryl have been made, but most of it appears to be of high grade, i.e., its BeO content is 12 percent or more. Incorrect chemical and spectrographic analyses of alleged beryllium-bearing material have created considerable confusion among the operators of several mines. These analyses have given rise to the impression that much feldspar, particularly the microcline of certain deposits, contains 1 to 5 percent BeO, either as admixed beryl or in some more complex form. None of the feldspar, when properly tested, has been found to contain more than a trace of beryllium. At the present time there are no shortcuts to accurate quantitative determination of beryllium content, and reliable analyses are expensive. Although satisfactory spot tests for beryllium are available,[16] they are not wholly quantitative. The relation between the BeO content of beryl and its index of refraction, which is easily determined, is now under investigation by W. T. Schaller; his results may well be of great value for rapid and inexpensive approximate analyses. Meanwhile the BeO content of Petaca beryl is best determined by correct mineralogic identification, followed by careful estimates of the amount of mechanically intergrown impurities.

OCCURRENCE

The occurrence of beryl in the Petaca deposits follows three general patterns. A little beryl is present in many concentrations of albite and mica, and is distributed without regard to zones in the pegmatite bodies. This late beryl is colorless to pale yellowish green, and commonly occurs in well-formed tabular crystals that are too small and scattered to be of current economic interest. In the second mode of occurrence beryl is restricted to specific zones or parts of zones. Such beryl has been recovered commercially from several deposits. Its distribution is as follows.

A. Core beryl. Well-formed prismatic crystals a few inches to 8 feet long are present in quartz cores, and are related to the quartz in the same general way as the giant microcline crystals that occur in many cores and inner intermediate zones. None of these deposits has been mined for beryl (Sandoval, Nambe deposits).

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[16] Kulcsar, Frank, How prospectors can detect beryllium in ores: Eng. and Min. Jour., vol. 144, p. 103, 1943.

Fletcher, M. H., and White, C. E., A simple test for the detection of the beryllium minerals: Amer. Mineralogist, vol. 31, pp. 82-83, 1946.

B. Core-margin or intermediate-zone beryl. This is present as coarse rough to well-formed greenish crystals, and is most abundant in the inner parts of inner intermediate zones. It can be recovered by hand sorting, and some of these deposits are of economic importance (Lonesome, Kiawa, Werner, Hidden Treasure deposits).

C. Wall-zone beryl. Small ragged masses are scattered through the wall zones. The color is commonly more blue than green. Recovery generally necessitates milling, and hence such deposits are of little current economic interest (Kiawa, Globe, North Star deposits).

D. Border-zone beryl. In occurrence and characteristics this is similar to beryl present in the wall zones. In general the masses are even smaller (Kiawa deposit).

E. Pocket or pod beryl. Small rough masses occur in irregular pods of quartz-rich pegmatite that are exposed by coarse-grained microcline-quartz pegmatite. No deposits of commercial interest are known (Cribbenville deposit).

F. Beryl in pegmatites or parts of pegmatites in which zoning is not distinct. The size range of such material is great; some occurs in concentrations sufficiently rich and coarse to be of economic interest (Alma, Vestegard, Bluebird deposits).

Beryl of more than one of these types may be present in a single pegmatite body. Wall-zone, intermediate-zone, and border-zone beryl are present in the Kiawa deposit, and the mineral occurs in two different intermediate zones in the Lonesome deposit. Much of this relatively early, zone-controlled beryl has been corroded and partially replaced by albite and mica. Groups of relict fragments testify to the previous existence of large crystals of core beryl in the mica-rich keel of the Nambe deposit, and the beryl of the Lonesome and Alma deposits contains penetrating blades and small rosettes of cleavelandite.

The third general mode of occurrence is in altered country rock, where the beryl forms cigar-shaped crystals with crudely rounded ends. They are $\frac{1}{2}$ inch to 6 feet long and $^1/_{16}$ inch to 7 inches in diameter. The enclosing material generally is mica-rich schist, but some crystals are surrounded by vein quartz or are partially embedded in it. There is no physical connection with pegmatite; indeed, no pegmatite is visible in the general vicinity of some deposits. Several occurrences of this type are known, but only one, the Sunnyside, has been mined.

None of the Petaca beryl appears to be in concentrations rich or continuous enough to form the sole basis of mining operations.

Where it occurs in or adjacent to concentrations of other desirable minerals, however, it can be recovered as a by-product. No large production can be anticipated.

COLUMBITE-TANTALITE AND ASSOCIATED MINERALS

GENERAL FEATURES

Members of the columbite-tantalite series are the chief sources of the metals columbium and tantalum. Columbium, as a constituent of certain recently developed ferro-alloys, imparts favorable welding characteristics and high-temperature strength properties. Such alloys are in demand for turbine and aircraft engine parts. Columbium is also alloyed with nickel, copper, and aluminum. Tantalum metal is corrosion resistant, and hence is used in pumps, nozzles, spinnerets for synthetic textile fibers, and other instruments and equipment that are exposed to corrosive chemicals. Its ability to absorb gases accounts for its use in radio and neon tubes, and it is uniquely satisfactory as a surgical metal in the form of wire, rods, and plates. It is alloyed with columbium and tungsten to form dies and cutting tools, which are also made with cemented tantalum carbides. Tantalum-bearing glass is used in special camera lenses and other optical equipment.

Prices quoted for columbite-tantalite ores vary according to the content of tantalum and columbium oxides. The most desirable ores are low-tantalum columbite and low-columbium tantalite; intermediate compounds generally command lower prices. The most objectionable impurities are tin and titanium. During pre-war years columbium ore was valued at 22c to 40c per pound, and tantalum ore at \$1.80 to \$2.75 per pound of contained oxide, but prices have increased greatly since 1941. The highest prices paid by the Metals Reserve Company were effective during the period July 1943 to January 1, 1945, after which most purchases were discontinued. They ranged from \$2.20 per pound of contained tantalum oxide for tantalite concentrates assaying 40 percent Ta_2O_5, to \$4.30 per pound of contained oxide for 70 percent concentrates. Columbite containing 50 percent Cb_2O_5 or more was purchased at 50c per pound of contained Cb_2O_5. Tolerances for tin and titanium were 3 percent in tantalite, and 5 percent and 7.5 percent, respectively, in columbite.

Compounds of the rare-earth elements, which are derived chiefly from monazite, have limited use. Thorium and cerium oxides are essential constituents of the incandescent mantles used in gas illumination. These and other compounds are also used in the dyeing and decay-proofing of textiles, as catalysts for industrial organic chemicals, and as constituents of special refractories, abrasives, glasses, and ceramic products. Thorium metal is contained in some alloys used in electrodes and filaments. The price of monazite was quoted at $60 per ton for an 8 percent grade in 1939.[17]

Samarskite is a potential source of columbium, tantalum, and uranium. The chief uses of uranium are in the fields of ceramics, paint, and chemical manufacture; it is also a constituent of some ferro-alloys. During recent years experiments have been made in the use of the element as a source of atomic power, and further developments in this field may well increase the demand tremendously.

DETERMINATION OF GRADE

The wide range in the price scale for columbite-tantalite makes assays in advance of mining a practical necessity. It is unfortunate that quantitative chemical analyses with determination of the relative amounts of columbium and tantalum oxides, are both time-consuming and costly. A rough quantitative appraisal can be made on the basis of the constant relation between specific gravity and Ta_2O_5 content of members of the columbite-tantalite series. The gravity increases with increase of tantalum oxide, as shown in Figure 7. As gravity balances are available in many laboratories, the approximate tantalum-oxide content of a given specimen is readily obtainable. If enough material is present in a deposit to warrant a more accurate determination, a chemical analysis can be made. The desirability of submitting samples of such material to reputable analysts cannot be too strongly emphasized.

OCCURRENCE

All the columbite, tantalite, and monazite, as well as most of the samarskite and uraninite, occur in albite-rich pegmatite. These minerals can rarely be identified in definite shoots. Although no minable concentrations are known, they have been recovered on a small scale as by-products in many of the operations for mica. They commonly are most abundant in the most thoroughly albitized pegmatites, but their distribution cannot be predicted accurately. Bismutite, samarskite, and uraninite commonly occur in or adjacent to late-stage veins of smoky quartz and in larger quartz masses that are flanked by albite-rich pegmatite. Small quantities of these minerals have been recovered as by-products from several mica-bearing pegmatites.

FELDSPAR

GENERAL FEATURES

Feldspar is used chiefly as a ground raw ingredient of glasses, pottery, and glazes. It is also processed for use in abrasives, building materials, and various fillers. Potash feldspar is

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[17] Tyler, P. M., Minor metals (chapter in Minerals Year Book): U. S. Bur. Mines, 1940.

preferred for pottery manufacture, soda spar (chiefly albite and oligoclase) is widely used in glazes, and both types are satisfactory for most glass-making. Feldspar is generally graded on the basis of its content of free silica or quartz, and in nearly all grades the tolerance for iron-bearing impurities is very low. The best grades contain less than 5 percent quartz, and the poorest acceptable material contains about 30 percent quartz. Thus graphic granite, or "corduroy spar", most of which contains 15 percent or more of free quartz, commands a relatively low price.

Most domestic feldspar is produced and consumed east of the Mississippi River. There is so little difference between the unit price and the unit cost of production that the expense of a long haul from mine or grinding plant is a serious factor. Most western deposits that have been worked successfully yield high-grade spar. Prices for crude pegmatite feldspar at or near the mine range from about $3.50 to $12.00 or more per long ton, with a general average for all common grades of about $6.00. The average for material containing 5 percent or less of free quartz is distinctly higher. Producers, grinders, and buyers of feldspar are listed by the U. S. Bureau of Mines.[18]

OCCURRENCE

Many of the Petaca pegmatites are potential sources of high-quality feldspar. They contain so little biotite or other common iron-bearing impurities that the ratio of feldspar to quartz would be the chief consideration in selecting material for mining. If albitized pegmatite were mined, the scrap mica and tantalum minerals could be removed and the residue marketed as a mixed potash-soda spar. Large crystals of almost pure perthitic microcline, many of which weigh 50 tons or more, occur with massive quartz in the cores or inner intermediate zones of some deposits. Most of these crystals lie adjacent to mica shoots and either are accessible from existing mine workings or could be mined in connection with operations for mica. High-grade potash spar of this type is common in the Kiawa, La Jarita, Lonesome, North Star, Werner, Conquistador, Keystone-Western, Apache, Pinos Altos, Queen, Coats, North Cribbenville, Cribbenville, Nambe, White, Alamos, Red, Globe, Guadalupe, and Hidden Treasure deposits. As it is generally surrounded or flanked by massive quartz, it is easily identified on the maps.

Aggregates of coarse poorly formed microcline crystals are present in several deposits, where they tend to form rock units that weigh many hundreds of tons. Some quartz is present as small pods, irregular veinlets, and interstitial masses, and locally the microcline contains abundant albite with minor amounts of mica. The content of potash feldspar in such units, generally intermediate zones, ranges from about 85 to 97 percent or more,

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[18] Metcalf, R. W., Marketing feldspar: U. S. Bur. Mines Inf. Circ. 7184, pp. 7-13, 1941.

and a relatively pure product could be obtained by coarse cobbing. These zones tend to occur in the central or westerly exposed portions of plunging dikes and near the main bends of most trough-like bodies. They are flanked by mica shoots in some deposits, but occur in relatively barren portions of most. In general, they can be traced westward into coarse microcline-quartz pegmatite or pegmatite rich in graphic granite, and eastward into massive quartz with or without giant microcline crystals. They constitute most of the material shown on the maps as blocky microcline.

Many large pegmatite bodies are rich in graphic granite and other coarse-grained pegmatite of which microcline is the principal constituent. The Kiawa, Cribbenville, Silver Spur, Alma, Wyoming, and Hidden Treasure deposits are good examples. Such material is the dominant constituent of bodies that are not sharply zoned, but is also present in the westerly portions of many zoned deposits. It offers possibilities for bulk mining and milling with recovery of scrap mica and mixed feldspar containing 10 to 35 percent quartz. Rough selectivity in mining might reduce the average quartz content to 20 percent or less.

None of the albite concentrations is sufficiently extensive or free from impurities to sustain an operation for soda feldspar. However, albite would be a significant constituent of much of the potash feldspar.

DESCRIPTION OF DEPOSITS

HISTORICAL SKETCH

Mica deposits in the Petaca district were systematically worked as long ago as the seventeenth century, when large books were split and trimmed into window panes for buildings in Santa Fe, Espanola, and other villages. Jones[19] states that much of the mica evidently came from the "Cribbensville deposits" near Petaca in Rio Arriba County, and these appear to have been the most extensive deposits known in the district until the beginning of the present century. According to Just,[20] the modern epoch of mining dates from about 1870, when operations on a commercial scale were based on the use of mica in stove doors. The old settlement of Cribbensville (now deserted), near the end of the present Cribbenville road, was a center of mining activity named after the maker of a popular brand of stoves. For many years only plate mica was taken from the deposits, and it was transported by pack animals to Pueblo, Colorado.

Mining operations were greatly expanded outside of the Cribbenville area about 1900, when several deposits in the mesa country west and northwest of Petaca were opened up for scrap mica. Interest in stove mica gradually dwindled, and it was not until 1912, with the first strong demand for electrical mica, that attention was again directed to the recovery of sheet material. The Globe and new Cribbenville mines had been opened by this time, and were operated along with several older mines during the period of World War I. Mining activity decreased appreciably with the general decline in prices after the war, but the period of near-idleness was short. By 1923 at least nine mines were in operation, and the following seven-year period was the most productive in the history of the district. Although much sheet and punch mica was recovered, most of the output was sold as run-of-mine books to brokers and mica grinders, some of whom resold the material or processed it entirely as scrap. During this period the Apache, Cribbenville, Red, White, Alamos, Kiawa, North Star, Silver Spur, Fridlund, Conquistador, La Paloma, Nambe, Capitan, and several other mines were important producers. A punching and dry-grinding plant was operated at the Apache mine, and grinding was also done in Las Tablas.

The larger operations were curtailed or discontinued by 1931, when depression prices prevailed. Production during succeeding years represented the efforts of individuals, chiefly local

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[19] Jones, F. A., New Mexico mines and minerals (World's Fair Edition): Santa Fe, New Mexico, pp. 260-261, 1904.

[20] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, p. 59, 1937.

inhabitants who turned to mining by hand methods as the only means of earning a living. A few of the larger mines were reopened during the period 1935-1940, but it was World War II, with its great demand for mica of superior quality, that stimulated recent activities. Production of strategic-grade material was recorded from at least twenty deposits during the period 1942-1944. By January 1945, however, the district was virtually deserted, and only the Globe mine was being operated.

PRODUCTION

Records of mica production from the Petaca deposits are so fragmentary that estimated totals for any period may be seriously in error. Although some of the operators of the larger mines maintained a close check on each lot of plate or scrap mica sold, deals between buyers and most miners and mining groups appear to have been informal. Several jobbers and mica processors consistently reported their purchases, which were summarized in volumes of the Mineral Resources of the United States; but the records of most have disappeared. Moreover, it is virtually impossible to determine accurately the relative amounts of sheet, punch, and scrap mica produced, chiefly because run-of-mine mica was commonly sold and shipped out of the district for processing. Reliable records regarding sheet mica obtained from such material are too incomplete to be significant.

As recorded in volumes of the Mineral Resources of the United States, the production of sheet mica (all grades) from the Petaca district during the periods 1899-1902, 1923-1930, 1932, and 1934 amounted to 165,785 pounds, valued at $36,363.00. During the same periods 7,943 tons of scrap mica, valued at approximately $125,906.00, was produced. Not only are these figures incomplete for the periods indicated, but they do not provide coverage for other periods during which appreciable quantities of mica are known to have been mined. The total production can be estimated by adding to these figures (1) supplementary information recently furnished by several local residents who once mined or purchased Petaca mica, and (2) estimates of output based on size of workings and known characteristics of the mica concentrations in those deposits for which no production data exist. It seems probable that at least 235,000 pounds of sheet and punch mica (all grades) has been obtained during the period 1900-1942; this amounts to about 0.5 percent of total domestic production for the same period. Total production of such material since 1800 may well have amounted to more than 300,000 pounds, which represents about 850,000 pounds of "plate", or selected mine-run mica that would yield sheet stock. About 18,000 tons of scrap is the estimated production for the period 1900-1942.

The average values for sheet and scrap micas were approximately $0.22 per pound and $15.85 per ton, respectively, during the forty-year period preceding World War II. On the basis of these figures, the values of the mica in average concentrations containing 7 to 10 percent recoverable material range from less than $1.00 to as much as $8.00 per ton of rock mined, depending upon the relative proportion of plate material present. The average value is probably less than $3.00 per ton, although distinctly higher values have been obtained from time to time in most of the larger mines. Several of the rich shoots that have been worked for scrap mica alone have yielded returns of $6.00 to $14.00 per ton of rock mined, but for short periods only. Per-ton values of mine-run mica in the district have ranged from about $12.50 to $20.00 for material sold as scrap to as much as $200.00 for material unusually rich in large-sheet stock. The average probably has not exceeded $35.00 for all deposits that have been worked, or $65.00 for the largest and richest deposits.

The total production of strategic mica during the wartime period February 1, 1942-January 15, 1945 amounted to approximately 6,750 pounds of trimmed punch and sheet material, nearly three-fourths of which was derived from the Globe and Cribbenville mines. The value of this mica was $31,200.00. About 1,500 tons of scrap was recovered from at least twenty-seven deposits during the same period. Recent production of sheet mica is difficult to compare with that of previous years, owing chiefly to fundamental differences in preparation. The amount of half-trim, three-quarter-trim, and full-trim material sold as strategic mica represents only a fraction of the amount of sheet and punch material that could have been recovered from an equivalent amount of mine-run mica under pre-war requirements. However, the high price scale for strategic-grade mica compensated for the fuller preparation required, and in fact raised considerably the value of mine-run mica obtained from most deposits. This value ranged from $16.00 to as much as $300.00 per ton during the period 1942-1944, with a probable average of $75.00 or more for the output from those mines that yielded the bulk of production.

Approximately 9,300 pounds of beryl, valued at $670.00, was obtained from the Lonesome, Alma, Sunnyside, Werner, and other deposits during the recent wartime period. Production during all previous years probably did not greatly exceed this figure. Production of tantalum minerals, chiefly columbite with subordinate quantities of tantalite and samarskite, has amounted to more than 8,500 pounds since 1930 and at least 12,000 pounds since 1910; data concerning its value are not available. Most of the columbite-tantalite sold during recent months was obtained from the Lonesome, Globe, and Werner deposits. The value of this material was about $800.00. Total production of monazite and bismutite probably has not amounted to more than a few thousand pounds, although accurate records are not available.

KIAWA GROUP

GREEN PEAK DEPOSIT

The Green Peak deposit (1, Plate 1) is situated on the steep west side of a canyon that drains south and south-southeast for half a mile into Kiawa Canyon. It is in the NE¼ SE¼ sec. 10, T.27N., R.8E., and lies 1.5 miles east-southeast of Kiawa Mountain at altitudes of 8,300 to 8,440 feet. It can be reached by trail from the Kiawa mine a few hundred feet to the east. The deposit is said to have been first prospected about 1880, when several shallow pits were dug in a search for copper. Attempts to obtain mica were made later, especially during the period 1920-1935.

In outcrop plan the pegmatite body resembles a compressed horseshoe that is open toward the east. The ends of both limbs are covered by landslide material, but each is at least 250 feet long and 5 to 30 feet thick. The north limb trends due west and dips steeply north, and the south limb trends N. 85° W. and dips south, generally at steep angles. The limbs are 40 to 50 feet apart. The west end of the body, which is 50 feet in maximum outcrop breadth and forms a prominent knob on the hill slope, plunges moderately to steeply west-southwest and forms the crest of the body. An adit that was driven southward to intersect it at a depth of about 35 feet is now caved.

Most of the pegmatite lies in thinly foliated quartz-muscovite schist, but its west end projects into a belt of dark greenish gray amphibole schist that is 25 to 65 feet in outcrop breadth. The amphibole schist, which is thinly foliated and locally much contorted, wraps around the plunging crest of the body as an open fold or large wrinkle that also plunges moderately to steeply west-southwest. It has been thoroughly biotitized in a zone 8 to 16 feet wide along the pegmatite contact. In general the country-rock foliation trends N. 85° W. and dips 40° to 60° S. Drag folds, minor crenulations, and rows of aligned biotite flakes plunge southwest and west-southwest at moderate to steep angles. Several lenses and veins of quartz, 6 inches to 8 feet thick and 5 to 150 feet long, are exposed west and south of the deposit. A thin sinuous pegmatite dike, which lies 100 feet to the south, trends west-northwest and can be traced for at least 800 feet along the strike.

The main pegmatite body consists principally of coarse microcline-quartz pegmatite, with small amounts of garnet and traces of pale green fluorite. The size of the feldspar crystals increases markedly toward the center of the body. Several elongate quartz pods occur in the interior portions of both limbs, and one large bulbous mass is present in a conspicuous bulge on the north limb. Two quartz ribs, 50 to 55 feet long and 4 feet in average thickness, occur near the west end of the north limb and in a part of the crest of the pegmatite body. They may be late-stage, vein-like bodies. Both are strongly copper-stained.

The pegmatite contains very small quantities of monazite, bismutite, chalcocite, pyrite, chalcopyrite, bornite, chrysocolla, and malachite. Monazite and bismutite occur in and near the quartz masses, and the sulfides appear to be concentrated in the crest of the body, chiefly in the two quartz ribs. Most of the muscovite is present in the limbs, where it occurs with albite in narrow shoots adjacent to massive quartz. It is green to brownish green, hard, and easily split. Most books are 3 by 4 inches or smaller, and are badly ruled, warped, and broken. Though locally rich, most of the shoots are small. The deposit offers little promise as a source of either mica or copper.

KIAWA DEPOSIT

GENERAL RELATIONS

The Kiawa deposit (2, Plate 1), near the west edge of sec. 11, T.27N., R.8E., and about 1.6 miles east-southeast of Kiawa Mountain, is exposed on the steep irregular slopes of a south-flowing tributary to Kiawa Canyon. The altitude of its west end, which is at the canyon bottom, is 8,240 feet; its east end is on a gently rolling upland surface 300 feet higher. The mine workings are most easily reached over a narrow steep road that connects South Kiawa Lake and the Mesa road with Kiawa Canyon; from the canyon bottom a wagon road extends north 0.4 mile to the west end of the deposit. Other means of access are a 4.5-mile wagon road that can be followed up the Tusas River Valley and Kiawa Canyon from Las Tablas, and a trail that extends eastward from the end of another wagon road high on the east slope of Kiawa Mountain.

The deposit consists of two pegmatite bodies, one a very large irregular dike-like mass and the other a long thin dike that lies 200 to 300 feet to the north (Plate 6). Mining operations are said to have been started about 1880, when much of the Old Lower pit and several small cuts were worked for stove mica. The pit, which is now 50 feet long, 25 feet in maximum width, and 12 to 20 feet deep (Plate 6), was enlarged by Daniel Espinosa in 1914, and downward continuations of the rich mica concentrations exposed therein were subsequently mined underground through a shaft (Espinosa shaft) and narrow tortuous "rat-hole" workings that locally reached a depth of about 35 feet. During 1914 and 1915 Espinosa also opened several small cuts higher on the slope, as well as numerous pits and cuts in the eastern part of the north dike. From some of the latter workings short drifts and inclines appear to have been driven, but these are now caved and inaccessible. The Porcupine stopes, which extend eastward from an open cut 100 feet northeast of the Old Lower pit, were worked in 1923 and 1924. They consist of at least three long low drift-like openings that are partly back-filled and caved. About 75 feet east-southeast of these stopes is the Upper pit, which is hook-shaped in plan. It is 75 feet long, 7 to 25 feet wide, and 2 to 15 feet deep, and appears to have been sunk on an exceptionally rich mica concentration. Farther east are the Twin stopes, worked by Espinosa in 1925. These are irregular steeply inclined rooms that were sunk to a maximum depth of 20 feet beneath the floors of open cuts 35 feet or less in diameter. Two smaller cuts were opened immediately west of these.

In 1941 the deposit was claimed by Daniel Espinosa and J. M. Maestas of Vallecitos, S. H. Wells of Chamita, and G. O. Fowler of Los Angeles, California. These men exploited the ground southwest of the Old Lower pit by open-cut methods, and their workings, the New Lower pits, are the most westerly of the productive openings in the main pegmatite body (Plate 6). Attention was again turned to the north dike in 1942, when Espinosa and Maestas enlarged several old cuts in its western part and drove 45-foot and 62-foot drifts. Both drifts are now caved at their portals. In September 1943 Philip S. Hoyt of Van Horn, Texas, leased the property and began operations for strategic mica in the main pegmatite body. A cut was excavated at the country rock-pegmatite contact south of the New Lower pits, and from it an adit was driven to a point immediately west of the largest pit and about 45 feet beneath its floor. Large masses of "bull mica" were encountered, but the returns were less satisfactory from irregular drifting that was subsequently extended to points 55 feet northwest, 20 feet north-northeast, 85 feet northeast, and 35 feet east-southeast. A raise was driven 19 feet vertically from a point about 20 feet east of the main junction of workings, and at its head a small room, crescentic in plan, was excavated in a rich mica concentration (Plate 6). The bottom of an old finger-like stope from the Espinosa shaft and one of the New Lower pits was encountered at the southeast edge of this room.

In addition to the workings already noted, numerous pits, cuts, shallow inclines, and short adits are present in other parts of the deposit. The history of these workings is imperfectly known, as most represent small-scale efforts of individuals. The mica obtained from them, however, amounts to an appreciable part of the total production from the deposit, and represents the bulk of production during the period 1926-1937. Production from both pegmatite bodies probably is in excess of 2,200 pounds of prepared sheet mica, an additional 9,000 pounds of plate (selected mine-run) mica, and 600 tons of scrap. Included in these amounts are about 500 pounds of strategic-grade mica and 110 tons of scrap obtained since October 1943.

GEOLOGIC SETTING

The dominant rock in the vicinity of the Kiawa deposit is silvery to greenish gray platy to slabby micaceous quartzite. It is especially rich in fine-grained mica adjacent to pegmatites and quartz veins. Its foliation and bedding, which are essentially parallel, trend east-northeast and dip steeply south-southeast. Bedding has been obscured in the more micaceous parts by crenulation of the foliation planes.

A dark green amphobile schist, well-exposed south and west of the main pegmatite body, forms a prominent stratigraphic unit 35 feet to more than 200 feet in outcrop breadth. This thinly foliated rock is conformable with the adjacent quartzite and probably represents a metamorphosed sill or flow of andesitic or basaltic composition. It can be traced along its strike for at least half a mile, and across the strike it grades into quartzite through 2- to 20-foot zones of quartz-mica schist that has been impregnated with blades and needles of greenish black amphibole.

Both quartzite and schist have been compressed into southwesterly plunging folds that range from less than half an inch to several hundred feet in flank-to-flank dimension. The moderate plunge of these folds is reflected by the pitch of several linear structures. Most common are rows of mica flakes, closely spaced crenulations, and lines of intersection of bedding and foliation planes. The metamorphic rocks are offset along at least nine cross faults south of the main pegmatite body. Maximum horizontal displacement along any fault is about 105 feet. Most of the movement was pre-pegmatite in age, for unsheared pegmatite and quartz veins occur in several of the fault planes, and pegmatite bodies that transect the faults are only slightly displaced. Late-stage movements along the Lower Pit fault (Plate 6), and possibly along one or two others, have developed slip planes in the pegmatites and have contributed to severe warping and ruling in some of the mica books.

The north pegmatite dike, which is 38 feet in maximum outcrop breadth and at least 1,240 feet long, trends in general N. 75° E. and dips steeply south. It is thickest near its west end, but tapers eastward to a stringer less than 2 feet thick. This stringer probably continues for about 100 feet beneath a cover of slope debris, and thence swells to form the eastern two-thirds of the dike, the average thickness of which is about 6 feet. To the west the dike may connect with the Green Peak pegmatite, but relations are obscured by dump and landslide material. The rather consistent plunge of zones and other units, and of corrugations in their contacts, suggests that the dike itself plunges moderately to steeply southwest.

The main pegmatite body, which is roughly lenticular in plan, is 1,430 feet long and 275 feet in maximum outcrop breadth (Plate 6). It trends N. 75° E. and in general dips southward at moderate to steep angles. Local north dips, however, are common. As exposed in the canyon bottom, the crest appears to plunge steeply west-southwest, but elsewhere the plunge of the body is moderately southwest, as shown by the attitudes of its constituent pegmatite units, elongate inclusions, and irregularities along its contacts. The central and eastern parts of the body are complicated by numerous curving septa and irregular inclusions of country rock, which range in thickness from a few inches to 30 feet or more and in length from a few feet to as much as 200 feet. They tend to be elongated parallel to the trace of the pegmatite contacts, but a few inclusions lie normal to the general trend of the body. Most have been impregnated with igneous material, chiefly microcline, albite-oligoclase, and mica, and some have been so thoroughly digested that they have been mapped as parts of the pegmatite. Much of the extreme eastern part of the body, which lies east of the area shown in Plate 6, consists of such composite material. It appears as a large trough-like mass that is crescentic in plan, and from it a long thin spine extends eastward.

Both quartzite and amphibole schist are cut by numerous thin, elongate, sinuous quartz veins that trend west-northwest to west-southwest and dip steeply south. Many are conformable with the schistosity of the country rock. Swarms of smaller, less regular quartz veins occur in the area between the two pegmatite bodies. Where the veins are in quartzite, the surrounding rock is generally rich in introduced pale green muscovite; where they are in amphibole schist, it has been locally altered to a biotite- or epidote-rich schist.

PEGMATITE

The north dike appears to have contained a discontinuous quartz core flanked by a wall zone of coarse microcline-quartz pegmatite and a border zone of fine- to medium-grained microcline—quartz—albite-oligoclase pegmatite. As widespread replacement by albite has obliterated all but local patches of the border zone and core, the precise distribution of primary pegmatite units can be determined only by means of relict textures. The core was thickest and most continuous near the west end of the dike, but apparently was absent from much of the eastern part. The wall-zone pseudomorph, which contains minor quantities of garnet, green fluorite, and beryl, is present in the western three-fourths of the dike, where it is 1½ to 15 feet thick. The thin east end or tail of the dike consists wholly of albitized border-zone material.

The distribution of rock units in the main pegmatite body follows a broad general pattern, but is extremely irregular in detail. The border zone, which consists of sugary plagioclase-quartz-microcline pegmatite that is rich in partly digested country rock, is generally about ½ inch thick, but reaches thicknesses of 15 feet or more in the eastern part of the body. Some masses of this rock are within the body, but were clearly formed through the pegmatitization of country-rock inclusions or roof pendants. The wall zone, which ranges in thickness from a knife edge to 25 feet, is a medium-grained intergrowth of microcline and quartz, with minor mica, albite, garnet, and fluorite, and rare beryl. It is most extensively developed in the western third of the body, where it forms the outermost mapped unit (Plate 6). The most widespread unit is the outer intermediate zone, which consists of very coarse-grained microcline-quartz pegmatite that is rich in graphic granite. Some of the largest graphic-granite masses are distinguished from the remainder of the unit in Plate 6. Where less rich in graphic granite, the zone contains irregular bodies of coarse blocky microcline and massive quartz. Some of the quartz pods, which are as much as 110 feet long and 18 feet in outcrop breadth, might be considered separate zones.

The inner intermediate zone, which is also rich in microcline, is best exposed in the vicinity of the Graphic Cliffs west of the New Lower pits. Coarse blocky microcline and graphic granite are its chief constituents. Irregular masses of very coarse-grained microcline-quartz pegmatite and pod-like bodies of massive quartz are also present. As in the outer intermediate zone, some of the quartz masses are relatively large. The core of the body is white to gray massive quartz that contains microcline crystals and crystal groups of giant size. The potash feldspar is most common in the area north of the Upper pit, where individual masses are as much as 40 feet in outcrop breadth. The core consists almost wholly of quartz where it is exposed north of the Lower pits, but large feldspar bodies are present in the most recent underground workings. No attempt has been made to indicate the distribution of zones in Plate 6, but individual rock types are shown instead. Many of the quartz or microcline bodies are merely parts of zones. Moreover, zone boundaries and locally the zones themselves have been transgressed and obscured by other units of later-stage development.

Albite is scattered throughout the main pegmatite body as sugary crystalline aggregates and groups of coarse cleavelandite blades. It is not abundant in the western third of the body, but is common farther east, especially along the flanks of quartz masses. Locally plagioclase has almost completely replaced microcline-quartz pegmatite. Some of the massize quartz has been penetrated and corroded by the albitizing solutions, and rosettes of coarse cleavelandite that were formed at its expense can be seen in the walls of the Old Lower pit, the Upper pit, and the

Pocupine stopes. Near the east end of the body albitization is most common along country-rock contacts, the margins of partly digested inclusions, and throughgoing fractures.

The microcline ranges from white or greenish gray through flesh to brick red. In the coarse-grained pegmatite and blocky microcline units it occurs as crystals 4 inches to 7 feet in maximum dimension. Some contain irregular stringers and platy to pod-like masses of quartz, and in many the quartz occurs in graphic intergrowth. This material grades into irregular pods of massive quartz. Quartz masses are more abundant adjacent to graphic granite than to bodies of quartz-poor blocky microcline. Little of the rock mapped as graphic granite shows evidence of albitization, but some albite-rich units appear to have been formed from graphic material through selective replacement of the microcline, with preservation of the structure in the form of somewhat corroded but nonetheless clearly oriented quartz spindles.

Spessartite garnet, the most common accessory mineral, occurs in all parts of the deposit. It is especially abundant in the border zones and in albite-rich units. Many crystals 4 inches or more in diameter appear in albite-oligoclase-quartz-microcline pegmatite 70 feet east of the Twin stopes. Most of the fluorite, which is pale green and severely fractured, occurs near the walls of the pegmatite and in albite-rich material exposed in the mine workings. Alteration of this mineral and adjacent feldspars has formed irregular vugs ½ inch to 5 inches in diameter. These are especially common in the Twin and Porcupine stopes and in the workings that connect with the Espinosa shaft. Most are partly filled with a yellow to reddish-brown clay that contains small gritty particles of fluorite. A half-inch octahedron of clay, possibly a pseudomorph after fluorite, was observed in the Upper Twin stopes. Beryl is present in the border zone and wall zone as small pale waxy yellow to bright blue-green masses, and locally along the margins of the quartz-rich core as well-formed prismatic crystals 2 inches or more in diameter. The border-zone beryl is well exposed at the mouth of the Hoyt adit, the wall-zone material in pegmatite north of the Graphic Cliffs and southwest of the Twin stopes, and the core-margin crystals in the Old Lower pit and Porcupine stopes.

Columbite, monazite, purple fluorite, and small pods of fine-grained green sericite occur in the albite-rich pegmatite exposed in most of the workings. Samarskite, magnetite, and bismutite are present along fractures in massive quartz, particularly in the Old Lower pit. Pyrite, chalcopyrite, chalcocite, and pale pink muscovite are rare accessory constituents that were observed in dump material only.

MICA

Muscovite occurs in the Kiawa deposit as (a) small books scattered throughout microcline-quartz pegmatite; (b) small books in albitized pegmatite along country-rock contacts or around the margins of inclusions; (c) somewhat larger books along throughgoing fractures; and (d) small to very large books in albite-rich pegmatite along the margins of quartz masses. The last mode of occurrence is by far the most common and is of greatest commercial importance.

The richest mica shoots in the north dike are on the south side of the remnants of the quartz core. As exposed in the underground workings (now caved) near the west end of the dike, the main shoot appears to plunge west-southwest at moderate angles, in general more steeply than the slope of the canyon wall. Many mica concentrations are present in the western part of the main pegmatite body, but they flank small quartz masses and are small and relatively discontinuous. The richest of these shoots have been worked by open-cut methods north of the cabin in the canyon and south and southeast of the Graphic Cliffs.

Much mica was obtained from the New and Old Lower pits and the workings that connect with the Espinosa shaft and Hoyt adit. These are along the south flank of a large quartz mass that dips southward to points 15 to 25 feet beneath the surface and thence steeply northward. As exposed in the workings, the main mica concentration plunges west to southwest at moderate to steep angles and is associated with many partially pegmatitized wisps of country rock. Other concentrations have been worked on both flanks of a tabular quartz mass to the east-northeast. The Upper pit has been excavated along the south-dipping hanging wall of this mass, and the Porcupine stopes lie along its footwall 15 to 25 feet below. The mica concentrations, as well as those worked in the Twin stopes farther east, appear to have been very rich.

The largest and best mica books are in direct contact with massive quartz. Some are 3 feet in diameter and a foot or more thick, but average dimensions are 10 inches and 6 inches, respectively. Shoots along the main quartz mass are said to have contained 25 percent mica, and locally as much as 90 percent. That such figures may be reasonably accurate is suggested by the mica content of faces in the accessible workings (Table 7).

The mica is pale green to rather dark greenish brown. The brown books, which contain the hardest mica, occur in the largest shoots in the main pegmatite body. Much of the mica is slightly wavy, but it splits easily. Hematite and magnetite stains are not common. The chief defects are "A" and wedge structure, ruling, wrinkling, and buckling. Herringbone structure, albitization, silica and garnet inclusions, and clay stain are present locally. The mica in contact with massive quartz occurs as large

TABLE 7. MICA IN FACES, KIAWA DEPOSIT

Location	Area of face (square feet)	% mica in face (by volume)
Mica shoot not in contact with massive quartz:		
Upper Twin stope	22	7
Lower Twin stope	19	9
Stope from Espinosa shaft	31	13
Pit north of cabin in canyon	20	5
Average		8.5
Weighted average		8.0
Mica shoot in contact with massive quartz:		
Upper Twin stope	18	15
Lower Twin stope	17	19
Upper cut	14	27
Porcupine stopes (average of 4 faces)	77	21
Stopes from Espinosa shaft (average of 3 faces)	52	24
Main junction of workings from Hoyt adit	23	36
Northeast drift from Hoyt adit	32	12
Room at head of raise from Hoyt workings	38	16
Average		21
Weighted average		21

individual "A" books, from whose central portions flat sheets and ribbons can be obtained, whereas the material in other parts of the shoots tends to be tightly intergrown in buckled, wedged, and tangled masses. Ruling, warping, and breaks are very common in material adjacent to slip planes that can be traced into faults in the country rock.

RECENT OPERATIONS AND FUTURE POSSIBILITIES

The nature of past operations at the Kiawa deposit makes it impossible to determine mica quality on the basis of production. Much sheet mica was obtained by mining large books selectively and leaving most of the mica in the ground. Perhaps the best example of this technique was the mining of large mica masses from the Old Lower pit by Espinosa in 1914. After rough thumb trimming, a ton of this material was shipped to a Denver concern as a selected mine-run product, and when prepared yielded 71 percent half-trim sheet mica. In 1941, when Maestas encountered a rich concentration in the north dike, he obtained 1,500 pounds of book mica in one and a half days. This material yielded more than 110 pounds of large sheets, and one 72-pound book yielded 12 pounds of 14-inch half-trim sheets. Such "high-grading" has been somewhat offset by operations aimed at the production of scrap mica, in which much sheet material has been broken up and included with the mine scrap. Study of the most recent operations in unusually rich mica-bearing pegmatite, based in part upon data furnished by Maestas, also bears testimony to the irregularities in the mica shoots (see Table 8).

TABLE 8. OPERATIONS FOR STRATEGIC-GRADE MICA, KIAWA MINE

	Operations from 1940 to September 1943	Operations in "bull mica" concentration at main junction of workings from Hoyt adit	Operations in room at head of raise from Hoyt workings
Volume of pegmatite mined (calculated) (cubic feet)	———	2,700	2,250
Weight of pegmatite mined (tons)	———	225	188
Mine-run mica recovered (tons)	15	29	15
Total mica removed (tons)	19[a]	45[b]	23[b]
Proportion of mica in pegmatite mined	———	20%	12%
Proportion of recovered mine-run mica in pegmatite mined	———	12%	8%
Plate mica (selected mine-run) recovered (pounds)	820	1,350	3,425
Prepared strategic-grade mica recovered (pounds)	67	76	165
Proportion of prepared strategic-grade mica in plate mica	8.2%	5.6%	4.8%
Proportion of prepared strategic-grade mica in recovered mine-run mica	0.22%	0.13%	0.55%
Approximate value of recovered mine-run mica per ton [c]	$41	$31	$82
Approximate value of pegmatite mined per ton [c]	———	$3.74	$9.75

[a] Based on assumption that about 20 percent of total mica was discarded on the dump as fines and as small books in large rock masses.

[b] Based on assumption that about 35 percent of total mica was stocked on dump for future mechanical recovery.

[c] Based on price of $15.60 per ton for scrap and $6.00 per pound for prepared strategic-grade mica.

Although selected parts of many mica concentrations have been mined, it seems likely that in future operations the bulk of a given shoot must be worked and a high percentage of its contained mica recovered. The "high-grading" of plate or scrap mica has been a wasteful process, in which favorable financial return has depended upon the presence of unusually rich concentrations near the surface and upon very low labor costs. Those concentrations of reasonable promise that cropped out at the surface now have been mined by crude methods to depths below which even the richest masses could not be economically handled. Further mining of the deposit, therefore, should be aimed at the downward extensions of known shoots and at adjacent unmined shoots that do not appear at the surface. The most recent operations by Hoyt and Maestas illustrate the recognition of this necessity.

Relatively large concentrations of sheet and scrap mica appear to remain in the Kiawa pegmatite. Although much of the ground above the level of the Hoyt adit and in the vicinity of the Lower pits appears to have been worked out, mica-bearing material remains at lower levels. The most promising part of the deposit for future development may well be the downward continuation of the mica shoot worked in the Upper pit. This is probably below and southwest of the pit floor. The geologic setting in the Twin stopes appears to be favorable for additional mica concentrations, but the latest working faces are choked with muck and cannot be examined. It seems likely that a high proportion of mica produced from the pegmatite will be scrap.

Although the deposit is relatively inaccessible to heavy trucks, it constitutes a potential source of potash feldspar of all grades. Large bodies of No. 1 spar are exposed north and east of the Upper pit, and material of lower grade is very abundant in the vicinity of the Graphic Cliffs.

SOUTH KIAWA DEPOSIT

About 1,000 feet southeast of the Kiawa mine is the South Kiawa deposit (3, Plate 1), which forms a bold knob at an altitude of 8,470 feet. It is 0.3 mile north of Kiawa Canyon in the NW¼ SW¼ sec. 11, T.27N., R.8E., and is connected with the Kiawa mine by a trail. It was last worked in October 1943 by Philip S. Hoyt of Van Horn, Texas, under lease from Joseph M. Maestas and associates, of Vallecitos. The openings comprise three open cuts, the largest of which is 30 feet long, 7 feet wide, and 4 to 15 feet deep. The mica obtained from them has amounted to a few tons of scrap.

The pegmatite body is very irregular in detail (Figure 8), but its general form is that of an asymmetric trough that plunges moderately southwest. Its walls are well exposed. The country rock is platy to thinly foliated micaceous quartzite, greenish gray

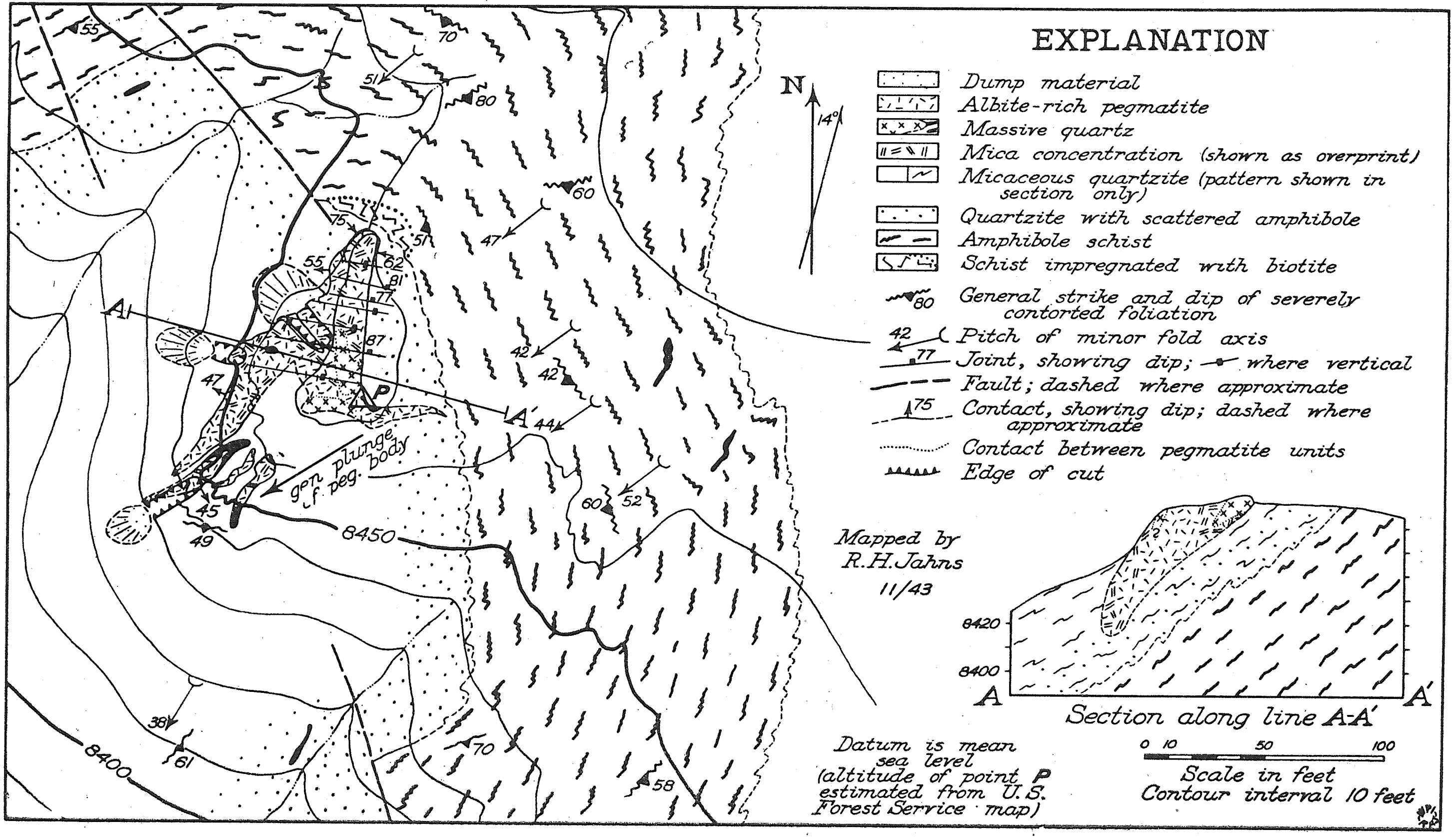

FIGURE 8. Geologic map and section of the South Kiawa deposit.

quartz-mica schist, and dark green to black amphibole schist. Though not actually in contact with the keel of the pegmatite, the amphibole schist that is nearest the keel has been biotitized. As shown by the contact between the schist and quartzite, the country rock has been folded into a large syncline whose axis pitches moderately southwest. The general structure of the pegmatite body thus reflects the structure of the country rock. Its west arm is about 80 feet long, trends N. 25° E., and dips moderately to steeply west-northwest. The east arm, which is broader and much shorter, trends N. 5° W. and dips steeply west. A thin septum of pegmatite projects eastward from its end. Several irregular pegmatite lenses and stringers are well exposed immediately east of the end of the west arm.

Two large pods of massive quartz are present in the east arm, but the bulk of the deposit consists of medium- to coarse-grained microcline-quartz pegmatite that has been rather thoroughly albitized. The chief accessory minerals are cinnamon-colored garnet, green fluorite, and deep blue-green beryl, all of which are transected and corroded by veinlets of albite. Columbite, samarskite, monazite, and bismutite are minor constituents.

Mica occurs (1) along and near the walls of the pegmatite body; (2) along the margins of quartz masses; and (3) along transverse fractures in the thickest portion of the body. The concentration exposed in the middle cut (Figure 8) appears to have been controlled by such early-stage fractures, which trended northwest and dipped very steeply. These are in contrast to a well-defined set of later joints that strike N. 80° W. and dip very steeply north. The early mica-guiding fractures are concordant with near-by faults in the country rock. The muscovite is green and hard. Most of the books are reeved, warped, ruled, and broken, especially near the late-stage cross-joints mentioned above. Little sheet material, even of small size, could be obtained from the shoots, and the total amount of recoverable mica appears to be small.

BUENA VISTA DEPOSIT

The Buena Vista deposit (4, Plate 1) is on the steep east side of a short canyon about 0.1 mile north of Kiawa Canyon and 0.3 mile south-southeast of the Kiawa mine. The workings, which are at altitudes of 8,200 to 8,300 feet, lie in the SW¼ SW¼ sec. 11, T.27N., R.8E., and are accessible from Kiawa Canyon over a poor trail. Neither the details of mining operations nor the present ownership of the deposit is known. It is said to have been operated by Joseph M. Maestas of Vallecitos about 1939, and appears to have yielded a moderate amount of scrap mica.

Two large continuous pegmatite dikes occur in micaceous quartzite that strikes N. 70° W., dips 50° to 65° south-southwest, and contains minor linear elements that plunge gently west. The south dike trends N. 70° W. and can be followed up the steep hill slope for several hundred feet. It dips very steeply and is 10 to 25 feet thick. In it are many cuts and pits, the largest of which is 35 feet long, 8 feet wide, and 18 feet deep. The dike is distinctly zoned, and contains a core of massive quartz with individual microcline crystals of giant size. The wall zone consists of medium- to coarse-grained microcline-rich pegmatite that has been much albitized. Accessory minerals are samarskite, monazite, columbite, fluorite, garnet, and rare beryl. Mica is present in narrow but rich concentrations of small books along the margins of the dike, and in leaner concentrations of much larger books along the borders of the quartz core. It is light green, hard, and fairly flat. The chief defects are ruling, reeves, and breaks. Some of the books have been partly replaced by albite.

The other dike, which is 250 feet to the north, trends N. 80° E. and dips steeply north. It has been opened in many pits and cuts for a distance of 450 feet along the strike. Several of these cuts are at least 20 feet long, 10 to 15 feet wide, and 15 feet in maximum depth. The dike, which is 15 to 25 feet thick, contains a well-defined core of quartz, with local large microcline crystals, near its west end. To the east the central part of the pegmatite consists of coarse microcline with local small masses of quartz, but near its east end a thin irregular quartz core is present. This distribution of quartz, which is unusual for pegmatites in the Petaca district, may indicate that the mean plunge of the dike is shallower than the slope of the canyon wall and that the quartz core exposed near the west end is actually near the keel of the dike. This structural interpretation is compatible with the gentle plunge of minor structures in the country rock.

The wall zone is very rich in coarse microcline, but has been partly albitized near the two ends of the dike. The accessory minerals are similar to those in the south dike. Mica occurs in the outer part of the wall zone and along the margins of the quartz masses. Impressions of books 18 inches in diameter were observed in quartz on the faces of several cuts. Most of the mica, including that in the large books, is much ruled and broken. Although an appreciable proportion of punch and small-size sheet material could be obtained, none of the shoots appears to be rich or extensive.

PERSIMMON PEAK-LAS TABLAS GROUP

EUREKA (LOMA) DEPOSIT

The Eureka or Loma mine (5, Plate 1) is near the center of the south edge of sec. 24, T.27N., R.8E. It lies at an altitude of 8,320 feet on a broad terrace-like flat 0.8 mile due east of Persimmon Peak and a mile west of Las Tablas, and is about 100 yards north of the intersection of the Hoyt wagon road and the Las Tablas-Vallecitos trail. The deposit was discovered and opened

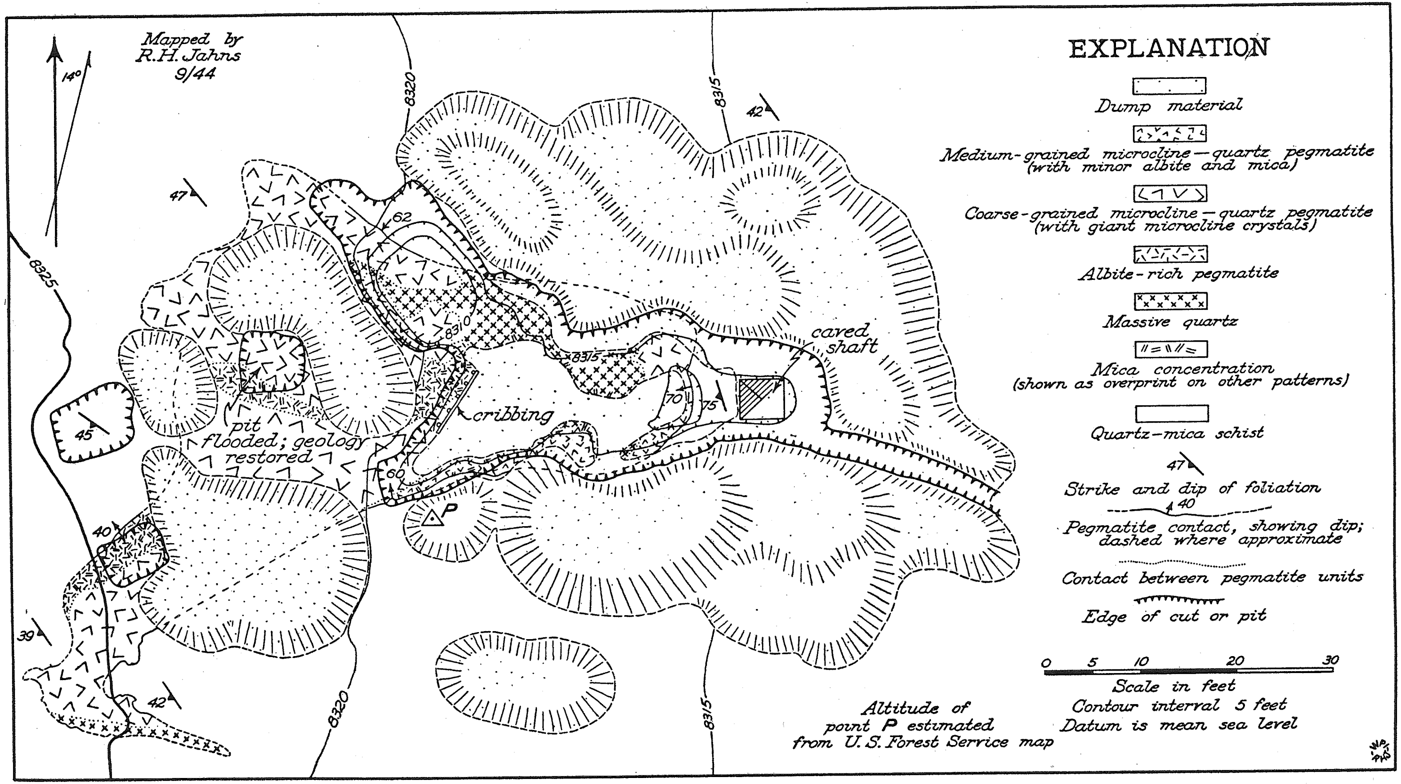

FIGURE 9. Geologic map of the Eureka deposit.

about 1900, but was most extensively mined during the period 1925-1929, when more than 100 tons of scrap and minor quantities of punch mica were obtained. The mine has lain idle for more than ten years. Its present ownership is not known.

The pegmatite body is wedge-shaped in outcrop plan (Figure 9). Its axis strikes N. 70° E. and the tapering end points east. From its other end a hook-like projection extends southwest. The entire eastern third of the deposit has been opened by means of a cut 60 feet long, 10 to 25 feet wide, and 5 to 13 feet deep. A shaft, now caved, was sunk from a point in the cut near the east end of the pegmatite, and shallow irregular workings extend westward from the west end of the cut. Three pits lie farther west. The underground workings and the floor of the main cut are choked with muck, but probably none of the workings extended much farther than its present visible limits.

The country rock is poorly exposed quartzite and mica schist whose foliation trends N. 40° W. and dips 45° SW. No linear structures were observed. The foliation is markedly disturbed near the pegmatite contacts, where the schist has been pervaded with pegmatite material to form spotted feldspathic and pale green mica-rich hybrid phases. As exposed in the main cut, the north wall of the pegmatite dips steeply south and south-southeast, the south wall dips steeply north-northwest, and the east end plunges steeply west. These relations and the attitude of the southwestern prong suggest that the body as a whole plunges west and west-southwest at moderate to steep angles.

A core of massive quartz, which is partly exposed in the northern part of the main cut, grades outward into coarse-grained quartz-microcline pegmatite. The microcline is gray to pale flesh in color and locally is cut by thin veinlets of quartz. Small quantities of albite are scattered through most of the pegmatite, and ill-defined concentrations are present here and there along the margins of the quartz core. Fluorite, garnet, columbite, monazite, bismutite, ilmenite, and sulfides are minor constituents.

Mica occurs as small books along the pegmatite-country rock contacts, as much larger books along the edges of the quartz core, and in local layer-like masses rich in albite that appear to have been developed along sets of closely spaced fractures. It is light to dark green, flat, hard, and free-splitting. Most of the books are 1 by 1½ inches or smaller, though several impressions of 18- by 24-inch books were observed in the massive quartz in the main cut. "A" structure is present but is not common. Ruling, haircracks, and breaks are the principal defects. This deposit might yield a moderate amount of scrap mica and small proportions of sheet and punch material. As the underground workings are inaccessible, however, the distribution of the concentrations down the plunge cannot be precisely predicted.

SILVER SPUR (OLD EUREKA, HOYT-SEWARD, LAS TABLAS) DEPOSITS

The Silver Spur deposits, also known as the Las Tablas group (6, Plate 1), are at the south end of a bold rocky ridge 0.6 mile west-southwest of Las Tablas. They lie at an altitude of about 8,200 feet near the northeast corner of sec. 25, T.27N., R.8E., and can be reached over the Hoyt wagon road, a 3-mile circuitous route from Las Tablas, or over less than a mile of more direct but very steep trail from the same village. The deposits were worked on a rather large scale during the period 1925-1930 by the Hoyt Mineral Company of Las Tablas. According to Philip S. Hoyt, president, 600 to 700 tons of scrap was sold to Chicago and Denver consumers. No records of the sheet and punch mica recovered from these operations are available. Much of the scrap mica was ground in Las Tablas.

The south workings, once known as the Old Eureka mine, are in a large pegmatite dike that trends N. 20°-40° W. and dips steeply to very steeply west-southwest and east-northeast. A cut 25 feet long, 12 feet wide, and 3 to 16 feet deep lies along the east wall of the dike and marks the south end of the workings. A 30-foot tunnel, now partly flooded, was driven N. 20° W. from the face of this opening. A second cut, 20 feet long, 6 feet wide, and 4 feet deep, is several yards up the hill to the north, and other shallow irregular openings lie farther north. Many of these also have been sunk along the east wall of the dike. Approximately 225 feet N. 15° W. of the tunnel is a hanging-wall incline, now flooded, that strikes S. 75° W. It slopes at an angle of 55° and is said to be about 35 feet long. The dike appears to pinch out about 175 feet north of this incline.

The country rock is thick-bedded quartzite that forms large bold outcrops and rough slopes. Its foliation, which is commonly very faint, strikes N. 40° W. and has an average southwest dip of about 40°. On fresh surfaces the quartzite, which is somewhat feldspathic, superficially resembles a fine-grained non-porphyritic granite. It is cut by many dikes and sill-like masses of medium- to coarse-grained pegmatite. Though irregular in detail, most of these trend either N. 20°-40° W. or N. 70°-85° E. The dips of both groups are generally very steep.

The main pegmatite dike, which is 30 feet in maximum outcrop breadth and about 15 feet in average thickness, is a coarse aggregate of microcline, quartz, and subordinate albite. Most of the microcline is gray to creamy white, but a little is pale green. It is markedly coarser in the interior parts of the dike than along the walls, but no core can be readily recognized. Garnet, the most abundant accessory mineral, occurs near the pegmatite borders as crystals ¼ inch to 2 inches in diameter. Many of these are rimmed with green chlorite. Fluorite, samarskite, monazite, and columbite are rare; one small crystal of pale blue beryl was observed.

Mica, which is closely associated with albite, is scattered throughout the pegmatite, but is appreciably concentrated near the walls. Its position appears to have been governed by fractures along contacts between minerals and by throughgoing joints. None of the concentrations is rich and most of the books are small and badly broken. Little high-quality material could be obtained from the deposit.

The north workings, which constitute the Hoyt-Seward mine, are said to have yielded most of the mica obtained during the operations of the Hoyt Mineral Company. They lie in a sill-like pegmatite body that trends N. 35° W. and dips 35°-45° SW. The largest of the workings is a pit 50 feet long, 15 to 20 feet wide, and 10 feet deep, which lies 550 feet N. 13° W. of the Old Eureka tunnel. A shaft at the north end of this pit is said to have been 60 to 70 feet deep, but is now back-filled and caved. Thirty feet south of the pit is a shallow elongate shaft, now flooded, and 60 feet south of the pit is an irregular slot-like cut 25 feet long, 15 feet wide, and 10 to 30 feet deep. Several smaller cuts lie farther south.

The ends of the pegmatite are poorly exposed, but the lithologic units within it plunge gently northwest and may reflect the structure of the entire body. The foliation of the surrounding country rock, platy to massive feldspathic quartzite, strikes N. 35° W. and dips 40° SW. Aligned flakes of biotite form minor linear elements that plunge south at moderate angles; in marked contrast, local drag folds plunge gently northwest. The plunge of the drag folds is probably concordant with the plunge of the pegmatite sill and the structures within it.

The pegmatite is a coarse aggregate of microcline and quartz, parts of which have been strongly albitized. Although no large masses of relatively pure quartz are present, several poorly defined bodies of coarse pegmatite contain an unusually high proportion of interstitial quartz. Most of these are more heavily albitized than the remainder of the pegmatite. Where exposed in three dimensions they can be seen to plunge gently northwest. The proportion of albite in the pegmatite as a whole is highest in the largest pit, i.e., near the north end of the pegmatite.

Garnet, in well-formed wine-red crystals, is the most common accessory mineral. Some of the crystals are partly altered to green chlorite. Pale green fluorite is present as severely fractured euhedral to subhedral masses as much as 6 inches in diameter. Monazite in well-formed tabular crystals is especially abundant near the north end of the main cut, where it occurs with marble- and almond-shaped masses of columbite and samarskite in albite. Beryl, which is rather rare, occurs as pale blue to yellowish green masses in microcline-rich pegmatite near the hanging-wall contact. Bismutite and other secondary bismuth minerals fill fractures in quartz, but appear to be rare.

Although mica occurs throughout the pegmatite, it is most abundant near the hanging-wall contact. It is present as individual books and as 1- to 6-foot rosettes of tanglesheet scrap material that is intergrown with albite and minor garnet. It is pale to dark green and moderately hard. Most of the books are ruled, warped, twisted, and broken. Wedge, "A", and herringbone structures are common. Although the amount of sheet material that could be obtained from the deposit is probably very small, both pegmatites might be satisfactory sources of feldspar and scrap mica, especially if they were mined by bulk methods and the two products were separated by milling.

CANARY BIRD DEPOSIT

The Canary Bird deposit is at the east edge of an elongate meadow 0.75 mile southeast of Persimmon Peak (7, Plate 1). It lies 500 feet south of the Las Tablas-Vallecitos trail at an altitude of about 8,270 feet, and is in the NW¼ SW¼ sec. 25, T.27N., R.8E. The deposit, a single pegmatite dike 18 feet in outcrop breadth, has been opened by means of three small shallow pits, at least one of which has been worked during recent years. The dike trends a little west of north and dips steeply west. Neither end is exposed, but it appears to taper northward.

The surrounding rock is platy micaceous quartzite whose foliation strikes north-northwest and dips moderately west-southwest. Near the pegmatite it has been impregnated with white albite-oligoclase, white to pale green microcline, and abundant small flakes of bright green muscovite. A distinct layering is characteristic of the pegmatite border zone. The following sequence is generally present from the country rock into the pegmatite.

1. Mica-rich schist formed through the action of pegmatitic solutions on quartzite country rock.
2. White to bluish quartz in a layer ⅛ to ⅜ inch thick.
3. Fine-grained sugary microcline—albite-oligoclase pegmatite, locally much albitized, in a layer ½ inch to 1½ inches thick.
4. Sugary microcline-albite-oligoclase pegmatite with abundant small crystals of garnet; this garnet-rich layer is ⅛ to ¼ inch thick.
5. Fine- to medium-grained platy albite with abundant fine-grained dark green mica, forming a layer ¼ inch to 1½ inches thick.
6. Typical medium-grained microcline-quartz pegmatite, partly albitized; this material forms the wall zone.

The pegmatite body contains a quartz core 3 to 8 feet in breadth; near its north end this unit contains a few large microcline crystals. Flanking the core is a zone of coarse microcline-rich pegmatite. Albitization appears to be confined to the contact between these two units, and much of the microcline-rich pegmatite has been completely replaced by curving blades of cleavelandite ½ inch to 2 inches long. Replacement by similar material has extended into the quartz of the core along a network of fractures. Small crystals and rounded masses of columbite, monazite, samarskite, and bismutite occur in the albite; the latter two minerals are also present in the quartz. Small red to cinnamon-colored garnet crystals, pale green fluorite, and blue-green beryl are present near the borders of the dike, and one transparent deep green crystal of tourmaline ⅛ inch in diameter was seen in the largest pit. A few flakes of pale pink muscovite are present in the albite-rich zones.

Book mica is concentrated in the strongly albitized pegmatite at the margins of the quartz core. Most of the books are small, badly broken, and marked by "A" structure. Inclusions of garnet and albite are common. A few larger books, some as much as 11 inches in diameter, are partly embedded in the quartz of the core. These are light green in color, hard, and free-splitting. Some of the smaller books, in contrast, are dark green in color and can be split only with difficulty. None of the mica concentrations is markedly rich, and the amount of high-quality material that could be obtained from the deposit is very small.

MEADOW DEPOSIT

Eight hundred feet north of the Canary Bird deposit and on the eastern edge of the same elongate meadow is a series of workings that have been sunk in a large pegmatite sill known as the Meadow deposit (8, Plate 1). The main workings are at an altitude of 8,300 feet in the SW¼ NW¼ sec. 25, T.27N., R.8E. They are north of the Las Tablas-Vallecitos trail and 500 feet west of its crossing with the road to the La Jarita mine. Four cuts have been driven eastward into a short steep hill slope, thence westward and down for short distances along the hanging wall of the pegmatite body. Most of the shallow underground parts of these openings are now filled with muck.

The pegmatite sill strikes N. 10° - 15° W. and dips 20° - 40° W. It is 6 to 8 feet thick, although its outcrop, which is on a west slope, suggests a much greater thickness. The rock is extremely coarse-grained and consists chiefly of microcline and interstitial quartz. Graphic granite is present locally. Albite is a subordinate but widespread constituent, and its distribution appears to have been controlled by throughgoing fractures, fractures along quartz-microcline contacts, and cleavage cracks in the potash feldspar. The accessory minerals are garnet, fluorite, beryl, and minor columbite and samarskite. Much of the fluorite has been dissolved, leaving small cavities near the walls of the sill.

Mica occurs as widely scattered books in all parts of the pegmatite that contain moderate quantities of albite. It also is concentrated near the hanging wall and footwall of the sill as individual books 6 to 14 inches in diameter and as larger tangled intergrowths of books. It is medium green in color and moderately hard. Most of the books are strongly ruled and broken, so that little strategic-grade material could be obtained from them.

ALMA (KANSAS CITY) DEPOSIT

By E. Wm. Heinrich

The Alma or Kansas City deposit (9, Plate 1) is near the center of sec. 26, T.27N., R.8E. It lies at an altitude of about 8,400 feet on the steep northeast side of a canyon that drains into La Jarita Canyon, and is 0.35 mile north of Russian Ranch. It can be reached by automobile from the Mesa road over about 2 miles of ungraded road that passes immediately north of Poso Spring, or on foot over a poor trail from Russian Ranch. The deposit was worked about 1900 by the Standard Mica Company, and about 90 tons of crude scrap mica is said to have been shipped to the Atlantic seaboard for grinding. The deposit was later operated by Philip S. Hoyt of Van Horn, Texas. In 1943 the property was held under claim by A. C. Bohrnstedt of La Madera, who leased it during June of that year to Messrs. W. L. and W. R. Marion. The Marion brothers operated the mine for about eight weeks, and obtained 500 pounds of plate (selected mine-run) mica, 3 tons of scrap mica, and 1,265 pounds of beryl. The plate mica yielded about 83 pounds of strategic-grade sheet material.

The workings, which are in a single sill-like body of pegmatite, consist of a large open cut 5 to 15 feet deep, 185 feet long, and 45 feet in maximum width, a crosscut and raise, and several small prospect pits and trenches (Plate 7). The crosscut, in which the pegmatite was encountered about 30 feet from the portal, is 38 feet long. A 30-foot raise was driven along the hanging wall of the pegmatite body from the adit to the surface at an angle of about 35° (Figure 10).

The country rock is a micaceous quartzite that contains numerous small stringers of pegmatite and many quartz veins. In general both stringers and veins are conformable with the country-rock foliation, which strikes north-northwest and dips moderately west-southwest. Rows of biotite flakes and parallel needles of hornblende plunge moderately south-southwest. The axes of drag folds and local crenulations pitch west-southwest at somewhat lower angles.

Northwest of the main pegmatite body the country rock has been injected lit-par-lit by many small pods and stringers of quartz-rich pegmatite. This complex extends at least 250 feet northwest from the mine workings; its maximum width is 70 feet. Within it the quartzite has been permeated with much fine-grained muscovite to form a fissile rock with highly crumpled foliation. Southwest of the mine workings a biotite-bearing rock occurs in the quartzite as dark-colored lenses and pods. The largest of these is 65 feet long and about 2 feet thick.

The main pegmatite body, which is 560 feet long and 15 feet in maximum thickness, strikes N. 20° W. and dips 20°-55°WSW. It is broadly conformable with the structure of the country rock, but locally cuts across it. Its crest and keel, as well as some of the mica concentrations and other lithologic units, appear to plunge moderately to gently west-southwest in accord with the plunge of some of the minor country-rock structures. The thickest part of the body has been mined over a strike length of 270 feet. Southeast of the main pit the pegmatite thins mark-

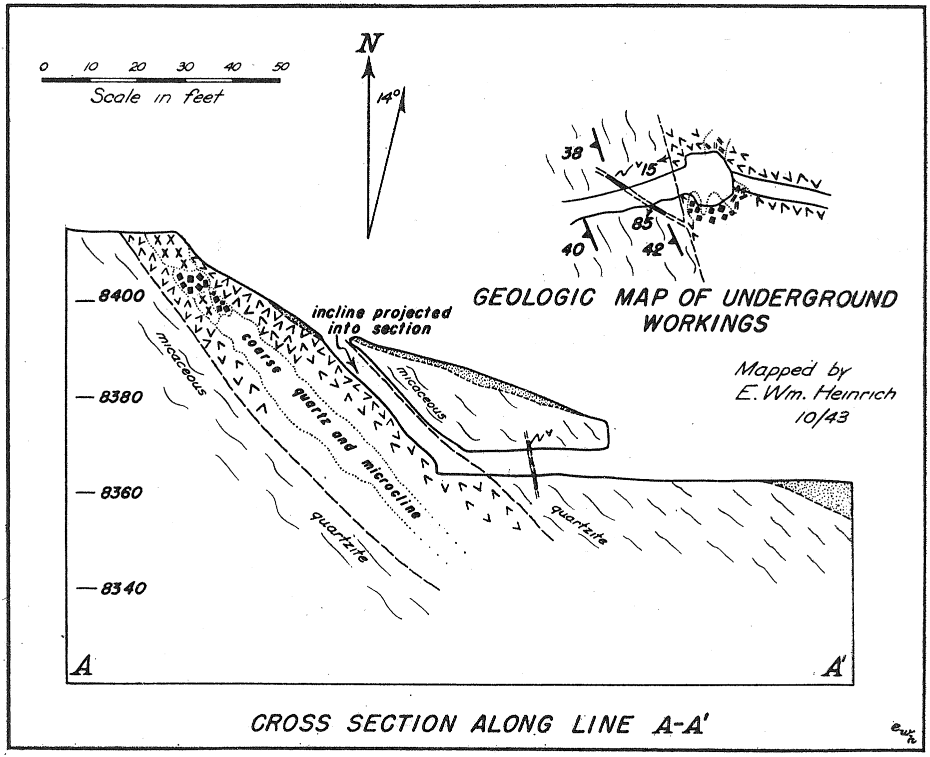

FIGURE 10. Plan of workings and cross section, Alma mine (see Plate 7 for legend).

edly, and thence gradually dwindles to a thin stringer (Plate 7). Minor offshoots, most of which are too thin to be shown on the map, project from this stringer into the wall rock at acute angles. A persistent 2-foot quartz vein, which contains minor feldspathic masses, crops out northeast of the main pegmatite body and can be traced for 400 feet. Where it crosses the road it appears to be offset about 15 feet along a fault, which probably trends northeast.

The main pegmatite is not sharply zoned. It contains a poorly defined core of massive quartz and coarse blocky microcline in crystals as much as 6 feet in diameter. Surrounding this core is medium- to coarse-grained pegmatite that consists of quartz and microcline with subordinate quantities of albite, muscovite, and garnet. No zoning is present in the thin southeastern part of the pegmatite, which is a medium-grained intergrowth of quartz and microcline with minor albite and muscovite.

Near the margins of the body both quartz and microcline have been replaced by albite. Replacement of quartz by platy cleavelandite is common, and much of the adjacent microcline occurs in relatively unaltered euhedral masses. Muscovite is closely associated with the plagioclase. Of the accessory minerals, beryl, garnet, and fluorite occur in the wall zone, and bismutite, columbite, samarskite, and monazite occur in both wall zone and core. They are associated with cleavelandite and appear to be late-stage minerals. This also is true of some of the fluorite. Pale yellow to yellow-green beryl occurs as subhedral to anhedral masses transected by blades of cleavelandite and by veinlets of muscovite and quartz.

Mica appears to be confined chiefly to the hanging-wall portion of the pegmatite body, where it forms a selvage near the quartzite contact. Additional books are sparsely scattered through the wall zone. The mica is light green, hard, generally flat, and mostly free from mineral spots and surface stains. The chief defects are numerous cracks, ruling, and local reeves. Garnet inclusions are rare. Most of the books are 2 to 3 inches in diameter, but impressions of books as much as 9 inches in diameter can be seen along the margins of some of the quartz masses.

Only a few crystals of beryl were observed in place, but numerous fragments occur in the dumps below the main open cut. A block of this dump material 10 by 10 feet in plan and 2 inches deep was outlined near the south end of the open cut and then was handpicked for beryl. It was found to contain 0.1 to 0.2 percent beryl. On this basis the beryl in the entire dump would amount to about 300 pounds.

Little mica is exposed in the Alma deposit at present, either in the main open cut or in the underground workings. Although the few books in the underground workings appear to be of better quality than those in the cuts, the proportion of recoverable sheet mica would be small. In general the deposit should be considered as a source of scrap mica with a potential small-scale by-product of sheet and punch material and beryl, but the immediate outlook for production is not encouraging.

OTHER DEPOSITS

Several small irregular pegmatite dikes have been opened by means of five prospect pits half a mile east-northeast of the Eureka mine. Most of these pits lie within a few yards of the Las Tablas-Vallecitos trail. The pegmatites are in highly crenulated quartz-mica schist whose foliation strikes N. 15° W. and dips 40° W., and are not far from the contact zone with the Tusas granite. They consist of extremely coarse-grained microcline and minor interstitial quartz. The dikes are 8 to 15 inches in thickness, and several contain microcline crystals that extend from wall to wall. Similar large crystals of graphic granite, in which quartz rods as much as 4 inches in diameter are present, were observed in some of the smallest dikes.

Muscovite and albite are scattered irregularly through the pegmatite. Much of the mica appears to mark the positions of partly or wholly digested wisps and plates of included country rock. The books are pale green and hard, but much ruled and broken. Most are less than 2 inches in diameter. None of the concentrations appears rich enough to support even a small-scale mining operation.

Several sill-like pegmatite bodies have been prospected in the area between the Eureka and Canary Bird deposits. Local concentrations of mica are present, generally along the hanging walls, but the books are small and badly broken. Several poorly exposed pegmatites 0.2 mile west-southwest of the Meadow deposit have been opened by means of small pits. The showings are poor and little mica appears to have been obtained. Hematite-molybdenite streaks have been exposed in quartz veins and thin quartz-rich pegmatites on both sides of a wagon road that extends south and south-southeast along a prominent ridge 0.3 mile east of Russian Ranch. Pits that have been sunk on these deposits have exposed concentrations too small to warrant further development.

LA JARITA-APACHE GROUP

LA JARITA DEPOSIT

By Lauren A. Wright

The La Jarita pegmatites (10, Plate 1) are exposed along a south-flowing tributary to La Jarita Canyon in the SW¼ SW¼ sec. 25, T.27N., R.8E. They are 0.7 mile east of Russian Ranch at an altitude of about 8,200 feet, and can be reached by automobile from the Mesa road via Poso Spring over about 4 miles of poor road. The deposit was originally located by E. B. Seward in 1920 and was later taken over by J. C. Valesquez, who sold it to the Eureka Mica Mining Company of Vaughn, New Mexico, in 1923. B. F. Harelson and R. H. Harelson of Albuquerque, New Mexico, and J. C. Harelson of San Jose, California, are the chief officers of this company. About 25 pounds of plate (selected mine-run) mica valued at $50.00 was obtained by the Harelson brothers in 1923, but no production was recorded during the following twenty years. The latest operations, during the period August-October 1943, yielded 279 pounds of selected book mica and a few thousand pounds of scrap. About 20 pounds of strategic-grade material was obtained from the books.

Three mica-bearing pegmatite bodies, here designated as the North, Middle, and South dikes, have been explored by shallow trenches and cuts. A shallow discovery shaft was sunk on the North dike by Seward in 1920, and a second shaft was sunk near the east end of the South dike by the Harelson brothers in 1923. Both openings are now caved and water-filled. Shallow cuts were also dug near the east end of the South dike in 1923, and a broad area near its west end was stripped. The North dike has been worked by means of an open cut 55 feet long, 7 to 13 feet wide, and 14 feet in maximum depth. This has been abandoned and is now partly caved. The most recent workings consist of a cut and an appended drift that extends about 20 feet eastward into the Middle dike near the bottom of the small canyon.

The country rock is typical platy to thick-bedded micaceous quartzite that forms bold irregular ledges throughout the mapped area (Plate 8). Its foliation strikes north to north-northwest and dips west to southwest at moderate angles. Where recognizable, its bedding tends to be conformable with the foliation. Many linear structures, chiefly the axes of small drag folds and local crenulations, pitch west and west-southwest at moderate angles. As in many other parts of the district, much mica is present in the country rock wherever pegmatite dikes and quartz veins are present.

The pegmatites and associated rocks can be divided into three groups, as follows.

1. Many thin, irregular, and discontinuous quartz veins and quartz-rich pegmatite dikes trend parallel with the country-rock foliation, but in general dip more steeply west. They can be traced for distances ranging from a few inches to 160 feet, and rarely are more than 3 feet thick. They are virtually barren of mica.
2. A few thin dikes that consist chiefly of coarsely intergrown quartz and feldspar also trend parallel to the strike of the country-rock foliation and dip steeply west to west-southwest. One of these dikes is more than 300

feet long, though extremely sinuous in detail and locally discontinuous in its exposure (Plate 8).

3. The larger mica-bearing pegmatites are dikes that trend east to northeast and dip steeply north to northwest. All are elongated lenses that plunge west to west-southwest at moderate angles. The North dike is 275 feet long and 13 feet in maximum depth, and pinches downward in the long cut. The Middle dike is 165 feet long and 12 feet in maximum width. The South dike, whose general outcrop plan is that of an irregular dumbbell, is 155 feet long, 5 feet wide in its central portion, and 31 feet and 19 feet wide near its east and west ends, respectively. The contacts between pegmatite and country rock are everywhere sharp.

The large dikes are distinctly zoned, with cores of massive quartz, intermediate zones of coarse blocky microcline and coarse aggregates of quartz and microcline, and wall zones of finer-grained microcline-rich pegmatite that has been partly albitized. The mica occurs in this microcline-quartz-albite rock. The zones and mica shoots plunge west at moderate angles, thus tending to conform with the plunge of the dikes.

The North dike contains a thin discontinuous core of massive quartz. The Middle dike is much less distinctly zoned, though a central quartz rib is present near its eastern end. The breast of the recent drift shows only a progressive coarsening of the pegmatite from the walls toward the center. The eastern bulge of the South dike contains a quartz core near its east end or keel, and an intermediate zone of blocky microcline is present farther west. In the center of the west bulge is coarse blocky microcline. The thin "neck" of the dike appears to consist of quartz and minor albite.

The quartz in the pegmatites is colorless to smoky. Most is interstitial to microcline, but local late-stage veinlets cut across the Middle and South dikes and a larger quartz vein transects the wall zone of the North dike and merges with its core. The microcline is gray to flesh colored and coarsely perthitic. It occurs in the intermediate zones of the South dike as irregular masses and well-formed crystals 10 inches in average diameter. Both cleavelandite and the sugary varieties of albite are present. In the hanging-wall portion of the North dike albite is unusually abundant; elsewhere it is irregularly distributed through the outer parts of the dikes. Locally it occurs in layers along fractures in quartz and potash feldspar, as well as in large rosettes that appear to have replaced earlier feldspar.

The common accessory minerals are fluorite, samarskite, spessartite garnet, ilmenite, and magnetite. Minor accessories are columbite, monazite, and beryl. Most of the ilmenite and magnetite occurs in the quartz veins and in the quartz cores of the dikes. The garnet is present as pale orange to red masses in quartz and albite, and rarely as flattened crystals in the mica. Fluorite is abundant in the outer zones of the Middle dike, generally as pale green masses less than an inch in diameter. The beryl occurs as small waxy pale yellow-green masses near the south margin of the eastern bulge of the South dike. It is commonly cut by late-stage quartz veinlets, and in such places is associated with samarskite. The columbite and monazite are rare constituents of the albite-rich zones.

The mica in the Middle dike is pale to bottle green, flat, and very hard. It is generally free from spots and surface stain. Its chief defects are breaks, ruling, some waviness, and local "A" structure. The edges of many books are corroded by albite. Although diameters of 10 to 14 inches are common, the average diameter is probably about 3 inches, and much of the mica is too small to yield sheet material. The mica in the North and South dikes is softer, slightly darker in color, and probably somewhat smaller than that in the Middle dike. Most of this mica is scrap. Inclusions of quartz and albite are common, and flattened garnets have also been observed.

The mica concentrations occur, in decreasing order of relative abundance, along hanging-wall contacts, footwall contacts, and margins of quartz masses. Most of the books thus far produced have been taken from the hanging-wall portions of the North and Middle dikes. Even where the richest concentrations occur, the proportion of mica in the pegmatite is generally less than 5 percent. As shown by production data for a recent period of operations, however, the proportion of recoverable strategic-grade material is relatively high (Table 9).

Any future production of mica will probably come from westward down-plunge extensions of the hanging-wall shoot already worked in the North dike, and possibly from similar down-plunge extensions of shoots that flank the quartz core in the Middle dike. Scattered mica books and impressions of books that have been weathered or mined out along the west borders of the quartz mass in the South dike also suggest a potential small source. Although the concentration of mica in most of the shoots is relatively low, the shoots themselves can be reasonably extrapolated to depths of several tens of feet.

LONE WOLF (SILVER DOLLAR) DEPOSIT

The Lone Wolf or Silver Dollar deposit (11, Plate 1), is on the south side of a short steep ridge south of La Jarita Canyon and 1/4 mile south-southeast of Russian Ranch. It lies at an altitude of about 8,300 feet in the NW1/4 NE1/4 sec. 35, T.27N., R.8E. Access from Russian Ranch and the Las Tablas-Vallecitos trail is by a short wagon road, and from the ends of newly completed

TABLE 9. OPERATIONS FOR STRATEGIC-GRADE MICA, MIDDLE CUT, LA JARITA DEPOSIT

Volume of rock mined (calculated)	2,080	cu. ft.
Weight of rock mined	173	tons
Weight of pegmatite mined	158	tons
Mine-run mica recovered	2,500	lbs.
Total mica removed [a]	2,780	lbs.
Proportion of mica in pegmatite mined	0.9	%
Selected book mica recovered	279	lbs.
Prepared strategic-grade mica recovered	16.75	lbs.
Proportion of prepared strategic-grade mica in selected book mica	6.0	%
Proportion of prepared strategic-grade mica in recovered mine-run mica	0.6	%

[a] Based on assumption that about 10 percent of total mica was discarded on the dump as fines and as small books in large rock masses.

all-weather roads at the Lonesome mine and Goodge sawmill by automobile trails and a wagon road. The deposit is reported to have been worked for scrap mica about 1900, during the period 1918-1922, and about 1935. A little work has been done during recent years by Joseph M. Maestas of Vallecitos.

The main workings are in a large pegmatite dike that is 15 to 85 feet in outcrop breadth and at least 300 feet long. It trends nearly due west and is essentially vertical. The east end of the workings is marked by a shallow shaft, the west end by a short tunnel. Between these are several irregular pits and cuts whose maximum depth is about 20 feet. An adit, said to have been driven in 1922, runs about N. 35° W. from a point near the canyon bottom and extends beneath the east end of the surface workings. It furnishes about 50 feet of backs. Ninety feet from the portal this adit splits into two branches, one 20 feet and the other 30 feet long. A little overhead stoping was done at this junction point.

The south contact of the pegmatite is well exposed 2 to 10 feet south of the surface workings, but little of the north contact, which is probably very irregular, can be seen on the rubble-strewn hill slope. The country rock, a mica-rich schist, has been markedly disturbed near the walls of the dike. It occurs within the pegmatite as long thin inclusions and septa, some of which have been thoroughly impregnated with feldspar and other pegmatitic material.

The dike is rudely zoned. Its core, which is 10 to 40 feet thick, consists of quartz and extremely coarse aggregates of quartz and euhedral microcline. It is not symmetrical within the dike, but appears to lie near its south margin at the surface and near its north margin in the underground workings (Figure 11). The wall zone consists of very coarse-grained microcline-quartz pegmatite that is locally rich in graphic granite. In at least two places in the large cut near the east end of the surface workings this graphic granite is transected by 2-inch to 4-inch veinlets of microcline. The accessory minerals are garnet, fluorite, and minor beryl, which occur in all parts of the wall zone, and columbite, monazite, bismutite, ilmenite, and magnetite, which are more common in albite-rich pegmatite along the margins of the core.

Mica occurs as books 2 to 10 inches in diameter in albite-rich pegmatite along the margins of the core, as much finer-grained aggregates at or near the borders of the pegmatite, and as small but locally rich aggregates in quartz at contacts between crystals of graphic granite or between crystals of graphic granite and microcline. In some places the microcline of graphic-granite masses has been selectively albitized, and abundant small mica books are present among the spindles of quartz. The mica is pale green, clear, flat, hard, and free-splitting. Its chief defects are ruling, breaks, and local "A" structure.

The only books that would yield usable sheet mica are those adjacent to the quartz-rich core. Most of the sheets trimmed from these would be very small, though a few of the largest blocks would yield ribbon material 2 to 3 inches wide. The most promising mica concentration appears to be that along the contact between the core and the wall zone, particularly along the south side of the core. This shoot was worked near the surface and

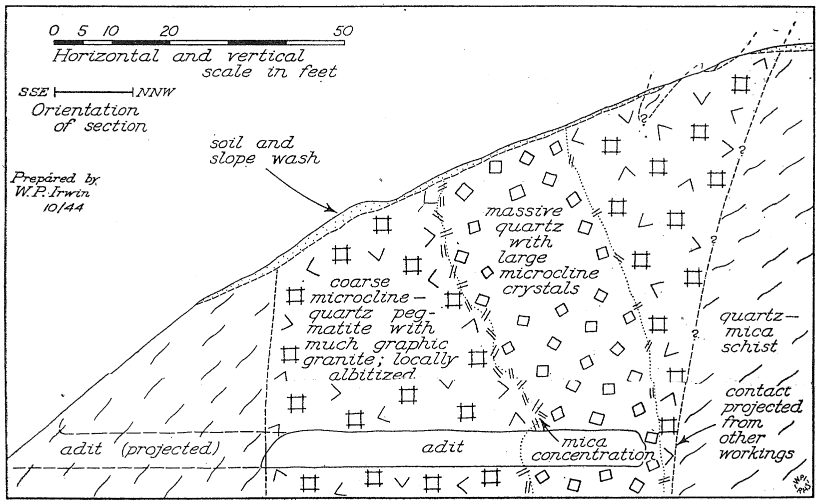

FIGURE 11. Cross section of the Lone Wolf deposit in vicinity of main underground workings.

was encountered in the underground workings at the point where the adit branches. Even this concentration may not be rich enough, however, to support an operation for scrap mica.

About 100 feet northwest of the main workings are three shallow pits in a 15-foot pegmatite dike. This dike trends N. 60° W. and appears to dip steeply north-northeast. It contains a well exposed quartz core in which a few scattered crystals of microcline are present. The wall zone consists of mildly albitized medium- to coarse-grained microcline-quartz pegmatite. Mica is present at the margins of the core, but most occurs in poorly defined pods 2 to 6 feet in maximum exposed dimensions. These pods merge into the microcline-quartz pegmatite, but are distinguished from it by their relative richness in interstitial quartz. The mica is light green, flat, free-splitting, and clear. The small size and severe ruling of the books, however, make it unfit for any but scrap uses. Garnet and a little fluorite are present near the borders of the dike, and a few crystals of pale green beryl occur along the margins of the core.

VESTEGARD DEPOSIT

The Vestegard deposit (12, Plate 1) is on rolling upland country 1¼ miles east of Goodge sawmill and 0.4 mile north-northeast of the Lonesome mine, which is at the end of a graded and gravelled road from Petaca. The deposit lies at an altitude of 8,015 feet near the center of the west half of sec. 36, T.27N., R.8E. It is connected with the Lonesome mine by an ungraded road. The workings consist of a cut 25 feet long, 6 to 15 feet wide, and 8 feet in maximum depth, and of several small shallow pits. Most were excavated by A. B. Vestegard and associates in 1942 and 1943. A little beryl and several hundred pounds of scrap mica were obtained, and a few tons of feldspar is stockpiled at the deposit.

Several irregular dikes and pods of pegmatite occur in partly pegmatitized mica-rich schist. The contact zones are made extremely irregular by many intricately branching pegmatite apophyses and small pods of coarse feldspar. The dikes themselves consist chiefly of coarse dark gray, creamy white, and green to blue-green microcline. Some of the larger feldspar masses contain irregular spindles and rods of quartz arranged in a rudely graphic pattern. The other constituents of the pegmatite are quartz, albite, mica, beryl, columbite, and samarskite. The tantalum minerals occur with cleavelandite and fine-grained yellowish green muscovite in veinlets that transect masses of potash feldspar. Small irregular vugs that are present in the wall zones of the pegmatite bodies may have been formed through alteration of fluorite and adjacent feldspar. Some contain thin crusts of calcite, and the walls of others are coated with fine-grained yellow mica.

Most of the mica is pale to dark green, and occurs in books too small to yield sheet or punch material. These books are strongly concentrated along the borders of the pegmatite masses, but are not sufficiently abundant to be considered a promising reserve of scrap mica. The deposit was recently worked because the microcline feldspar was thought to be medium- to low-grade beryllium ore. This belief may have been based on an analysis of a composite sample that contained some fragments of beryl; tests of the feldspar itself have revealed little more than traces of beryllium.

VESELEY DEPOSIT

About 2,000 feet east-northeast of the Lonesome mine and 0.3 mile southwest of La Jarita Canyon is the Veseley scrap-mica deposit (13, Plate 1). It lies at an altitude of 8,230 feet on relatively flat ground immediately north of a small canyon, and is at the center of the south half of sec. 36, T.27N., R.8E. It is easily reached by automobile from the Lonesome mine. The deposit was discovered by Joseph E. Veseley of Petaca and worked by him during the fall of 1944. About 2 tons of rather pure fine-grained scrap mica was produced.

The deposit consists of a series of small discontinuous veins and pods of quartz, around which the country rock (quartzite) has been thoroughly impregnated with mica. Most of the quartz masses are less than 6 inches thick and 5 feet long, but a few are as much as 3 feet thick and 15 feet long. Much of the quartzite has been so altered that the resulting rock consists wholly of pale green to yellowish green mica in flakes $^1/_{64}$ to ½ inch in diameter (average ⅛ inch). Such material grades into unaltered quartzite through intermediate phases of thinly foliated quartz-mica schist. Most of the mica-rich bodies are irregular lenses whose outcrop areas amount to a few tens of square feet or less, and do not appear to continue to depths in excess of 10 feet.

The deposit has been worked by simple methods. The mica-rich material has been loosened and broken with picks, further broken with mauls, sieved to eliminate most of the quartz fragments, and then shovelled into bags. The silvery to greenish gray product has been remarkably pure and free from grit. Although the reserves of scrap mica may amount to many tens of tons, the occurrence of the material in small lens-like masses would necessitate working of the deposit on a small scale, and operations might not be profitable at current scrap prices.

EL CONTENTO DEPOSIT

The El Contento pegmatites (14, Plate 1) are exposed on a low ridge a few hundred feet east-northeast of the Lonesome mine. They lie at an altitude of about 8,100 feet near the center of the SW¼ sec. 36, T.27N., R.8E. Little is known concerning the date of discovery and the early exploration of this deposit, but it was worked by Charles Flandsburg of Tesuque, New Mexico, and Joseph Veseley of Petaca during 1943. Several tons of feldspar and scrap mica, and a little beryl and sheet mica, were produced.

The largest pegmatite dike is well exposed in three main pits and in several shallow cuts. The west pit is 20 feet long, 10 feet wide, and 5 feet deep, and the others are somewhat smaller. The main dike strikes N. 80° W. and dips very steeply south. It is 4 feet thick in the west pit and appears to pinch out in the east pit, about 350 feet distant. The country rock is micaceous quartzite and thinly laminated mica-rich schist whose foliation strikes N. 55° W. and dips 40° SW.

The pegmatite is not well zoned, although it is much coarser near its center than along its borders. It consists chiefly of coarse, buff, flesh-colored, and greenish microcline, white to gray quartz, and white albite. Pale red garnet, green fluorite, and yellowish to blue-green beryl occur near the walls of the dike. Columbite, samarskite, and monazite are minor constituents of its albite-rich portions, and secondary bismuth minerals are present in some of the quartz.

The mica occurs in local pod-like bodies that are rich in albite and quartz. The distribution of these concentrations, most of which are only a few feet in maximum dimension, appears to be haphazard. The richest exposed concentration is in the west pit, where the pegmatite is unusually coarse-grained. The mica, which is light to dark green, occurs in books whose average diameter is about 4 inches. A few larger books, some with cleavage faces as much as 3 by 4 feet, are present. Most of the mica is severely ruled and bent, and narrow ribbons are common. Despite these defects, a little sheet and punch material can be trimmed from some of the books. The outlook for production of large quantities of mica from this deposit is not encouraging.

About 200 feet south-southeast of the east pit is a cut 15 by 15 feet in plan and 5 feet deep. It exposes a dike or vein of quartz that contains very small quantities of feldspar. A small pegmatite dike approximately 300 feet south-southwest of the east pit has been exposed in a pit 7 feet long, 5 feet wide, and 4 feet deep. The pegmatite consists of microcline, quartz, and albite, with numerous very small blebs of samarskite. Little mica is present.

ST. JOSEPH DEPOSIT

The St. Joseph deposit is on a gentle ridge 0.3 mile east-southeast of the Lonesome mine (15, Plate 1). It lies at an altitude of 8,120 feet near the center of the north edge of sec. 1, T.26N., R.8E., and can be reached by trail from the Lonesome mine or from an old road 700 feet to the east. The deposit was worked during 1943 by Joseph Vesely and associates of Petaca, who obtained a few pounds of sheet and punch mica and a little beryl, columbite-tantalite, and samarskite from five shallow cuts.

The deposit consists of two large dikes that trend N. 50°-60° W. Although the contacts are not well exposed, they appear to be marked by zones of mixed pegmatite and country rock. Numerous small feldspar pods and irregular pegmatitic veinlets in the wall rock are similar to those in the contact zones of the Vestegard deposit. Both dikes are rich in white, gray, and blue-green microcline. Quartz occurs as interstitial material, as irregular spindle-shaped masses within microcline crystals, and as scattered pods 6 inches to 12 feet in maximum dimension. Albite, a common constituent of the pegmatite as a whole, is particularly abundant along the margins of the small quartz masses. Pale blue beryl and salmon-colored garnet are present near the walls of both dikes as rounded crystals and irregular masses corroded by albite. Bismutite and samarskite occur in the quartz, and columbite in the albite. A little ilmenite is present in late-stage quartz veinlets.

Most of the mica occurs as small books along and near the margins of the dikes, and as somewhat larger books in albite-rich pegmatite flanking the quartz masses. It is medium green, fairly hard, clear, and nearly flat, but in general is too severely ruled and broken to yield much sheet material.

North of the main dikes are quartz veins and lens-like masses of quartz-rich pegmatite that contain columbite and platy ilmenite. These minerals also occur in a strikingly layered rock in which veinlets of quartz $^{1}/_{16}$ to $^{3}/_{16}$ inch thick are spaced closely and uniformly in altered mica-rich schist.

Beside an old road about 900 feet east-southeast of the St. Joseph deposit are three small pits in a well-marked zone of irregular pegmatite lenses and stringers that are surrounded by highly altered country rock. This zone trends N. 20° W. Many pods of quartz and quartz-rich pegmatite are present, though most of the bodies consists of coarse white, gray, and blue-green microcline. Individual microcline crystals, some as much as 8 inches in diameter, are scattered through the country rock. A little mica occurs along pegmatite-country rock contacts, chiefly as very small closely spaced books. Beryl and bismutite are minor constituents of the largest pegmatite lenses.

LONESOME DEPOSIT

By E. Wm. Heinrich

The Lonesome pegmatite (16, Plate 1) is 2.6 miles west-northwest of Petaca in the SW¼ SW¼ sec. 36, T.27N., R.8E. It may be the deposit described by Just [21] as the Beryl prospect. It lies on a gently rolling mesa at an altitude of 8,100 feet, and can

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[21] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull 13, p. 66, 1937.

be reached from Petaca over 3½ miles of gravelled all-weather road that was completed in the fall of 1943 by the U. S. Forest Service.

The deposit is said to have been discovered about 1932, but details of the early mining operations are not known. The old workings consist of a group of small surface cuts and open slot-like stopes that extend to a maximum depth of 40 feet. The property was purchased late in 1942 by Charles Besre of Tesuque, New Mexico, who organized the El Nido Mica Company and began operations in November of the same year. A steeply inclined shaft was sunk, short crosscuts were driven to the hanging wall at the 50-foot and 77-foot levels, and hanging-wall drifts were run east and west at these levels. From the east end of the 77-foot level an inclined raise was driven to connect with old workings and with the surface. Some of these old workings were also intersected by the new shaft. Regular mining was suspended late in 1943, but Joseph Veseley of Petaca continued independent small-scale operations, chiefly near the surface at the east end of the deposit, until October 1944. The mine was sold a few weeks later to an organization represented by H. S. Coulter of La Madera, but has not been reopened.

Several tons of feldspar and a little mica, beryl, and columbite were obtained during the early operations, chiefly in the period 1934-1937. During the most recent operations production amounted to 130 pounds of high-quality sheet mica, 30 tons of scrap mica, 4,500 pounds of beryl, 375 pounds of columbite and tantalite, 12 pounds of samarskite, and a little monazite and bismutite. About 80 tons of microcline feldspar has been stockpiled on the surface and in the mine.

Three bodies of pegmatite and several small quartz veins and pegmatite stringers are present in the area (Plate 9). They occur in micaceous quartzite whose foliation strikes north-northwest and dips 25° to 55° west-southwest. Linear elements in the country rock, chiefly the axes of crenulations and small drag folds, plunge moderately to steeply west. Near the contacts with the pegmatite bodies the quartzite has been altered to a schistose rock containing much feldspar and fine-grained muscovite. The original structure is preserved by the orientation of layers of muscovite foils. Some fine-grained biotite was also formed in the quartzite along the margins of the pegmatite mass; specimens of this contact rock were found only on the dumps.

The three pegmatite bodies strike a few degrees north of east and dip very steeply. The northern or largest body, the only one that has been extensively worked, dips north at angles ranging from 60° to 85°, whereas the other bodies dip steeply south. The smaller pegmatite stringers and quartz veins trend slightly west of north and dip to the southwest; they tend to be conformable with the structure of the country rock.

Each of the two southern pegmatite bodies is 85 to 90 feet long. Both are lens-like in shape; the eastern one is 7 feet in maximum thickness, the western 17 feet. The strike length of the northern or main pegmatite body is 165 feet. Its maximum thickness is 18 feet, and it has been explored for a vertical distance of 78 feet. Both of its ends are exposed at the surface, and the eastern end is also exposed in the mine workings. The body is cigar-shaped in plan, and probably is lens-shaped or lath-shaped in three dimensions. Its eastern end is the surface trace of a well-defined keel that plunges westward at angles ranging from 40° to 54° (section A-A′, Plate 9). The plunge of the crest is not known, but is believed to be similar to that of the keel.

The main pegmatite body can be divided into six zones, as follows.

A. Outer zones.
   1. Border zone. Thin rind of medium-grained microcline-quartz pegmatite, partly albitized; contains irregular, poorly defined masses of partly digested country rock.
   2. Wall zone. Medium- to coarse-grained microcline-quartz pegmatite, locally much albitized.

B. Inner zones.
   1. Outer intermediate zone. Extremely coarse-grained microcline-quartz pegmatite.
   2. Middle intermediate zone. Coarse blocky microcline.
   3. Inner intermediate zone. Massive quartz with large well-formed crystals of microcline.
   4. Core. Massive quartz.

As shown in Plate 9 and Figure 12, all the zones plunge west at steep to moderate angles in approximate conformity with the plunge of the pegmatite mass. The quartz core, which lies near the keel of the dike, is very small at the surface but is considerably larger at the level of the lowest mine workings. The configuration of this unit at intermediate levels is not known, inasmuch as it was not reached by the short east drift (Plate 9). The inner intermediate zone, which generally lies between the quartz core and the zone of blocky microcline, is prominent at the surface but tapers downward. Its microcline crystals are extremely large; one exposed at the surface is 19 feet long and occupies the full thickness of the zone.

The middle intermediate zone of coarse blocky microcline is well exposed in the workings at the 50-foot level. In plan it

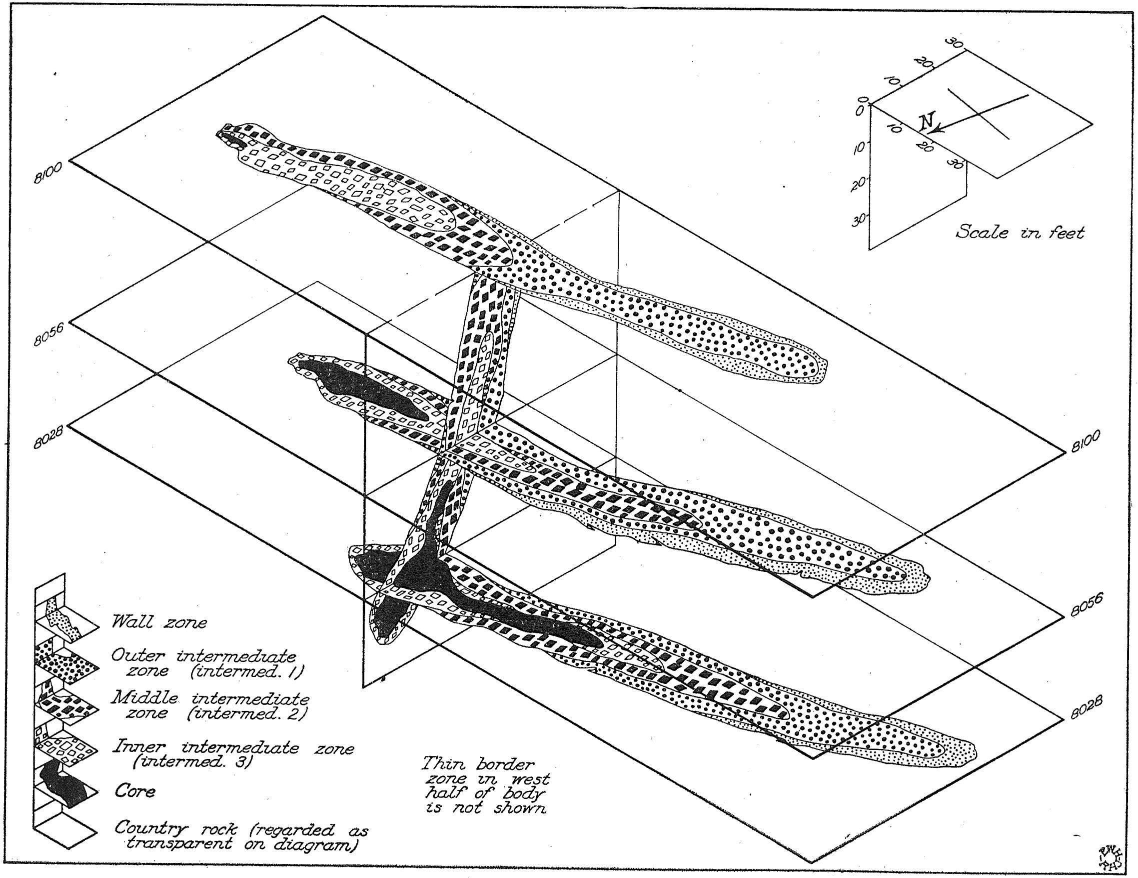

FIGURE 12. Isometric plate diagram of the Lonesome deposit showing distribution of pegmatite zones.

forms a compressed "U" that is open toward the east end or keel of the pegmatite body. Thus it is a narrow deep inverted trough. The arms of the trough flank the core and the inner intermediate zone, and are locally in contact with the country rock in the east part of the dike. The principal exposures of the outer intermediate zone, which is also trough-like in shape, are in the pit at the west end of the dike and in the upper 25 feet of the main shaft. The wall zone and border zone are both well developed in the western part of the dike, but elsewhere are present only as thin lenses and small patches between the inner zones and the country rock.

Microcline and quartz are the chief primary pegmatite minerals. Veins and large irregular masses of cleavelandite, muscovite, and late-stage quartz transect many of the potash feldspar crystals, chiefly along cleavage planes. Quartz and cleavelandite veinlets also cut across crystals of beryl, garnet, and fluorite, which are the principal accessory minerals of the outer zones. A little late-stage beryl occurs as small flattened crystals with cleavelandite. Purple fluorite, columbite, tantalite, samarskite, and monazite are also associated with plagioclase. Some samarskite occurs as veinlets that transect masses of albite and columbite-tantalite, and elsewhere it is present with sulfides in veinlets of smoky quartz.

The eastern or thinner of the two southern pegmatite bodies consists chiefly of medium-grained quartz-microcline pegmatite and medium-grained quartz-microcline-albite pegmatite, with several small masses of coarse blocky microcline. The western body contains a well-defined core of massive quartz with large microcline crystals. This unit is enveloped by quartz-microcline-albite-muscovite pegmatite. Both bodies have been explored by shallow pits.

Most of the mica in the main body occurs in albite-rich pegmatite near the margins. Many concentrations lie along the contacts with the quartzite, but others follow contacts between zones and are separated from the country rock by narrow discontinuous bodies of massive feldspar or by thin lenses of coarse-grained quartz-microcline pegmatite. The mica shoots occur on both the footwall and hanging-wall sides of the dike, but most of the new workings are in hanging-wall concentrations, which are locally very rich. As determined by measured areas of exposed minerals, mica constitutes 25 percent of the face at the east end of the workings on the 50-foot level, and 18 percent of the face at the west end. The general mica content of the main hanging-wall shoot, as mined during the latest period of operations, is reported to have ranged from 12 to 20 percent.

The mica is pale to dark green in color. Although it is relatively free from mineral stain, a pale green mottling or vegetable stain is common. The largest book observed was 24 inches in diameter, but the average is probably about 4 inches. The general quality is very poor. Most of the mica is soft, badly ruled, wavy, and strongly marked by "A" structure. Some is tangled. Many thick books are so soft and inelastic that they can be easily bent and crumpled, and retain the shapes thus imparted to them. A small "pocket" of higher-quality material was encountered in the short east drift (50-foot level) at a point not far from the shaft. This concentration yielded mica as follows.

Mine-run mica obtained	1,800 lbs.
Selected book mica obtained from mine-run material	300 lbs.
Prepared sheet and punch material of strategic grade obtained from selected books	62 lbs.
Proportion of prepared strategic-grade material in selected books	27%
Proportion of prepared strategic-grade material in mine-run mica	3.3%

It seems likely that the average proportion of recoverable sheet mica in the books from the hanging-wall concentrations is less than 0.3 percent.

Beryl crystals are scattered irregularly through the outer zones of the deposit. In addition, distinct concentrations occur in albite-rich pegmatite in the eastern part of the dike, chiefly along contacts between the quartz core and the middle intermediate zone and along contacts between intermediate zones. In these concentrations the mineral forms irregular masses and crystals ½ inch to 10 inches in diameter. It is pale yellow to pale blue-green in color. Much of it contains veinlets of quartz and is coated with small flakes of muscovite. The first ton of concentrates produced in 1943 assayed 11.91 percent BeO, and the second ton, which was sold late in 1944, about 12 percent.

The distribution of columbite, tantalite, and samarskite is similar to that of the beryl, and the four minerals were recovered in a single operation. Most of the tantalum minerals were obtained from the old workings and from recent surface cuts near the eastern end of the dike. They occur as pod-like masses and rudely formed crystals ½ inch to 6 inches in diameter. Unlike most deposits in the district, the Lonesome dike contains both columbite and tantalite. The maximum Ta_2O_5 content of the tantalite, as estimated on the basis of specific-gravity tests, is about 50 percent, but much of the columbite-tantalite material contains 20 percent or less. Samarskite and bismutite are present only in very small quantities, but have been recovered in operations for beryl, columbite, and tantalite.

The outlook for future production of more than minor quantities of sheet mica, beryl, or tantalum minerals from the Lonesome deposit is not encouraging. Although the mica shoots are thick, persistent, and relatively rich, the material is chiefly of scrap grade. The deposit contains abundant microcline feldspar, but large-scale mining of this mineral has not been considered feasible under current economic conditions. With an increase in prices or a decrease in costs of mining and haulage, however, it is possible that a feldspar-scrap mica operation would be practicable, particularly if beryl and tantalum minerals were recovered as by-products.

MICA LODE DEPOSIT

The Mica Lode deposit (17, Plate 1), in the NE¼ NE¼ sec. 1, T.26N., R.8E., lies on the west side of a broad glade at an altitude of about 7,930 feet. It is about 0.3 mile north of Brown cabin and 1,000 feet north of a large earth tank beside Sawmill road, and can be reached by automobile from the old road to the Lonesome mine (Plate 1). Nothing is known concerning operations at this deposit, and the workings are partly caved and filled with muck. A cut 15 by 20 feet in plan and 6 to 10 feet deep appears to represent the earliest mining. A shaft was sunk from the floor of this cut near its west edge, and the remainder of the cut was then partly filled with waste. From the base of the shaft, which appears to be about 20 feet deep, a small stope extends north-northwest. The lowest parts of both workings are flooded.

The pegmatite is a dike 2 to 12 feet thick. It trends north-northwest and dips west-southwest at steep to moderate angles, and where exposed in the northwest wall of the shaft it appears to plunge gently north-northwest. It is not sharply zoned, but is a mosaic of microcline and subordinate quartz that is very coarse-grained in its central portions and distinctly finer-grained near the walls. Most of the quartz and much of the gray to flesh-colored microcline have been albitized, and many large blocks of coarse cleavelandite are present on the dump. Garnet and fluorite, the chief accessory constituents, are locally abundant near the borders of the dike. Beryl, columbite, and monazite were observed in dump material.

The mica occurs as small closely spaced books along the margins of the dike and as somewhat larger books in poorly defined albite-rich bodies that contain a relatively high percentage of interstitial quartz. The average diameter of the larger books is about 3 inches, the maximum observed diameter 7 inches. The mica is pale green and is badly ruled, warped, and broken. It would yield little sheet material. None of the mica shoots appears to be large or particularly rich.

NORTH STAR (MILLER) DEPOSIT

Near the north end of a prominent ridge about 2 airline miles northwest of Petaca is the North Star or Miller deposit (18, Plate 1). It lies at an altitude of 8,075 feet, less than 0.2 mile south of La Jarita Canyon and about half a mile north-northeast of Brown cabin. It is in the SW¼ SW¼ sec. 30, T.27N., R.9E., and in the SE¼ SE¼ sec. 36, T.27N., R.8E. The mine workings are connected with Sawmill road by half a mile of poor automobile trail that extends north from a point at the top of the main grade northwest of Petaca.

According to statements of long-time residents, the deposit was first worked during the period 1895-1902. Operations for scrap mica were conducted in 1926 and 1927 by the Hoyt Mineral Company of Las Tablas, in 1929 by the American Mica Products Company, and briefly in 1938 and 1939 by R. H. Maulsby and J. J. Maulsby. About 100 tons of scrap mica and a little sheet and punch material were obtained by these and other operators during the period 1920-1940. The mine was reopened in 1943 by A. C. Bohrnstedt of La Madera, who gave particular attention to the west end of the deposit. Small quantities of scrap mica, beryl, and monazite were obtained. All workings have been idle since the fall of 1943.

The deposit consists of a single long sinuous pegmatite dike that trends N. 65° W. and dips steeply north-northeast near its east end and south-southwest elsewhere (Plate 10). The oldest workings are two narrow pits along the south margin of the dike near its east end. These are 28 to 34 feet long, 4 to 10 feet wide, and 5 to 15 feet deep. Both are partly filled with muck and may have been much deeper at one time. Irregular pits 10 to 30 feet long, 8 to 20 feet wide, and 3 to 15 feet deep, have been sunk along both walls of the dike farther west. The most recent cut, near the west end of the deposit, is 40 feet long, 3 to 20 feet wide, and 2 to 10 feet deep.

The country rock, which is best exposed in the workings, is greenish gray quartz-mica schist. The average strike of its foliation is N. 45° W., the average dip 50° SW. No linear structures were observed. The pegmatite dike is about 525 feet long, 64 feet in maximum outcrop breadth at a prominent bulge near its west end, and 25 feet in average thickness. Its keel is not well exposed, but its crest or nose plunges gently west. Minor irregularities along the borders of the dike, as well as the lithologic units within it, plunge moderately to gently west or northwest, depending on the dip of the body at the point in question. Pegmatite-country rock contacts are offset along several minor faults and shear zones, particularly in the workings immediately west of the Old pits. None of the displacements is more than a few feet.

The North Star deposit is one of the most clearly and regularly zoned pegmatites in the district. A quartz core 370 feet in exposed length and 10 feet in average width forms a continuous central spine in the eastern two-thirds of the dike. West of this core, and flanking its west end, is an intermediate zone of massive white to gray quartz with abundant crystals and irregular masses of microcline 2 to 12 feet in diameter. Rude crystal faces are present on even the largest of the feldspar masses. Isolated parts of this zone are exposed in the west bulge of the dike. The wall zone, which consists of very coarse-grained microcline-quartz pegmatite, originally formed a complete envelope around the inner zones; but replacement by albite has all but obliterated its original constituents in the east half of the deposit, where it now appears as a partial zonal pseudomorph. Where it flanks the quartz core the partly replaced wall zone is 5 feet in average thickness, but farther west it constitutes the bulk of the dike. A border zone of finer-grained microcline-quartz pegmatite that contains much partly digested country-rock material is in general ¼ inch to 6 inches thick. Along the crest of the dike, however, it thickens to a foot or more.

The microcline is white, light gray, tan, and brick red. The albite, in contrast, is lustrous and white. The sugary variety of albite appears to have been formed at the expense of microcline and is abundant in the west cut. Coarse cleavelandite is predominant in the wall-zone pseudomorph in the eastern two-thirds of the dike, where it appears to have been formed through replacement of both microcline and quartz. Selective replacement of potash feldspar by albite was most common in the intermediate zone near its contact with the quartz core. Garnet, green fluorite, and a little pale green beryl are abundant accessory constituents of the wall zone, and locally have been corroded and partially replaced by albite. Columbite, samarskite, monazite, and purple fluorite are most abundant in albite-rich pegmatite exposed in the old workings, and bismutite and samarskite are present near the margins of the quartz core. Small thin flakes of bright yellow muscovite occur along cracks in feldspar and quartz, especially in the West cut.

The richest concentrations of mica appear to have been taken from the wall-zone pseudomorph along the south margin and near the east end of the dike, and the largest books seem to have lain against the quartz of the core. Impressions of these books in the north walls of the Old pits suggest that many were 18 inches or more in diameter. The concentration of mica appears to decrease westward along the strike of the dike. Books exposed in the West cut, for example, are 1 inch to 3 inches in diameter and are sparsely scattered throughout the pegmatite.

The mica is light to dark green, clear, and relatively hard. Most of the books are badly ruled, warped, broken, haircracked, and marked by "A" structure. Those that lay against the quartz core, however, were "flat-A" mica and are said to have yielded satisfactory sheet and punch material (Plate 10). Future attempts to obtain mica from the deposit might profit by developing and mining the down-plunge continuations of the concentrations worked in the Old pits. It is unfortunate that the floors of these openings are so fouled with muck that inspection of the old working faces is not possible.

MARY DEPOSIT

The Mary deposit (19, Plate 1) is about 400 feet south of the main North Star workings in the southwest corner of sec. 30, T.27N., R.9E. It consists of two large pegmatite dikes that trend west-northwest across the top of a broad ridge and part way down its steep west slope. The workings comprise several shallow cuts said to have been dug about 1927, and three long narrow cuts of more recent origin. The westernmost cut is about 15 feet long, 6 feet wide, and 8 feet in maximum depth, and from its face a short tunnel extends several feet north-northeast. These workings are said to be the result of operations during 1943 by A. C. Bohrnstedt of La Madera.

The pegmatites are very coarse aggregates of microcline and quartz, and are similar in mineralogy and texture to the pegmatite in the west part of the North Star deposit. A few small masses of quartz that range from 1 to 5 feet in maximum dimension are present in the inner parts of the dikes, and poorly defined bodies that are rich in interstitial quartz are more widely scattered. Garnet, fluorite, and beryl are minor constituents of the outer few feet of each dike, and columbite, monazite, bismutite, and fine-grained, bright yellow, late-stage muscovite occur with albite in the interior parts. Much of the feldspar is dark brick-red. Mica-albite concentrations are present along the borders of the dikes, along the borders of the quartz masses, and within the quartz-rich bodies. These minerals are also sparsely scattered through the remainder of the pegmatite. The mica books are small and badly broken, and none of the concentrations appears rich enough to support an operation for scrap material.

ETTER DEPOSIT

By William P. Irwin

The Etter deposit (20, Plate 1) lies at altitudes of 8,030 to 8,090 feet, 0.2 mile southeast of the North Star mine in the NW¼ NW¼ sec. 6, T.26N., R.9E. It is a long pegmatite dike that trends nearly due west across the broad top of a prominent ridge and part way down its sides. The main workings, which are a few hundred feet east of the road to the North Star mine, consist of two open cuts 15 feet long, 10 to 20 feet wide, and 5 to 15 feet deep. Both are undercut a few feet to the west. The history of early mining operations is not known, but the deposit was last

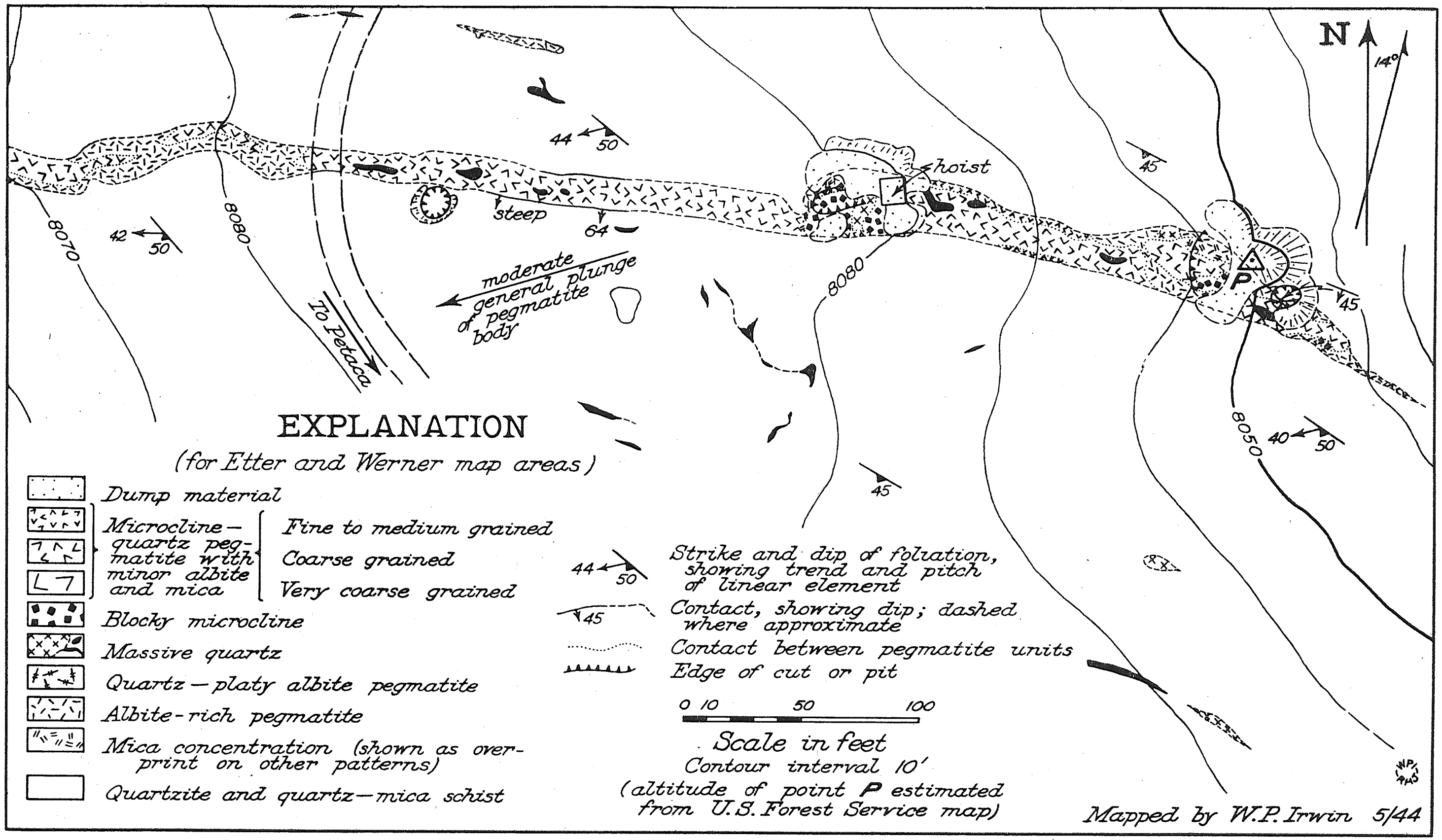

FIGURE 13. Geologic map of the Etter deposit.

and most intensively worked by A. C. Bohrnstedt and associates in 1943. They produced a few pounds of strategic-grade mica, several thousand pounds of scrap, and a little beryl.

The pegmatite dike, much of which is nearly vertical, is 700 feet long and about 15 feet in average thickness. Its eastern third is marked by prominent bulges 25 to 30 feet thick (Figure 13). The trace of this dike makes an acute angle with the trace of the country-rock foliation, which trends N. 40° W. to N. 65° W. and dips 45° to 50° SW. Oriented flakes of biotite form linear elements that plunge gently southeast; a second set of linear elements is represented by the axes of crenulations and larger drag folds that plunge moderately west. As shown in the short west incline, one of the bulges in the dike plunges west-southwest at a low angle in general accord with the crenulations and larger drag folds in the country rock. A similar plunge appears to be characteristic of the pegmatite units exposed in the eastern bulge.

The dike is irregularly although sharply zoned. In its eastern two-thirds a discontinuous core of massive quartz appears as thin lenses 5 to 20 feet long. In the two bulges there are intermediate zones of coarse blocky microcline and rudely to well-formed microcline crystals in massive quartz. The most common rock type is a coarse-grained aggregate of microcline and quartz that forms an outer intermediate zone. It is flanked by a wall zone, similar in composition but much finer in texture, that occupies the entire thickness of the dike 100 feet west of the west bulge, but elsewhere tends to be less than 5 feet thick. A still finer-grained border zone, too thin to be shown on the map, forms a rind around the entire deposit. It is thickest near the west end.

The microcline is white, flesh colored, and light green. It commonly occurs as well-formed crystals in the inner zones. Both the sugary albite and cleavelandite are scattered throughout the dike, and they are particularly abundant along contacts between intermediate zones or between intermediate zones and the core. A large part of the wall zone near the west end of the deposit has been sufficiently replaced to be mapped as albite-rich pegmatite (Figure 13). Garnet is abundant in the wall zone, as well as in the albite-rich pegmatite exposed in the main workings. It occurs as individual crystals 1/16 inch to ¼ inch in diameter, and as irregular vein-like crystal aggregates. Fractured crystals of light green beryl, 1½ to 3 inches in diameter, are scattered sparsely through the wall and outer intermediate zones. Columbite, monazite, and bismutite are minor accessories. Much of the albite adjacent to the columbite and monazite is stained pinkish to brick red.

Small books of mica are scattered through the outer parts of the dike, but larger books are present in distinct concentrations in the albite-rich pegmatite exposed in the main workings. The average size of the books, as measured on cleavage faces, is about 3 by 3 inches, but books a foot or more in diameter were encountered during the recent mining. The mineral is light to dark green, fairly hard, and generally free from stain. The quality is poor, owing chiefly to ruling, warping, and "A" structure. Most of the books not strongly reeved are broken into narrow ribbons by persistent ruling. The proportion of strategic-quality material obtainable from the deposit is extremely low; moreover, it is doubtful whether the concentrations are sufficiently rich or continuous to support a scrap-mica operation on more than a very small scale.

WERNER DEPOSIT

By William P. Irwin

The Werner deposit is at the top of a long slope 400 feet south-southeast of the Etter workings (21, Plate 1). It can be reached by automobile from the North Star mine road, which is a short distance to the west. During the past 30 years many small pits and cuts have been excavated, but the most extensive operations were conducted in 1926 and 1927 by the Hoyt Mineral Company of Las Tablas. About 80 tons of scrap mica, chiefly green "A" material, and several hundred pounds of columbite were obtained, according to Philip S. Hoyt, who directed the work. The deposit was reopened early in 1943 by A. C. Bohrnstedt of La Madera, and about 50 pounds of high-quality sheet mica, several thousand pounds of scrap, and a little columbite and beryl were obtained before work was suspended in August of the same year. The amount of scrap mica taken from all the workings probably does not exceed 100 tons.

The latest mining was done near the east end of the deposit in a cut 40 feet long, 15 feet wide, and 15 feet in maximum depth. From the bottom of this opening an incline 20 feet long, which slopes at an angle of 25°, follows the footwall of the pegmatite body. Footwall mica concentrations immediately west of this incline were worked during 1927 and 1928 by means of surface openings. Many of these are now choked with waste rock, but none appears to have been more than 25 feet deep. At least ten shallow cuts and pits have been sunk elsewhere in the deposit, but do not appear to have yielded large quantities of mica.

The pegmatite is an irregular, trough-shaped body whose general structure may well have been controlled by a broad warp in the country rock (Figure 14). The axis of this trough appears to pitch west at a moderate angle. The country-rock structure strikes N. 17° E. to N. 60° W. Its average strike is about N. 25° W., its average dip 35° WSW. Linear elements similar to those in the Etter area pitch gently south or gently west. As measured along the center of its exposed portions, the pegmatite body is approximately 640 feet long and 60 feet or more in maximum breadth. An arm 15 to 40 feet thick extends southeast from

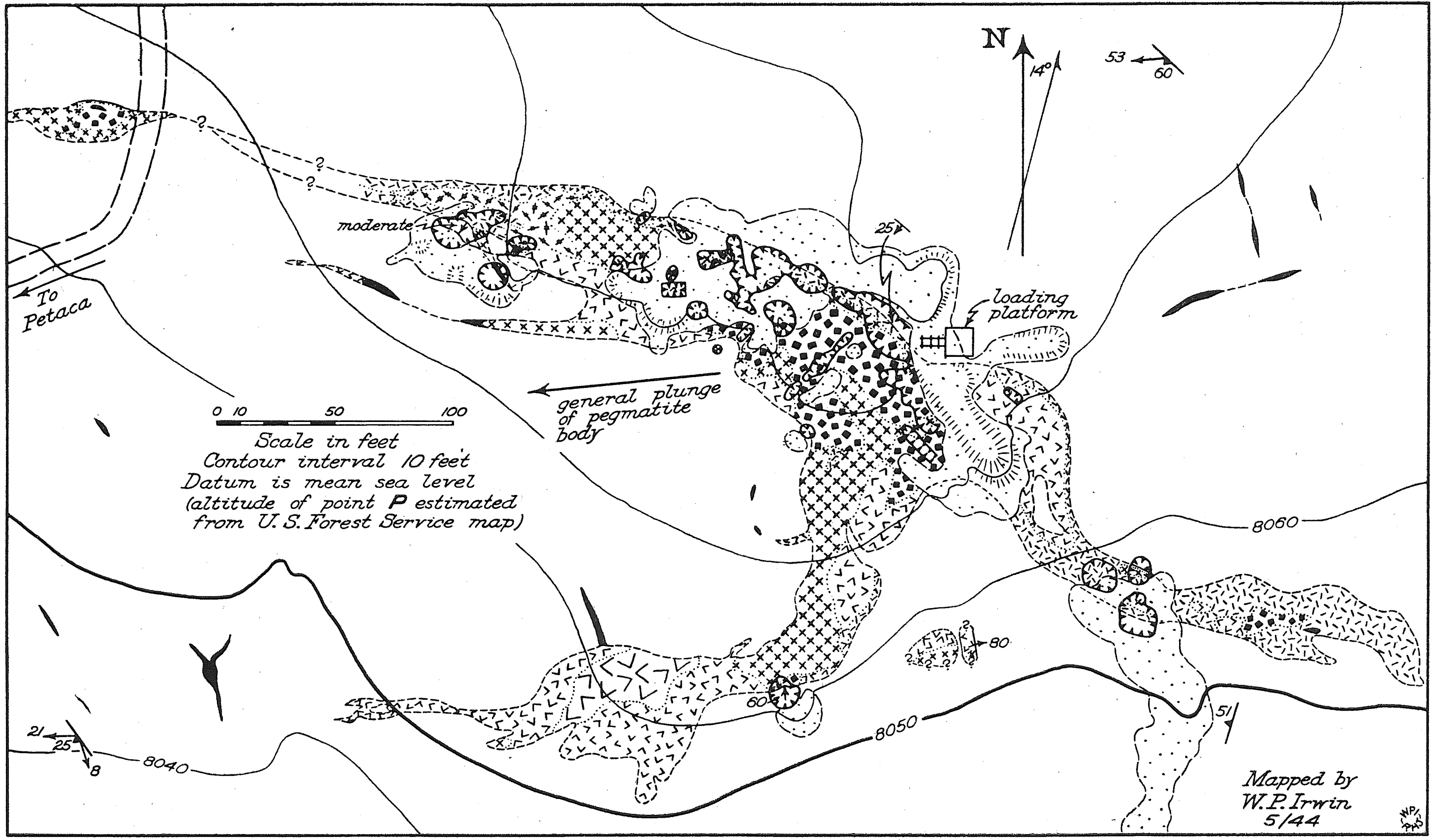

FIGURE 14. Geologic map of the Werner deposit (see Figure 13 for legend and for position of reference point P).

the keel of the trough for a distance of 220 feet, and the north limb of the trough may connect with irregular pegmatite bodies that can be traced northwestward for at least 450 feet.

The south limb of the body consists chiefly of coarse microcline-quartz pegmatite. This forms a wall zone that encloses an irregular mass of similar composition which is distinguished by its extremely coarse texture. The wall zone is itself enclosed by a border zone of finer-grained material. The north limb contains a core of massive quartz that is flanked by a partially albitized wall zone of microcline-quartz pegmatite. The large southeast projection appears to have been originally coarse microcline-rich pegmatite with irregular bodies of blocky microcline in its central portions. Much of this material has been albitized also. In the main bend of the pegmatite body are broad inner zones of massive quartz and extremely coarse blocky microcline. The quartz and feldspar might be regarded as separate units throughout this part of the deposit, but it seems probable that at least a part of this material represents the development on a giant scale of the structural unit referred to in other deposits as massive quartz containing large crystals of microcline. In general the quartz is dominant in the south half of the bend and blocky microcline in the north half.

Most of the minerals are similar in properties and occurrence to those at the Etter deposit. Much of the garnet has been altered to chlorite. The beryl crystals found in place, as well as beryl-bearing dump material, indicate that this mineral is present most commonly along the margins of the quartz core, particularly in the north limb of the body. Some beryl crystals are present along the footwall immediately north of the base of the eastward-projecting arm. Both green and purple fluorite were observed in the face of the incline, where much of the purple material is associated with tantalum minerals.

The richest mica shoot occurs in the albitized footwall zone north of the keel of the deposit. It is said to have contained 20 to 35 percent mica, but the pegmatite in the present heading of the incline is somewhat leaner. Less continuous concentrations are present along the general contact between the inner and outer zones on the south side of the north limb. The mica occurs in light green books 3 inches in average diameter and 15 inches in maximum diameter. The largest of these lie against massive quartz or microcline of the inner zones. Few of the books would yield sheet or punch material, owing chiefly to "A" structure, ruling, and haircracks. A small proportion of the mica is stained by black spots. Any future operations might best be aimed at down-plunge continuations of the main footwall shoot, which probably would yield a moderate amount of scrap.

DE ARAGON DEPOSIT

The De Aragon deposit (22, Plate 1) is 0.4 mile east-northeast of Brown Cabin and about 150 feet north of Sawmill road at the top of the main grade northwest of Petaca. It lies at an altitude of 8,020 feet in the SW¼ NW¼ sec. 6, T.26N., R.9E. A cut 25 feet long, 5 to 14 feet wide, and 6 feet in maximum depth has been excavated in mica-rich schist and in a sill-like mass of quartz-rich pegmatite that trends north-northwest and dips 30° west-southwest. This mass is 3 to 4 feet thick, but tapers to the southeast. In the opposite direction it expands into a large body of quartz 50 feet long and 25 feet in maximum breadth.

The pegmatitic material exposed in the cut is dominantly quartz, with a few scattered microcline crystals near the footwall. These crystals, which are ½ inch to 4 inches in diameter, are associated with mica books ⅛ inch in average diameter (½ inch maximum). Ilmenite is scattered through the quartz as tabular masses 6 inches or less in maximum dimension. A rough radial grouping is characteristic of some of the tablets. Columbite is present as almond-shaped masses and as minor intergrowths in the ilmenite. Both minerals are concentrated near the footwall and occur in parts of the sill that are stained with hematite. Several small fragments of garnet were observed on the dump. The deposit appears to have been prospected for tantalum minerals rather than mica.

CONQUISTADOR (AUGUSTA) DEPOSIT

The Conquistador or Augusta mine (23, Plate 1) is on a broad ridge 1,800 feet west-southwest of Brown Cabin and 1,400 feet south of Sawmill road. It is in the NE¼ SW¼ sec. 1, T.26N., R.8E., at an altitude of 8,020 feet. A rough automobile trail connects it with Sawmill road. The deposit was discovered about 1917 by Charles H. Berry, Sr., of Petaca, who sank a 20-foot incline and several shallow cuts. In 1926 and 1927 the Hoyt Mineral Company of Las Tablas obtained about 300 tons of scrap mica and a small amount of punch material by enlarging and deepening the incline. Since 1927 a little assessment work has been done, and small quantities of scrap mica have been obtained from the dump. The deposit is now held under claim by A. C. Bohrnstedt of La Madera.

The main pegmatite body is very irregular in shape, but is essentially trough-like (Plate 11). The trace of the axial plane of this trough trends about N. 75° W. The north limb dips steeply south-southwest; the dip of the south limb is also steep but is variable in direction. The trough is open to the west, but its limbs nearly join to form an elliptical plan of outcrop. The country rock is quartz-mica schist, the foliation of which has an average strike of N. 40° W. and an average dip of 45° SW. Minor drag folds plunge gently west. Some of the pegmatite-country rock contacts are sharp, but most are marked by a zone of mixed rock. As exposed in a shallow pit 50 feet west-southwest of the portal of the main incline, this mixed zone is 1½ to 3 feet thick. It is even thicker about 50 feet east of this pit, but is incompletely exposed. The mixed rock appears to have been formed through impregnation of the schist with pegmatitic material. It contains abundant small scales of bright green muscovite, small "knots" of microcline and albite-oligoclase, somewhat larger scattered metacrysts of microcline, and salmon-pink crystals of garnet.

The length of the pegmatite body, measured between the exposed tips of its main limbs and around the outcrop of its keel, is approximately 210 feet. Its maximum width at the outcrop is at least 30 feet and may be much greater near its partly concealed east end. An arm 10 feet thick extends northwest from the north limb and grades along its strike into a quartz vein 2 to 4 feet wide. A thinner projection from the south limb trends west-southwest and may connect with a lens-like body 60 feet long and about 12 feet in maximum thickness (Plate 11). The continuity of the main body is broken locally by septa and inclusions of country rock that plunge moderately toward the west. This is in general accord with the plunge of the body itself, as well as the plunge of minor irregularities in its borders. Exposures in the incline show that this plunge is about 30°.

The limbs of the trough, as well as the arms that project from it, consist of medium to coarse microcline-quartz pegmatite and lens-like bodies of massive quartz about 25 feet in maximum dimension.

Eastward the feldspathic pegmatite surrounds inner zones of quartz and blocky microcline. It constitutes the wall zone, and is in turn surrounded by a finer-grained border zone of similar composition. A core of massive quartz is exposed in the north wall of the entry to the main incline and is present in the incline itself, generally along the south wall and probably beneath the floor as well (section A-A′, Plate 11). Much of the core has been albitized along a network of fractures. Near the incline portal, for example, angular fragments of quartz about 2 inches in diameter form a mosaic in white to buff cleavelandite. An inner intermediate zone of large individual microcline masses in gray quartz occurs both above and below the core (section B-B′). The ratio of microcline to quartz ranges from 1:1 to 4:1. The outer intermediate zone consists of nearly pure coarse blocky microcline, and is best developed near the centers of the two limbs.

Cinnamon- and wine-colored garnet is present in fractured crystals in the outer zones, and also as flattened inclusions in the mica. Green fluorite is sparsely distributed in the wall zone immediately west and south of the main entry, chiefly as crystals

1 to 1½ inches in diameter. Columbite, samarskite, and monazite occur as very small masses associated with albite, and bismutite is present as smears in quartz. Small almond-shaped pods of extremely fine-grained pale green and pink muscovite also occur in the albite-rich parts of the deposit.

The mica occurs chiefly as small flakes and books scattered through the border zone and as coarser books scattered through the wall zone. Several minor concentrations have been explored by shallow cuts, and one well-defined rich continuous shoot has been followed in the incline. This shoot is bounded above by the hanging-wall contact and below by the core and inner intermediate zone. It lies along the junction of the northwestward-projecting arm and the north limb of the pegmatite body and to one side of the main loop of the trough (Plate 11). Near the surface, where the richest concentrations flank a thin septum of country rock (section B-B′), the deposit has been worked by means of two inclines. These inclines join to the west where the septum becomes less prominent.

The parts of the shoot worked in 1926 and 1927 are said to have been very rich, possibly averaging 25 to 30 percent mica. Measurements on present faces suggest that the remaining material may be leaner.

The average diameter of the books is 2 by 3 inches, the maximum at least 11 inches. The mica is dark green, hard, and flat. It splits well. Some books contain scattered black spots and local brown lattice-like stain, but most are clear. Severe ruling, hair-cracks, and breaks are the chief defects. These, together with the small average size of the books, eliminate the deposit as a source of sheet mica. When it was worked, a little punch and washer material was obtained, but the principal product was scrap. The scrap is said to have yielded a ground product considerably darker than that from other deposits in the district.

The heading in the incline suggests that the main shoot has not been worked out down the plunge. Much of the south wall of the incline is lean, possibly because it represents the flank of a downward-projecting mass of relatively barren inner-zone ma-

TABLE 10. MICA IN FACES, CONQUISTADOR MINE

Location	Area of face (square feet)	% mica in face (by volume)
Heading, incline	17	19
South wall of incline, adjacent to heading	23	8
South wall of upper incline, from North entry	30	14
South wall of incline, half way between heading and portal	35	11
	Average	13
	Weighted average	12.5

terial. Whether the mica continues downward and to the south cannot be determined because the floor of the incline is covered with a foot or more of muck. Much of the north face is likewise inaccessible, owing to tightly packed backfill. The main dump is unusually rich in scrap mica, and according to A. C. Bohrnstedt, small-scale tests made in 1943 indicate a content of 20 to 45 percent in some places. Although more detailed sampling would be required to establish the mica content of the entire dump, it may contain as much as 15 percent of readily recoverable material.

WYOMING DEPOSIT

Five hundred feet east of the Conquistador mine is the Wyoming deposit (24, Plate 1), a large nearly vertical pegmatite dike that trends N. 80°-85° E. along the high flat southwest of Brown Cabin. It is at least 500 feet long and 40 to 55 feet thick. It has been prospected by means of many shallow pits and cuts.

The pegmatite is a very coarse-grained body rich in microcline and graphic granite. Several quartz masses 4 to 30 feet long and 2 to 6 feet thick are present in its central part, but it is not conspicuously zoned otherwise. Local concentrations of albite and mica are present around the quartz, but elsewhere these minerals are minor constituents. Accessory minerals are garnet and green fluorite, which occur chiefly near the walls of the dike; beryl, columbite, monazite, and samarskite are rare.

The mica is in light to medium green books, 2 by 3 inches in average size. A few 11-inch books are present at the margin of the quartz masses, but these are widely scattered. Minor concentrations of small books and foils occur along the margins of the dike, but are of little economic interest. All the mica is badly ruled and broken, and the proportion of recoverable sheet material is very low.

KEYSTONE-WESTERN DEPOSIT

By Lauren A. Wright

The Keystone-Western mine (25, Plate 1) lies at an altitude of nearly 8,000 feet at the edge of the gently rolling upland north of Apache Canyon. It is in the SW¼ SE¼ sec. 1, T.26N., R.8E., and is 2 airline miles west of Petaca and 0.3 mile east-southeast of the Conquistador mine. A poor but passable road connects it with Sawmill road via the Conquistador mine and Brown Cabin. The deposit was first prospected at least seventy years ago, but was not opened up until about 1900, when it was worked for scrap mica. The product was sent in crude form to Cleveland, Ohio, for grinding. Intermittent operations during the period 1900-1942, particularly in the years 1912, 1916, 1925, 1926, and 1935, are said to have yielded at least 200 tons of scrap. The mine was last worked during the spring and summer of

1943 by A. E. Lyons of Santa Fe. Fifty-five pounds of prepared sheet mica and about 15 tons of by-product scrap were produced.

The most recent workings are a steep 30-foot incline and two appended drifts. A 12-foot drift extends east at the 15-foot level, and a very irregular 20-foot drift extends west from the bottom of the incline. A 53-foot vertical shaft is on the hanging-wall side of the pegmatite at a point 50 feet east-northeast of the incline. Twenty-foot drifts extend east and west from its bottom. The more easterly parts of the pegmatite have been explored by means of a short adit, a shallow shaft (now caved), and several cuts and pits. Most of these workings are old.

The plan of the pegmatite body is somewhat like that of a broad "U" open to the southeast (Plate 12). The outcrop breadth of its central, curving portion is about 35 feet, and it tapers somewhat toward the end of each limb. Discontinuous quartz prongs extend southward from the ends of the limbs, which are about 310 feet apart. The east limb dips 65°-80° N. and the southwest limb, which is not so well exposed, dips west-northwest at lower angles. The entire mass appears to have the form of an inverted trough that plunges northwest at moderate to steep angles.

The country rock is typical micaceous quartzite with interlayered quartz-mica schist. The foliation strikes north to north-northwest, and dips 40°-50° W. Small flexures and crenulations are present in the eastern part of the mapped area. Their axes plunge northwest at moderate angles and are in approximate conformity with the axis of the main pegmatite body. The schist and quartzite adjacent to the pegmatite are rich in fine-grained mica, and locally they contain many closely spaced feldspar metacrysts. This alteration is most conspicuous along the very irregular gradational footwall contact. The hanging-wall contact is sharper in general and much less irregular.

Most common at the south end of the deposit is medium- to coarse-grained microcline-quartz pegmatite with minor albite and muscovite. A few small irregular quartz masses and albite-rich bodies are present. To the north this rock grades into much coarser material of essentially the same mineral composition. The proportion of albite increases in the same direction and reaches a maximum at the main bend, where the pegmatite is thickest. The margins of the body are not exposed, but they probably consist of similar though finer-grained material. The body thins eastward from its main bend and consists of several poorly defined zones. The inner units consist of coarse microcline and massive quartz that contains crudely formed microcline crystals 3 feet or more in diameter. Flanking these is coarse-grained pegmatite similar to that exposed west of the bend, and a discontinuous zone of medium-grained microcline-quartz pegmatite is present along the margins of the body. A large, irregular mass of quartz marks the eastern end of the deposit.

The microcline is gray, flesh-colored, and deep pink. Many of the larger crystals contain rough quartz spindles oriented to form a crude graphic structure. The albite, which is white to brick red, appears to have replaced microcline and quartz along fractures. Coarse platy cleavelandite is the dominant variety. The chief accessory mineral is fluorite, in small pale-green and deep-purple masses. Samarskite and beryl were observed in specimens from the dump, and columbite, monazite, and spessartite garnet occur in dark red albite in several of the workings. The garnet also is present in quartz and as small flattened crystals in mica. Bismutite and associated secondary bismuth minerals occur as thin smears at the edges of small quartz masses, especially near the bottom of the main incline.

The mica occurs in (a) poorly defined concentrations adjacent to masses of quartz and microcline in the central portion of the pegmatite body near the main bend, (b) hanging-wall shoots, (c) local concentrations adjacent to inclusions of country rock, and (d) minor footwall shoots. Most of it lies between the pit 30 feet east of the shaft and the stream bed 25 feet southwest of the incline, or along a strike distance of about 150 feet (Plate 12). The richest concentrations are in the central and hanging-wall portions of the pegmatite. The average diameter of the books is about 5 inches, but the cleavage surfaces of many are as large as 8 by 12 inches. Rich concentrations of much smaller books, few of which would yield sheet material, occur along both walls of the pegmatite body.

The mica is light green, hard, and generally free of stain. Chief among its defects are "A" structure, herringbone structure, and ruling. Breaks and ruling are especially widespread in the footwall mica. The edges of many books have been corroded by albite and quartz, and a few contain inclusions of quartz and garnet. Some are distinctly darker in color and are lightly stained with magnetite and hematite. None of this mica was seen in place, but it appears to represent a small proportion of the material recently mined.

The richest shoots are small, but the mica in them constitutes 10 to 20 percent of the rock. Approximately 5 to 10 percent of this mica would yield some sheet and punch material, chiefly from the flat portions of large "A" masses. In the more extensive hanging-wall and footwall shoots, mica constitutes 3 to 5 percent of the rock, and probably would yield a lower percentage of sheet stock. During the most recent operations in the richer shoots, the sheet mica recovered from the mine-run mica probably amounted to less than 0.2 percent. The thickest part of the pegmatite body seems most promising for future exploitation of mica. A 30-foot extension of the western drift at the bottom of the shaft should intersect the albite-mica concentrations about 15 feet below their general position at the bottom of the incline. This would give access to that part of the deposit known to have yielded the largest quantities of mica.

MAULSBY DEPOSIT

The Maulsby deposit (26, Plate 1), on the steep east wall of a deep canyon, is in the SE¼ SE¼ sec. 1, T.26N., R.8E., at an altitude of about 8,030 feet. It is most easily reached on foot from Brown Cabin, less than half a mile to the north, or from the Keystone-Western mine, 0.3 mile to the west. A small prospect pit has been sunk in mica-bearing pegmatite adjacent to an exposed rib of massive quartz 4½ feet thick. This quartz is traceable to the east for several hundred feet—for the first few yards as a core flanked by 1 to 3 feet of feldspathic pegmatite, and thence as a quartz vein with little or no feldspar along its walls. The transition from pegmatite dike to quartz vein is accomplished by a gradual thinning and disappearance of the pegmatite wall zone and border zone.

Although the border zone and wall zone of the dike contain much albite, none of the mica concentrations is rich. Moreover, the mica occurs in such small badly ruled and broken books that the deposit does not appear to be of economic interest.

SILVER PLATE DEPOSIT

The Silver Plate pegmatite is on the south wall of Apache Canyon, 0.9 mile by airline west-southwest of the Conquistador mine (27, Plate 1). It is in the NW¼ NE¼ sec. 11, T.26N., R.8E. It can be reached from the Conquistador mine by wagon road and trail. Another trail connects it with the Apache mine, which is about 0.7 mile down the canyon. The deposit is said to have been opened prior to 1900 and worked intermittently during succeeding years, but the history of these operations is imperfectly known. Production appears to have been greatest during the period 1923-1928, chiefly from operations by the Eureka Mica Mining Company of Vaughn, New Mexico. According to several reports, the output amounted to a few hundred tons of scrap mica.

The workings are at three levels in a large pegmatite dike that trends N. 60° - 70° E. and in general dips steeply north-northwest. Near the canyon bottom is a 90-foot tunnel with one short branch. About half way up the steep hill slope is a cut 40 feet long, 15 feet wide, and 10 feet in average depth. It is on the northwest side of the dike, which is at least 20 feet thick at this point. Near the top of the hill is another cut 7 feet long, 6 feet wide, and 4 feet deep.

The country rock is thick-bedded to platy micaceous quartzite. Both bedding and foliation trend N. 35° W. and dip about

55° SW. Linear structures are not common, but the few observed pitch moderately west. The pegmatite in general is sharply separated from the country rock. It is about 25 feet in maximum thickness and 200 feet in outcrop length. Its keel and some of the minor structures within it appear to plunge to the west at a moderate angle.

The dike is one of the most thoroughly albitized in the entire district. Its lower or easterly portion has been almost completely replaced by plagioclase, so that only traces of what appears to have been a well-developed quartz core can be seen. As exposed in the large cut, the pegmatite contains a sharply defined central unit of massive quartz with local crystals of microcline. Relations between this zone and the apparent quartz core have been obscured by albitization, but it probably is an intermediate zone that in part lay west of the core and in part flanked it. It is flanked in turn by a wall zone of medium- to coarse-grained microcline-quartz pegmatite. These units can be traced west-southwest into parts of the deposit less completely replaced by albite. Here their primary characteristics are more easily recognized.

The chief accessory minerals, garnet and green fluorite, occur in the wall zone, where they have been partially replaced by albite. Pale green beryl is also present in the wall zone but is not common. Monazite, columbite, and samarskite were observed in the lower workings, and bismutite occurs in quartz-rich fragments on the lowest dump.

The richness of the mica concentrations does not appear to be commensurate with the high degree of albitization in the deposit. A few minable shoots are present near the keel of the body, as well as along the margins of the quartz-rich intermediate zone. The mica is very light green and is said to yield excellent "white scrap". It is hard and generally free of stain, but the books are badly ruled, crinkled, broken, and albitized. Some sheet and punch material might be recovered from the larger books that lie against massive quartz, but in general the deposit would yield little but scrap mica. Should the large but lean mica shoots be the basis for a satisfactory operation at some future date, the lowest workings would give access to unmined portions of the deposit. Much of the mica occurs in shoots that are not well defined, and probably lies between the levels of the main tunnel and the large open cut. In general the mica concentrations may be expected to plunge west at moderate angles.

NAVAJO (SUMMIT, HIGHLAND) DEPOSIT

The Navajo (Summit or Highland) deposit (28, Plate 1) is in the NW¼ NW¼ sec. 12, T.26N., R.8E. It lies at an altitude of 8,000 feet at the east edge of a prominent knob immediately north of Apache Canyon and north-northwest of the Apache mine. It is connected with the mine by a steep trail, but is more easily reached on foot from the near-by end of a road that extends south and southwest from the Conquistador mine. The deposit was opened about 1890 and was worked intermittently and on a small scale. It has been idle during recent years. Total production probably has not exceeded 50 tons of scrap and a few hundred pounds of punch mica.

The pegmatite is tadpole-shaped in plan. Its "head", which lies to the west and forms a prominent topographic knob, is about 100 feet long and 56 feet in maximum outcrop breadth, and its "tail" is 125 feet long and 2 to 18 feet thick. The entire body trends N. 85° W. and dips steeply toward the south. The workings include several small cuts and pits and a west-sloping 30-foot incline that lies about 40 feet east of the "head" of the pegmatite body. A long, narrow cut at the south side of the bulge evidently represents an attempt to begin underground mining at a lower level.

The pegmatite is in a quartzitic mica schist whose foliation in general strikes N. 40° W. and dips 50° - 60° SW. Aligned mica flakes and amphibole needles and the axes of closely spaced crenulations form linear elements that pitch south-southeast at moderate angles. A second set of linear structures consists of the axes of other crenulations and somewhat larger drag folds that pitch moderately west. Both the pegmatite body and some of its constituent units plunge moderately toward the west in general accord with this second set of linear structures.

A thin quartz vein extends north from a point in the "tail" of the pegmatite body near the incline. This branch connects with a complex group of quartz veins and irregular pegmatite dikes that range in thickness from a knife edge to 15 feet. Several of the veins can be traced along their strike into pegmatite bodies in which they continue as cores. Another typical relation can be seen at a point about 125 feet north-northeast of the incline, where a quartz vein that joins a 10-foot pegmatite dike cuts across the feldspathic wall zone of the dike and merges with its core.

The bulge of the Navajo dike contains a central body of massive quartz 80 feet long and about 30 feet in maximum breadth. The outer parts of the quartz contain large irregular crystals of microcline; the inner portion contains no microcline. The border and wall zones consist of medium- to coarse-grained microcline-quartz pegmatite that is locally rich in albite, especially near the incline. Much of the feldspar in the outer zones is deep pinkish to brick red, particularly where it is adjacent to masses of monazite and columbite. Small cavities are common in the wall zone. They contain reddish brown clay and abundant fragments of pale green fluorite. Some are lined with prismatic crystals of clear quartz. Other accessory minerals are garnet, bismutite, magnetite, and green sericite. The sericite occurs in turnip-shaped aggregates 1 to 8 inches in maximum dimension, and appears to have been formed by replacement of potash feldspar.

The mica is moderately hard and light green to yellowish green. Most occurs as "flat-A" books or as large masses of tangled books. Warping, breaks, and ruling seriously restrict the amount of sheet and punch material obtainable. Much of the mica occurs in ribbons 3 inches in maximum width. Although the shoots, especially those exposed east of the main bulge, are rich, the total amount of recoverable sheet material does not appear to be large. At only one place, about 200 feet northeast of the main bulge in the Navajo dike, has any of the other pegmatites been explored for mica. Little usable material appears to have been recovered.

COYOTE (CALIFORNIA) DEPOSIT

The Coyote or California deposit (29, Plate 1) lies 400 feet east-northeast of the Navajo deposit and on the opposite side of a narrow ravine. It also trends N. 85° W. and is tadpole-shaped in plan, but its "tail" extends west rather than east. The body is 250 feet long and 27 feet in maximum thickness. At its east end it is divided into two blunt prongs by a thin septum of mica-rich schist. The line of intersection of these prongs and the axes of minor bulges in the contact between pegmatite and country rock pitch moderately west in approximate conformity with many of the linear structures in the country rock.

In the eastern part of the body a thin continuous quartz core is surrounded by a wall zone of coarse-grained microcline-quartz pegmatite. A border zone that ranges from a knife edge to 15 inches in thickness is mineralogically similar but much finer in texture. The accessory minerals are garnet, green fluorite, columbite, monazite, bismutite, magnetite, and green sericite.

The mica is similar to that in the Navajo deposit, and is most abundant near the east end of the body. The richest concentrations flank the east end of the quartz core. Most of the shoots have been worked by open-cut methods. The largest cut is 20 by 20 feet in plan and 3 to 10 feet deep, and from it short inclines follow down-plunge continuations of the mica concentrations on each side of the quartz core. Four small pits lie farther west. The deposit does not appear to contain enough mica to support a large-scale operation, but the core-margin shoots appear rich enough for a one- or two-man operation, especially if appreciable quantities of by-product sheet and punch material can be recovered.

SANDOVAL (OLD BLACK HORSE, KENTUCKY) DEPOSIT

The Sandoval (Old Black Horse or Kentucky) deposit (30, Plate 1) is on a prominent knob at the north rim of Apache Canyon. It lies at an altitude of 7,950 feet in the north half of the

NW¼ sec. 12, T.26N., R.8E., and is about 350 feet above the canyon bottom. A poor automobile trail that extends south-southwest from Brown Cabin and the Conquistador mine furnishes access to the property from Sawmill road, and the workings also can be reached from Apache Canyon over a short very steep trail. The deposit is owned by Elmer Burch of Taos and C. L. Johnson of La Madera.

Pegmatite occurs as three separate bodies: the South Sandoval, the North Sandoval, and the Sandoval Extension. A prominent knob of massive quartz at the south body, known locally as "The Blowout", attracted the attention of prospectors prior to 1880, but it was not until about 1900 that mining operations were attempted. Intermittent work since that time, chiefly during the periods 1922-1931 and 1936-1939, led to the development of irregular cuts along the eastern margin of the quartz (Plate 13). These were 25 to 40 feet deep, but are now only partially accessible. The north body was opened by means of a relatively shallow cut 55 feet long and 10 to 15 feet wide, and the Sandoval Extension by means of a similar cut. A gently inclined stope, now caved and flooded, was sunk along the hanging wall of the pegmatite from the floor of the latter cut. At least twelve small pits and cuts have exposed other parts of the three bodies.

Although existing production figures are not complete, more than 2,500 pounds of thumb-trimmed plate and punch mica and 80 tons of scrap probably were taken from the deposit since 1900. Much of the plate material was very large. During 1943 Burch reopened the northeast and east cuts in the south body and deepened them several feet. He obtained more than 100 pounds of trimmed sheet mica, 15 to 20 tons of scrap, and nearly 100 pounds of bismutite.

The pegmatite bodies lie in micaceous quartzite whose foliation strikes northwest and dips 40° to 60° SW. Rows of mica flakes and the axes of crenulations in mica-rich layers pitch south at moderate angles. A second set of linear structures, which plunges toward the west, is represented by small tightly compressed drag folds and by pipe-like masses of vein quartz in the crests and troughs of corrugations in mica-poor layers. A 35- to 75-foot belt of thinly foliated, mica-impregnated quartzite trends north-northwest and northwest across the area. It is conformable in general with the structure of the adjacent rocks, but transects it in detail. The North Sandoval body lies athwart this belt, and the south body is in contact with its southwest edge. As shown in Plate 13, this zone of mica-rich country rock appears to be more closely related to numerous large quartz veins than to masses of pegmatite.

The south pegmatite body is an asymmetric inverted trough that plunges moderately to steeply west to west-northwest. In plan it is an irregular compressed "U" open to the south-southeast. Its broadest portion is marked by a prominent funnel-shaped core of massive quartz that plunges northwest (Plate 13). This core is 85 feet long and 35 feet in maximum outcrop breadth. It is flanked by a wall zone of coarse microcline-quartz pegmatite and a finer-grained border zone of similar composition. The southwest limb of the body is 170 feet long and about 5 feet in average thickness. It tapers gradually to a knife edge south of the area shown in Plate 13. A lenticular body of coarse blocky microcline is present in its thickest part, and this may represent an intermediate zone. Similar material may also occur in the broad northwest part of the body, which is very poorly exposed. In the northeast limb there is a distinct bulge, much of which is covered by dump material. A quartz core is present in this bulge, but is not connected with the main quartz mass to the north-northwest.

Albite is very abundant along the flanks of the main quartz core, especially on its east and north sides, where little other feldspar is present in the wall zone. Associated minerals are columbite, monazite, beryl, and samarskite. Garnet is present as irregular masses ½ inch to 14 inches in diameter, and fluorite occurs as irregular fractured crystalline masses. Much of it has been altered, some has been removed leaving small vugs, and some has been corroded by albite along fractures. Samarskite and bismutite are most common in the quartz. The bismutite is abundant in prismatic masses ¼ inch to 3 inches wide and as much as 20 inches long. Bismuthinite is said to have been found in the cores of several of the larger masses.

The north pegmatite body is extremely irregular (Plate 13). It is elongated in an east-west direction, but protuberances extend southward almost to the south body. The irregularity of this body is reflected in the shape of its discontinuous quartz core. As in the south pegmatite, the massive quartz is surrounded by a wall zone of coarse-grained microcline-rich pegmatite and a thin finer-grained border zone. Albitization is most prominent at the extreme east end of the body and in the large cut near its west end. Accessory minerals are garnet, green fluorite, monazite, and columbite.

The Sandoval Extension is about 200 feet north and northwest of the main workings in the South Sandoval pegmatite, and thus is north of the area shown in Plate 13. Much of it is a dike-like mass that trends N. 70° E. It is at least 300 feet long and 25 to 45 feet in outcrop breadth. The plan of its western part is that of a very irregular "U" open to the north-northwest. Thin projections extend north-northwest and south-southeast from this part of the body, and a thicker, shorter mass projects westward from the broad west limb of the "U". As exposed in the upper parts of the old stope, this limb dips gently east-northeast, and thus the "U" shape of the western part of the body may be the surface expression of a gently plunging trough-shaped mass.

The core of the Sandoval Extension pegmatite consists of massive quartz, and is most fully exposed southwest of the main workings. By far the most widespread unit, however, is an intermediate zone of coarse blocky microcline with minor quartz and local pods of coarse microcline-rich pegmatite. It is 35 feet in maximum breadth as exposed in the dike-like portion of the body. The wall and border zones, which consist of microcline-quartz pegmatite, are 5 feet and ¾ inch respectively in average thickness. Much of the wall zone has been moderately albitized, and plagioclase is especially abundant in the old stope and near pods of massive quartz in the eastern part of the body.

Mica is most abundant in the most thoroughly albitized parts of the Sandoval pegmatites. Unusually rich concentrations were encountered in the main workings of the south body, and the working faces, as measured in November 1943 and October 1944, contain 12 to 28 percent mica with an average of more than 15 percent. The mica is pale to medium green. It is fairly hard and splits easily. Most books are 6 inches or more in diameter, and the very large "flat-A" books in contact with massive quartz yield much sheet material 4 by 4 inches to 10 by 12 inches. The bulk of the mica in other parts of the shoots is intergrown in tangled masses. The chief defects in all the books are "A" structure and ruling. Ribbons ½ inch to 2 inches wide are common, and much 6-inch ribbon material has been reported. Minor defects are haircracks, clay stains, albite and silica intergrowths, and included flattened crystals of garnet. Mineral spots are rare.

The most promising parts of the deposit for future operations are continuations of the shoots mined in the main workings in the south body and in the Sandoval Extension. Although the Sandoval Extension workings are not accessible, it seems likely that the mica shoots plunge north-northwest. Their richness is not known, either through observation or reliable reports. The pegmatite in the south body has been assumed by several operators to connect at depth with the mica-rich Apache pegmatite that is exposed in the canyon below. Not only is there little to support such an hypothesis, but it appears likely that the keels of the concentrations most recently worked do not lie far beneath the floors of the present stopes. The probable relations are shown in the sections of Plate 13. On the other hand, the down-plunge portions of these mica shoots, which probably lie northwest of the workings, may warrant future development.

APACHE (PORTER, BLUE) DEPOSIT

GENERAL RELATIONS

The Apache (Porter or Blue) deposit (31, Plate 1) is on the steep north wall of Apache Canyon near the center of the NW¼ sec. 12, T.26N., R.8E. The mine workings, which lie at altitudes of 7,660 to 7,810 feet, are 2.3 airline miles west of Petaca. They can be reached from that village by automobile over approximately 3½ miles of very poor road. Ownership of the property is in dispute at present. It is claimed by Elmer Burch of Taos and by C. L. Johnson of La Madera.

The deposit has been worked intermittently for nearly a century, but the greatest production was probably obtained during 1920-1927, when the mica was shipped to a Chicago concern for processing. C. L. Johnson, under whose direction most of this work was done, reports that the mica shoots were extremely rich and that operations were profitable. Large books, some with cleavage faces as much as 3 by 4 feet, were abundant, and it is stated that more than half the plate mica obtained would yield 3 by 3 inch sheets. During the decade 1930-1940, a punching and scrap-grinding plant was operated on the property by Johnson, but work was suspended in 1939 and the mine has been virtually idle since that time. Total production, which amounts to about 85,000 pounds of sheet, a similar quantity of punch, and at least 4,000 tons of scrap mica, is the largest from any single deposit in the district.

GEOLOGIC SETTING

Thick-bedded micaceous quartzite is the most widely exposed type of rock in the Apache Canyon area. In the vicinity of the mine its bedding and foliation trend northwest and dip moderately to steeply southwest. Local variations are common. As in the Sandoval area to the north-northeast, two sets of linear elements are present. One plunges south-southwest at variable but generally moderate angles, the other west at moderate angles. Small stringers and pods of quartz are abundant, especially in the crests and troughs of minor folds. The quartzite in the exposed noses of several tightly compressed folds contains rude crystals of feldspar ⅛ to ½ inch in diameter. These are elongated in conformity with the southwest plunge of the folds.

A broad belt of thinly foliated and crenulated mica-rich schist can be traced northwest from a point near the west end of the main pegmatite body (Plate 14), and is coextensive with a group of quartz veins and quartz-rich pegmatite dikes. Most of the quartz veins in the Apache area are essentially conformable with the country-rock foliation, but a few trend west to west-northwest and dip steeply north. Many are small irregular lenses, but others are 4 inches to 20 feet thick and can be traced for distances of 300 feet or more. At least five of these are known to grade along the strike into the quartz cores of pegmatite dikes.

Some of the dikes appear to have been injected along faults in the country rock, which shows pronounced drag effects along the contacts. Whether the drag effects were produced prior to pegmatite injection or were caused by it in part is not clear.

The main pegmatite body is 8 to 27 feet in outcrop breadth. It dips 30° - 45° northwest to north-northwest, and can be traced diagonally along the north wall of the canyon from a point near the canyon bottom to a steep ridge about 150 feet higher and 450 feet to the east (Plate 14). Beyond the ridge it tapers to a sharp keel that plunges moderately west-northwest. Near the bottom of a gully about midway between the exposed ends of the pegmatite a quartz-rich dike branches northward for 25 feet, and thence extends east for 180 feet. The bodies are nearly parallel and both are offset along a fault whose trace, on the steep southwest slope of the ridge, strikes north-northwest.

Although the main pegmatite appears to be a dike that plunges west to northwest, it swings south and east to form a well-defined, moderately plunging "nose" at its west end. The body may have been an inverted trough, only one limb of which is well preserved. The south limb, which probably trended west-northwest and dipped moderately south-southwest, must have occupied the general position of Apache Canyon, with its keel above the present canyon floor. Its remnants are exposed at the portal of the lowest adit and as a dip slope along the west edge of the dump 30 feet to the east. The pegmatite in these remnants is thin; hence the south limb may have been much thinner and shorter than the north limb.

WORKINGS

The eastern part of the deposit was opened by means of several irregular cuts and a stope along the hanging wall. The stope is about 45 feet long and is said to have been extended down dip to the keel of the pegmatite, or for a vertical distance of 40 to 70 feet. Approximately 150 feet west of this stope a second opening was made in a rich mica concentration along the hanging wall of the pegmatite. This appears to have been the only outcrop of the main mica shoot. After it was mined down the dip by underhand methods for distances of 20 to 40 feet, Adit No. 1 was driven from a lower outcrop of the pegmatite to improve haulage (see Figure 15). This adit is a drift several feet below the hanging-wall zone of the deposit. Stoping was continued to adit level and slightly below. An attempt was made to obtain mica from the footwall zone of the pegmatite by means of a shaft sunk near the outcrop of the hanging-wall mica shoot, but work was abandoned after a small room had been excavated.

The main adit (Adit No. 2) was driven across the nose of the pegmatite body, and thence along the footwall of its north limb, from a point about 50 feet below Adit No. 1 and 25 feet above the nearby canyon floor (Plate 14 and Figure 15). The

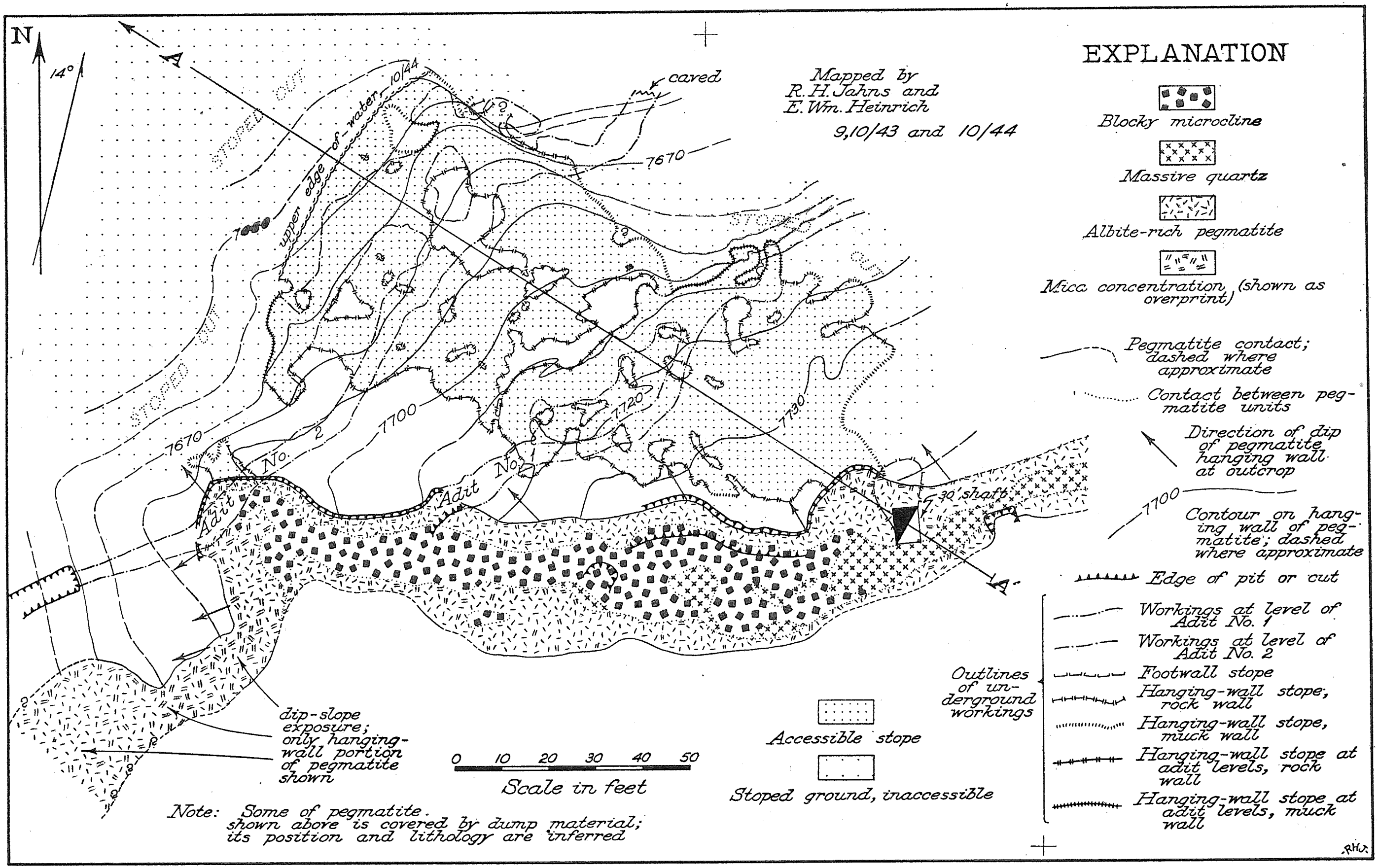

FIGURE 15. Geologic map of a part of the Apache deposit and plan of the principal mine workings.

hanging-wall mica shoot was encountered 130 feet from the portal, where a broad roll in the pegmatite brought it athwart the trend of the adit. A hanging-wall drift then was run back toward the canyon wall for 70 feet and the mica-bearing material was stoped overhand to the level of Adit No. 1. Extensive operations were later carried to lower levels by means of an inclined winze and stopes, but in 1925 a large part of these workings collapsed. The winze was reclaimed and the ground between it and the south edge of the mica shoot was then mined to depths 60 to 100 feet below the main adit level. The keel of the pegmatite is said to have been encountered at the base of these workings, which are now flooded. The main adit was continued beyond the roll in the pegmatite body, and C. L. Johnson states that extensive stoping was done in another mica shoot, chiefly below adit level. These workings are now blocked by caved ground.

Adit No. 3 was driven 315 feet northward from a point 330 feet east-southeast of the main adit portal in an attempt to intersect unmined parts of the deposit beyond the workings that caved in 1925. It was extended at least 20 feet by Elmer Burch in 1943, and the Federal Bureau of Mines extended it about 195 feet farther and to the north-northwest early in 1944, but no large mass of pegmatite was encountered. It seems likely that this exploratory adit lies well beneath the keel of the pegmatite body, as suggested in Plate 14 (section B-B′). In 1943 Burch also dewatered the workings below the level of Adit No. 2, but extremely dangerous ground forced him to abandon plans for mining.

PEGMATITE

A thin, nearly continuous quartz core is present in the east half of the pegmatite body. It increases in width toward the west and is 5 to 7 feet thick in the vicinity of the vertical shaft. West of this the central part of the body is rich in coarse microcline. An inner intermediate zone consists of blocky microcline with large pod-like bodies of massive quartz, and an outer intermediate zone, which lies farther west, is virtually quartz-free. The wall zone, which now appears as an albite-rich pseudomorph, formed a nearly complete envelope around the inner zones and was itself surrounded by a finer-grained border ⅛ inch to 5 inches thick. Both outer zones appear to have consisted of typical microcline-quartz pegmatite. The wall-zone pseudomorph is breached by the quartz-rich branch dike, which connects with the quartz core of the main body. Although shown on the map (Plate 14) as a quartz dike, the outer portions of this branch contain irregular masses of microcline and albite, as well as local concentrations of garnet and mica.

Albite has replaced most of the outer zones, and has also encroached upon the core and intermediate zones. Coarse cleavelandite has replaced quartz and some masses of microcline.

Sugary albite is common elsewhere. Large rosettes of cleavelandite are exposed in the central parts of the pegmatite in many of the underground workings, particularly along the walls of Adit No. 1. Associated with the albite are irregular masses of purple fluorite and long thin blades of columbite and monazite. Garnet, pale green fluorite, and magnetite are present in the outer zones and show evidence of partial albitization. Samarskite and bismutite are common in quartz, especially in late-stage veinlets, but are also present in albite-rich pegmatite. Pod-like masses of pink muscovite and fine-grained green sericite are abundant on the dump beneath the stope in the eastern part of the dike. Apparently these occurred in the hanging-wall mica zone. Beryl was not observed in the main pegmatite, but occurs as well-formed crystals in the quartz core of a thin pegmatite dike 70 feet east of the portal of Adit No. 2.

MICA

Most of the mica in the Apache deposit occurs in albite-rich rock between the hanging wall of the pegmatite body and unalbitized portions of the inner zones. The main shoot is 2 to 9 feet thick and from 20 to more than 120 feet wide. It appears to widen down dip. It rakes west and west-northwest down the north-northwest- to northwest-dipping north limb of the pegmatite body (Figure 15). In the workings above the main adit level its northern edge lies along a steep roll, which appears to have been caused by a steeply dipping fault that locally guided the intrusion of the pegmatite. There is no evidence of extensive post-pegmatite movement along this fault. The south edge of the mica shoot trends parallel with the crest of the pegmatite body and is 5 to 25 feet down dip from the outcrop on the canyon wall. For this reason, the extensive hanging-wall stope was extended to the surface in only two places between the original outcrop of the shoot and the portal of the main adit (see Figure 15).

The hanging-wall mica concentrations in the eastern part of the deposit were probably thinner and leaner than the main shoot. The mica books there are reported to be smaller and less free from structural defects. Scattered pockets of mica are also present along the foot wall of the pegmatite over a strike length of more than 350 feet. This mica is relatively soft and is so severely buckled and broken that it has not been mined.

Apache mica is light green and most is fairly hard. Most flat pieces have been obtained from the interior portions of large "A" books. The chief structural defects are reeves, ruling, and warping. Haircracks, clay stain, garnet inclusions and intergrowths of silica and albite are locally present. Mine-run mica from the main shoot is said to have yielded an unusually high proportion of sheet material, much of which was large. Several 12-

by 16-inch trimmed sheets that have been preserved as specimens by C. L. Johnson are clear and of excellent quality.

FUTURE POSSIBILITIES

The shape of the pegmatite and distribution of mica within it have been determined by mining and underground exploration. The keel of the north limb is not only exposed at the surface, but is known with reasonable assurance to lie above the level of Adit No. 3 and appears to have been encountered at the foot of the winze below the main adit. The main mica shoot probably has been mined out to its south edge over its full vertical extent, so that the only remaining unmined ground must lie beyond the stopes that collapsed in 1925. The extension of the main adit, which may be the best means of access to the unmined part of the deposit, was deliberately caved at the close of the last mining operations. Although definite conclusions cannot be drawn, it seems doubtful whether large reserves of mica-bearing pegmatite are present, and the difficulties that would be involved in reaching unmined ground make prospects for future production poor. It would be wise to defer complete reopening of the mine until adequate study could be made of the workings that lie beyond the caved part of Adit No. 2.

PINOS ALTOS DEPOSIT

By William P. Irwin

The Pinos Altos deposit (32, Plate 1) lies at altitudes of 7,770 to 7,860 feet in the NE¼ SW¼ sec. 6, T.26N., R.9E. It is on a steep east slope 350 feet west of Sawmill road and 1.2 airline miles west-northwest of Petaca. Mining operations were begun by Gabino Alire of Petaca about 1932, and continued with few interruptions for at least six years. Production during this time is said to have amounted to more than 250 tons of scrap and several hundred pounds of punch mica. The deposit was last worked under lease by A. E. Lyons of Santa Fe in 1933, when a few tons of scrap was obtained. In the fall of 1944 Alire sold the property to R. L. Riley of Miami, Florida, who plans to attempt recovery of punch and scrap mica from the dumps by flotation in the Albuquerque plant of the Rocky Mountain Fluorspar Company.

Pegmatite occurs as a sinuous dike more than 350 feet long (Plate 15). Its general trend is N. 45° E., but its main mica-bearing segment strikes N. 70° E. and dips steeply north-northwest. For most of its mapped length the dike is 5 to 26 feet or more in outcrop breadth, with an average of about 20 feet. It cuts across the country-rock structure in most places, but near its west end it swings south to form a short sill-like mass that trends N. 15° W. and dips 40°-60° W.

The foliation of the country rock, a platy micaceous quartzite, trends N. 5°-25° W. and dips moderately west in the vicinity of the deposit. Many small folds and corrugations in this rock plunge 30°-45° west to west-southwest. As exposed at the surface and in mine workings, minor irregularities in the pegmatite walls and the long axes of lithologic units within the pegmatite body also plunge west to west-southwest at moderate angles. The walls of the thicker parts of the dike are sharp, with little distortion of the foliation in the adjacent country rock. Near the thinner parts, however, much feldspar and fine-grained mica has been introduced into the quartzite.

The mine workings consist of two small pits, three shallow cuts that open into small stopes, and three larger openings. The Lower cut, which is 35 feet long and 6 to 12 feet wide, is the easternmost of the larger openings. From it a short branching tunnel extends west about 12 feet. The North and South inclines were sunk along hanging-wall and footwall mica shoots, respectively, in the main part of the pegmatite body. Both are high slot-like stopes, whose floors slope westward at angles of 30° to 35° in accord with the plunge of the shoots. The North incline extends 83 feet to its western heading, and the South incline, which is partially flooded, is at least 50 feet long (Plate 15).

A massive quartz core, 4 to 10 feet in width at the outcrop, is present in parts of the dike northeast of the Lower cut and immediately east of the portal of the North incline. West of each core segment is massive quartz that contains large crystals of white to deep flesh-colored microcline. This intermediate-zone material is particularly abundant in the large bulge near the west end of the deposit. Coarse blocky microcline that contains pods of massive quartz is exposed in the workings west of the two inclines. Intervening areas are covered by dump material, so that it is not clear whether this rock constitutes an outer intermediate zone or is merely present as unusually large masses of feldspar in the intermediate zone adjacent to the core. The wall zone, which is continuous, ranges in thickness from 1½ to 5½ feet, with an average thickness of 3½ feet. It consists of coarse microcline-quartz pegmatite that has been partially albitized. Similar but finer-grained material forms a ¼-inch to 1-inch border zone. Albite is disseminated throughout the wall and border zones as fine-grained crystalline aggregates. It also occurs in coarser and richer concentrations in those parts of the deposit that have been mined. Cleavelandite is common at the border of masses of quartz, but is rare elsewhere. Garnet, fluorite, and columbite are the chief accessory minerals. Monazite and bismutite are rare, and beryl has been reported to occur in the deposit.

Mica is scattered through the outer zones of the dike, but the largest books are in the two main shoots that were worked in the inclines. Within these shoots the largest books occur along the quartz and blocky, microcline masses, rather than near or at the country-rock contact. The average size of the books is about 3 by 4 inches and the maximum observed was 6 by 8 inches. The mica is light to dark green and is so marred by reeves, ruling, waviness, and mineral specks that only small quantities of clear sheet and punch material are obtainable. Most of the flat mica occurs as narrow ribbons.

Although the mica from the Pinos Altos deposit is chiefly of scrap grade, the mined concentrations appear to have been sufficiently rich to yield satisfactory returns. It seems likely that the principal reserves in the deposit lie in the down-plunge continuations of the main hanging-wall and footwall shoots. The heading of the South incline is not accessible for examination, but the faces in the North incline contain numerous books.

PRINCE DEPOSIT

The Prince deposit (33, Plate 1), which is near the west edge of the NW¼ NE¼ sec. 7, T.26N., R.9E., lies 0.4 mile southeast of the Pinos Altos workings. It is on the northeast slope of a small gulch below and about 200 feet east of Sawmill road. The pegmatite is an irregular sinuous dike 405 feet long and 30 feet in maximum width. It trends N. 60° W. and dips steeply south-southwest. The foliation of the country rock, typical platy quartzite, trends N. 35° W. and dips 30°-50° SW.

The deposit is irregularly zoned. A small quartz core is exposed at the east end of the dike, and this may be the remnant of a much larger mass that was almost wholly replaced by coarse cleavelandite albite. Several lenses of blocky microcline 8 to 32 feet long and 2 to 10 feet wide are present in the west half of the dike, and probably represent a discontinuous intermediate zone. The dominant rock type, which forms the wall zone, is a coarse-grained intergrowth of microcline and quartz, with minor garnet and green fluorite. A thin discontinuous border zone of finer-grained microcline-quartz-mica pegmatite is also present.

Three cuts have been driven into albite-rich portions of the pegmatite. The largest, near the thick east end of the deposit, is 38 feet long, 3 to 11 feet wide, and 9 feet in maximum depth. In its walls are scattered books of pale green mica. This mica, as well as that exposed elsewhere in the deposit, is not only too small to yield sheet material, but is badly ruled, warped, and broken. Moreover, none of the concentrations appears to be sufficiently rich to furnish large quantities of scrap.

QUEEN DEPOSIT

By William P. Irwin

The Queen deposit (34, Plate 1) is in the NW¼ NE¼ sec. 7, T.26N., R.9E. It lies at altitudes of 7,460 to 7,570 feet on the rough eastern slope of the main upland mass about a mile west of Petaca, and is immediately east of Sawmill road. The mine was opened many years ago, but the history of early operations is not known. The main workings date from about 1912 and were operated most intensively by Philip S. Hoyt during the decade 1920 to 1930. The most recent activity consisted of prospecting west of the main workings during the spring and summer of 1943. This was done under the direction of A. C. Bohrnstedt of La Madera, who holds the deposit under claim. It is reported that nearly 800 pounds of sheet and punch mica was obtained from the workings during the past two decades, and that about 1,200 pounds of plate (selected mine-run) and 100 tons of scrap mica have been produced since 1910.

The pegmatites occur in micaceous quartzite and quartz-mica schist whose foliation strikes north-northwest with an average southwest dip of 45°. The country rock is cut by numerous pegmatite dikes and stringers, as well as by thin discontinuous quartz veins (Plate 16). Most of the smaller dikes and veins are conformable with the foliation, though a few are discordant. Some of the larger dikes cut across the foliation at high angles, and most are discordant in detail.

A belt of mica-impregnated quartzite trends north-northwest across the area (Plate 16). Fine-grained pale green muscovite locally constitutes more than half of this rock, which is 10 to 75 feet in width and has been traced along the strike for at least 1,500 feet. The strike of the mica-rich belt and of the foliation within it is parallel with the strike of the adjacent quartzite. At least two large masses of pegmatite and many small lenses of quartz occur within its borders.

The Queen pegmatites range from stringers a few feet long and an inch thick to dikes more than 450 feet long and 40 feet thick. They consist chiefly of coarsely intergrown quartz and white to flesh-colored microcline, with minor quantities of albite and mica. Most have been prospected by means of small cuts and pits, but only one of these contains substantial quantities of mica.

The main pegmatite is "U"-shaped in plan and is 465 feet long and nearly 45 feet in maximum thickness. The north arm of the "U" strikes about N. 25° W., with an average west-southwest dip of 30°; the other arm strikes N. 85° E., with moderate to steep north dips. The pegmatite is thickest a short distance to the west of the base of the "U" and thins out into stringers at the extremities of both arms. The dip of its thickest part, which is 55° at the surface, flattens with depth (see Plate 2, top). Thus the body is trough-like in form (section A-A′, Plate 16), with an axis that pitches west at moderate angles.

The deposit has been worked in a hanging-wall open cut 45 feet long, 8 feet wide, and 20 feet deep. From the bottom of this cut, a muck-filled stope extends downward along the hanging wall of the pegmatite to a reported depth of more than 50 feet (section B-B′, Plate 16). A small drift follows the hanging wall to the west for 30 feet, and a crosscut extends southward through the pegmatite to connect with a footwall cut that is 20 feet long, 5 feet wide, and 5 feet deep. Other workings include six shallow cuts and pits at intervals along the pegmatite, and two cuts that were excavated in 1943. These recent workings are 20 to 30 feet long, 2 to 12 feet wide, and 8 feet in maximum depth.

The thickest part of the deposit consists of three well-defined layers: (1) an albite-rich unit (wall-zone pseudomorph) about 5 feet thick; (2) a coarse central zone of blocky microcline with local masses of quartz; and (3) an albite-rich footwall unit about 2 feet thick. The upper end of a septum or inclusion of schist is exposed at the middle of the small crosscut, where it is approximately 5 feet thick and is conformable with the walls of the pegmatite. Massive quartz occurs at the north end of the north arm of the deposit. It may be a vein-like body that is younger than the adjacent feldspathic pegmatite. Microcline occurs as irregular masses and poorly formed crystals, both of which are partially replaced by sugary aggregates of albite. Coarse cleavelandite replaces quartz. Where albitization is relatively mild the wall zone consists of coarsely intergrown microcline and quartz. Accessory minerals are pale green fluorite, blue-green to yellowish green beryl, spessartite garnet, magnetite, coarse platy ilmenite, monazite, columbite, and rare bismutite. Ilmenite, magnetite, beryl, and bismutite generally are associated with quartz, the other minerals with albite.

The mica, which is most abundant in the wall-zone pseudomorphs, is clear and pale green; it is fairly hard and splits easily. Its cleavage surfaces are wavy. Ruling, haircracks, and breaks are common structural imperfections, and "A" structure and tanglesheet blocks also occur. The largest books are approximately 3 by 5 inches. No sheet mica is exposed in the faces of the main workings, and no reliable descriptions of the faces in the filled stope are available. The mica concentrations in the more recent cuts to the west appear to be fairly rich, but the quality of the books is poor. The outlook for future production from the Queen deposit, especially of sheet material, is not encouraging.

COATS (AMERICAN) DEPOSIT

By E. Wm. Heinrich

The Coats or American deposit (35, Plate 1), which is less than a mile west-southwest of Petaca, is in the SE¼ NE¼ sec. 7, T.26N., R.9E. It lies on the east slope of a prominent rocky ridge at altitudes from 7,450 to 7,500 feet, and can be reached over a dirt road that extends west and west-southwest from Petaca. The Petaca-Vallecitos or Sawmill road crosses the pegmatite body immediately west of the old surface workings of the mine, and passes directly over the main underground workings.

The mine is probably the oldest in that part of the district north of the Cribbenville area. By 1900 several cuts that had been sunk along the pegmatite outcrop were being enlarged by the American Mining and Milling Company; from these some sheet and much scrap mica was recovered. These cuts were later joined to form a narrow irregular opening 60 feet long and 25 feet in maximum depth, and a second, shallower opening about 30 feet long (Plate 17). Lower levels of the deposit were later worked through an adit driven west-northwest from a point 70 feet east of the outcrop. The main pegmatite body was encountered 120 feet from the portal. Subsequent mining operations developed a room 25 feet high, an inclined overhand stope that was connected with the surface workings, and an extensive irregular underhand stope. Much of this work was done during the period 1925-1927, when both plate and scrap mica were sold to a Chicago concern for processing.

During recent years the deposit has been owned by Ross Martinez of Petaca, who leased it in 1943 to the New Mexico Mica Company of Santa Fe. The mine was operated from July to October, 1943, under the direction of J. H. Russell, John Kelly, and C. L. Schockey. A 35-foot crosscut was driven north from a point near the end of the adit, a 25-foot winze was sunk from the end of the adit, and small-scale mining was done in several of the old stopes. According to Mr. Schockey, superintendent for the company, 500 pounds of sheet and punch mica (including about 180 pounds of prepared strategic material) and about 6 tons of scrap were produced. Exact production figures for earlier operations are not available, but the amount of sheet and scrap material obtained must have been large.

The country rock in the vicinity of the mine is a slabby to thick-bedded micaceous quartzite whose foliation strikes northwest and dips southwest at moderate angles. Both quartzite and pegmatites are locally veneered with patches of Quaternary gravels, and are overlain by remnants of andesitic volcanic rocks near the base of the slope east of the mine. Pegmatite is present as several large irregular bodies and numerous small dikes and stringers in the quartzite, which is also cut by many quartz veins. Most of the smaller pegmatites and many of the veins trend N. 50° W.

The main body of pegmatite, which is the only one that has been worked, is "U"-shaped in plan and trough-shaped in form. The northeastern limb of the trough strikes north-northwest and dips 45° west-southwest, and the longer, broadly sinuous southern limb strikes nearly west and dips steeply north in its eastern portion and moderately to steeply south farther west. The keel of the trough plunges west-northwest, probably at moderate angles. Local reversals in the dip of the contacts, as well as a large septum of quartzite that projects downward toward the keel of the body along its axial plane (Plate 17, section A-A′), complicate its general shape. The maximum thickness of the body is about 30 feet at the surface and may be much greater at the level of the adit. Pegmatite is exposed underground for a distance of 160 feet along the strike of the south limb, and is present in the heading of the winze. Some of the smaller pegmatite bodies are even more persistent; one of these was mapped for a distance of 550 feet along the strike, and continues beyond the mine area.

The main pegmatite body is sharply zoned. A thick core of massive quartz is present along the keel and tapers out in both limbs. The central part of the south limb consists of coarse blocky microcline, but this unit is not well developed in the other limb, in which coarse microcline-quartz pegmatite is dominant. The wall-zone material is partially albitized medium- to coarse-grained microcline-quartz pegmatite that forms a complete envelope around the inner zones. Locally it contains abundant muscovite with minor garnet. The border zone, which is ¼ inch to 3 inches thick, consists of fine- to medium-grained microcline-quartz pegmatite with minor albite-oligoclase, albite, and small flakes of mica.

Pale blue-green beryl, green fluorite, columbite, monazite, ilmenite, and magnetite are present in the border zone, generally associated with albite. Bismutite occurs along fractures in the massive quartz. Of these accessory minerals, only monazite is common. It occurs in unusually large reddish to clove brown crystals, some of which are 5 inches or more in diameter and weigh as much as 9 pounds.

Mica is particularly abundant in the albite-rich portion of the hanging-wall zone along the keel of the pegmatite body. Subordinate shoots are present around the septum of country rock that is exposed in the main overhand stope (Plate 17), and locally along the footwall of the south limb wherever the dip of the contact is reversed to the south. The mica is pale to dark green and is relatively free from spots and other staining. Warping, ruling, and "A" structure are present, but the chief defects are cracks and thin films of albite and quartz that are intergrown parallel with the cleavage. Most of the mica is nearly flat, and some is soft. Remnants of books as much as 16 inches in diameter were observed in the walls of the old workings, but most of those obtained during the last operations were small and of relatively poor quality.

The outlook for future production of mica is not encouraging. The richest shoot appears to have been mined out at the level of the present workings, and the old winzes and stopes from which it was last mined are inaccessible or in poor condition. Recent work at the western end of the main adit shows that little high-quality mica may be expected where the hanging-wall contact of the pegmatite is very steep or vertical.

BLUEBIRD DEPOSIT

The Bluebird deposit (36, Plate 1) is about 600 feet north of Apache Canyon in the SW¼ NE¼ sec. 7, T.26N., R.9E. It lies along the crest of a low ridge less than 300 feet south of Sawmill road and about 800 feet south-southwest of the Coats mine. The property was claimed in 1924 by Gabino Alire of Petaca, and was operated intensively under lease in 1925. About 25 tons of scrap and minor quantities of sheet and punch mica were obtained. The deposit, which has lain idle for many years, is now claimed by Adonais Gutierrez and Frederico Esquibel of Petaca.

The thin pegmatite body is broadly arcuate in plan. Some segments strike north-northwest and are sill-like. Others strike north-northeast (Figure 16), but the general trend of the body is north, with moderate westerly dips. The country rock is slabby to platy micaceous quartzite whose foliation strikes north-northwest and dips west-southwest at moderate angles. Minor folds and corrugations plunge moderately southwest. Pegmatite-country rock contacts are gradational, and contact effects in the quartzite are pronounced. Many of the beds are rich in sugary feldspar and fine-grained flakes of mica. Books of muscovite ⅛ inch in average diameter and ⅛ to ⅜ inch thick are scattered through some of the thicker quartzite beds, particularly beneath the pegmatite footwall (Figure 16).

The pegmatite body is more than 280 feet long and about 4 feet in average thickness. It tapers south-southeastward to a sinuous stringer. One thin curving branch extends southward from this part of the body. The middle third of the body is distinctly thicker and has been opened by means of three cuts 15 to 30 feet long, 6 to 20 feet wide, and 12 feet in maximum depth. The largest of these exposes the full width of a prominent bulge in the pegmatite, where its strike swings from north-northwest to north-northeast (Figure 16). This bulge is about 25 feet in maximum breadth and plunges 30° southwest. The pegmatite in it has been mined down the plunge by means of an incline 15 feet wide, 5 to 15 feet high, and at least 40 feet long. Its lower end is backfilled and flooded.

The core of the pegmatite body, which occurs in and immediately south of the main bulge, consists of massive quartz with scattered individual microcline crystals as much as 10 feet in diameter. It is flanked by almost completely albitized pegmatite that is rich in mica, particularly along the upper surface of the core. In the long cut to the south, the central part of the body is a coarse-grained aggregate of microcline and quartz. Elsewhere it consists of medium-grained pegmatite that is rich in flesh-colored microcline, quartz, and partially digested slabs of country rock. Albite is a minor constituent.

Pale green fluorite is abundant in the outer portions of the deposit. In some places it has been altered and removed, leaving

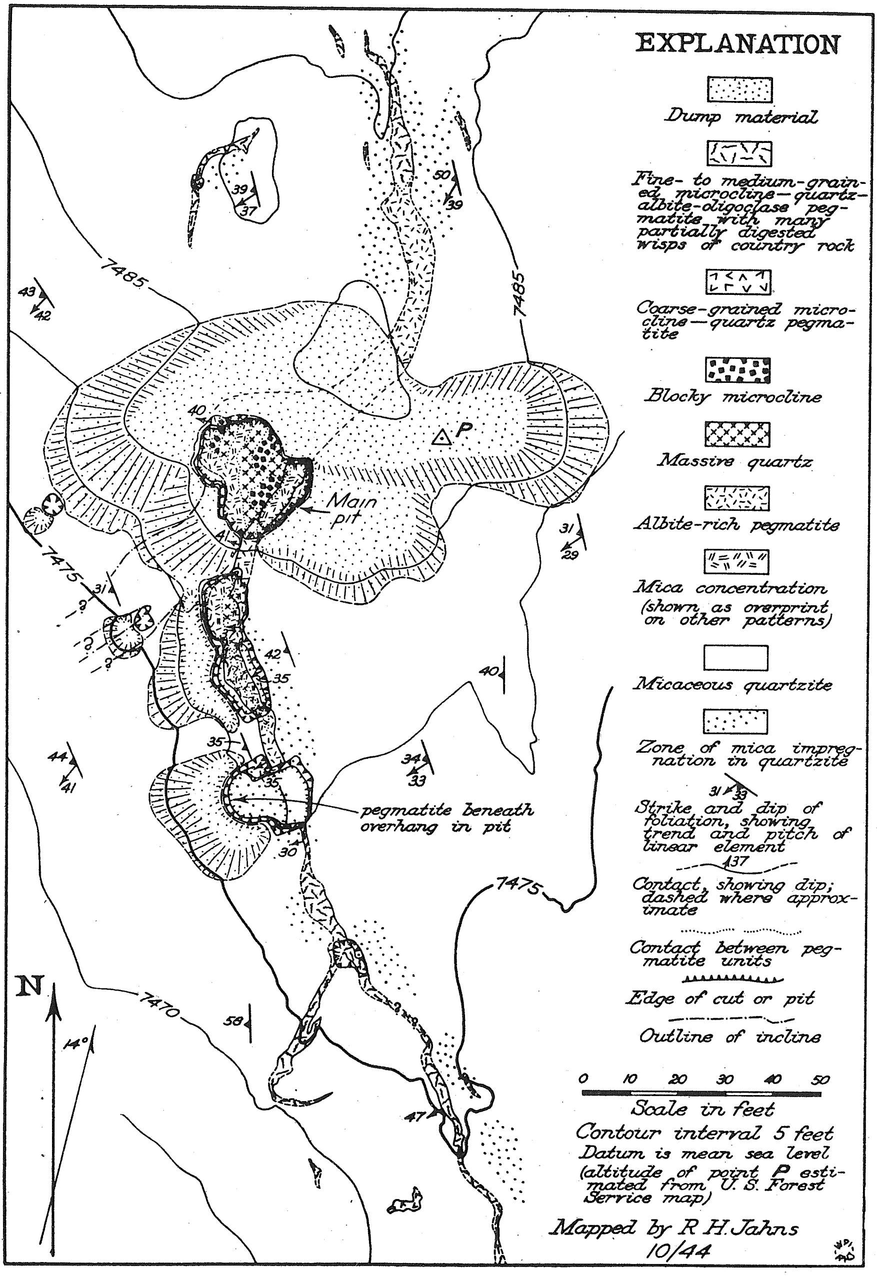

FIGURE 16. Geologic map of the Bluebird deposit.

small irregular vugs. Wine-red garnet and small masses of blue-green beryl are commonly associated with the fluorite. The distribution of these minerals does not appear to be related to albitization. Other accessories are columbite, samarskite, monazite, bismutite, purple fluorite, and sulfides. Columbite and monazite are especially common in the walls of the incline, and bismutite, samarskite, bornite, chalcocite, malachite, and covellite are associated with numerous late-stage veinlets of quartz in the main surface workings.

The mica is medium green, hard, and free-splitting. Little mineral stain is present. The chief defects are ruling, breaks, waviness, garnet inclusions, and intergrowths of albite and silica. Even in the main shoot, which was mined in the incline, the books are rather small, with few cleavage faces larger than 2 by 3 inches. The chief reserves in the deposit probably lie beyond the heading of the incline and in a down-plunge direction. Even though the main shoot is rich, the total amount of recoverable mica is not very large.

OTHER DEPOSITS

A small pegmatite dike 900 feet east of the La Jarita mine has been opened by means of shallow prospect pits. It is rich in flesh-colored microcline and contains minor quartz, albite, and mica. Some fluorite, garnet, and columbite are present. The mica books are small and scattered. Several dikes have been prospected in the area between Russian Ranch and the El Contento deposit. Most contain coarse green to flesh-colored microcline, quartz, and moderate quantities of albite. The mica concentrations are poor but some beryl has been obtained. Small quartz-rich dikes are abundant in the rough country between the Keystone-Western deposit and Sawmill road to the east. Mica is present locally in rich concentrations, but most of the books are badly warped, ruled, and broken. Moreover, the mica-bearing portions of these deposits are too small to yield scrap in large quantities.

CRIBBENVILLE GROUP

GABALON DEPOSIT

The Gabalon deposit (37, Plate 1) is on a steep east slope immediately south of Gabalon Canyon. It lies at an altitude of about 7,800 feet at the north edge of the NW¼ NW¼ sec. 18, T.26N., R.9E., and is 300 feet northeast of a camp site at the end of a poor automobile trail. A few prospect pits have been dug in a large pegmatite dike, but little is known concerning their history. The latest work was done during the fall and winter of 1944 by Joe Thompson and associates of Los Angeles, California. A cut 35 feet long, 10 to 18 feet wide, and 20 feet high at the face, was excavated in highly sheared pegmatite, and from it a drift was run westward along the north wall of the dike. This work was intended to provide 35 to 60 feet of backs for stoping.

The pegmatite dike, which is very irregular and 30 to 65 feet thick, trends N. 80° - 88° E. with a nearly vertical dip. It is enclosed by thick-bedded micaceous quartzite whose foliation strikes N. 10° W. and dips steeply west. Linear structures that pitch 40°-70° west comprise the axes of drag folds and crenulations in the country rock, irregular corrugations in pegmatite-quartzite contacts, and the axes of elongation of quartz masses within the pegmatite. The dike contains many tabular inclusions, some of which have been so pegmatitized that only wisps of schistose material remain. These inclusions are parallel with the adjacent wall-rock contacts, and the attitude of their relict foliation, which is normal to their elongation, suggests that they have not been rotated appreciably from their original orientation. The long axes of several that are well exposed in the workings pitch moderately to steeply west.

The inner units of the dike include extremely coarse-grained microcline-rich pegmatite and scattered pods of massive quartz as much as 15 feet in maximum dimension. These units are flanked by finer-grained microcline-quartz pegmatite that contains minor but widespread albite. The borders of the dike are marked by an irregular zone of medium-grained microcline—albite-oligoclase—quartz pegmatite that contains much digested country-rock material. Garnet occurs in this unit as irregular cinnamon-colored masses, and in albite-rich portions of the inner zones as well-formed dark red crystals. Green fluorite and beryl also occur near the walls of the dike, and columbite, samarskite, monazite, and bismutite are associated with albite in its interior. Fractures in these minerals are commonly coated with aggregates of small, bright yellowish-green mica flakes.

Mica is present as widely scattered small books and in larger books concentrated along the north wall of the dike and along the pods of massive quartz. Although the concentrations are not extensive, some are very rich. The mica is green to brownish green, and is heavily stained. Few books have yielded material that is free from spots or brown and black lattice-like intergrowths of magnetite and hematite. Moreover, most are severely ruled, buckled, and broken by movement along closely spaced shear planes that lie in approximate conformity with the walls of the dike. There is little reason to anticipate a decrease in the proportion of stained material with further operations, and the deposit can be considered only as a source of dark-colored scrap mica.

FRIDLUND DEPOSIT

The Fridlund deposit (38, Plate 1) is in the NW¼ NW¼ sec. 18, T.26N., R.8E., approximately 800 feet south-southwest of the Gabalon deposit. It lies on an east slope at an altitude of

7,950 feet, and can be reached over half a mile of poor automobile trail that extends northwest from the Cribbenville road. The deposit is said to have been opened many years ago, but was not worked intensively until O. M. Fridlund began systematic mining about 1920. From that time until his death in 1925, Fridlund obtained about 250 tons of scrap mica, 1,000 pounds or more of plate (selected mine-run) mica, several hundred pounds of bismutite, and probably as much as 5,000 pounds of columbite, samarskite, and monazite. The mine has lain idle for twenty years, but recently was purchased by the Southwestern Mica Company of Los Angeles, California. H. F. Mason is president and Joe Thompson is property manager.

The mine workings consist of two open pits, two adits, and several small cuts. The main pit is 63 feet long, 15 to 30 feet wide, and about 30 feet in maximum depth. The smaller pit, which is immediately southeast, is 28 feet long, 23 feet wide, and about 30 feet deep. It is partially caved. Operations in the main pit involved hoisting to the surface until an adit was driven west from a point about 30 feet east of the east rim and 15 feet below it. A lower and much longer adit was later driven from a point 80 feet southeast of the pit, and was used for most of the haulage from both workings (see Figure 17). It is now caved.

In plan the pegmatite has the outline of a boomerang, and in form it is an irregular open trough. Exposures in the main pit show that the axis of the trough pitches steeply southwest. The pitch may decrease in that direction. The long, broad, sinuous west limb trends east-west and dips steeply to the south. The narrow, curving south limb strikes N. 15° E. and dips very steeply west (Figure 17). Relations at the main bend are obscured by dump material, but the keel of the body may be narrow and spine-like. The plunge of minor folds in the micaceous quartzite country-rock is moderately southwest to west-southwest in general, but near the main pit it is distinctly steeper. This is in approximate conformity with the variation in plunge of the pegmatite body from northeast to southwest.

A well-defined core of massive quartz, with subordinate microcline in scattered large crystals, is present in the west limb of the pegmatite. As exposed in the workings, it is 40 feet long and 4 to 7 feet thick. It grades westward into coarse blocky microcline with minor quartz. Flanking these inner units is medium- to coarse-grained microcline-quartz pegmatite, much of which has been replaced by fine-grained albite. The border zone, which consists of partially albitized microcline—quartz—albite-oligoclase pegmatite and much partially digested schist material, is thickest along the south side of the west limb. In the main pit, this rock is characterized by irregular pods, lenses, stringers, and crystals of microcline, abundant fine-grained mica, and altered country rock with distinct foliation. Several irregular pegmatite

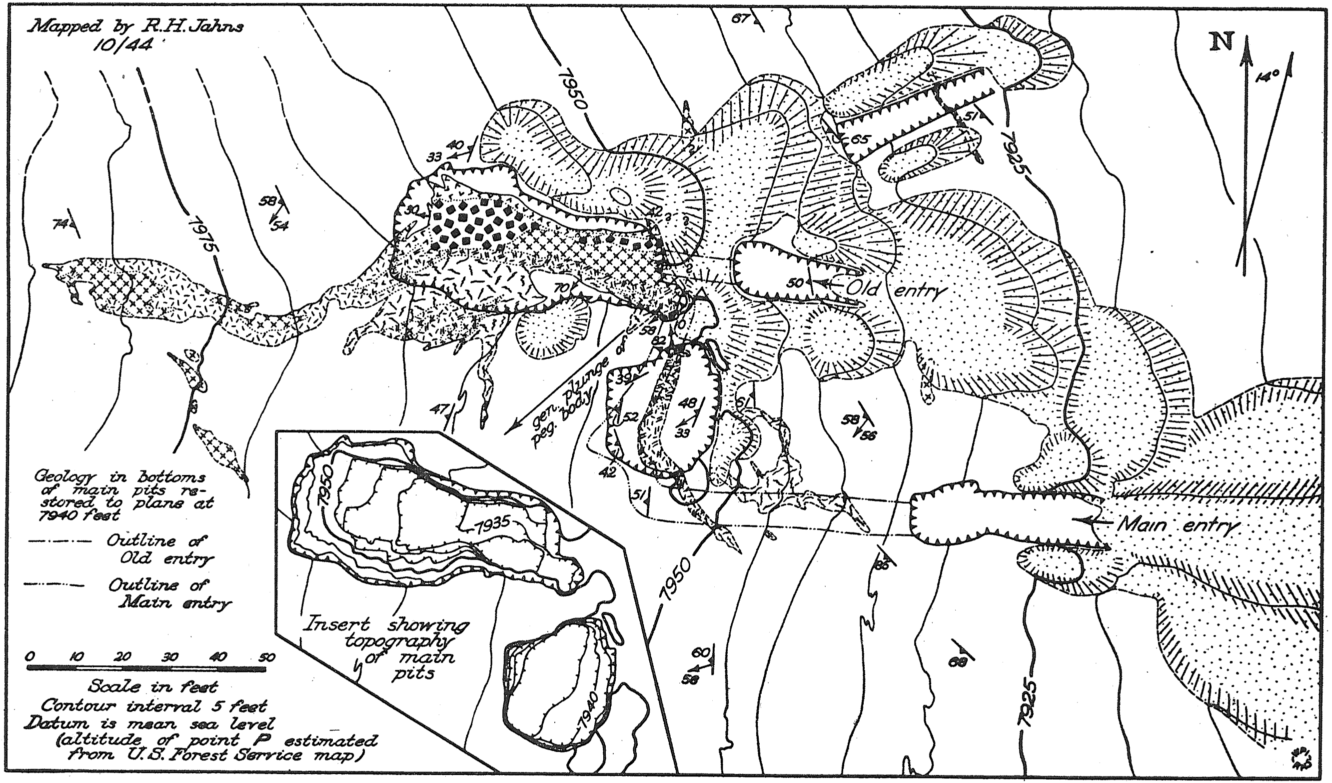

FIGURE 17. Geologic map of the Fridlund deposit (see Figure 18 for legend). (Reference point P is in small triangle at east end of main pit.)

stringers southeast of the smaller pit also consist of this material. Few of the contacts between pegmatite and country rock are sharp.

Most of the microcline in the inner zones is pearl gray to buff, but in the outer zones it is flesh colored to brick red, particularly where it is associated with albite and accessory minerals. Monazite, samarskite, and columbite are abundant, especially on the hanging-wall side of the quartz core and near its east end. Masses of columbite and samarskite as large as 14 inches in diameter were obtained during 1924 and 1925. Elongated crystals of bismutite, some of which contain residual cores of fibrous bismuthinite, are present along the south side of the quartz core. Garnet, green and purple fluorite, beryl, pink muscovite, copper sulfides, and fine-grained sericite in small pale green pods are the other accessory constituents.

Concentrations of mica occur along the hanging walls of both pegmatite limbs, along the hanging wall of the quartz core, and to a lesser extent along the footwalls of the south limb and the east third of the west limb. The richest shoot appears to be at the main bend in the body, i.e., at the east end of the core. Most of the mica is in books 6 by 6 inches or smaller, although the massive quartz contains impressions of some whose diameter must have been at least 15 inches. The largest books consist of "flat-A" material, whereas the smaller mica is little reeved but tends to occur in tangled intergrowths. Its color is light to dark green. Most is clear, but some is objectionably soft. The chief defects in material from the flat portions of "A" books are ruling, cross-grains, and waviness.

The Fridlund deposit might be a satisfactory source of scrap mica, with minor sheet and punch material, bismutite, monazite, and tantalum minerals whose aggregate value would bear significantly upon the economics of operations. Any further work should be directed at developing the down-plunge extensions of the hanging-wall mica concentrations exposed near the main bend of the pegmatite body.

PINO VERDE (LUNA) DEPOSIT

The Pino Verde or Luna deposit (39, Plate 1) lies at an altitude of 8,000 feet near the crest of a prominent ridge at the south edge of the SW¼ NW¼ sec. 18, T.26N., R.9E. It is about 0.3 mile due south of the Fridlund mine, and can be reached from the road to that mine over 0.2 mile of steep wagon road. Although the deposit had been prospected previously, it was first mined in 1922 by O. M. Fridlund. It is said to have been worked intermittently during the period 1922-1925, as well as during more recent years, but the quantities of mica produced were small. Total production probably did not amount to more than

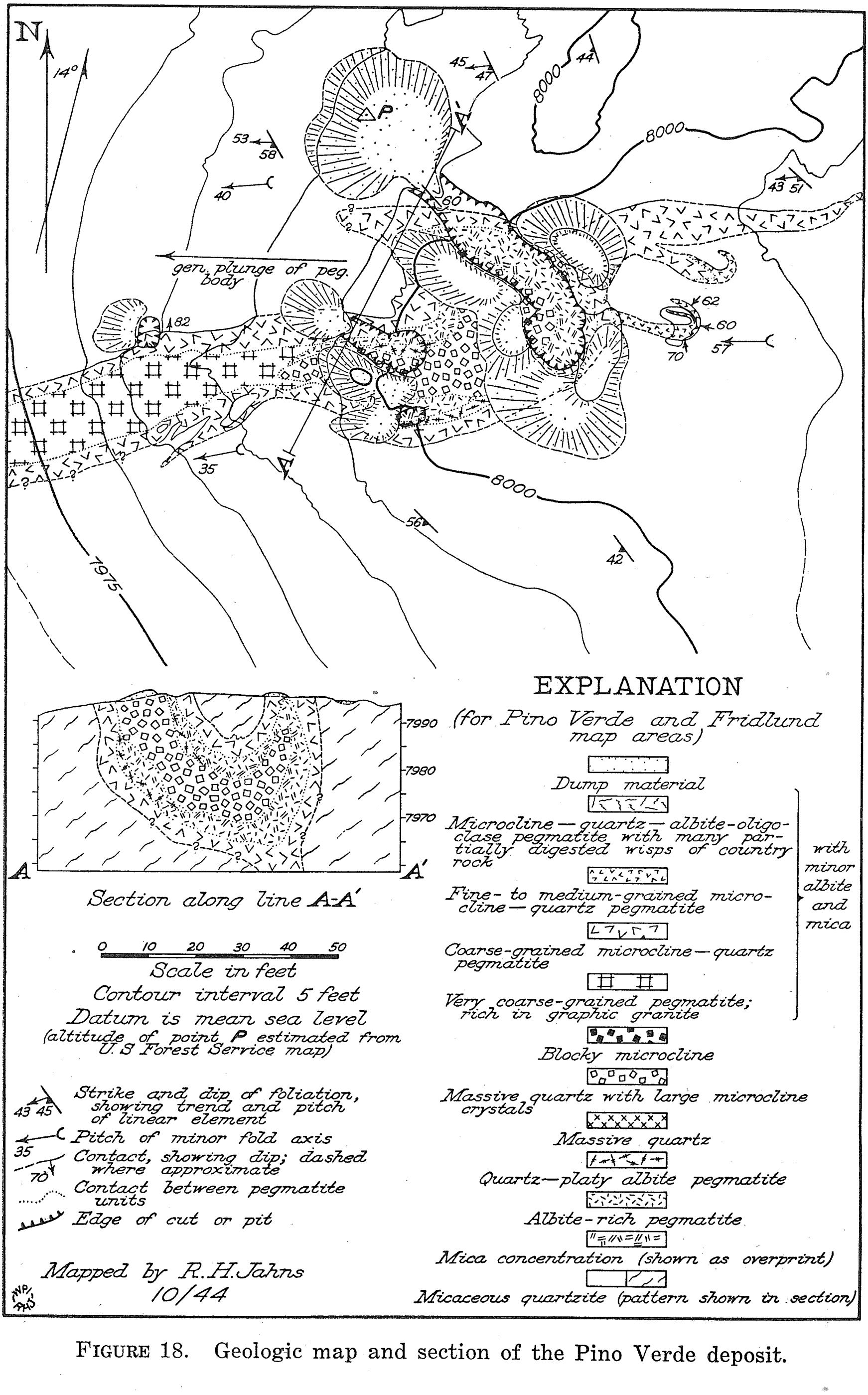

FIGURE 18. Geologic map and section of the Pino Verde deposit.

a few tons of scrap mica and a few hundred pounds of monazite and bismutite.

The pegmatite is a long dike that trends nearly due east and dips very steeply north. Its east end is a thick, hook-like bend, from which several smaller dikes project. At least two of these are also fishhook-shaped in plan (Figure 18). The main dike is about 20 feet wide in most places, but expands to an outcrop breadth of more than 40 feet at its bend. The smaller dikes are 2 to 9 feet thick. The deposit has been opened by means of at least four cuts, the largest of which is at the east end of the main dike and is 50 feet long, 7 to 12 feet wide, and about 12 feet in maximum depth.

The attitudes of the well-exposed pegmatite-country rock contacts indicate a general moderate to steep westerly plunge, not only for the main body but for its eastern appendages as well. This is in general accord with the moderate westerly pitch of linear elements in the country rock, a micaceous quartzite whose foliation strikes N. 35° W. and dips 40°-60° SW.

The core of the main dike is a crescentic body of massive quartz that contains microcline crystals as much at 11 feet in maximum dimension. It is about 75 feet long, as measured along a line midway between its borders, and 20 feet in maximum exposed width. It grades westward into extremely coarse-grained microcline-rich pegmatite that contains irregular bodies of quartz and scattered masses of graphic granite. The wall zone consists of coarse microcline-quartz pegmatite that has been thoroughly albitized near its contacts with the core. The small dikes that extend east from the main cut also consist of microcline-quartz pegmatite that ranges widely in texture. Garnet, green fluorite, columbite, samarskite, monazite, uraninite, bismutite, and fine-grained green sericite occur in albite-rich pegmatite at the east end of the main dike, and monazite and tantalum minerals also are present in albitized portions of the large microcline crystals contained in the core. Garnet and fluorite occur in parts of the wall zone where albite is relatively sparse.

Mica occurs with albite at and near the margins of the quartz core, particularly near the footwall of the dike at its main bend. The largest books lie against the quartz and are characteristically marked by "A" structure. The mica is dark olive green and unusually hard. Most books are small. Ruling, breaks, and waviness are the chief defects, and vegetable stain, light spotting, and flattened inclusions of garnet are also present. The mica not only would yield an extremely low proportion of sheet material, but it occurs in rather lean concentrations.

FREETLAND DEPOSIT

Near the crest of a subdued ridge 600 feet east of the Pino Verde workings is the Freetland deposit (40, Plate 1). It lies at an altitude of about 7,930 feet near the southeast corner of the SE¼ NW¼ sec. 18, T.26N., R.9E. It can be reached on foot from the Fridlund road to the northeast or from the Pino Verde road to the north. Little is known concerning the history of the small-scale mining operations at this deposit, and none of the workings show evidence of recent activity.

A narrow well-defined pegmatite belt that trends nearly due west consists of individual dikes 150 to 300 feet long. Most are distributed en echelon. The largest dike has been opened by means of shallow cuts and pits for a distance of 200 feet along its strike. The most productive operations appear to have been in its thickest part, in which a well-defined quartz core is present. A pit 25 feet long (east-west), 12 feet wide, and 7 feet in maximum depth exposes a medium- to coarse-grained aggregate of microcline, quartz albite, and mica along the north or footwall side of the core. Also present are garnet, green fluorite, beryl, columbite, and monazite. The monazite is relatively common in albitized portions of large microcline crystals.

Mica occurs as aggregates of small crystals at the borders of the dike and as coarser books in the wall zone. It is light green, fairly hard, and generally free from stain, but most of it is badly warped or broken.

A few tens of feet to the west is another cut 30 feet long, from which an irregular tunnel-like stope has been driven for 35 feet. The dike contains a quartz core at the east end of the cut, but this gives way to an intermediate zone of extremely coarse-grained white microcline at the west end. The potash feldspar is seamed with quartz, albite, and fine-grained green mica. Fluorite, garnet, monazite, and columbite are present in albite-rich portions of the wall zone. Mica in books 1½ inches in average diameter is scattered through the wall zone, particularly on the north side of the core. The concentrations are not especially rich, and the material is so badly broken that it is usable as scrap only.

TEDDY NO. 2 DEPOSIT

The Teddy No. 2 pegmatite (41, Plate 1), near the top of a rounded knob 900 feet east-southeast of the Freetland deposit, lies immediately south of the road to the Fridlund mine and a few hundred feet west of the Cribbenville road. It is at the north edge of the NE¼ SW¼ sec. 18, T.26N., R.9E. At least six shallow cuts and pits have been excavated in a pegmatite dike that is 15 feet in average thickness and is exposed for a distance of at least 850 feet along the strike. The largest dimension of these workings is about 20 feet. The dike trends N. 45° W. and dips very steeply. As traced southeast from the workings and across an old road, it curves to the south and to the south-southwest, with progressively more gentle westerly dips. This part of the body is very thin. Wherever its contacts are exposed, the dike appears to transect the foliation of the country-rock schist and quartzite, which trends due north and dips 35° W.

The pegmatite is a medium- to coarse-grained aggregate of microcline and quartz. It contains scattered lenses and pods of massive quartz, which are most abundant where the dike is thickest. Albite occurs as sugary to platy aggregates, and is most abundant adjacent to the quartz masses. Garnet and fluorite are relatively common near the borders of the dike, and beryl and columbite were noted in albite-rich material on the dumps.

Mica is scattered through the pegmatite in books 2 by 3 inches and smaller. Molds of books as large as 12 by 18 inches, however, are present in some of the massive quartz pods. The mica is light green. "A" structure, ruling, warps, breaks, and tanglesheet intergrowths are the chief imperfections. The deposit shows little promise as a source of sheet or scrap mica in large quantities.

BLUEBIRD NO. 2 DEPOSIT

The Bluebird No. 2 deposit (42, Plate 1) is on the crest and east slope of a broad ridge 600 feet south of the Teddy No. 2 workings. It is less than 300 feet west of the Cribbenville road, but is most easily reached over a wagon road and trail from a cabin near the Cribbenville mine to the southwest. The main workings are an open cut 30 feet long, 5 to 10 feet wide, and 12 feet in maximum depth, and an appended stope or room 10 by 15 feet in plan and 10 feet high. About 50 feet to the west is a very shallow cut 45 feet long and 3 to 15 feet wide. The history of these workings is not known.

The pegmatite is a nearly vertical dike that strikes east-west and is 15 to 20 feet thick. Its walls are extremely irregular and the foliation of the adjacent country rock, a quartz-mica schist, is markedly disturbed. The strike of the foliation ranges from N. 70° W. to N. 5° E., and the dip from 80° south-southwest to 40° west. Inclusions and septa of partially pegmatitized schist plunge 30° west in conformity with the pitch of linear elements in the country rock. At least three large corrugations along the north wall of the dike also plunge moderately west.

The core of the pegmatite body consists of coarsely intergrown quartz and microcline, and is flanked by coarse microcline-quartz-albite pegmatite that is rich in graphic granite. Contacts between these zones are gradational. The albite, which is fine-grained, is scattered evenly through the wall zone. Garnet, green fluorite, columbite, samarskite, and monazite are the accessory constituents.

The mica is green to brownish green and occurs as relatively small "A" books. It is most abundant along the contact between the core and wall zone. The chief structural defects are ruling, cracks, and hairlines. Some books are specked and many contain layers of silica. Little sheet material could be obtained from this deposit, and none of the mica shoots appears to be rich.

TEDDY DEPOSIT

The Teddy deposit (43, Plate 1) is at the west edge of the NE¼ SW¼ sec. 18, T. 26N., R.9E. It lies near the bottom of a small gulch less than 200 feet north of the cabin near the Cribbenville mine, and can be seen from the Cribbenville road. It was first prospected prior to 1900 and has received attention intermittently since then. The largest workings were excavated in 1943 by Joe Thompson of Los Angeles, California. A few tons of scrap mica was produced.

Two nearly parallel pegmatite dikes about 40 feet apart are present at the bottom of the gulch. They are 15 to 20 feet thick, trend N. 25° W., and appear to be dipping toward each other at high angles. They have been opened by means of six small pits and cuts, as well as by two adits low on the hill slope. The south adit is 20 feet, and the north adit about 45 feet long. Both are caved. Five hundred feet north-northwest of these portals the two dikes curve and join, but 50 feet beyond this point they reappear as separate bodies. That part of the deposit in which the two dikes are merged may plunge northwest at moderate angles, as suggested by the attitude of corrugations in the walls and by the plunge of minor folds in the adjacent micaceous quartzite country rock. Moreover, the dikes themselves appear to have been emplaced in the crest and flanks of a sharp anticlinal fold that plunges north-northwest to northwest. Both are offset a few feet along a fault near the adit portals. Flanking this fault is a zone of severe shearing and crushing.

The pegmatites are sharply zoned. The cores consist of massive quartz, which is especially abundant in the south dike. Massive quartz that contains large crystals of microcline occupies a central position at the junction of the two dikes, and probably constitutes an intermediate zone. The wall zone, a coarse intergrowth of microcline and quartz, has been partially albitized. Accessory minerals are garnet, fluorite, beryl, columbite, and bismutite.

Light to medium green muscovite is very abundant in the albite-rich portions of the deposit. The average size of the books is about 4 by 4 inches, although much larger books are present along the quartz masses. Much of the mica is strongly marked by "A" structure and ruling, and heavy mineral stains are common. Other defects are warping, hairlines, and softness. Although little sheet material is present, the deposit appears to contain reserves of scrap mica in small but rich shoots.

BLANCA DEPOSIT

At the west edge of the Cribbenville area, in the NE¼ SE¼ sec. 13, T.26N., R.8E., is the Blanca deposit (44, Plate 1). It lies on the east slope of a prominent ridge at altitudes of 8,000 to 8,090 feet, and can be reached from the end of the Cribbenville road over a 0.4-mile automobile trail. The workings, which represent little more than prospecting efforts, are in the east half of a large pegmatite dike (Plate 18). They include eight small pits, a short crosscut, and four open cuts 30 to 35 feet long, 8 to 15 feet wide, and 2 to 12 feet deep. The crosscut and three of the larger surface openings were excavated in 1943 and 1944, when a few pounds of sheet mica and several tons of scrap were obtained by G. C. Stout of Grand Junction, Colorado.

The dike is 20 to 70 feet in outcrop breadth and nearly 900 feet long. It trends roughly east-west and dips moderately to steeply north. The country rock is platy micaceous quartzite with interlayered light gray porphyritic rhyolite and associated metavolcanic rocks. The foliation of these rocks strikes northwest and dips moderately to steeply southwest. The crests and troughs of drag folds and the axes of elongation of deformed phenocrysts in the rhyolite plunge moderately west-southwest.

The pegmatite contains a discontinuous core of massive quartz, individual lenses of which are 10 to 60 feet long and 4 to 18 feet thick. The surrounding zones consist chiefly of white to flesh-colored microcline. Quartz is the interstitial material in the coarse-grained wall zone, and is present with pegmatitized country rock in the thin, finer-grained border zone. The intermediate zone is rich in coarse, rudely formed graphic granite. Locally, where it contains quartz other than that in the graphic granite, this rock resembles the wall-zone material, and the boundaries mapped between the units are necessarily somewhat arbitrary. Microcline-rich pegmatite is also common in a smaller dike that lies 50 feet northwest of the west end of the Blanca dike.

Parts of the quartz core have been replaced by cleavelandite, the distribution of which was controlled by fractures. Albite is scattered through the other zones also, and is markedly concentrated in those parts of the wall zone and intermediate zone that are rich in quartz or lie adjacent to segments of the core. The accessory minerals are garnet, fluorite, columbite, and ilmenite, of which only the garnet is common.

Most of the mica is pale green. Its chief imperfections are ruling, "A" structure, and haircracks. Mineral staining is not common. The books average about 3 by 3 inches, and most occur in albite-rich pegmatite adjacent to small pods and larger masses of quartz. Concentrations have been encountered near the west end of the dike and in two prominent bulges 350 and 450 feet from its west end. None appears to be sufficiently rich to support mining operations.

CAPITAN DEPOSIT

The Capitan mine (45, Plate 1) is at the east edge of the NE¼ SE¼ sec. 13, T.26N., R.8E. The workings are about 400 feet east-southeast of the main Blanca workings and are in the same large pegmatite dike. They lie immediately south of an automobile trail that extends northwest from a point near the end of the Cribbenville road. The deposit was first mined in the seventeenth century, when sheet mica was obtained from shafts and an open cut. More extensive operations yielded stove mica during the period 1870 to 1900, after which emphasis was shifted to the production of scrap. The Hoyt Mineral Company of Las Tablas shipped about 250 tons of scrap to Richmond, Virginia, for wet grinding in 1928 and 1929, but no production data are available for other periods of operation. More than 1,500 tons of scrap and 1,200 pounds of sheet and punch mica are said to have been taken from the main workings during the past century, but the deposit has lain nearly idle for at least ten years.

The Main open cut, which lies on the north or hanging-wall side of the dike, is 50 feet long, 5 to 20 feet wide, and 5 to 30 feet deep. Near its west end it connects with a narrower, deeper cut to the south. Both openings furnish access to a partially caved westward-sloping room that is 20 to 40 feet wide, 8 to 25 feet high, and at least 50 feet long. From this room large quantities of scrap mica were taken during the most recent operations. About 30 feet southwest of the Main cut is the South cut, a large oval opening 25 feet in maximum depth, and to the east are several small pits. West and west-northwest of the Main cut are five shallow cuts 40 feet or less in maximum dimension. Inclines that slope west-northwest from three of these openings are caved and flooded, but do not appear to have been extensive.

In the vicinity of the workings the pegmatite dike is 40 to 70 feet thick and very irregular in detail (Plate 18). It is marked by at least three prominent bulges, one of which has been mined in the Main cut and appended stope. To the east the dike fingers out into three quartz-rich projections. All these irregularities, as well as the dike itself, appear to plunge 35°-50° west to west-northwest, and are in general accord with the pitch of the linear structures in the micaceous quartzite country rock. A fault, which is exposed along the west side of the South cut, trends north-northeast and dips very steeply east-southeast. It offsets the pegmatite dike horizontally about 45 feet (Plate 18). Both pegmatite and country rock have been shattered near the fault and have been converted to a grayish brown gouge along the fault plane.

The border zone of the dike, which ranges in thickness from a knife edge to a foot or more, is a fine- to medium-grained aggregate of microcline, albite-oligoclase, quartz, albite, and mica. Where it is thickest it contains partially digested inclusions of country rock. The adjacent quartzite has been thoroughly penetrated by pegmatitic solutions, and mixed rocks rich in oligoclase and microcline feldspars and fine-grained pale green mica have been formed. The wall zone of the dike is 3 to 25 feet thick. It is coarser but otherwise similar to the border zone. Mica-rich wisps show that country-rock material is present in it.

The inner units of the pegmatite comprise a discontinuous core of massive quartz and intermediate zones of blocky microcline and extremely coarse-grained microcline-rich pegmatite. Both feldspathic zones contain much graphic granite. Many of the zone boundaries and some of the more broad zone relations have been obscured by widespread albitization, especially near the borders of quartz masses. The proportion of albite in the pegmatite decreases westward from the Main cut. Accessory minerals include garnet, pale green fluorite, columbite, samarskite, monazite, bismutite, purple fluorite, and sulfides. Monazite, unusually abundant, occurs with albite, both as well-formed tabular crystals and as elongate "feathers" that are imbricate aggregates of tabular crystals. A few of the "feathers" contain small blebs of columbite, and most are coated with thin scales of pale yellowish green muscovite.

Mica is especially abundant as large books in albite along the margins of quartz masses. Elsewhere the books are much smaller, with average cleavage faces about 1½ by 2 inches. The mineral is light to medium green, relatively hard, and free-splitting. Most is clear. The chief defects are "A" structure, ruling, and hairlining. Large "A" blocks, which are most common alongside quartz masses in the main workings, yield flat sheets 4 by 6 inches or larger. However, the proportion of such material in all mica recovered in mining is very low. Much of the pegmatite mined for scrap consisted of quartz and mica with minor feldspar. The mica occurred as books about an inch in average diameter, and constituted 35 to 80 percent of this rock.

Operations in the Main cut and attached stope are said to have been very profitable. The mica shoot plunged westward and lay between massive quartz and the hanging wall of a broad roll along the north contact of the dike. Although caving of the stope prevents examination of the old working face, it is reliably reported that this shoot was mined down its plunge to the approximate position of the cross fault mentioned above, and that it was "worked out". It seems likely, however, that the shoot is faulted off, and that its continuation lies 45 to 60 feet north of the old working face and perhaps at a slightly deeper level. This seems worthy of careful testing, possibly by means of a shaft sunk from a point about 70 feet northwest of the Main cut. Another mica shoot, which was mined in the South cut, is also truncated by the fault. Its possible extension lies in the faulted segment of the dike to the north and west, but its outcrop there is obscured by dump material and slope wash. Further exploration and mining in the Capitan deposit should be aimed at the down-plunge continuations of these two mica shoots. Although the eastern segment of the dike probably is worked out, the western segment, which lies beyond the fault, may well contain appreciable reserves of mica-bearing material.

BONANZA DEPOSIT

The Bonanza deposit (46, Plate 1) is about 600 feet south-southeast of the main Capitan workings. It consists of a dike, cigar-shaped in plan, that is 195 feet long and 40 feet in maximum outcrop breadth. It trends east-west and dips steeply north. A little mining has been done in three long shallow cuts, but evidently the amount of mica produced was small. The deposit has received little attention for many years.

The country rock is platy micaceous quartzite and quartz-mica schist whose foliation trends N. 30° W. and dips moderately west-southwest. Two sets of linear structures, both represented by crenulations and aligned flakes of mica, plunge moderately west and gently south-southeast. The pegmatite dike appears to plunge moderately west. Its core consists of milky to light gray massive quartz and well-formed crystals of white to flesh-colored microcline. The bulk of the body is very coarse-grained microcline-quartz pegmatite, which appears as a wall zone enclosing the core. A thin border zone consists of similar but distinctly finer-grained material. Accessory minerals are garnet, green fluorite, and columbite.

Albite is scattered throughout the pegmatite, but is especially abundant along the north side of the core. Some parts of the core itself have been converted to an albite-rich rock, chiefly by replacement along fractures. Much mica occurs in the plagioclase, but the books are small. A few "flat-A" books 10 to 15 inches in diameter are present immediately adjacent to massive quartz, but the average size of cleavage faces is only 1 by 2 inches. The mica is pale to medium green, and is badly bent, reeved, ruled, and cracked. "A" structure is common, and some mineral staining is present. The deposit appears to hold relatively little promise as a source of either sheet or scrap material.

Immediately west and southwest of the Bonanza deposit is the Bonanza Extension body, a westward-plunging trough-like pegmatite whose limbs trend N. 60° W. and east-west, with steep south-southwest and north dips, respectively. The north limb is somewhat longer and thicker, and the length of the entire body, as measured along a line midway between its walls, is 130 feet.

Most of the pegmatite is a coarse intergrowth of quartz and microcline, with minor albite and mica, but a relatively thin layer of albite-mica pegmatite is present in the west half of the north limb. None of the mica concentrations is rich, and the books are small, badly ruled, and bent.

NORTH CRIBBENVILLE (OLD CRIBBENVILLE, CRIBBENS) DEPOSIT

The North Cribbenville (Old Cribbenville or Cribbens) deposit (47, Plate 1) is in the NW¼ SW¼ sec. 18, T.26N., R.9E. The main workings, on a ridge about 500 feet northwest of the end of the Cribbenville road, cannot be reached by automobile, although they once were served by a wagon road. The mine is said to be the oldest in the district and was known as early as 1800 as a producer of large sheet mica. Much stove mica was taken from it during the period 1870-1910, and subsequently it was worked intermittently for scrap and clear sheet stock. There has been little mining activity since 1936. Total production probably amounts to at least 40,000 pounds of stove mica, 20,000 pounds of clear sheet mica prepared for other uses, and 1,500 tons of scrap.

The main pegmatite body, which is a gently curving dike about 220 feet long and 43 feet in maximum outcrop breadth, was first opened near its east end by means of a pit. Work progressed downward from the floor of the pit along the north or hanging-wall side of the dike to form a steeply dipping slot stope. Other cuts were excavated in mica-bearing material along the footwall side, and in 1884 the San Carlos tunnel was driven 60 feet northward to intersect the pegmatite from a point near the bottom of the adjacent gulch (see Plate 18). Stoping was carried eastward along the footwall to connect with a room-like incline that was sunk from the surface. The mica shoot was later mined for about 60 feet west-northwest along the strike, as well as down the dip for slope distances of 30 to 55 feet. These workings were operated for at least 45 years. During the period 1932-1936, C. L. Johnson of La Madera extended the stope 30 feet west-northwest and also deepened an old cut on the hanging-wall side of the dike. From this cut a large room is said to extend 50 feet or more to the west, but it is caved and no longer accessible. In 1932 and 1933 S. Rabaul of Petaca sank a pit 40 feet long, 10 to 15 feet wide, and 6 to 15 feet deep at the extreme west end of the dike (Plate 18). He obtained some good mica but was forced to abandon operations owing to the partial caving of the workings shortly after he attempted to advance the face underground.

The dike, which strikes N. 65° W. and in most places dips north-northeast at steep angles, is enclosed by platy micaceous quartzite whose foliation strikes N. 35° W. and dips moderately southwest. This rock is locally garnetiferous. Two sets of linear elements are present. One plunges gently south-southeast and the other, represented by the axes of minor drag folds, plunges gently west-northwest. That the pegmatite body itself plunges gently to moderately west-northwest to northwest is shown by the plunge of its keel, which was encountered in the bottom of the old east stope, as well as by the plunge of its crest, which is exposed in the Rabaul pit (Plate 2, bottom), and by the plunge of mica shoots, other lithologic units, and at least one distinct bulge along the hanging-wall contact.

In most places the pegmatite walls are sharp, though locally they are complicated by septa of country rock that project into the dike at acute angles. Many small masses of partially digested quartzite are present in the thin pegmatite border zone, which is a fine- to medium-grained aggregate of microcline, albite-oligoclase, quartz, albite, and mica. The wall zone consists of coarse-grained microcline-quartz pegmatite, and is best developed in the western third of the dike. The core, which is relatively large, contains massive quartz and scattered large crystals of microcline. One of these crystals, as exposed in the two main inclines, is more than 20 feet in diameter. Albite is abundant in all the zones, and in the east half of the dike the wall zone and the marginal portion of the core have been almost completely replaced by albite. Other, less severely affected parts of the core contain much albite along fractures.

The most common accessory minerals are salmon-colored spessartite and pale green fluorite, which form irregular, highly fractured masses 6 inches or more in diameter. One 12- by 19-inch mass of fluorite is exposed in the main stope near the San Carlos tunnel. In many places this mineral has been altered and partially removed, leaving vugs that contain a reddish brown clay. Monazite and purple fluorite are common minor constituents of albite-rich pegmatite, and large "niggerheads" of columbite are said to have been encountered in mining. Bismutite and sulfides occur with albite in quartz. Beryl is reported.

Mica is abundant in the albitized wall zone and in the albite-rich pegmatite adjacent to massive quartz, particularly in the east half of the dike. It is light to medium green, hard, clear, and free-splitting. The average size of books in the main mica shoots is about 4 by 5 inches, although many larger books occur against massive quartz. The quartz hanging wall in parts of the main stope contains impressions of mica crystals as much as 2 feet in diameter. The chief imperfections are ruling, reeves, and hairlines, but the quality of most of the material is unusually good. Mineral staining is rare.

When J. A. Holmes[22] and D. B. Sterrett[23] visited the mine in

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[22] Holmes, J. A., Mica deposits in the United States: U. S. Geol. Survey 20th Ann. Rept., p. 706, 1899.

[23] Sterrett, D. B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, p. 160, 1923.

1898 and 1911, respectively, they saw great promise of future successful operations. Subsequent mining demonstrated the correctness of these predictions, but future possibilities are now more difficult to appraise. Not only are the present workings very large with respect to the size of the dike, but backfill prevents examination of most of the working faces. It seems clear that the mica shoots plunge west-northwest at gentle to moderate angles, and for this reason the nearly barren heading of the west-northwest drift from the San Carlos tunnel probably lies above the main footwall shoot. Both footwall and hanging-wall shoots appear to have been mined out from top to bottom in the present workings. Down-plunge continuations of these shoots, however, might permit successful mining at deeper levels to the west-northwest. It would be necessary to clean out some of the old stopes to permit inspection of faces and the planning of future operations.

South and immediately west of the main deposit is another pegmatite dike that trends N. 75° W. and has very steep north and south dips. It is 225 feet long and about 30 feet in maximum width, and appears to plunge gently west. A cut about 60 feet long was excavated at its east end in 1885, and from it an adit was driven westward for 40 feet beneath and along the keel of the pegmatite. The adit and appended small underground workings have been inaccessible for many years, and the production of mica from them is not known.

Most of the pegmatite is a coarse-grained intergrowth of microcline and quartz, with minor albite and mica. Local pods of quartz 3 to 12 feet in maximum dimension are common in the east third of the dike and probably represent a discontinuous core. A larger mass of blocky microcline occurs near the west end. Albite and mica are most abundant along the keel of the body, as well as locally along its north wall. Most of the mica, which is pale green, is small and badly ruled, warped, and broken. The deposit offers little promise as a source of mica.

CRIBBENVILLE (NEW CRIBBENVILLE) DEPOSIT

GENERAL RELATIONS

At the end of the Cribbenville road, 2.1 airline miles southwest of Petaca, is the Cribbenville or New Cribbenville mine (48, Plate 1). The workings lie on a steep northeast slope at altitudes of 7,870 to 7,970 feet, and are near the northeast corner of the SW¼ SW¼ sec. 18, T.26N., R.9E. The lower, recent parts of the mine can be reached over the graded and gravelled Cribbenville road, which extends westward from State Highway 111 at a point 1.8 airline miles south of Petaca. The upper workings lie immediately north of an automobile trail that connects the Cribbenville road with the Capitan and Blanca deposits.

The deposit was first prospected when the Old Cribbenville mine, about 400 feet to the north, was opened. A few pits were dug, but no large mica shoot was exposed. In 1886 and 1887 the I Excell tunnel was driven about 300 feet westward from a point near the east end of the main pegmatite body. Little usable mica was found, so work was suspended; the portal caved a few years later. During the period 1900-1908 exposures of two rich mica shoots were opened on the hill slope about 100 feet west of the tunnel mouth, and the first real mining in the deposit was begun. The New Mexico Mutual Mining Company of Milwaukee, Wisconsin, sank a shaft, drove a short tunnel, and excavated several irregular cuts. As mining progressed, one of the mica concentrations was stoped downward and westward to form an irregular slot-like opening 50 feet long, 3 to 20 feet wide, and about 55 feet in maximum depth. This opening, the South cut, lay against the footwall or south side of the dike (section D-D′, Plate 19). The other concentration was mined in the smaller but wider North cut, most of which lay against the hanging wall. Both openings are now only partially accessible.

Little mining was done for the three decades following 1910, but during recent years mineral rights on the property were acquired by Felix Martinez and Ross Martinez of Petaca. Joe Thompson of Los Angeles, California, operated as a lessee for a short time in 1942, then reassigned his lease to the Petaca Mica Products Company, of which R. L. Schneider of San Francisco, California, is president and general manager. The caved portal of the I Excell tunnel was cleaned out and extensive operations were carried on in parts of the pegmatite below and west of the old surface workings. Production of mica was begun in May 1942 and continued to November 1944. Work during this period was chiefly at and above tunnel level. It included about 400 feet of drifting and cross-cutting, designated as exploratory and dedevelopment work, as well as mining in two large and several smaller stopes. A rich footwall mica shoot was stoped by cut-and-fill methods for a strike length of 70 feet and to heights of 25 feet or more above the tunnel floor. The Central stope, a shorter but wider opening, was developed to the north and east in the interior of the pegmatite (Plate 19), and was connected with the surface by means of an air shaft. By the time operations were concluded the central and footwall mica shoots had been worked down to tunnel level, and the footwall or Schneider stope had been holed through into the two main surface openings.

West of the largest surface workings are sixteen cuts and pits, none of which is more than 15 feet deep. Most have been sunk on minor, discontinuous mica concentrations. From a long cut 20 feet southwest of the air shaft, a tunnel extends 18 feet in a southerly direction. Much of it is in a large inclusion or pendant of country rock. Short inclines slope from the floors of cuts 80 feet south and 180 feet southwest of the air shaft, but are now caved. Most of these small westerly workings represent prospecting efforts during the periods 1900-1915 and 1923-1928. A smaller pegmatite dike that lies south and southeast of the main workings has been opened by means of seven shallow cuts and pits. The largest of these, which is immediately southwest of the mine road, is 15 feet long, 5 to 9 feet wide, and 3 to 8 feet deep. It continues west-northwest as a gentle incline that is now flooded and partially caved.

From recent operations of the Petaca Mica Products Company about 1,500 pounds of strategic-grade sheet mica, valued at slightly more than $6,000, was produced. By-products included about 9,000 pounds of stained mica that was sold as punch, and at least 125 tons of scrap. Although detailed data for previous operations are not available, production since 1900 probably amounts to at least 5,000 pounds of clear plate (selected mine-run) mica, 20,000 pounds of stained sheet material, and 400 tons of scrap.

GEOLOGIC SETTING

The main pegmatite dike in general trends N. 85° W. and dips steeply north. It is 795 feet long and about 60 feet in average outcrop breadth. Two hundred and fifty feet from its east end is a prominent bulge in which the pegmatite is at least 100 feet thick. A second dike, 490 feet long and about 40 feet in maximum thickness, extends eastward from a point near the south side of this bulge. Its general trend is west-northwest, with steep north to north-northeast dips. The two pegmatite bodies converge strongly at the surface (Plate 18), but are not connected there. They are joined at the level of the I Excell tunnel, and their combined thickness is about 70 feet in the west end of the recent workings. Their line of junction probably plunges steeply northwest.

The main dike plunges moderately to gently west. Its keel crops out near the corner of the compressor shed near the mine portal, and in the tunnel and the first crosscut farther west it appears to split into downward-tapering "roots". Irregularities in the walls, as well as lithologic units within the pegmatite, also plunge in a westerly direction. The smaller pegmatite dike, which trends more northerly, appears to plunge moderately to steeply west-northwest.

The foliation of the enclosing micaceous quartzite trends N. 45°-50° W. and dips southwest at moderate to steep angles. Two well-defined sets of linear elements are present. One pitches moderately south-southeast, and the other west in approximate conformity with the plunging structures of the pegmatites. Some of the quartzite beds have been permeated with fine-grained pale green flakes of mica. The distribution of this micaceous material is not clearly related to the distribution of pegmatites, but does appear to be most common where lenses, veinlets, and large pod-like masses of quartz are present. Other parts of the country rock contain large closely spaced feldspar metacrysts. These are common only near pegmatites. Thinly foliated dark greenish gray amphibole schist is interlayered with the quartzite near the mine portal, but forms a very minor part of the terrane. Ninety-five feet from the mouth of the I Excell tunnel is a strongly sheared 2-foot layer of this material, in which much of the amphibole has been altered to biotite.

Although neither pegmatite body appears to be offset along conspicuous faults, joints and minor shears are common (Plate 19). One well-defined joint set trends parallel with the elongation of the main dike and dips very steeply. A second set with similar trend dips gently to moderately south. Most of the other fractures strike parallel to the country-rock foliation, but cut across its dip. Shearing is common along the pegmatite borders, especially along a prominent bulge in the hanging-wall contact opposite the Schneider stope (Plate 19). Farther west along this contact, loose heavily sheared ground has caved to block at least 40 feet of the I Excell tunnel.

PEGMATITE

Both dikes are clearly zoned, but the distribution of rock units is very irregular in detail. The smaller south dike contains a discontinuous quartz core, individual segments of which are 8 feet to more than 200 feet long and 2 to 20 feet in average exposed thickness. They are flanked by coarse-grained microcline-quartz pegmatite, which forms a wall zone that reaches thicknesses of 20 feet or more where the core is thin or absent. A discontinuous border zone consists of fine- to medium-grained pegmatite similar in composition to the wall-zone material. It ranges in thickness from a knife edge to 5 feet.

The South dike can be traced east-southeast into a long quartz-rich stringer that is 3 to 6 feet thick. A little feldspar occurs throughout this material, and a thin medium-grained feldspathic border zone is present in a few places. East of the Cribbenville road the quartz-rich dike grades into a quartz vein in which feldspar is rare. Albite is most abundant in the middle third of the entire dike or in the eastern half of its zoned, feldspar-rich portion. The plagioclase appears to have replaced much of the wall-zone material, especially along and near its contact with segments of the core. Some coarse albite was formed by replacement of massive quartz, and little of the core remains in parts of the dike, especially near the workings immediately west of the road and in the bulge at its extreme west end.

The border zone of the main dike occurs as small, lenticular masses of fine- to medium-grained microcline—quartz—albite-oligoclase pegmatite, in which partially digested inclusions of country rock are abundant. This material is as much as 8 feet thick along the hanging wall in the mine workings and along the footwall near the east end of the dike, but is not more than 3 feet elsewhere. A partially albitized wall zone of coarse microcline-quartz pegmatite, with local masses of graphic granite, forms a nearly continuous envelope in the outer part of the dike. Its average thickness is about 5 feet, but it reaches a maximum of 40 feet where exposed from wall to wall near the west end of the dike. Three poorly defined intermediate zones are present. The outer and westernmost of these consists chiefly of coarse graphic granite in which large irregular spindle-like masses of quartz occur in deep flesh-colored to red microcline crystals 6 to 15 inches in diameter. Pod-like masses of quartz 6 inches to 8 feet in maximum dimension are distributed irregularly through this unit, and in a few places coarse-grained microcline-rich pegmatite lithologically similar to the wall-zone material is present. The graphic-granite zone grades eastward and inward into blocky microcline pegmatite, through which small masses of quartz, coarse microcline-quartz pegmatite, and graphic granite are scattered. This unit is at least 55 feet thick immediately west of the main bulge in the dike. Boundaries between the wall zone and either of these two intermediate zones are gradational and hence are not shown on the map.

An inner intermediate zone of massive quartz with large well-formed microcline crystals is not exposed at the surface, but appears in the mine workings, particularly along the north wall of the Central stope. Small core segments of massive quartz are present near the main cuts and near the west end of the dike, but much of this unit has been replaced by albite. The general progression of inner units from east to west involves an increase in microcline and a decrease in quartz. At the surface the most conspicuous changes in lithology occur near and immediately east of the main bulge in the dike. In the mine workings, on the other hand, corresponding changes lie farther west, attesting the general plunge of the dike and its constituent units (Plates 18 and 19).

Large inclusions of mica-impregnated country rock are present at the surface southwest of the air shaft and in the mine workings west of the Central stope. These range in thickness from a knife edge to 15 feet, and are 4 to about 75 feet long. Flanking each is a discontinuous hood of typical border-zone material, much of which has been replaced by fine-grained albite. Late-stage plagioclase is also abundant along the contacts of the dike itself and along contacts between pegmatite zones. East of the Central stope it occurs with quartz in sugary aggregates of lenticular form. Some of these appear to represent thoroughly altered inclusions of country rock. Coarse cleavelandite fills fractures in the massive quartz of the inner zones. Where these fractures are numerous, as in parts of the core immediately west of the main surface workings, the plagioclase occurs as extensive stockworks to form a very conspicuous rock type. Several of the large microcline crystals that are enclosed by massive quartz have been partially or completely replaced by fine-grained sugary albite. The selective formation of these pseudomorphs is shown by the absence of plagioclase feldspar from the adjacent quartz. Similar selective replacement is apparent in graphic granite farther west, where all stages in the attack of microcline by albite are present, but where few of the quartz spindles have been affected. Several of the irregular bodies of albite-rich pegmatite shown in Plate 18 represent replaced graphic granite, as demonstrated by the occurrence of residual quartz spindles.

Pale yellow to deep wine red spessartite garnet, the most common accessory mineral, occurs as small well-formed crystals and larger somewhat granulated masses as much as 8 inches in diameter. It is most common in the border zones, where it occurs with white to blue-gray albite-oligoclase, and in albite-rich pegmatite, especially along the footwall contact in the Schneider stope. In fine-grained albite it forms pinpoint disseminations. Grass-green fluorite in crystals and pod-like masses ½ inch to 4 inches in diameter is most abundant in the wall zones. It also forms thin crosscutting veinlets, generally in albite-rich pegmatite, but these veinlets are plainly transected by some albite crystals. Deep purple fluorite is relatively rare and appears to have been formed at a much later stage. It occurs in veinlets that cut albite, mica, and masses of green fluorite, and also appears as rims around crystals of green fluorite. Beryl, another uncommon accessory, is present as pale blue-green masses in the outer parts of the wall zone and as well-formed crystals along the outer margin of the inner intermediate zone.

Long, thinly tabular crystals of monazite are most abundant in albite-rich pegmatite that contains irregular cavities. The walls of these vugs are coated with films of hematite and limonite. Columbite, a common associate, is reported to have been encountered during early operations at the mine in the form of large "slugs" weighing 10 pounds or more. Much of the albite that surrounds crystals of both monazite and columbite is stained red to red brown. Pale green, gray, and canary yellow bismutite occurs as films and small rod-like masses in quartz-albite pegmatite in the interior of the dike. The occurrence of samarskite is reported to be similar. Magnetite and ilmenite are abundant in quartz stringers that branch from or lie adjacent to the main dike, but are rare in the pegmatite itself. Almond-shaped aggregates of fine-grained pale green sericite and pale pink muscovite occur in albite-rich pegmatite near the bottom of the South cut, but are not common. Sulfide minerals, chiefly chalcocite and bornite, are scattered throughout the pegmatite as veinlets and small pod-like masses. Much of the adjacent feldspar is stained green.

MICA

Book mica occurs in albitized zones only, and throughout both dikes its abundance is roughly proportional to that of the albite. The richest concentrations of both minerals occur in the eastern third of the main dike. A large mica shoot along the footwall has been worked by means of the slot-like South cut and the Schneider stope. A second shoot extends from the eastern end of the footwall concentration diagonally across the dike. Where it was worked from the surface by means of the North cut, it lies near the hanging wall of the pegmatite. Its richest part plunges downward and away from this wall, as shown by the position of the Central stope. This shoot lies at the north edge of the quartz core on the surface, but appears to cut through it in several places. In the Central stope it is associated with the inner intermediate zone. Although its distribution between the two levels is not clear, it appears to transect zone boundaries at acute angles. Several smaller mica shoots are present along

TABLE 11. MICA IN FACES, CRIBBENVILLE DEPOSIT

Location	Area of face (square feet)	% mica in face (by volume)
Central stope:		
Back near east end	22	12
Back near west end	41	14
West face	36	15
Back (November 1945)	48	12
	Average [a]	13
	Weighted average [a]	13
Schneider (footwall) stope:		
Floor near west end	28	15
East face (January 1944)	64	12
Back (January 1944)	310	14
Back (March 1944)	178	9
Back (November 1944)	408	11
	Average [b]	12
	Weighted average [b]	12
Other workings:		
West wall of crosscut, west end of workings	136	4
Northwest wall of haulageway west of Central stope	80	10
Back of drift west of Schneider stope	220	11
	Average	8
	Weighted average	9

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[a] Average probably somewhat higher than average for all material stoped; individual measurements were made on accessible faces only.

[b] Average probably represents entire mica shoot mined during period of measurements.

the margins of inclusions and zones of quartz and coarse-grained microcline-rich pegmatite, as shown on the map (Plate 18) and underground plan (Plate 19). Other concentrations appear as disseminations through large masses of pegmatite, but mining operations in such material have not been successful. The distribution of mica shoots at the surface is clearly shown by the positions and shapes of the pits and cuts. The mica content (by volume) of several concentrations, as estimated from measurements of accessible faces, appears in Table 11.

The mica ranges from light green through shades of greenish brown to dark brown. It is hard, relatively flat, and splits easily. The chief defects are ruling (Plate 3, bottom) and mineral staining. The stain appears as small black and brown spots and as black, brown, and red lattice-like intergrowths of trigonal pattern. Most of the stain appears to be hematite. The ratio of stained to clear sheet mica ranges from 3 to 1 to nearly 7 to 1, with a probable average of about 5 to 1. The staining is irregularly distributed within the pegmatite, within mica shoots, and within individual mica books. It is most widespread in the brownish mica in the main footwall shoot. Careful rifting of the larger stained books yields much high-quality sheet mica, inasmuch as ruling, waviness, and "A" structure are relatively uncommon in such books. There appears to be little consistent difference in quality or size between the mica that lies immediately adjacent to massive quartz and that near the walls of the dike. Much occurs as tangled masses and can be processed only as scrap. Some of the books contain intergrowths of albite near their edges, and flattened inclusions of garnet are present in others. Neither defect is quantitatively serious.

RECENT OPERATIONS AND FUTURE POSSIBILITIES

Through the courtesy of R. L. Schneider, who directed the recent mining operations for the Petaca Mica Products Company, detailed production and cost data have been made available for analysis in terms of mining methods and geologic conditions. During the period January 1, 1943-April 1, 1944 mining was carried on in the Central and Schneider (footwall) stopes, and in at least two other smaller stopes, in part by low-cost cut-and-fill methods. During the same period, however, extensive development work was done in adjacent parts of the pegmatite with relatively low recovery of mica. This comprised drifting, crosscutting, and the driving of ventilation openings. The results of all these operations (summarized in Table 12) indicate that the proportion of recovered mica in the total pegmatite mined was 2.4 percent, and that the value of this rock was $1.77 per ton. In contrast, the pegmatite taken from the richer shoots in the stopes yielded a much higher proportion of mica, and its value was $3.87 per ton. The 0.65 percent yield of prepared strategic-grade ma-

TABLE 12. DEVELOPMENT WORK AND MINING OPERATIONS FOR STRATEGIC-GRADE MICA, CRIBBENVILLE MINE JANUARY 1, 1943, TO APRIL 1, 1944

Mica produced		
Total mine-run mica	126,389	lbs.
Scrap mica	120,266	lbs.
Stained mica, selected books	4,798	lbs.
Clear mica, selected books	1,325	lbs.
Total selected book mica	6,123	lbs.
Proportion of clear mica in selected books	21.6	%
Proportion of clear selected book mica in mine-run mica	1.0	%
Prepared strategic-grade mica	824	lbs.
Proportion of prepared strategic-grade mica in total selected book mica	13.5	%
Proportion of prepared strategic-grade mica in clear selected book mica	62.2	%
Proportion of prepared strategic-grade mica in mine-run mica	0.65	%
Richness of mined material		
Volume of rock mined (calculated)	34,500	cu. ft.
Weight of rock mined (calculated)	2,875	tons
Weight of pegmatite mined (estimated)	2,600	tons
Total mica removed [a]	84.26	tons
Mine-run mica recovered	63.20	tons
Proportion of mica in pegmatite mined	3.2	%
Proportion of recovered mine-run mica in pegmatite	2.4	%
Volume of rock mined from Central, Schneider, and smaller stopes (calculated)	16,570	cu. ft.
Weight of rock mined from stopes (calculated)	1,381	tons
Weight of pegmatite mined from stopes (estimated)	1,150	tons
Mine-run mica recovered	61	tons
Proportion of recovered mine-run mica in pegmatite mined from stopes	5.3	%
Values		
Prepared strategic-grade mica	$ 3,431.87	
Stained mica (sold as stained punch at 5c per pound)	239.90	
Scrap mica (sold at $15.60 per ton)	938.07	
Total value	$ 4,609.84	
Total mine-run mica produced	63.19	tons
Value of mine-run mica per ton	$ 72.95	
Value of pegmatite mined per ton [b]	$ 1.77	
Value of pegmatite mined from Central, Schneider, and other stopes per ton [b]	$ 3.87	
Costs [c]		
Labor [d]	$ 6,269.19	
Powder and fuse	514.38	
Gasoline and oil	590.82	
Other supplies	917.66	
Freight and drayage	104.18	
Insurance	323.77	
Taxes	287.47	
Total costs	$ 9,007.47	

Summary

Total expenses	$ 9,007.47
Total value of mica produced	4,609.84
Loss, to be charged to development	$ 4,397.63

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[a] Based on assumption that about 25% of total mica was discarded on the dump as fines and as small blocks in large rock masses.

[b] Based on assumption that mica, sold at prices noted above, represents entire value of pegmatite.

[c] Does not include cost of compressor or cost of building pilot road to mine.

[d] Mining at $4 per day per man, mica preparation at $1.40 per pound of strategic-grade product.

terial from the mine-run mica was high, considering the widespread mineral stain in otherwise usable stock.

The operations during this period of more than a year were conducted at a substantial loss (see table), which was charged off by the operators as development expense. It is unfortunate that lack of specific cost data for operations in the stopes precludes an economic analysis of the actual mining operations as contrasted with development work, but it seems likely that the stoping may have been profitable. This is suggested by the results of subsequent operations in the Schneider stope, an example of which is summarized in Table 13.

The higher proportion of mine-run mica recovered from the pegmatite during this later work is thought to reflect increased success by the operators in minimizing dilution with low-grade material from beyond the limits of the mica shoot. Such dilution may have been a serious factor in some of the earlier stoping, as suggested by the discrepancy between the proportion of mica in the material mined (about 7 percent) and the proportion of mica in the present exposed parts of the mica shoots (12 percent).

During the spring of 1944 a haulageway was driven around the Schneider stope on its north side and a crosscut was run southward from the point where the main and south dikes join. No minable concentration of mica was encountered and preparations were then made for cut-and-fill stoping of those parts of the footwall mica shoot that remained above tunnel level. The back was shot down a little at a time, and the mica was cobbed and sorted on the surface of the muck. Surplus muck was dropped into the Central stope to the north or pushed into the drift to the west. No attempt was made to maintain an even working face, but projections were shot away as they developed. These operations are said to have been profitable, and were continued until the mica concentration was worked out to the floors of the old surface cuts. At one point where the old and new workings join, both the North and South cuts and the Central and Schneider stopes are connected.

The records of recent operations in the Cribbenville mine

TABLE 13. SUMMARY OF OPERATIONS IN SCHNEIDER STOPE, CRIBBENVILLE MINE, DURING A SHORT PERIOD IN MAY 1944

Volume of pegmatite mined (calculated)	680	cu. ft.
Weight of pegmatite mined (calculated)	56.7	tons
Mine-run mica recovered	10,200	lbs.
Total mica removed [a]	13,600	lbs.
Proportion of mica in pegmatite mined	12.0	%
Proportion of recovered mine-run mica in pegmatite mined	9.0	%
Prepared strategic-grade mica recovered	101.42	lbs.
Proportion of prepared strategic-grade mica in mine-run mica	1.0	%
Value of prepared strategic-grade mica	$ 585.72	
Value of scrap mica	$ 78.00	
Total value of mine-run mica	$ 663.72	
Value of mine-run mica per ton	$ 130.14	
Estimated cost of mining	$ 64.00	
Estimated cost of sorting, transportation, and overhead	$ 45.00	
Cost of rifting and trimming	$ 111.25	
Total cost	$ 220.25	
Net profit from operations	$ 443.47	

[a] Based on assumption that about 25% of total mica was discarded on the dump as fines and as small blocks in large rock masses.

tend to show that careful planning of mine workings in terms of geologic information, the adoption of low-cost mining methods, and the nearly complete extraction of all economically desirable material from the ore are essential to the successful exploitation of such a deposit, particularly during periods of relatively high labor costs. Although the main Cribbenville pegmatite is relatively large and contains rich mica shoots, the unusually high proportion of stained mica reduces the returns from mining to the point where a carefully planned operation is vital. Future operations should be directed toward the mining of down-plunge continuations of the two main mica shoots below the level of the present underground workings. Both shoots plunge gently to moderately in a westerly direction and might be worked by overhand stoping methods from a lower level.

None of the exposed mica concentrations in the smaller South dike offers much promise as a source of commercial mica. In the west half of the main dike are large reserves of medium- to high-quality microcline feldspar, but little potential by-product mica occurs in this part of the deposit.

PAVO DEPOSIT

The Pavo deposit (49, Plate 1) is about 700 feet east of the Cribbenville mine in the SE¼ SW¼ sec. 18, T.26N., R.9E. It lies near the bottom of a narrow canyon immediately south of the Cribbenville road (Plate 18). Most of the mine workings, which are in two large irregular pegmatite dikes, date back to the period 1875-1895, when operations for stove mica in the Cribbenville area were most active. Although several thousand pounds of plate mica are said to have been obtained from the deposit, few of the operations were profitable and the mine never became known as a large producer. It has lain virtually idle for at least forty years.

The deposit consists of three pegmatite dikes that trend N. 70°-80° W. The North dike, which crops out on the north side of the canyon, is 22 feet thick where it is crossed by the Cribbenville road, but tapers to a thin stringer at its east end. It is at least 350 feet long, and dips steeply south-southwest. Much of the Middle dike, which is 625 feet long and dips moderately to very steeply south, lies near the bottom of the canyon, but its extreme western part can be traced up a steep slope to the Cribbenville road. The dike thickens gradually from its east end, reaching a maximum of at least 50 feet along the canyon bottom and thence thinning abruptly. The South or largest dike, which is exposed along the south side of the canyon, is 510 feet long and 105 feet in maximum outcrop breadth. Its south wall dips moderately to steeply south and its north wall steeply north to very steeply south. This dike splits and tapers abruptly at both ends.

The largest opening in the South dike is a cut that is 90 feet long, 4 to 25 feet wide, and 18 feet in maximum depth. It lies along the north wall near the east end of the pegmatite, and from its face the Columbia tunnel extends about 45 feet southward. As exposed in the tunnel heading, the south contact of the dike dips steeply north in contrast to its southerly dip at the surface. Three smaller cuts have been excavated in the three prongs that mark the east end of the dike (Plate 18), and a fourth cut lies near the middle of the dike to the west. Near the east end of the Middle dike is the Rafugea tunnel, which trends southward and is about 35 feet long. Above and immediately south of the portal is an irregular cut 65 feet long, 8 to 20 feet wide, and 12 feet in maximum depth. It has been excavated in a pegmatite projection that is separated from the pegmatite exposed in the tunnel by a thin septum of country rock. At least six small shallow cuts represent efforts to open up mica concentrations elsewhere in the pegmatite body. Little prospecting appears to have been done in the North dike.

The country rock is platy micaceous quartzite with interlayered quartz-mica schist. Its foliation trends northwest, and has an average dip of 40° SW. Linear structures pitch moderately south and moderately west to west-southwest. Gentle to moderate west to southwest plunges are characteristic of the South and Middle deposits. One of the prongs at the west end of the South dike plunges gently west, but the other is not well exposed. The keel of this dike may also plunge in a westerly direction, as suggested by the attitudes of at least two of its three prongs. Moreover, the convergence of the dike walls in the vicinity of the Columbia tunnel, due chiefly to a reversal of dip in the south wall, may indicate that the keel lies near the surface and hence has a relatively gentle plunge. Irregularities in the walls of both the South and Middle dikes, as well as the lithologic units within them, have similar plunges.

The North dike is markedly sinuous in plan. It consists chiefly of medium- to coarse-grained microcline-quartz pegmatite with minor albite and mica. Inner zones of massive quartz and blocky microcline are present as small pods in the mapped portion of the dike. The most extensive unit is a wall zone of coarse microcline-rich pegmatite. The finer-grained border zone is relatively continuous and in most places is at least 3 feet thick. Albite is a widespread minor constituent in all the zones, but appears as rich concentrations in few places.

The border and wall zones of the Middle dike are similar to those in the North dike. In places near the west end where the border zone is not present, the wall zone is 30 feet or more in outcrop breadth, but to the east it grades into an intermediate zone in which coarse graphic granite is abundant. This material is exposed along the strike for nearly 400 feet and forms the dominant unit in the dike. The two prongs at the east end of the body contain massive quartz that probably represents the core. This material is not symmetrically distributed within each of the prongs, but lies along their edges on both sides of the intervening schist septum (Plate 18). Near the center of the south prong is massive quartz with large crystals of microcline, which probably represents a poorly developed inner intermediate zone. Albite is a widespread minor constituent in all the pegmatite, but is most abundant in the east half of the dike, where it has formed chiefly at the expense of microcline in the graphic granite. Local concentrations of coarse cleavelandite represent replacement of massive quartz in the two prongs.

The South dike contains a massive quartz core that is at least 260 feet long and 40 feet in maximum outcrop breadth. It is in the east half of the dike near the north wall. An inner intermediate zone probably is represented by several scattered masses of quartz with giant microcline crystals. Intermediate zones of blocky microcline and coarse graphic granite, and wall and border units of microcline-quartz pegmatite, form the remainder of the dike. Albite-rich pegmatite is most common between the north wall and the quartz core. Other, smaller concentrations are present along the south wall and at the east end of the core. Evidently most of the late-stage feldspar was formed at the expense of microcline in graphic granite and other coarse-grained pegmatite.

Spessartite garnet, the most widespread accessory mineral, is present in all the dikes. It is especially abundant in the wall zones, where it is accompanied by pale green fluorite. Small poorly formed crystals of blue-green beryl are locally abundant in the outer parts of the wall zone, and several larger crystals were observed along the margin of the core in the South dike. Columbite and sulfides were observed on two of the dumps.

Mica, like albite, is scattered throughout the dikes as a minor constituent, but occurs in distinct concentrations only at the east ends of the Middle and South dikes, where it has been mined from open pits. The mica is light green and is generally hard, flat, and clear. The chief defects are ruling, reeves, and breaks. Much ribbon material is said to have been produced from the flat portions of "A" books. Impressions of such books, some as much as 20 inches in diameter, can be seen in the main workings, but the bulk of the mica appears to be small. Although future operations in the down-plunge continuations of the mica shoot south of the Rafugea tunnel and the shoot at the mouth of the Columbia tunnel might be satisfactory, production probably would not be large. The proportion of recoverable large-sheet material might well be very small. Other parts of the dikes are virtually barren of minable book mica, and none of the pegmatites appears to offer much promise as a source of beryl or feldspar of superior grade.

NAMBE DEPOSIT

The Nambe deposit (50, Plate 1), southernmost in the Cribbenville group, is near the southeast corner of the SW¼ SW¼ sec. 18, T.26N., R.9E. It lies at an altitude of 7,850 feet on a low ridge at the north edge of Abrevadero Canyon, and can be reached by trail or wagon road from the Cribbenville road 600 feet to the northeast. Several open cuts on the property are said to have been dug more than a century ago, but most of the workings were developed during the period 1920-1926, when more than 250 tons of scrap mica was obtained by the Hoyt Mineral Company of Las Tablas. Additional quantities were mined on a smaller scale by other operators. Most of the mica was shipped to Richmond, Virginia, for wet grinding. Some scrap and punch material obtained by robbing shallow accessible workings was sold during the period 1934-1936, but the mine has been idle since that time.

Several connected open cuts occupy the east part of a large pegmatite dike that trends N. 85° W. and dips steeply north. This series of workings extends along the north edge of the dike for a distance of 130 feet. The average width of the excavations is about 20 feet and the average depth was 20 feet or more, but all are now partially filled with muck and large blocks that have slumped from the walls. At least two narrow inclines slope gently west from the faces of the eastern pits, and near the west end of the main pit are drifts at two levels (Figure 19). Some of these openings are said to have connected with small stopes, but they are no longer accessible. A 65-foot shaft was sunk in pegmatite immediately west of the main pit by S. Rabaul of Petaca in 1924. This opening, which intersected a stope and other workings west of and slightly below the floor of the pit, is now filled to a level about 20 feet below the collar.

The pegmatite dike is several hundred feet long and 20 feet in average thickness. It is partially covered by dump material, but appears to bulge in the vicinity of the mine workings to a maximum outcrop breadth of 54 feet, tapering to a blunt termination a short distance farther east. No prominent irregularities are present in the mapped portions of the pegmatite walls, but a branch dike extends northwest from the north wall at the Rabaul shaft. This dike grades into a 3- to 8-foot quartz vein a short distance beyond the shaft (Figure 19). The keel of the country-rock septum between the two dikes plunges west to west-northwest at moderate angles. Such a plunge probably is characteristic of the main dike itself, as suggested by reported exposures of the keel in some of the easternmost workings and by the plunge of individual lithologic units exposed between the east pit and the Rabaul shaft. Numerous minor corrugations in the north wall also plunge moderately west.

The micaceous quartzite country rock is poorly exposed. Its foliation trends north-northwest and dips moderately to steeply west-southwest. Irregular layers and lenses of mica-rich schist are present, but the distribution of this material with respect to pegmatite or vein quartz could not be determined. Immediately south and east of the east pit are red to reddish brown andesite and interlayered gray felsite, which appear to form a thin veneer over the quartzite. These volcanic rocks once covered much of the area between their present outcrop and the Cribbenville mine to the north, as shown by several scattered thin remnants. None remains, however, on the Nambe pegmatite.

The pegmatite border is marked by a thin selvage of fine-grained microcline—quartz—albite-oligoclase pegmatite that is rich in small flakes of pale green mica. This material forms a unit too thin to be shown on the map. A discontinuous wall zone that consists of coarse microcline-quartz pegmatite ranges in thickness from a knife edge to at least 12 feet. It appears to be most extensive in the poorly exposed part of the dike south of the main workings. The most prominent of the inner zones, which forms much of the dike west of the Rabaul shaft, consists of very coarse microcline-rich pegmatite in which graphic granite is abundant. Near the shaft it wraps around the west end of an inner intermediate zone in which well-formed crystals of microcline 8 inches to 12 feet in diameter occur in massive quartz. This unit lies much closer to the north wall than to the south wall of the dike,

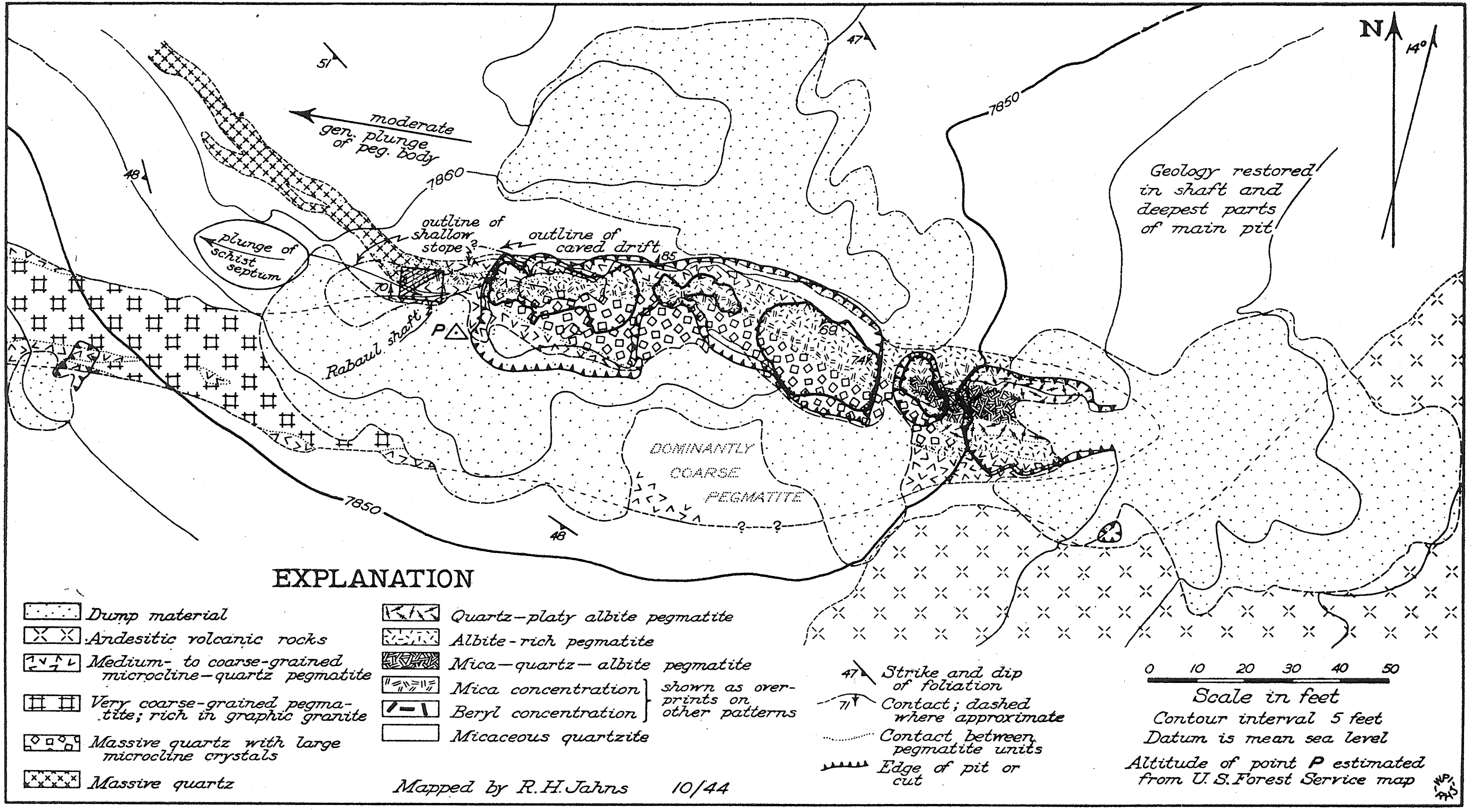

FIGURE 19. Geologic map of the Nambe deposit.

and is well exposed in the floors and south walls of the pits. At the east end of the dike are the remnants of a quartz core that was lozenge-shaped in plan. It appears to have been about 40 feet long and 15 feet in maximum thickness.

Albite is an unusually abundant late-stage constituent at and near the keel, or east end of the dike, and along its north wall between the east pit and the Rabaul shaft. It occurs in part as a wall-zone pseudomorph at the keel, but farther west it appears to have replaced only the inner half of the wall zone. The wall zone at corresponding positions along the south margin of the dike has been little affected. Much of the quartz core has been replaced by fracture-controlled albite, and only small irregular residual masses of quartz remain to mark the centers of original fracture-bounded blocks. The central part of the core has been converted to a large pipe-like body of scrap mica-albite-quartz rock, in which the mica occurs as thick books ¼ to ¾ inch in diameter. Albite is much less abundant in parts of the pegmatite west of the Rabaul shaft, but is a widespread minor constituent of the unit rich in graphic granite.

The chief accessory minerals are salmon-colored garnet, green fluorite, rusty brown monazite in feathery to thick tabular crystals, columbite in small irregular masses, and pale green beryl. Bismutite, purple fluorite, and secondary copper minerals are minor constituents, and the occurrence of samarskite has been reported. Associated with the columbite and monazite is much late-stage, fine-grained, yellowish green muscovite. Most of the beryl occurs in the albitized quartz core (Figure 19) as small irregular fragments that appear to be unreplaced remnants of large prismatic crystals.

The rich concentration of small mica books near the east end of the dike constituted an excellent ore body whose upper end is now mined out. All the material in this unit is said to have been too small to yield sheet or punch stock. In the pits farther west, however, larger crystals occur with albite along the north margin of the inner intermediate zone. Impressions of individual books as much as 15 inches in diameter can be seen in the massive quartz. The mica is pale to medium green and clear, but much of it is relatively soft. Other defects are waviness, ruling, breaks, and "A" structure. Most of the largest books are broken and partially albitized near their edges. None of the visible concentrations appears to be rich.

It is not clear whether the mica shoots have been exhausted by mining. Most of the workings are clogged with muck, and in any future operation must be cleaned out or by-passed. Unmined down-plunge parts of the keel probably offer the best possibilities for future development. Although no minable concentrations of mica were encountered in the Rabaul shaft, its bottom may not be more than a few tens of feet above the pegmatite keel, and hence it may not have been sunk far enough to encounter the more productive parts of the deposit. The results of past operations suggest that future work must be predicated almost wholly upon the recovery of scrap mica.

ALAMOS GROUP

LITTLE JULIA NO. 1 DEPOSIT

The Little Julia No. 1 deposit (51, Plate 1) is on a northeast slope between upper Abrevadero and Alamos canyons, near the center of the east edge of sec. 23, T.26N., R.8E. It lies at altitudes of 7,940 to 8,050 feet, and is the northernmost and highest deposit in the Alamos group. The main workings are immediately south and west of a poor 3.5-mile automobile trail that extends west from State Highway 111. Small quantities of mica were obtained from these workings during the period 1923-1926, but the history of other operations is not known. Total production from the deposit probably amounts to little more than 500 pounds of punch mica and 50 tons of scrap. Mineral rights are now controlled by Joseph M. Maestas and associates of Vallecitos.

The pegmatite is a sinuous dike 955 feet long and about 18 feet in average thickness (Figure 20). It strikes N. 85° E. and dips north, generally at steep angles. Its keel and the irregularities in its walls plunge moderately west. Several large bodies of massive quartz are present on both sides of the dike, but none appears to intersect it. Most are vein-like and range in thickness from a few inches to more than 30 feet. They trend northeast to east, and dip southeast and south.

The country rock is greenish gray platy quartzite and quartz-mica schist with interlayered light gray meta-rhyolite. The foliation strikes N. 10° W. and dips west at moderate angles. The axes of small drag folds and minor corrugations in the quartzite, and rows of elongated phenocrysts in the metamorphosed volcanic rocks, plunge west and west-nothwest at moderate to gentle angles. Both pegmatite and country rock are offset along at least two faults that trend north to north-northeast (Figure 20). Maximum displacement appears to be about 10 feet.

The pegmatite is discontinuously but systematically zoned. Its core is represented by several thin segments of massive quartz, none of which is more than 30 feet in exposed length. Somewhat thicker masses of blocky microcline constitute an intermediate zone. The wall zone, a coarse aggregate of microcline and quartz with minor garnet and fluorite, is the most widespread unit, forming the entire thickness of the dike in many places. A discontinuous border zone, similar in composition but much finer-grained, is too thin to be shown on the map.

Albite is widespread and abundant. It occurs as stockworks in massive quartz, as large rosettes of coarse cleavelandite in

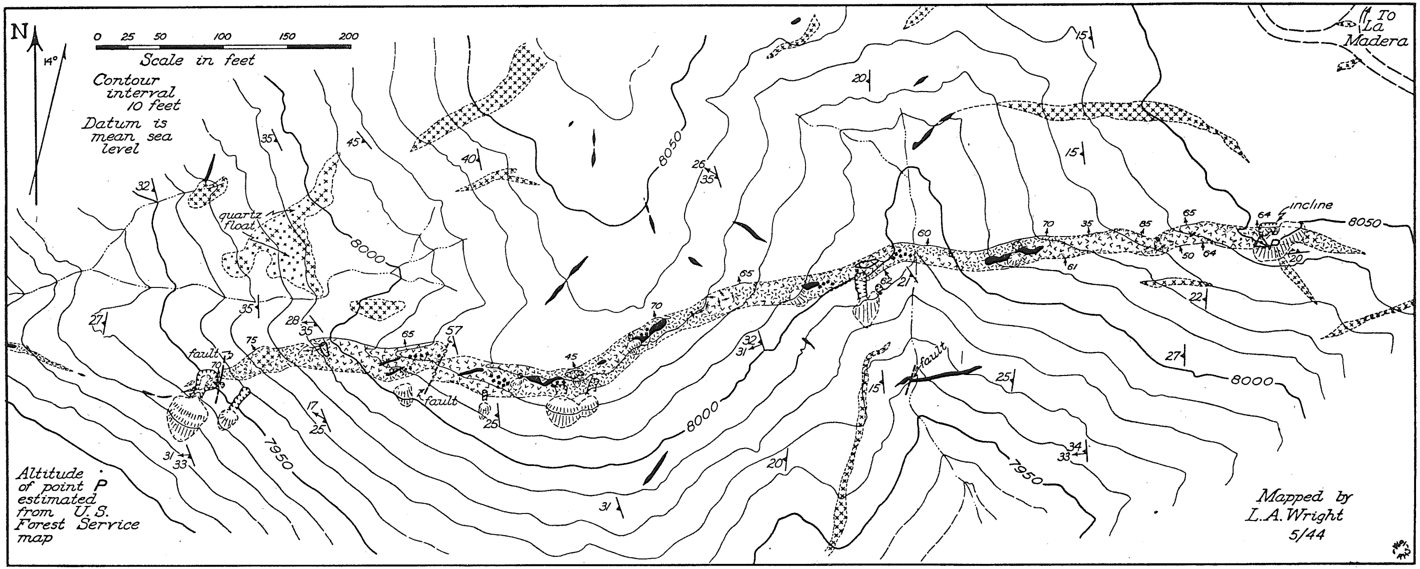

FIGURE 20. Geologic map of the Little Julia No. 1 deposit (see Figure 21 for legend).

quartz and blocky microcline, and as a somewhat finer-grained component of the wall zone. Partial or complete replacement of the wall zone is most common at the two ends of the dike and immediately adjacent to the walls elsewhere. Many of the contacts between zones have been obscured by this late-stage plagioclase, and it seems likely that many segments of the interior zones were once more extensive than they now appear on the map. The chief accessory minerals are garnet and fluorite. Irregular cavities in the wall zone contain granular aggregates of pale green fluorite, and in part may have been developed through alteration of this mineral. Columbite occurs as small masses in albite-rich pegmatite, and tabular crystals of ilmenite are common in some of the quartz veins.

Mica is most abundant near the ends of the dike and along the flanks of quartz masses. A small but relatively rich concentration was mined down its plunge in the main incline south of the road, and other concentrations have been prospected by means of small shallow cuts. The mineral is light to medium green. A few books that lie against massive quartz are as large as 9 by 12 inches, but most are 3 by 4 inches or less. The quality is poor. Reeves, ruling, "A" structure, and garnet inclusions are common, and many of the books occur as tangled intergrowths. The deposit offers little promise of future production.

LITTLE JULIA DEPOSIT

By William P. Irwin

The Little Julia deposit (52, Plate 1) is on a steep south slope above Alamos Canyon in the NW¼ SW¼ sec. 24, T.26N., R.8E. It lies at an altitude of 8,000 feet at the end of the automobile trail that serves the Little Julia No. 1 deposit, but it can also be reached on foot from the Alamos Canyon trail. Little more than intermittent prospecting was done until 1943, when an old cut was considerably enlarged in an attempt to obtain high-quality sheet mica. The mining was stopped after about 25 pounds of strategic mica and several tons of scrap were produced. At present the deposit is owned by J. M. Maestas and J. B. Martinez of Vallecitos.

The pegmatite body is a regular dike that strikes N. 75° E. and dips very steeply north (Figure 21). It is more than 1200 feet long, about 35 feet in average thickness, and probably plunges gently west-southwest. It has been explored by means of twenty-three pits and cuts, most of which are less than 10 feet in diameter. The main opening is an L-shaped cut whose entry lies athwart the dike. Most of the mining was done along the hanging wall of the pegmatite, where a hole 55 feet long, 10 to 15 feet wide, and 8 to 15 feet deep was excavated.

The country rock is micaceous quartzite with some interlayered meta-rhyolite. Its foliation trends N. 60° W. and dips gently south-southwest. Linear structures plunge gently west-southwest. The rock is markedly disturbed along the pegmatite contacts. Some of the foliation planes are severely contorted on a small scale, but most are broadly bent as if by dragging during injection of the pegmatite from below and to the west. The direction of drag is the same along both contacts; hence this feature is not readily ascribable to movement along a fault. A continuous 2- to 4-foot quartz vein lies 35 to 80 feet north of the pegmatite and is exposed for a strike length of about 1,000 feet (Figure 21). Similar veins lie farther north beyond the mapped area. Their uniform orientation suggests control by fractures.

Most of the pegmatite is an aggregate of microcline and quartz that coarsens inward from the walls. This material, which is interpreted as a wall zone, forms the full thickness of the dike in many places. It is bordered by a selvage of fine-grained microcline-quartz pegmatite that is 1 inch to 15 inches thick. Irregular bodies of coarse blocky microcline with minor quartz and rude graphic granite occupy central positions in the dike and probably are segments of a discontinuous intermediate zone. Some of this rock grades into the wall zone without break. Mapped boundaries between these zones are therefore arbitrary in places. The largest body of blocky microcline is 125 feet long and 15 feet in maximum thickness, and lies about 100 feet east of the main cut. West of this cut the central part of the dike is occupied by another intermediate zone, which consists of massive quartz with large crystals of creamy to pale flesh-colored microcline. Near the east edge of the mapped area is a long thin core of massive quartz. Three short lenses of similar material lie near the middle of the dike farther west.

About 40 feet east of the main cut is the west end of a thin continuous body of massive quartz that can be traced for 100 feet along its strike. An even longer quartz stringer that lies farther east is separated from the discontinuous core by only 20 feet of feldspathic pegmatite. Like the quartz veins to the north, these thin masses contain minor quantities of fine-grained feldspar. They differ from the quartz bodies identified as parts of the core in their occurrence near the footwall of the dike and in their tendency to cut across earlier-formed parts of the pegmatite. Similar quartz stringers that are too thin to be shown on the map are exposed in the footwall portion of the dike in the entry of the main cut and for more than 100 feet to the west. They are closely spaced fracture fillings, and are distinctly younger than the enclosing pegmatite. They may be contemporaneous with the quartz core to the east and hence may represent parts of the core that were injected into fractures in earlier-formed pegmatite.

Sugary to platy albite is a widespread minor constituent of the deposit. Unusually rich concentrations occur in the inner

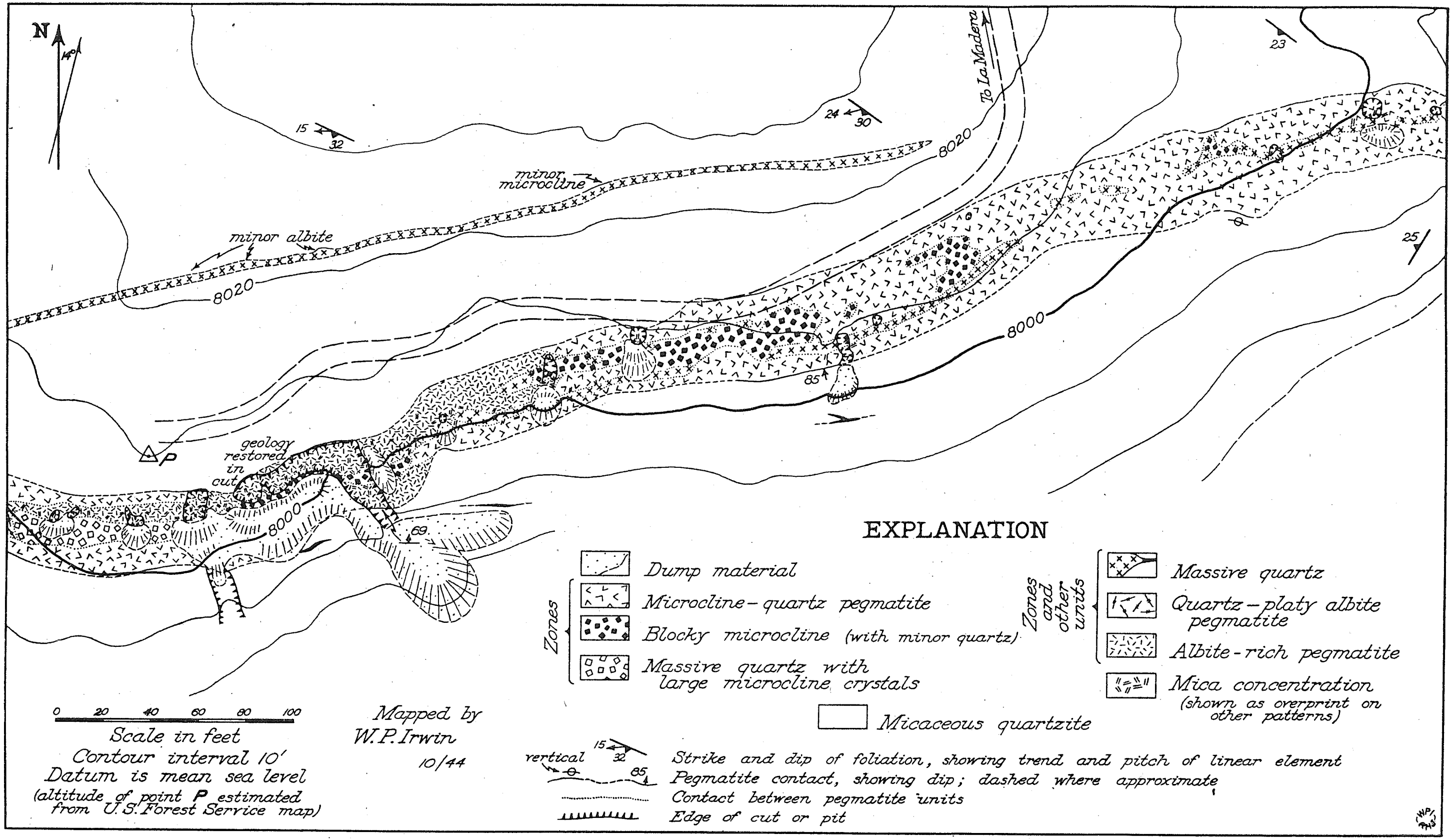

FIGURE 21. Geologic map of the Little Julia deposit.

part of the wall zone in and west of the main cut. They lie along the north side of intermediate zones that are rich in coarse microcline. Garnet is common near the borders of the dike as cinnamon brown crystals as much as 3 inches in diameter. Cores of green fluorite are present in some of these crystals. Fluorite also occurs as irregular crystalline masses 2 inches or more in diameter. Columbite, samarskite, monazite, and bismutite are rare.

The mica is medium green, hard, and relatively free-splitting. It is most abundant in the albitized portions of the pegmatite near the west end of the mapped area, but none of the concentrations is particularly rich. Most of the books are 4 by 5 inches or smaller, but a few 18-inch books were obtained during recent operations. The chief imperfections are ruling, reeves, "A" structure, and tangled intergrowths. The outlook for production from the part of the pegmatite shown in Figure 21 is poor, but the eastern end of the dike, in which massive quartz is more abundant, has not been so thoroughly prospected. Richer concentrations of albite and mica may be present near the keel of the dike.

ALTO DEPOSIT

The Alto deposit (53, Plate 1) consists of several pegmatite bodies exposed on the west side of Alamos Canyon in the north half of the NW¼ sec. 25, T.26N., R.8E. It can be reached by road and trail from the end of the improved Globe road, which is 1.1 airline miles to the south-southeast. Mineral rights are owned by A. C. Bohrnstedt of La Madera, but neither mining nor intensive prospecting has been done for many years.

The east pegmatite is exposed on the steep face of a knoll immediately west of the canyon bottom. It is a dike that trends N. 80° W. to N. 80° E. and curves southward at both ends to form thin prongs. Near the east end is a cut and a 25-foot footwall tunnel, in which the dike is 12 feet thick and dips 65° north. It comprises a core of massive quartz with giant microcline crystals and a partially albitized wall zone of coarse microcline-quartz pegmatite. The dip is gentler higher on the slope to the west, where the dike is exposed in a larger cut with appended irregular tunnels. It is at least 20 feet thick. The same zones are present, but the proportion of quartz is distinctly smaller. Garnet, fluorite, columbite, and monazite appear in minor quantities in both sets of workings. The mica is pale green and clear, and is most abundant along the inner margins of the wall zone. Most of the books are small and badly broken, and the pegmatite offers little promise.

The west pegmatite, which is much larger and richer in massive quartz, lies immediately west and south of the east pegmatite. The two bodies may be connected by means of a narrow poorly exposed stringer. The larger dike trends N. 85° W. along the south side of a prominent ridge and dips moderately north. It is 10 to 25 feet thick, and contains a massive quartz core that is almost completely albitized at its east end. A cut 20 feet long, 10 feet wide, and 9 feet deep has been sunk in this albite-rich material. Residual masses of the core, as exposed in the walls of the cut, are flanked by large rosettes or "bursts" of coarse cleavelandite. Along the outer surfaces of the feldspar masses are small books of yellowish green mica and well-formed tabular crystals of garnet and columbite. Small quantities of monazite and samarskite also are present.

Other excavations alongside the quartz core lie 60 to 150 feet to the west. They have been sunk in albite-mica pegmatite that appears to be a partial pseudomorph of the wall zone. The core bulges to form a prominent knob at the west pits. The mica concentrations that flank the quartz were worked at the surface and also were reached at a depth of 35 to 40 feet by a tunnel driven N. 35° E. from the bottom of a gulch to the south. A little overhead stoping was done in rich but narrow shoots. The mica is light green, hard, and flat. It is much broken and ruled, and few books are larger than 4 by 4 inches. Some are marred by garnet inclusions and intergrowths of albite.

Traced west from the quartz knob, the pegmatite becomes progressively richer in microcline and poorer in albite and mica. It has been opened by means of several small cuts and a larger pit in the bottom of a gulch. Beyond this pit the pegmatite trends southwest and can be traced 200 feet or more up a steep slope. A little mica is present in this part of the dike, chiefly at the margins of small bodies of massive quartz, but the concentrations do not appear to be of commercial value.

On a ridge west of Alamos Canyon and about 500 feet south of the east pegmatite there is a third dike that trends N. 80° E. and dips steeply west. It is 15 to 20 feet thick. Most of it consists of coarse microcline-rich pegmatite, but a discontinuous quartz core is present near its east end. Elsewhere the central part of the dike is composed of coarse-grained feldspathic pegmatite with a high proportion of interstitial quartz. The deposit has been prospected by means of several shallow cuts, chiefly along or near its walls. The mica is similar to that in the east and west pegmatites, and none of the concentrations appears to be sufficiently rich to support mining.

HILLSIDE DEPOSIT

The Hillside deposit (54, Plate 1) is on the steep east slope of Alamos Canyon opposite the Alto pegmatites. It lies in the NE¼ NW¼ sec. 25, T.26N., R.8E. A large pegmatite dike can be traced eastward up the steep slope to the crest of the ridge, where its west-plunging keel is exposed. It strikes N. 80° E., dips 65°-75° N., and is at least 550 feet long. Though only 8 to 10 feet thick at the canyon bottom, it thickens to at least 35 feet up the slope.

Most of the workings represent prospecting efforts during the period 1923-1927. They consist of a partially caved hanging-wall shaft, a short hanging-wall incline, and several shallow cuts and pits. The dike is not conspicuously zoned and consists chiefly of coarse microcline-quartz pegmatite. The proportion of quartz in this rock increases from west to east, and near the keel there are several 4- to 6-foot bodies of massive quartz. The pegmatite coarsens markedly inward from the walls, but in most places zones cannot be distinguished. Most of the microcline is gray to flesh colored, and some contains irregular spindles of quartz that are oriented in a crudely graphic pattern. Dark gray to pale blue-green microcline is exposed in the incline, but these colors are not common elsewhere. Fine-grained sugary albite and coarse cleavelandite are widespread but are most abundant near the walls of the dike. Accessory minerals are garnet, fluorite, beryl, monazite, samarskite, and columbite. All but the garnet and fluorite are rare.

The mica is pale green. It is fairly flat but considerably ruled and broken. The average size of the books is 1 by 1½ inches. Except for very small shoots along the walls, the concentrations are not particularly rich.

WHITE (LYONS) DEPOSIT

The White or Lyons deposit (55, Plate 1) lies on a steep east slope a quarter of a mile east of Alamos Canyon at altitudes of 7,650 to 7,700 feet. It is in the SW¼ NE¼ sec. 25, T.26N., R.8E., and can be reached from the end of the Globe road over about a mile of poor automobile road via the Red mine, or over a somewhat shorter high-level wagon road via the Triple EEE-A deposit. It is owned by C. L. Johnson of La Madera. Though its discovery date is uncertain, the deposit is known to have been worked intermittently for at least twenty-five years. Much of the early mining was done during the period 1922-1930 by Johnson and others, who sold most of the mica to a Chicago organization as scrap. No accurate production figures are available, but it is reported that 2,000 pounds or more of plate (selected mine-run) mica and several hundred tons of scrap were obtained. The mine was last operated about 1937.

The mica occurs in a single pegmatite body that is rectangular in plan (Plate 20). It trends N. 80° E. and in most places dips north at steep angles. It is approximately 220 feet long and 50 feet or more in maximum outcrop breadth. The footwall side of the deposit was worked by means of a series of cuts that were successively connected to form an irregular slot-like opening 105 feet long, 6 to 18 feet wide, and 5 to 25 feet deep. Beneath the floor of this slot are narrow steeply inclined stopes that extend to a maximum depth of about 65 feet. A lower adit with appended stopes, crosscuts, and an inclined winze is near the east end of the deposit. The stopes are connected with the footwall workings in several places (Plate 20). The principal hanging-wall opening, developed mainly during the period 1935-1937, is a hundred-foot incline that slopes west-northwest at angles of 20° to 25°. Other parts of the pegmatite body have been explored by six shallow pits.

The country rock comprises platy gray to buff quartzite and greenish gray quartz-mica schist. The foliation of these rocks is markedly crenulated, but in general trends N. 15° W. and dips moderately west. The axes of local drag folds and of many of the crenulations pitch west at moderate angles. The country rock is much contorted within a narrow zone immediately adjacent to the pegmatite contacts, especially at the west end of the deposit. Both the pegmatite and the country rock are offset a few feet along a fault that strikes N. 60° W. and dips very steeply north-northeast. An andesitic dike 3 to 6 feet thick lies in the fault zone, and is well exposed near the portal of the lower adit. It has been much sheared and forms very heavy ground in some of the lower workings.

The pegmatite body plunges west at low to moderate angles. The contact is well exposed along its crest, which plunges 35° to 50°. Its keel is concealed by dump material, but is said to have been encountered in workings (now backfilled) from the winze, where it plunges about 30°. The mean plunge of mica shoots and other traceable lithologic units in the pegmatite is also 25° to 40° W. Several minor rolls in the footwall contact are similarly oriented.

The pegmatite is distinctly zoned. Outer zones are well developed along the footwall, crest, and near the west end of the hanging wall. They are not present along the keel and most of the hanging wall, either because they were never developed there or because all traces of them were removed by reaction with residual pegmatite solutions before or during consolidation of the core. The interior units, which comprise two well-defined intermediate zones and a quartz core, constitute the bulk of the body.

The border zone is well exposed in the footwall workings and in outcrops at the west end of the deposit. It ranges in thickness from a knife edge to 7 feet. It consists of medium-grained microcline-quartz pegmatite that is rich in small partially digested inclusions of schist. The entire zone is mildly albitized. Unusual rosettes and angular aggregates of cleavelandite, 3 inches to 2 feet in maximum diameter, occur in its more quartz-rich phases near the west end of the footwall workings. Some contain highly corroded quartz centers and others appear to be pseudomorphs after microcline crystals. All are surrounded by selvages rich in fine-grained bright green mica. These selvages contain small crystals of samarskite and columbite that are arranged in one or more layers parallel with the cleavelandite contacts.

The wall zone, which appears to have extended along the border zone and 45 feet or more eastward along the hanging wall of the pegmatite, has been thoroughly albitized. As shown by several large remnants, it consisted chiefly of coarse-grained microcline and quartz, with minor garnet and fluorite. Much of the fluorite has been altered to clay-like masses and some has been removed by solution to form cavities an inch or two in diameter. Near the west end of the footwall workings the wall-zone pegmatite is cut by several veins of light smoky quartz that appears to have been fractured and then invaded by sugary albite. Both quartz and albite subsequently were fractured and dark smoky quartz was injected into the openings.

The west or outer intermediate zone, which consists of nearly pure coarse blocky microcline, is 25 to 35 feet in outcrop breadth and at least 50 feet long. Individual feldspar masses are approximately 10 inches in average diameter. The other intermediate zone, which wraps around the blocky microcline zone at its east end, is composed of large well-formed microcline crystals and massive quartz. The feldspar crystals constitute a little less than half the rock, and are about 8 feet in average diameter. This zone extends eastward to a point immediately southeast of the portal of the hanging-wall incline. It may be represented in the workings beneath this incline by large residual masses of quartz and microcline in albite-rich pegmatite. A small detached body of similar rock is exposed along the southeast wall of the lower (easterly) cut. The quartz core is exposed at the east end of the pegmatite body and extends westward along the hanging wall. In most places it has been extensively fractured and partially albitized.

Most of the microcline is light to dark flesh in color, and is in marked contrast to the white albite. The massive quartz is milky white to light gray, and some of the late-stage quartz veinlets are very dark and smoky. Garnet and green fluorite are scattered through the wall zone and the inner part of the border zone. A few small crystals of yellowish green apatite were observed in albitized quartz near the portal of the hanging-wall incline. Monazite, columbite, and samarskite are minor associates of albite, and secondary bismuth minerals are present along fractures in albitized quartz in several of the workings.

Muscovite occurs in books and in lozenge-shaped to turnip-shaped aggregates of extremely small flakes. Only a few of these fine-grained aggregates could be seen in place, but their abundance on the dump suggests that they were common in parts of the deposit, probably in the albitized wall zone. The presence of corroded cores of microcline suggests their formation through replacement of that feldspar. Most of the masses are 4 inches in maximum dimension, but the largest observed was 3 by 6 by 12 inches. Some of them contain curved flakes of pink muscovite ½ inch or less in diameter.

Book mica is present in well-defined shoots near the footwall, the hanging wall, and probably along or near the keel of the pegmatite body. The chief hanging-wall concentration, which appears to have been very rich, was worked in the main incline. This opening probably is at or very near the top of the gently to moderately plunging shoot. The mica is distributed in albitized quartz between the wall of the body and relatively fresh quartz and microcline of the inner intermediate zone, and the largest and most closely spaced books occur along the edge of the unalbitized quartz. The footwall mica shoot is in albitized wall-zone pegmatite. Its gentle to moderate plunge is well outlined by the distribution of workings. It appears to have been 2 to 5 feet thick and markedly leaner than the hanging-wall concentrations. Its outcrop length was about 120 feet, but its down-plunge extent is not known. Little mica is present along the crest of the body, but concentrations at or near the keel probably were mined in the winze and lower connected workings. The richness of exposed portions of the mica shoots, as determined by visual estimates, is shown in Table 14.

The mica is medium to light green, and in thin sheets is virtually colorless or "white". In the hanging-wall concentrations it occurs in books about 6 inches in average diameter. Many of these are unusually thick, so that they tend to be equant. The mica is hard and clear, but most is badly broken, ruled, haircracked, and reeved. Many of the books are "A" and "flat-A", from which some sheet material can be trimmed. Others are so badly bent that they would yield scrap only. Haircracks and

TABLE 14. MICA IN FACES, WHITE MINE

Location	Area of face (square feet)	% mica in face (by volume)
Hanging-wall shoot, breast of incline	32	17.5
Hanging-wall shoot, back of incline 30 feet from portal	40	13.0
Footwall shoot, west face of lowest stope	65	14.5
Footwall shoot, east face of lowest stope	42	10.5
Footwall shoot, shallow stope at east end	35	11.0
Footwall shoot, breast of lower drift	30	2.0
Footwall shoot, back of inclined winze	25	8.5
	Average	11.0
	Weighted average	11.6

ruling mar much of the mica, and some of the richest concentrations are of scrap grade because of strong albitization around the edges and along the cleavage surfaces of the books. Flattened inclusions of garnet are locally common.

The outlook for future production of mica from the White deposit is fair. Mining in the lower workings has been difficult because of caving ground and large irregularities in the footwall contact. Moreover, these concentrations of mica do not appear to have been very rich. Further mining should be aimed at parts of the deposit beneath the floor and westward from the breast of the hanging-wall incline, and possibly westward and downward from the footwall workings. Actual mining, however, necessarily would be preceded by much dead work, chiefly removal of backfill. The lower workings could be used as a means of access to unmined portions of the more westerly hanging-wall and footwall concentrations.

The microcline of the outer intermediate zone constitutes an appreciable reserve of moderate- to high-quality commercial feldspar, and should be considered if or when transportation and market conditions warrant feldspar operations in the district.

ALAMOS (PARKER) DEPOSIT

The Alamos or Parker deposit (56, Plate 1) is near the center of the west half of sec. 25, T. 26 N., R. 8 E. It lies at altitudes of 7,700 to 7,870 feet on a steep ridge 0.2 mile west of Alamos Canyon, and can be reached over an automobile trail that extends northwest from the end of the Globe road. At least 800 tons of scrap mica is said to have been taken from the main mine workings by C. L. Johnson of La Madera and others, chiefly during the periods 1925-1930 and 1934-1936. The mine was reopened early in 1943 and operated for several months by Russell Jones of Long Beach, California, under lease from A. C. Bohrnstedt of La Madera. A few pounds of sheet mica and several tons of scrap were produced, but work was stopped following a dispute over ownership of the deposit.

The pegmatite is an irregular sinuous body that comprises three large dike-like segments (Plate 21). The West segment, which is 355 feet long and about 25 feet in average thickness, trends slightly north of west and dips steeply north. It is thickest at its west end and tapers eastward to a thin quartz-rich "neck" that joins it with the East segment. From a point about 10 feet west of this connection, a thin sill-like branch extends 60 feet to the south. The East segment, which is 170 feet long and 25 to 40 feet thick, trends east-northeast and dips steeply north-northwest. Local variations in dip are common. A second "neck," much of which is covered by dump material, connects the thick east end of the body with another segment to the north-

northeast. Much of this third body is not exposed, but it is at least 100 feet long and 6 to 30 feet thick. It trends northeast and dips moderately to steeply northwest.

The country rock is a platy impure quartzite with interlayered, thinly foliated mica schist. These rocks are well exposed on the ridge south of the West pegmatite segment, but outcrops are small and widely scattered elsewhere in the mapped area. Foliation in the quartzite trends slightly west of north and dips moderately to steeply west. The axes of drag folds and small closely spaced crenulations pitch west at moderate angles. At least one small pegmatite body and several thin quartz veins lie parallel with the country-rock foliation, and several large more irregular quartz masses transect it.

The East and West pegmatite segments contain very thin border zones of fine- to medium-grained microcline—quartz—albite-oligoclase pegmatite; nearly continuous 2- to 10-foot wall zones of similar but much coarser material; outer intermediate zones of coarse blocky microcline with minor quartz and graphic granite; inner intermediate zones of massive quartz with microcline crystals 2 to 8 feet in diameter; and cores of massive quartz (Plate 21). The inner zones constitute at least two-thirds of each body. Massive quartz is rather evenly distributed from end to end in the West segment, but is concentrated in the thick east part of the East segment, where its maximum outcrop breadth is about 25 feet. Intermediate-zone material is most abundant in the west half of each body. As exposed on the surface and in the mine workings, the zones plunge moderately west to west-northwest. A roll in the north contact of the West segment and the nose of a blunt westward projection on the north side of the East segment plunge in a similar direction.

Albite is exceptionally abundant in all the pegmatite, and has replaced most of the core and wall zone in the east half of the West segment. In the East segment the outer part of the core has been replaced along fractures, and in much of the surrounding wall zone almost no trace of primary feldspar and quartz remains. Albitization is even more widespread in the pegmatite body to the north-northeast, in which it appears to have formed a complete wall-zone pseudomorph. Remnants of a large quartz core are present, chiefly as lenticular masses 4 to 15 feet long and 6 feet or less in thickness, and as numerous scattered residual fragments a few inches in maximum dimension.

Garnet and fluorite, the most common accessory minerals, occur in the wall zone and in albite-rich pegmatite in the main workings. Elongate feathery aggregates of thin tabular crystals of monazite and columbite are rather abundant in coarse cleavelandite-rich pegmatite near the keel of the East segment. Some of these aggregates are more than 6 inches long. Much of the surrounding albite is stained to a deep flesh color. Small masses of samarskite and films of yellowish to gray bismutite occur near the margins of the quartz core in both segments. A little pale blue-green beryl was observed in fragments of wall-zone material from the dumps. Several pods of pale green sericite, some as much as 4 inches long, occur in albite-rich pegmatite. A few contain cores of microcline. Sulfide minerals are relatively rare, except near the hanging-wall contact of the West segment. Abundant iron stains along the crest of a prominent bulge in this contact may have been derived from oxidized and leached pyrite and chalcopyrite.

The West pegmatite has been prospected and worked by means of six open cuts. The largest, which lies along the north or hanging wall, is 32 feet long, 8 to 10 feet wide, and 2 to 12 feet deep. Most of the others are along the walls in the eastern third of the segment, which is exposed below a talus slope (Plate 21). Seven pits have been excavated in the western two-thirds of the East pegmatite, but the main workings, including four large cuts, lie near the keel and along adjacent parts of the north wall. A vertical shaft, now caved, once gave access to old stopes in mica-albite pegmatite beneath the unreplaced part of the quartz core. An incline was later sunk from the bottom of a cut 10 feet north of this shaft, and some mica-bearing material was stoped. When haulage problems became serious, an adit was driven from a point 120 feet north-northwest of the incline portal to intersect the workings at a level 30 feet lower. A footwall drift was run at this level 75 feet southeast, where the floor of an old stope was encountered (Plate 21). After two exploratory crosscuts were driven, the incline was continued downward with steepening slope. Short drifts were run at a level 45 feet beneath the portal. During the most recent operations, the incline was deepened at least 10 feet, and from its bottom a stope 25 feet long and 12 feet wide was extended westward. Mined material was hauled partway up the slope by skip and thence trammed out the adit.

As traced downward in the accessible underground workings, the blunt protuberance that extends west-northwest from the hanging wall of the pegmatite body at the surface becomes a well-defined branch dike with an average thickness of 20 feet. At the inner end of the adit a broad roll in the hanging-wall contact plunges gently west. Pipe-like mica shoots occur beneath this and other sharp rolls. The mica books are scattered through coarse albite pegmatite, much of which occurs as a wall-zone pseudomorph. Concentrations of mica, however, are not found with concentrations of albite. Much albite-rich pegmatite is virtually barren of mica books, in some places because no mica was formed and in others because books that formed were subsequently partly or completely replaced by the feldspar. Though concentrations of large books are scattered, the average mica content of the material mined in the main workings is said to have been high. The present face in the lowest stope contains several wedge books a foot or more in diameter, as well as abundant smaller material.

The mica is light to medium green and mostly "wedge-A". The average size of the books is 4 by 6 inches, though many rosette-like aggregates of 2- to 3-foot books were found during the recent mining. The material is badly bent, broken, ruled, and reeved. Narrow buckled ribbons are common. Minor defects are hairlines and mineral staining. The proportion of recoverable sheet and punch material is extremely low. Mining for scrap mica might be continued westward and downward from the present face at the bottom of the incline, and additional mica might be recovered from parts of the pegmatite beyond the older workings along the keel of the quartz core. None of the concentrations in the West segment appears to be worth mining.

SUNNYSIDE DEPOSIT

The Sunnyside beryl-mica deposit (57, Plate 1) is at the top of a steep east slope 0.2 mile west of Alamos Canyon and 0.25 mile southeast of the Alamos mine. It is in the NE¼ SW¼ sec. 25, T.26N., R.8E., and is connected with the Alamos mine road by a recently completed truck trail. The beryl was discovered during the summer of 1943 by Juan Trujillo of La Madera, who attempted to trace float material to source-ledges of pegmatite. Small exploratory excavations, however, demonstrated its occurrence in mica-rich schist and small masses of quartz. Several hundred pounds of purple fluorite and more than 2,500 pounds of beryl were obtained late in 1943 from a pit 7 by 8 feet and 6 feet deep. Operations were then taken over by H. S. Coulter of La Madera, who sank an incline at the site of the pit. This incline trends N. 80° W. with a slope of about 40°, and is reported to be approximately 60 feet deep. From its bottom a crosscut extends westward for several tens of feet. Little beryl was obtained from these workings, which evidently were aimed at downward extensions of a large quartz outcrop, and the total production from the deposit is less than 2 tons.

The country rock is quartz-mica schist, in which a severely crumpled foliation trends N. 20° W. and dips 35° WSW. Much of this rock consists almost wholly of fine-grained pale green to colorless muscovite. Scattered through it, however, are thin lenses and larger irregular bodies of quartz, some of which are 10 feet or more in exposed length. These quartz masses and the mica-rich portions of the schist appear to be genetically related, inasmuch as many schist layers can be traced into beds of mica-poor quartzite from which vein quartz is absent.

Irregularly distributed through the schist are cigar-shaped crystals of beryl that taper to blunt ends. They are ½ inch to 6 feet long and 1/16 inch to 7 inches in diameter. Other, more sharply formed prismatic crystals occur in quartz, and a few extend from quartz into schist. Some are bent or broken, and most of the breaks have been healed with quartz. The mineral is pale to deep aquamarine in color and many specimens should have value as gem and ornamental material. Associated minerals in the schist are pale green to deep purple fluorite in irregular masses and crudely formed crystals 2 inches to more than 8 inches in diameter; white to pale yellow topaz in smaller, highly fractured lumps; ilmenite in well-developed tabular crystals 1/16 to ¾ inch thick and as much as 7 inches in maximum dimension; and garnet in tiny scattered crystals. Fluorite, ilmenite, magnetite, and thin tablets of columbite are common in the quartz, and bismutite, sulfide minerals, and pale yellow apatite are rare constituents. A little microcline was enclosed in several of the large beryl crystals and crystal aggregates.

The rock from which the first production was obtained was remarkably rich, with an average beryl content of about 6 percent. The occurrences are pockety, however, and the results of large-scale operations are likely to be disappointing. Some scrap mica of good quality was a by-product of the first mining, but the distribution of the mica-rich layers in the schist is also irregular. The high-grade material contains much vein quartz and tends to finger out into schist and quartzite relatively poor in mica.

About 150 feet southwest of the incline portal are two small pits that have been excavated in a lenticular body of mica schist. Quartz pods 3 to 4 feet thick contain scattered tabular crystals of ilmenite. These range from 1/16 to ⅜ inch in thickness and from 1 inch to 6 inches in length. Qualitative chemical tests demonstrate an appreciable content of columbium, which may occur in intergrown columbite. Other occurrences of platy ilmenite in massive quartz have been found on the hill slope north of the Sunnyside workings, and many float blocks of this material are present in the bottoms of adjacent gullies.

TRIPLE EEE-A DEPOSIT

The Triple EEE-A pegmatite (58, Plate 1) is exposed on the crest and steep west slope of a ridge immediately east of Alamos Canyon. It lies about a quarter of a mile due east of the Sunnyside mine and is accessible by automobile trail via Alamos Canyon or by wagon road via the ridge. On the property, which is claimed by A. C. Bohrnstedt of La Madera, is a large pegmatite dike that can be traced eastward from a point halfway up the hill slope to the top, whence it trends N. 65°-70° E. It dips steeply north and has a maximum thickness of about 30 feet. The workings include several shallow cuts and a hanging-wall shaft that is now flooded. A tunnel at the canyon bottom was driven eastward for 192 feet, apparently to intersect the pegmatite at depth. A short branch, now backfilled, extends east-northeast from a point 105 feet from the portal. All these lower workings are in barren micaceous quartzite.

The dike consists of coarse microcline-quartz pegmatite that is locally rich in graphic granite. A core of massive quartz appears as a discontinuous central rib 1 foot to 4 feet thick. Similar quartz segments farther west contain large crystals of microcline and may represent an intermediate zone. The surrounding microcline-rich pegmatite decreases in grain size toward the walls of the dike, and a thin fine-grained border zone that contains many fragments of altered schist is present along much of each wall.

Albite and mica are widespread but minor constituents of the pegmatite. Small concentrations occur along the walls and locally along the margins of quartz masses. Accessory minerals are garnet, fluorite, monazite, and beryl. Most of the mica, which is pale yellowish green, is soft, broken, and ruled. The books are small, and many occur as tangled intergrowths. The deposit offers little commercial promise.

RED (PEACOCK) DEPOSIT

The Red or Peacock deposit (59, Plate 1), which contains unusually rich concentrations of small book mica, is exposed on an east and southeast slope in the SE¼ SE¼ sec. 25, T.26N., R.8E. It is about 0.2 mile by airline northeast of the end of the Globe road, with which it is connected by a passable dirt road. From the main workings, which are at an altitude of 7,420 feet, more than 1,200 tons of scrap mica is said to have been taken during the periods 1927-1930 and 1933-1936 by C. L. Johnson of La Madera, and others. Much of the mined material was screened, and the coarser mica was sold to a Chicago concern for processing. Additional mica is present in the screenings, which are piled near the main workings. Smaller quantities of scrap are said to have been obtained during earlier operations. The deposit, now idle, is claimed by Johnson.

The pegmatite is a thick but poorly exposed dike-like mass that is at least 250 feet long and 65 feet in maximum outcrop breadth (Figure 22). It trends east-northeast and dips north-northwest, generally at steep angles. In its walls are several broad warps, including an indentation that separates the west end of the body into two blunt protuberances. These probably plunge north at moderate to steep angles, as suggested by exposures of the pegmatite walls and the distribution of constituent rock units in the mine workings (Figure 23). In contrast, the axes of linear structures in more easterly parts of the dike appear to plunge to the west and northwest. The linear elements in the surrounding country rock, a thinly foliated quartz-mica schist, are so poorly exposed that they cannot be correlated with those in adjacent parts of the pegmatite. The only observed set, consisting of closely spaced crenulations in mica-rich layers of the schist, pitches moderately west to west-northwest.

The dike contains an unusually high proportion of massive quartz, which occupies an interior position throughout its exposed length. Scattered through the quartz are irregular masses of microcline 5 to 80 feet long and as much as 10 feet wide (Figure 22). Many are single crystals. Much of the eastern part of the microcline-massive quartz core is partially albitized along fractures. This quartz-platy albite-microcline rock is poorly exposed, but appears to extend almost from wall to wall in the eastern part of the dike. Surrounding the core is albite-rich pegmatite, much of which appears to have replaced a wall zone of moderately coarse microcline-quartz pegmatite. Wall-zone material is exposed in the mine workings, and may lie along the footwall of the pegmatite beneath the main dumps. In most places, however, albitization is nearly complete, and only traces of the primary structure remain.

Medium-grained microcline—quartz—albite-oligoclase pegmatite that contains many partially digested slabs and wisps of schist is exposed in a long cut at the south wall of the deposit near the east edge of the mapped area. It contains irregular masses of spessartite garnet as much as 6 inches in diameter, and smaller masses of pale green fluorite. Other accessory minerals, which occur chiefly in albite and in quartz-albite pegmatite, are columbite, samarskite, monazite, and bismutite. Small quantities of sulfides, chiefly pyrite and chalcopyrite, are present in the lowest mine workings.

A shallow cut about 10 feet wide and more than 50 feet long was excavated along the south wall near the east end of the dike. It exposes a concentration of albite and mica between the border zone and the partially albitized core. Eleven smaller pits and cuts were sunk in small mica shoots to the north and west. Three of these, near the south wall of the dike, expose a thin body of albite-mica pegmatite that may have been formed by replacement along a well-defined set of fractures in the core. A hanging-wall shaft near the west end of the deposit gave access to stopes along the upper edge of the massive quartz. It is now caving, and most of the stopes are inaccessible.

The Main pit, which is immediately south of the shaft, is crescentic in plan and nearly 40 feet long. Its bottom slopes from south to north, and the opening continues underground as an inclined stope 95 feet long, about 20 feet in average width, and 8 to 15 feet high (Figure 23). The slope of its broadly un-

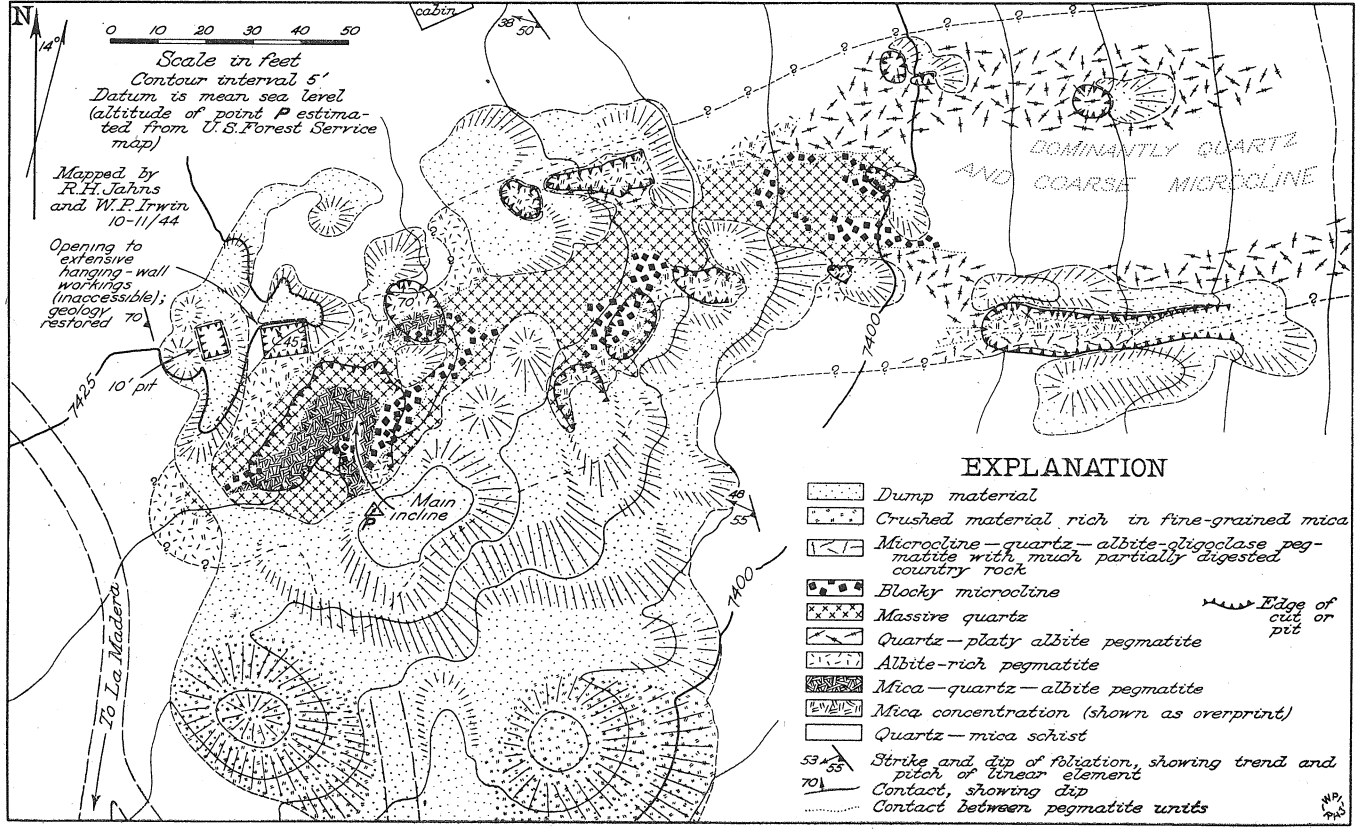

FIGURE 22. Geologic map of the Red deposit.

dulating surface increases downward from 30° to nearly 50°. Drifts 30 to 40 feet long extend to the east, to the west, or in both directions at levels 30 feet, 65 feet, and about 50 feet beneath the surface, respectively. These workings were developed in an exceptionally rich mica concentration, part of which was formed by replacement of the core. Near the present surface its shape is that of a plunging inverted trough, and it is enclosed by massive quartz. Downward, however, the mica shoot broadens somewhat and loses its trough-like shape. It transects the lower part of the core, and in much of the stope is underlain by microcline-quartz wall-zone pegmatite (Figure 23). From the back of the stope large pendants of coarse microcline project downward into the mica shoot. The shoot itself clearly cuts across zone boundaries and even across boundaries between large feldspar crystals in the faces of the drifts.

Many of the mica shoots are rich, particularly those worked in the main stopes. The books are small and closely spaced, and constitute 70 percent or more of the shoots in many places. This material resembles the high-grade scrap-mica pegmatite taken from the workings near the keel of the Nambe deposit. Nearly all the mica is heavily stained by reddish brown to peacock blue films of secondary iron oxides, and is locally stained by secondary copper minerals. The films are commonly marked by an iridescent tarnish. The mica itself is pale to medium green. Most of the books are ruled, reeved, hairlined, and bent. "A" structure and tangled intergrowths are common. The proportion of recoverable sheet and punch material is negligible. The stains in the mica probably are derived from sulfide minerals in the pegmatite itself. These were altered by oxidation and their alteration products were carried through the extensively fractured pegmatite by circulating waters. Although the stain is related to surface processes and should decrease and disappear with depth, it occurs in the lowest of the present mine workings. It is reported, however, that the staining material did not seriously affect the merchantability of the mica, inasmuch as it tended to slime off in grinding, leaving a nearly white mica product.

Although the footwall mica shoot is not bottomed in the present workings, it is distinctly narrower and leaner than the material worked at higher levels. Substantial reserves may be present beyond the west wall of the stope along the roll indicated by the contours in Figure 23. Nothing is known concerning the distribution of unmined mica-rich material in the hanging-wall workings. Future mining in this part of the deposit, either above or below the quartz, will involve extensive rehabilitation of existing workings. The east end of the pegmatite body is not exposed, but the large quartz core and the abundant albite in the exposures that lie near the bottom of the hill slope suggest that

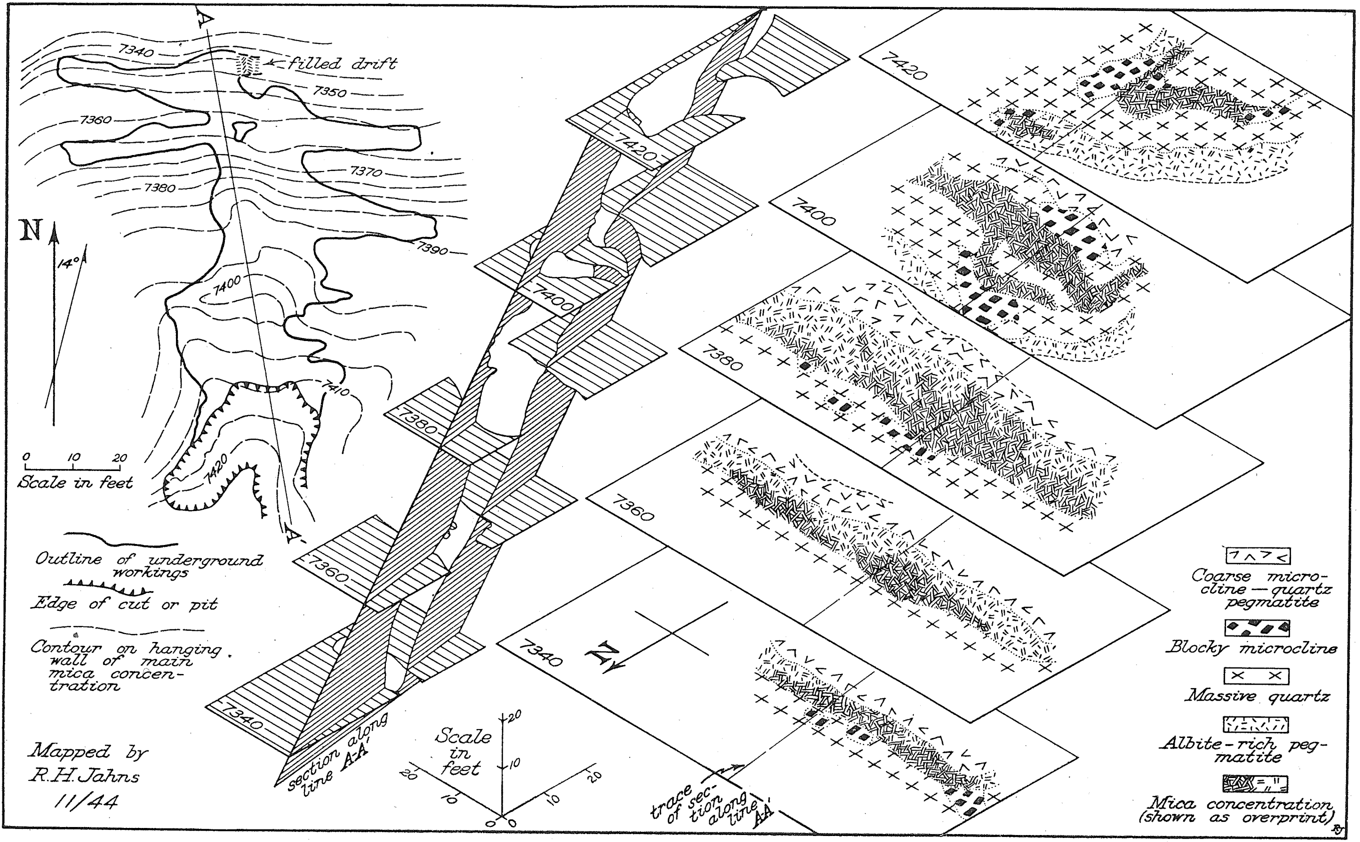

FIGURE 23. Plan of main workings and isometric plate diagrams of a part of the Red mine.

one or more mica shoots may occur farther east. Shallow trenches normal to the trend of the pegmatite should expose any workable concentrations.

GLOBE DEPOSIT

GENERAL RELATIONS

The Globe deposit (60, Plate 1) has yielded large quantities of sheet and scrap mica during recent years. It is in gently rolling country east of Alamos Canyon and 4.5 airline miles due north of La Madera. It lies at altitudes of 7,335 to 7,410 feet in the NE¼ NE¼ sec. 36, T.26N., R.8E., and is connected with State Highway 111 by a graded and gravelled road. The property consists of one patented claim owned by the Western Non-Metallics Company of Los Angeles, California, and has been worked since 1935 under the general direction of Joseph A. Stanko, president.

The deposit was opened in 1875, chiefly by means of open cuts, but production was small until about 1900, when a shaft and two inclines were sunk in rich mica concentrations. During the following decade other shafts were opened and much mica was taken from appended stope-like drifts. Operations were suspended following World War I, but were resumed on a small scale during the period 1923-1926. Subsequent mining was intermittent and production was moderate until 1935, when the present owner purchased the property. During the past ten years the mine has been the chief producer in the district. Cobbed mine-run mica is shipped to Pueblo, Colorado, for processing. Prior to 1942 some sheet and punch stock was sorted out and the remaining material put through a grinding plant. Owing to its superior whiteness, the ground product can be used for blending with darker colored micas from other districts.

During the recent war years, sheet material has been separated at the mine and processed locally. Production through January 1945 amounted to about 3,700 pounds of prepared strategic-grade mica. There is no record of sheet mica recovered prior to 1942, but according to Stanko slightly more than 3,000 tons of scrap mica has been shipped from the mine since 1936. Although production data for earlier operations are not available, it seems likely that the deposit has yielded at least 20,000 pounds of half-trimmed sheet mica (corresponding to about 80,000 pounds of plate mica), 5,000 tons of scrap, and nearly 5,000 pounds of columbite since 1900.

GEOLOGIC SETTING

The mine workings are in a long pegmatite dike that is tadpole-shaped in plan (Plate 22). It trends N. 85° W. and in most places dips steeply north. As traced from a 15-foot bulge at its east end, it thins abruptly, and thence gradually thickens westward to a maximum of about 60 feet. Beyond its thickest part it splits into three prongs, one of which trends west-northwest and grades into a large quartz vein. The other two extend westward to a diagonal fault beyond which no pegmatite is exposed. Their faulted-off portions, which probably are not large, evidently lie beneath the present surface. The total exposed length of pegmatite is about 645 feet.

The dike and its component lithologic units plunge moderately west. Thus, its three west prongs appear in section as diverging, upward-reaching "fingers" (see section C-C′, Plate 22). Another projection, exposed in the mine workings, extends west and upward from the north wall of the dike. It may be very thick at levels shown in sections B-B′ and C-C′, Plate 22, but eastward up its plunge it merges with the main pegmatite body, whose north wall is marked at the surface only by a broad bulge.

The country rock is buff to greenish gray micaceous quartzite, in which closely spaced foliation planes strike north to northwest and dip west to southwest at low to moderately steep angles. Mica-rich schist with markedly crenulated foliation is interlayered with the impure quartzite. The most micaceous parts of the terrane occur in the vinicity of veins and irregular pods of quartz. These range from lenses less than an inch in maximum dimension to veins 75 feet long and as much as 15 feet wide. Minor crinkling and warping of the country-rock structure are common near the pegmatite contacts, and zones of severe crumpling occur in the schist septa between the west prongs of the dike. Linear elements in both the schist and quartzite plunge moderately west.

A well-defined set of slip joints and faults trends northwest and dips steeply southwest. A few of these are filled with vein quartz or pegmatite that has not been appreciably fractured or sheared. There has been considerable post-pegmatite movement, and displacements in excess of 20 feet are common. A second set of slip planes, best exposed in the underground workings, is conformable with the pegmatite in strike but dips moderately to steeply south. As shown in the plan and sections in Plate 22, both walls of the dike have been disturbed by shearing. A particularly intricate mosaic of fault blocks and slices in which pegmatite and country rock are irregularly distributed occurs along the south wall in the main workings. Such structures have complicated downward development of the mine during recent years.

WORKINGS

In the east half of the deposit there are eight shallow pits, the largest about 15 feet in maximum dimension. Most are very old. Farther west are twelve surface openings, many of which give access to underground workings. The Long cut (Plate 22), near the south wall of the dike, is 70 feet long, 8 to 20 feet wide, and 5 to more than 15 feet deep. At its bottom is the filled East shaft, a steeply inclined 30-foot opening that connected with a west-trending drift and with a slot-like stope that is adjacent on the north. The top of this stope, most of which has been backfilled, can be seen in the cut at the base of the north wall. According to Sterrett,[24] a 25-foot shaft lies about 50 feet east of the East shaft, but evidently it is now covered with dump material. Immediately east of the Long cut is a small pit from which an irregular incline slopes gently westward for at least 40 feet. Its lower end is clogged with muck. About 20 feet farther east, short shallow drifts extend east and west from an even smaller pit.

Another series of workings, said to have been excavated during the period 1913-1926, includes the Lower pit and the Old incline. From the bottom of the pit, which is 40 feet long, 20 feet wide, and 20 feet in maximum depth, the incline slopes rather steeply west for 30 feet, and thence more gently for an additional 30 feet to a point where it is blocked with muck. Small irregular stopes flank the incline, both above and below. Twenty-five feet northwest of the Lower pit is an ovoid steep-walled pit, below which some stoping was done. None of the underground workings is accessible.

The largest of the older workings are near the west end of the dike. The Upper pit, which was sunk on rich mica concentrations at the junction of the north and central pegmatite prongs, is 60 feet long, nearly 40 feet wide, and 10 to 20 feet deep. The filled Main shaft can be seen near its southeast corner, and from its east face an irregular stope extends east to connect with a near-by smaller pit. The Main shaft was 35 feet deep in 1911, according to Sterrett,[25] who adds that "from the bottom . . . a drift was run 12 feet east and another 30 feet west. At the end of the west drift a crosscut tunnel has been carried 16 feet south. The drifts are 6 to 8 feet wide and about 15 feet high, so that they might be called small stopes."

The shaft was later deepened, and from its new bottom another mica concentration was mined to the west, east, and southeast in such a way that a gently undulating stope 60 feet long and 10 to 15 feet wide was developed. The old drift was extended 30 feet farther west, whence stoping was directed downward and to the south for 15 feet, as well as east-northeast and upward at a steep angle. The latter opening was broken through into the west end of the Upper pit to provide ventilation, and further mining was carried on through this new opening. The New incline was later opened near the south wall of the dike at a point southeast of the Upper pit. It was sunk about 65 feet in a westerly direction, with a general slope of 35°, and much large mica

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[24] Sterrett, D. B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, p. 162, 1923.

[25] Sterrett, D. B., *idem*, 1923.

is said to have been recovered. From a point near its bottom an irregular stope was extended 55 feet to the east. The heading lies immediately below the Old incline.

After a long period of idleness, the air shaft at the west end of the Upper pit was cleaned out in 1933, and mining was continued westward and downward to form a part of the Upper incline, a narrow stope-like opening along the sheared north wall of the dike. When intensive mining operations were resumed in 1935, the Main shaft was reopened and the stope at its base was extended westward and downward with increasing slope. From a point at the bottom of the stope almost directly beneath the collar of the air shaft a drift was run about 60 feet west along the north or hanging wall of the dike. The Upper incline is said to have been extended to its present length of about 110 feet in 1936, and a branch was driven south and east from it to connect with old workings from the 35-foot level in the Main shaft. These are now partially caved and the shaft has been filled.

The New incline was reopened in 1936 and two winzes were sunk from points along its south side. The upper winze was 25 feet deep, and the lower 10 to 12 feet, but both are now filled with muck. The incline was extended downward and to the west, with progressively decreasing slope, for a distance of 155 feet, and stoping of a rich mica shoot was carried to heights of 8 to 20 feet. Much of this slot-like chamber lies immediately below the Upper incline and its appended workings (sections A-A′ and B-B′, Plate 22). The main transverse fault is exposed in the lower end of the incline, where it truncates the dike. A short crosscut and small, irregular stopes represent efforts to obtain additional mica from parts of the pegmatite northeast of the fault and near the incline. The lowest stope, in which a rich mica shoot is reported to have been worked, is partially flooded.

A crosscut was driven 55 feet east-northeast from a point about 90 feet from the portal of the New incline to intersect the mica shoot previously worked from the bottom of the Main shaft. The old stope was intersected and timbered off. The wide, irregular North drift was run 50 feet to the east and connected with the overlying old stope near its east end (section D-D′, Plate 22). A 25-foot winze was sunk and mica-bearing material was mined from a 35-foot drift that extends west from its bottom. A second crosscut was driven north from the incline at a point about 160 feet from the portal, and a small stope was excavated in a mica shoot along the hanging wall of the dike and below the drift that was extended westward from the old stope. During 1944 operations were continued westward from the northeast end of the first, or long crosscut. The gently sloping North incline was formed. It is 80 feet long and its present heading is a few feet below the level of the lower crosscut to the south. It appears to lie in a branch pegmatite that is separated from the main dike by a long septum of country rock (plan and sections B-B′ and C-C′, Plate 22). The lower part of the New incline was being deepened when the mine was last visited late in 1944, and large quantities of mica (see Plate 5, top) were being recovered.

PEGMATITE

Though most of the primary lithologic units in the dike have been partially or wholly replaced by albite and associated minerals, a well-defined zonal structure can be recognized. Remnants of a massive quartz core, which was 5 to 25 feet wide and more than 300 feet long, are exposed between the Long cut and the east end of the dike. Immediately north of the cut the long thin west end of the core is flanked by an intermediate zone in which aggregates of microcline crystals 6 inches to 12 feet in diameter are separated by irregular bodies of massive quartz 5 to 20 feet in maximum dimension. This unit extends westward to points beyond the portal of the New incline and forms the central portion of the pegmatite in all the underground workings (Plate 22). Its average thickness is about 12 feet, with a maximum of 20 feet, and it plunges gently to moderately west. A second intermediate zone, which consists of extremely coarse-grained microcline-quartz pegmatite, occupies an interior position in the central prong of the dike west of the Upper pit.

Medium- to coarse-grained microcline-quartz pegmatite occurs as a nearly continuous wall zone 6 inches to 15 feet thick. It is absent from the poorly exposed margins of the central prong, and may be in part sheared out and in part obscured by two masses of late-stage quartz that appear to have been injected along or near the walls of the pegmatite (Plate 22). A discontinuous border zone, which consists of fine- to medium-grained microcline-quartz-mica pegmatite with abundant partially digested country-rock material, is too thin to be shown on the map.

Albite is scattered throughout the wall and border zones, but is most abundant along contacts between the wall zone and inner zones, chiefly the inner intermediate zone. The primary minerals in the inner parts of the wall zone have been almost completely replaced by fine-grained sugary albite and by aggregates of coarse cleavelandite. Albitization in the core evidently was guided by fractures. In some places the entire thickness of quartz has been replaced, so that in plan the large remnants of massive quartz are like beads on a string. Microcline crystals have been replaced along cleavage cracks and other fractures, and all stages in this process can be seen in the walls of the mine workings and in pegmatite blocks on the dumps. They range from microcline masses with tiny crosscutting veinlets of albite to large plagioclase aggregates in which only scattered residual masses of microcline are present. In the lower part of the New incline are several 1- to 4-inch albite-mica dikes. These crosscutting bodies consist of coarse cleavelandite, whose lamellae lie normal to the dike walls, and small books of yellowish green mica. Large rosettes of coarse cleavelandite that appear to have formed through replacement of blocky microcline and massive quartz are well exposed near the portal of the New incline and along the north wall of the Long cut. Pseudomorphs of sugary albite after microcline occur in massive quartz in the North pit and in the Upper incline. They clearly show the crystal faces of the replaced potash feldspar.

The microcline ranges from white through flesh to brick red. Coarse perthitic structure is widespread, particularly in the large crystals. The albite is lustrous and white, and hence contrasts sharply with most of the potash feldspar. Much of it is cleavelandite, with strongly curved lamellae as much as 2 inches long and 1/8 inch thick. Most of the quartz is milky white to light smoky gray, although several late-stage veinlets consist of very dark smoky material. Small irregular masses of garnet are present in the wall zone and in albite-rich pegmatite, but are not common. Apple-green fluorite is abundant in quartz-rich pegmatite, especially near the portal of the New incline (plan, Plate 22) and near the southeast corner of the North pit. It occurs as irregular masses 6 inches to more than 5 feet in diameter, and is commonly corroded by albite along fractures. Small masses of deep purple fluorite are scattered through albite-rich pegmatite in all the workings. This material forms rims around crystals of green fluorite and fills fractures within them.

Columbite, a widespread and abundant constituent of the albite-rich portions of the deposit, occurs in several forms. Well-developed equant crystals, an inch in maximum dimension, occur in deep flesh-colored albite, commonly with monazite and purple fluorite. Many appear to be slightly altered, and all have a dull earthy luster. Large "niggerheads" of columbite, several of which weighed 75 pounds or more, were found during the sinking of the New incline. Evidently their occurrence and associations were similar to those of the smaller crystals. Much of the columbite is present as long feather-like aggregates that consist of thin tabular crystals arranged in imbricate pattern. Most of the crystals are in contact with one another, but in some "feathers" they are separated by thin plates of albite. The aggregates generally are 3 to 5 inches long and less than an inch wide, but maximum known dimensions are 22 inches and 3½ inches, respectively. Some are scattered very irregularly through albite-rich pegmatite and others are arranged radially, particularly near the cores of large cleavelandite rosettes. Monazite occurs as yellowish brown to mahogany red crystals with resinous luster, and more commonly as small feather-like aggregates similar in habit to much of the columbite. Rough crystals a half inch or less in diameter are common as inclusions in the columbite "feathers". Both minerals generally are coated with tiny scales of yellowish green mica, and much of the albite that surrounds them is stained flesh colored to dark red.

Small dark brown to black masses of samarskite and somewhat larger pods of yellowish to gray bismutite are present locally in quartz-platy albite pegmatite. Pale green beryl is a minor constituent of the wall zone, and a few small crystals of yellowish green apatite were observed on the dump in material that may have been mined from the wall zone. Ilmenite and sulfide minerals were observed in the North pit and the Upper incline, but are rare. Pale pink muscovite in aggregates of flakes $^1/_{32}$ to ½ inch in diameter occur with quartz and albite near the top of the New incline and in dump material that was obtained from lower parts of the incline and from the North incline. Two small fragments of extremely fine-grained purple lepidolite were obtained from the North incline. On one of these is a cluster of coarse pink muscovite flakes. No lithium mineral is known to occur in any other deposit in the district.

MICA

Muscovite is exceptionally abundant, occurring with albite in all parts of the dike. The largest shoot or group of shoots lies along the footwall of the inner intermediate zone. At the surface it is exposed between the Long cut and New incline, or for a distance of more than 120 feet, and plunges westward at gentle to moderate angles. It is 3 to 16 feet wide, with a maximum vertical dimension of at least 50 feet. Other, less extensive shoots lie on the north side of the intermediate zone and have been mined by means of the Upper pit, Main shaft, and associated workings. Most of the shoots dip steeply and plunge moderately west, but where the structure of the dike is complicated by branches they may flatten in dip, as in the old stope at the foot of the Main shaft. Bulges, constrictions, and local reversals of plunge are also common in such places.

Though superficially conformable with the zone structures, the mica shoots plainly transect primary constituents of the pegmatite in many places. Thin albite-mica dikes are fracture fillings that cut all zones, and larger book-mica concentrations 2 to 6 feet wide transect giant crystals of microcline in the North incline and at several places in the New incline. On a still larger scale, mica-albite pegmatite cuts entirely across inner zones so that shoots on the north and south sides of the dike are joined in several places. One of these "diagonal shoots" lies near the lower end of the New incline (Plate 22). The mining of such shoots has resulted in extremely irregular workings (see, for example, the relative positions of the Upper and New inclines in sections A-A′, B-B′, and C-C′, Plate 22). The North incline has been excavated in a mica concentration along the south side of a body of extremely coarse microcline-quartz pegmatite that probably is the central unit in a branch dike. In the drift to the east, however, the same shoot lies on the north side of the inner intermediate zone of the main dike, and is separated from the north wall of the dike by only a few feet of wall-zone material (plan, Plate 22). The proportions of mica in several typical shoots, as estimated from exposed faces, are listed in Table 15.

The mica is light green and moderately hard. The largest books are marked by "A" structure, but flat material can be trimmed from portions between the two sets of reeves. Moreover, the reeves are not present in all the layers of most books, so that full-size sheet material can be obtained by careful rifting. Many of the books are 5 feet or more in diameter, and average about 12 inches in the largest and richest shoots. Trimmed sheets 12 by 15 inches have been obtained from the best books. Most of the mica, however, occurs as irregularly intergrown masses that are marred by wedging, ruling, haircracks, or herringbone structure. Scattered black specks are present in a few of the books.

TABLE 15. MICA IN FACES, GLOBE DEPOSIT

Location	Area of face (square feet)	% mica in face (by volume)
New incline:		
Back between crosscuts	340	26
Back below second crosscut	175	19
Breast, deepened part of incline (October 1944)	38	22
Breast, deepened part of incline (November 1944)	36	20
	Average	22
	Weighted average	23
North incline:		
Breast (November 1944)	42	11
Back adjacent to breast	87	14
Back near junction with crosscut	62	9
	Average	11
	Weighted average	12
Other workings:		
Upper incline, back	120	15
Back of stope from base of Main shaft	210	12
Back of stope extending east from upper part of New incline	90	14
Back of drift from 25-foot winze	62	9
Back of Old incline	120	14
Back of north stope from Old incline	25	20
	Average	14
	Weighted average	13

RECENT OPERATIONS AND FUTURE POSSIBILITIES

During the driving of the North incline and the deepening of the New incline, nearly all the mined material was hauled to the surface, where a record of recovered mica and cars of muck was maintained by Alberto Trujillo, mine superintendent. Over periods of several months the average proportion of mica taken from the pegmatite in the North incline was about 8 percent and that from pegmatite in the New incline slightly less than 15 percent. Inasmuch as an appreciable fraction of the total mica in the pegmatite was left in the muck as fines and as small books in large rock masses, these figures are compatible with the estimates of mica in the faces of the workings (see Table 15). The mica taken from the mine during the present wartime period has been roughly sorted at the portal and 70 to 80 percent of it has been sacked for shipment as scrap. The remaining books, which contain flat material of usable size, are thumb trimmed, rifted, and knife trimmed in La Madera. Results of these operations are shown in Table 16.

The rich concentrations of mica in the Globe pegmatite have permitted successful underground operations for scrap. Attempts to recover by-product sheet and punch material have been moderately successful, even during periods of low prices, owing in part to low labor costs for mining and mica preparation. It seems likely that future operations can be continued as long as additional mica-rich material is available, although with the extension of mining to deeper levels greater care may be needed in planning for haulage, ventilation, and drainage. Recent experience has demonstrated that attempts to rob the older, shallow workings rarely are profitable. According to Mr. Trujillo, from whom much specific information concerning the development of the deposit was obtained, its shallower parts are honeycombed

TABLE 16. OPERATIONS FOR STRATEGIC-GRADE MICA IN NEW INCLINE AND CONNECTED WORKINGS, GLOBE MINE

Proportion of rough-selected mine-run mica in total mine-run mica	20 -30 %
Proportion of prepared strategic-grade mica in rough-selected mine-run mica	1 - 1.5%
Proportion of prepared strategic-grade mica recovered from total mine-run mica	0.3%
Approximate value of recovered mine-run mica per ton [a]	$51.55
Proportion of sheet and punch mica said to be recoverable from mine-run mica	5 -10 %

[a] Based on prices of $15.60 per ton for scrap and $6 per pound for prepared strategic-grade mica.

with irregular workings and for all practical purposes are mined out. Workings other than those shown in Plate 22 may be present to depths of 50 feet or more.

The ground along the footwall of the inner intermediate zone and beneath the floor of the New incline, especially its lower two-thirds, offers good possibilities for future production. The down-plunge continuation of this mica shoot should contain substantial reserves. Although the shoot probably is truncated by the main diagonal fault, this fault should be found progressively farther west as mining is carried deeper. The mica concentration on the north side of the main dike opposite the lower half of the New incline can be developed further. Mining down its plunge was started a few years ago, but present pumping facilities are not adequate to handle the water from this deepest portion of the mine. The rate of water accumulation, however, is slow. The North incline can be extended and deepened along much of its present length. It lies near the south side of a branch dike and may be near its crest. Deeper exploration in this part of the deposit probably offers the best possibilities for development of additional mica shoots. Crosscuts could be driven north from the incline to determine whether another mica concentration is present on the north side of the branch pegmatite at this level.

BIG BUG NO. 3 DEPOSIT

A shallow incline and several small cuts have been sunk in a microcline-rich pegmatite dike about 600 feet south-southwest of the Globe mine. This dike, the Big Bug No. 3 (61, Plate 1), lies along the rim of Alamos Canyon immediately west of an old road. It trends N. 75° - 85° E. and dips steeply north. It is 5 to 14 feet in outcrop breadth at its east end, and it thickens westward. Most of the pegmatite is a coarse-grained aggregate of microcline and quartz with minor albite and mica. A discontinuous quartz mass forms a core near the east end of the dike, and farther west is an intermediate zone of blocky microcline. The wall-zone pegmatite is rich in albite where it is in contact with the core. Accessory minerals are garnet, fluorite, beryl, and monazite.

The mica occurs as scattered small books along the margins of the dike and somewhat larger, tangled masses of "A" material against the core. The average size of all books is 3 by 3 inches or less. The mineral is green and rather soft. Ruling, warping, breaks, and intergrowths of silica and albite are the chief imperfections. The commercial possibilities of the deposit are poor.

CARMELITA DEPOSIT

The Carmelita deposit (62, Plate 1) comprises several pegmatite dikes that are exposed on the west side of Alamos Canyon in the SW¼ NE¼ sec. 36, T.26N., R.8E. They lie about half a mile south-southwest of the Globe mine, and are connected with the Globe road by a short ungraded automobile trail. The deposit, owned by Frank Gallegos of La Madera, is said to have been prospected many years ago, but the first mining was done about 1923. Substantial quantities of sheet, punch, and scrap mica were obtained, chiefly from workings in the south dike near the canyon bottom. In 1943 the Rocky Mountain Mica Company of Santa Fe opened up the north dike, but small-scale operations yielded only a few pounds of strategic mica and several tons of scrap.

The most recent opening is a cut made in a large cliff-like pegmatite outcrop on the west side of the canyon bottom. The dike is 10 to 22 feet thick. It trends N. 80° W. and dips very steeply north. It plunges beneath the surface 75 feet west of the cut, but can be traced across the canyon for several hundred feet to the east. The country rock is micaceous quartzite whose foliation strikes N. 65° W. and dips 40° SSW. The pegmatite, which is not distinctly zoned, is rich in white, flesh-colored, and green microcline. Much of this feldspar contains crudely oriented rods and spindles of quartz. Albite is distributed irregularly through the dike along fractures, but is most abundant near the walls.

Pale yellow-green beryl, cinnamon-colored garnet, and green fluorite occur near the margins of the dike as irregular masses. Columbite, samarskite, and monazite, which are associated with albite, are more widespread. The mica is pale green and soft, and occurs in books 3 by 4 inches in average size. Much of it is heavily stained with black spots and brown to black lattice-like intergrowths of iron oxides. All is badly ruled, and haircracks, warps, and irregular breaks are common. This part of the deposit shows little commercial promise.

A second dike of comparable thickness lies north and west of the cut and can be traced westward up the hill slope for about 600 feet. As exposed in low ledges and several shallow pits, the pegmatite consists chiefly of coarsely intergrown microcline and quartz with an irregular, poorly defined central zone of blocky microcline. Pod-like masses of quartz 2 to 12 feet in maximum dimension may represent a discontinuous core. Several other sub-parallel dikes are arranged en echelon on the same slope, and form a pegmatite belt 200 to 450 feet wide. All are microcline-rich, and appear to contain discontinuous quartz cores at and near their eastern ends. The enclosing country rock is quartz-mica schist in which a well-developed foliation trends northwest and dips gently west. Many large blocks of float material have been derived from ledges of thick-bedded vitreous quartzite farther up the slope.

All the pegmatites are mildly albitized and contain small but rich shoots of plagioclase and mica near their walls and along the margins of quartz masses. The largest shoot, about 15 feet in exposed length and 3 feet thick, has been worked by means of a short incline. The amount of recoverable mica in these pegmatites is small and its quality poor.

The south dike, which is about 300 feet south of the recent cut, has been mined near the canyon bottom by both surface and underground methods. A large irregular stope was reached through a north-trending adit, but is now so badly caved that it appears as a continuation of an overlying open cut. Other cuts are present on the hillside to the west. The dike trends N. 85° W. and dips steeply north. It appears to range in thickness from 4 to more than 15 feet.

A core of massive quartz with a few scattered crystals of microcline is exposed in and near the workings, which are in the eastern third of the dike. An intermediate zone of coarse blocky microcline occupies a central position farther west, although discontinuous masses of the core are present at least 80 feet west of the workings. Flanking these inner units is a wall zone of coarse microcline-quartz pegmatite that has been thoroughly albitized. About 100 feet west of the workings the dike tapers abruptly and consists almost wholly of wall-zone material. A fine-grained microcline-rich border zone can be seen in a few outcrops. Accessory minerals are garnet, fluorite, beryl, columbite, samarskite, and bismutite.

Concentrations of small books of scrap mica occur along the walls of the dike, especially near its east end, and richer concentrations of larger books are present along the margins of the core and along fractures within the core. The average size of these books is 4 by 5 inches, but a few are as much as 10 by 16 inches. The mica is light to medium green, hard, and free-splitting. Most is "flat-A" that is ruled and locally broken. Flat ribbons ¾ inch to 2 inches wide are common. A few books are lightly spotted, but many would yield clear sheet mica as large as 3 by 4 inches. Although the present workings are in poor condition, there are fair possibilities for additional small-scale production of sheet and punch mica.

GUADALUPE DEPOSIT

A group of mich-rich pegmatite dikes that are exposed on the east side of Alamos Canyon in the NE¼ SE¼ sec. 36, T.26N., R.8E., constitutes the Guadalupe deposit (63, Plate 1). The property is controlled by H. S. Coulter of La Madera and associates, who have constructed a camp and have improved an old access road that connects the deposit with the Globe road 0.3 mile to the northeast. Large-scale operations for scrap mica are contemplated, presumably in six well-exposed sub-parallel dikes that were worked intermittently during the period 1920-1935. The old workings consist of at least fifteen cuts, two shallow pits, and several small stopes.

The dikes, which trend N. 65° - 85° W. and dip steeply north, are 3 to 20 feet thick. Several plunge west-northwest at moderate angles. All consist chiefly of coarse microcline-quartz pegmatite with minor albite and mica. Discontinuous cores, comprising pods of massive quartz, are most abundant in the eastern parts of the dikes. Farther west a rude zoning in microcline-quartz pegmatite is represented by an increase in the proportion of interstitial quartz from the walls inward. Coarse graphic granite occurs in most of the pegmatites and is well exposed in a small cut immediately north-northeast of the camp. Garnet and fluorite are abundant near the dike margins, and beryl, columbite, samarskite, monazite, and bismutite are minor accessory minerals.

Mica occurs mostly as small books with albite in concentrations near the walls of the dikes and along the margins of the quartz masses. Few of these concentrations are rich or extensive. Ruling, breaks, warping, and irregular intergrowths of two or more books are so common that little sheet or punch material could be recovered.

The most promising dike is immediately south of the camp. It trends N. 70° W., dips steeply north-northeast, and is 15 to 20 feet thick. It is well exposed in an old slot-like hanging-wall cut that is 30 feet long, 6 to 10 feet wide, and 14 feet in maximum depth, as well as in a smaller but deeper cut 50 feet to the east. A partially albitized wall zone surrounds a core of massive quartz that contains abundant well-formed crystals of microcline. Narrow but rich concentrations of mica occur at the margins of the core, particularly on its hanging-wall side. The books are 2 by 3 inches in average size and about 10 by 12 inches in maximum size. They are severely ruled, buckled, and broken, but some would yield small flat pieces of clear light green mica. This pegmatite might support small-scale operations for scrap and punch material.

OUTLYING MICA DEPOSITS

DEPOSITS BETWEEN LA JARITA CANYON AND LAS TABLAS

Numerous pegmatite dikes crop out in the very rough country 1 to 1.2 miles south-southwest of Las Tablas. These appear chiefly in the NE¼ NE¼ sec. 36, T.27N., R.8E., and in the SW¼ sec. 30, T.27N., R.9E. They are east of the broad bend in La Jarita Canyon and can be reached from that canyon by trail or from Las Tablas over the Hoyt wagon road (Plate 1). The dikes are large, with outcrop breadths of 10 feet or more and traceable lengths of 100 feet or more. Some trend west and dip steeply north to vertical, and others trend north-northwest with moderate westerly dips. Most of the latter are conformable with the country rock, a typical platy micaceous quartzite.

The pegmatites are coarse-grained and consist mainly of microcline and quartz with minor albite. Most of them, although not markedly zoned, coarsen conspicuously inward from their margins. Local pod-like masses are relatively rich in quartz. Small books of mica are scattered through these pods, and larger books occur along their margins. The pods have been opened up by means of many shallow prospect pits. Garnet and fluorite are present in most of the dikes, and crudely formed crystals of pale green beryl are present near the borders of several. None of these pegmatites appears to contain large enough concentrations of mica or other minerals to warrant more than small-scale prospecting.

LA PALOMA DEPOSIT

The La Paloma mine (64, Plate 1) is 3.8 airline miles south-southwest of Petaca. It lies in gently rolling country at an altitude of about 7,485 feet, and is near the center of the north edge of sec. 30, T.26N., R.9E. It can be reached over 1.8 miles of poor but passable road that extends west from State Highway 111 at a point 3 miles south of Petaca.

The deposit was discovered about 1910, but most of the mica produced from it was mined during the period 1921-1927. It is held under claim by Frank Gallegos of La Madera, and was most recently operated under lease by the Rocky Mountain Mica Company during the period July-October, 1943. Mining was done under the direction of Elwood Romney of Santa Fe. Detailed production figures for the earlier periods of operation are not available, but more than 2,500 pounds of sheet and punch mica and at least 75 tons of scrap are said to have been obtained. The last operation yielded about 30 pounds of strategic-grade sheet mica and 8 tons of by-product scrap.

The recent workings include the Romney shaft (50 feet deep), a 50-foot crosscut, and an irregular footwall drift about 90 feet long (see Plate 23). An old shaft, now caved and muck-filled, is about 30 feet north of the Romney shaft; it once gave access to a very irregular stope at about the 20-foot level. One finger of this stope was encountered in the sinking of the present shaft, and the elongated depression 17 feet north-northeast of the shaft is a result of surface collapse into another upward-reaching finger. A deeper stope at about the 40-foot level was reached by means of a short winze a few feet northeast of the old shaft. This stope, which is in the hanging-wall portion of the pegmatite, extends 80 feet west-northwest and at least 30 feet east from the winze. Its average width is about 10 feet. As most of the old workings are no longer accessible, their distribution is not precisely known.

The La Paloma pegmatite occurs in micaceous quartzite with interlayered quartzose schist. The foliation of these rocks, which are exposed along the bottom and sides of a small draw, strikes uniformly northwest and dips rather steeply southwest. Minor folds and crenulations plunge moderately northwest, whereas rows of mica flakes and a second set of crenulations plunge gently south-southeast. In the areas flanking the draw the quartzite and schist are veneered by lava flows and by coarse sedimentary beds that are rich in rounded fragments of rhyolite, felsite, and other volcanic rocks.

Five pegmatite dikes are exposed in the mapped area. The largest of these, the only one that has been worked, is 18 to 30 feet in outcrop breadth and can be traced for a distance of 260 feet between points where it is covered by younger rocks (Plate 23). It trends west-northwest and dips moderately to steeply north-northeast. The other dikes are 1 foot to 12 feet thick, and are exposed to the southwest. All are sub-parallel, lie 30 to 65 feet apart, trend west-northwest, and dip steeply south-southwest. They cut across the foliation of the country rock at small but distinct angles. At least two of these dikes pinch out to the southeast. From a third, long quartz-rich branches extend into the country rock at acute angles.

In the larger pegmatite masses are many xenoliths of country rock that generally are rich in fine-grained pale green muscovite, and locally in biotite as well. Although many of the pegmatite contacts are sharp, and obvious contact effects are lacking, the country rock has been considerably disturbed and altered along others. The chief effects appear to have been the introduction of feldspar and abundant mica, with preferential "soaking" of some of the quartzite layers with pegmatitic material. Irregular, gradational contacts between pegmatite and country rock are most common along the footwalls of the largest dikes (see section B-B′), although the hanging-wall contact of the main dike in the old stope at the 40-foot level is marked by many sharp, tightly compressed rolls with amplitudes ranging from 1 to 7 feet (see section A-A′).

The pegmatites consist chiefly of medium- to coarse-grained intergrowths of microcline, quartz, albite, and muscovite. Most contacts are marked by thin selvages of pale green muscovite, but the borders of the pegmatite 100 feet southwest of the main dike consist of massive quartz with minor feldspar and mica. In the larger dikes are cores of massive quartz, which are surrounded by coarse intergrowths of microcline and quartz. Large bodies of massive quartz are exposed in the main dike east of the Romney shaft and in the mine workings to the northwest (Plate 23). Their distribution suggests a gentle to moderate northwesterly plunge that is consistent with the more local and detailed plunges of other zones in the main dike.

Microcline, the most abundant mineral, occurs as large crystals and masses that are flesh colored, white, or green. Some are distinctly color-zoned. Irregular pods, spindles, and rods of smoky quartz are included in much of the microcline and have a crude graphic orientation. The larger masses of quartz are white, colorless, or faintly smoky, and extremely dark smoky quartz is present in several thin crosscutting veins. Most of the albite is white lustrous coarse cleavelandite. The remainder forms fine-grained sugary crystalline aggregates. Albite fills fractures in microcline, quartz, and locally in mica, and appears to have corroded and partially replaced these minerals.

Beryl occurs as pale yellowish green subhedra in quartz-rich pegmatite southwest of the main dike. Garnet, probably the spessartite variety, forms crumbly pale cinnamon-colored masses ¼ inch to 19 inches in diameter. Much of it has been altered to chlorite and is covered with a black manganese stain. It is most common along the margins of quartz masses. Pale green fluorite occurs as crumbly crystals and crystalline aggregates near the borders of the dikes. Lustrous brownish black samarskite in masses as much as ½ inch in diameter, black crumbly tablets of columbite, and flattened crystals of reddish brown monazite occur in the quartz- and albite-rich parts of the pegmatite. Where the columbite, samarskite, and monazite occur in feldspar, they are surrounded by an irregular zone of reddish brown stain. Bismutite is present in quartz as gray, yellow, or bright orange films and small rod-like masses. In a few places it is accompanied by sulfides.

Muscovite occurs as pale green to dark green books ½ inch to 2 feet in diameter. The average diameter of cleavage faces is

TABLE 17. MICA IN FACES, LA PALOMA MINE

Location	Area of face (square feet)	% mica in face (by volume)
Footwall:		
Back at junction of crosscut and drift	23	2.5
Back between footwall and quartz mass; drift, 40 feet from crosscut	32	5.1
Back near raise into old hanging-wall stope	27	3.7
Heading (October 2, 1943)	24	6.0
	Average	4.3
	Weighted average	4.4
Hanging wall:		
Pillar near old winze	11	12.4
South edge of stope, 20 feet east of raise	28	14.5
North edge of stope, opposite raise	44	15.2
South edge of stope, near raise	21	12.5
Heading (October 2, 1943)	18	9.6
	Average	12.8
	Weighted average	13.5

approximately 5 inches, and about 5 percent of the books are 12 inches or more in diameter. Much of the mica tends to be soft, particularly in the footwall portion of the pegmatite. Though not badly ruled, it contains abundant cracks and breaks, and commonly is wavy. Some books are marked by "A" structure, and about 15 percent contain sparse reddish to black mineral spots. Intergrowths of silica and albite are common.

All the mica obtained during 1943 was mined from the footwall portion of the main dike, where the books are concentrated along the contact, around the margins of country-rock inclusions, and to a minor extent along the margins of local quartz masses. This mica is of poor quality, chiefly because of softness, waviness, and breaks, and concentrations of it are rather sparse. The mica obtained during earlier operations was taken from much richer shoots along the hanging wall. It was not until the recent drift was broken through into the old stope at the 40-foot level that some of the old workings became accessible and comparison of the footwall and hanging-wall shoots became possible. The hanging-wall mica appears to be distinctly harder and flatter, and is much less broken. Lack of old production records precludes comparison of the quantity of mica per ton of pegmatite mined, but comparisons of representative faces in mica-bearing parts of the pegmatite are summarized in Table 17.

All the book mica is intimately associated with albite feldspar, and the richest concentrations are in the most thoroughly albitized portions of the pegmatite. Albite and mica are most abundant where the dike flattens in dip, but both minerals are irregularly scattered through the outer zones of the pegmatite, where its dip is steeper. The measurement of the recent workings and analysis of the quantities of scrap mica and sheet mica produced permit computation of the richness of the footwall portion of the main pegmatite, as shown in Table 18. The hanging-wall portion may be three to five times as rich.

In September and October 1943 the footwall drift was ex-

TABLE 18. OPERATIONS IN FOOTWALL DRIFT, LA PALOMA MINE

Volume of rock mined (calculated)	5,400 cu. ft.
Weight of rock mined (calculated)	477 tons
Weight of pegmatite mined (estimated)	265 tons
Mine-run mica recovered	5.6 tons
Total mica removed [a]	7.0 tons
Proportion of mica in pegmatite mined	2.4 %
Prepared strategic-grade mica recovered	30 pounds
Proportion of prepared strategic-grade mica in mine-run mica	0.2 %

[a] Based on assumption that about 20% of total mica was discarded on the dump as fines and as small blocks in large rock masses.

tended westward about 8 feet from the position shown on the map. The ground between this drift and the old hanging-wall stope was removed to form a large opening. The present heading is thus a composite of the old west heading in the stope and a much later lower face. The full thickness of the pegmatite is exposed and the hanging-wall mica shoot can be seen near the back. Both contacts of the pegmatite are extremely irregular, but the dike appears to be about 10 feet thick.

The more westerly and down-dip parts of the mica-rich hanging-wall zone, which is 1½ to 4 feet thick, appear to offer the best possibility for future production. As the dike appears to be thinning down the dip, the continuation of the mica shoots in this direction is difficult to predict. It seems probable that the richest parts of the shoots plunge northwest at moderate angles. Further development of the mine could proceed from the present heading.

EL FLOTO DEPOSIT

The El Floto pegmatite is in the NE¼ SW¼ sec. 30, T.26N., R.9E., at a point 0.6 mile south of the La Paloma mine and 0.8 mile northeast of the Globe mine. It can be reached from the former over a road and short trail, and from the latter over a wagon road (see Plate 1). The deposit is owned by Frank

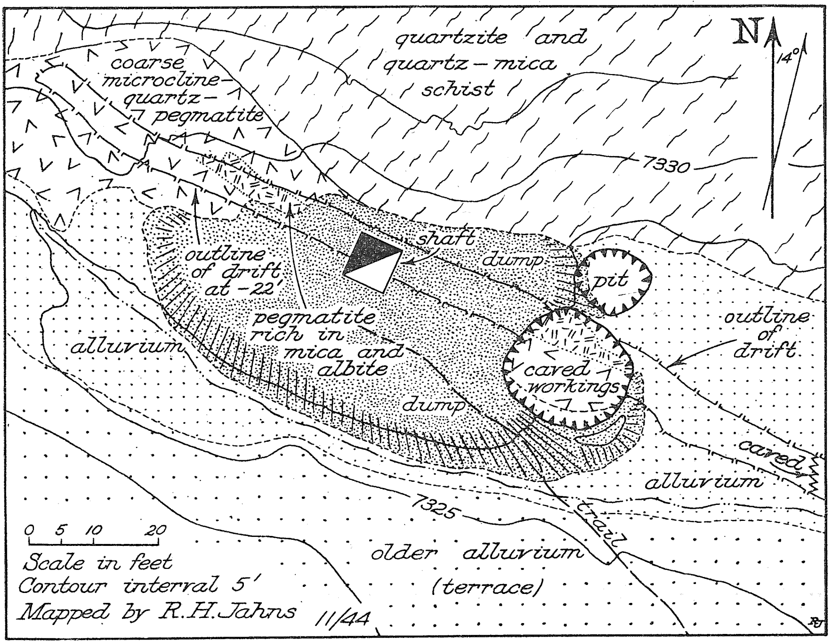

FIGURE 24. Geologic map of the El Floto deposit.

Gallegos of La Madera. The workings, which are in the bottom of a shallow canyon, consist of a 24-foot shaft, drifts from the bottom of this shaft that amount to at least 140 linear feet, and a flooded winze that slopes from the floor of the main drift at a point about 10 feet from the base of the shaft.

Most of the pegmatite is covered by alluvium and dump material, but it appears to be a rather large dike that trends west-northwest and dips very steeply north-northeast (Figure 24). It consists of coarse blocky flesh-colored microcline with minor quartz and albite. It is not conspicuously zoned, but its inner parts appear to be coarser-grained and richer in microcline than its margins. A poorly defined shoot of albite and mica, 1 foot to 4 feet thick, is exposed near the north wall of the pegmatite. This shoot, which contains most of the recoverable mica in the deposit, appears to have been controlled by a fracture or set of closely spaced fractures. It was mined in both directions from the shaft by drifts at the 22-foot level. As shown by the surface and underground relations, its crest plunges gently west-northwest. Its keel is reported to have been encountered in the workings southeast of the shaft, but these are now caved and inaccessible. Beryl, garnet, fluorite, columbite, monazite, and samarskite were observed on the dump, and most appear to have occurred in the albite-mica zone.

The mica books are 2 or 3 inches in average diameter. The mineral is light green and fairly hard, but all the books seen were very badly ruled. Little material of strategic grade, even of punch size, could be obtained from the deposit, but the streak that was worked appears to have been the basis for a satisfactory scrap operation. The richest concentrations were near the keel of the plunging shoot, but the workings in that part of the deposit are so shallow that they have been filled by the caving of overlying weathered pegmatite and loose alluvium of the canyon bottom.

A second microcline-rich dike crops out about 75 feet up the slope to the northeast. It has been explored by means of several small pits, but little mica has been exposed. This dike joins the El Floto pegmatite in the canyon bottom 180 feet west of the shaft to form a dike 75 feet to 90 feet in outcrop breadth. It can be traced along its strike to a point at least 650 feet from the shaft, and is well exposed in large outcrops and in three small pits. The size of its constituent microcline crystals appears to increase progressively toward the west, and the amount of mica diminishes in the same direction.

DEPOSITS WEST AND NORTHWEST OF SERVILLETA PLAZA

Several pegmatites and many quartz veins occur west and northwest of Servilleta Plaza in an area in which pre-Cambrian rocks form hills that project through Tertiary volcanic and sedimentary rocks and are exposed in the bottoms of canyons that have been cut through the younger rocks. Most of the pre-Cambrian terrane is light gray platy to schistose micaceous quartzite. Its foliation, which strikes north to north-northwest with moderate to gentle westerly dips, is much distorted in the vicinity of the pegmatite bodies.

AZTEC DEPOSIT

The Aztec deposit (66, Plate 1) is on a steep east slope in the SW¼ NE¼ sec. 32, T.26N., R.9E. It lies about 300 feet west of the La Madera-Petaca road at a point 1.4 miles north of its junction with the road to the Globe mine. As exposed in a small cut, a 5- to 7-foot pegmatite dike trends N. 70° W. and dips about 85° SSW. It is rich in coarse red microcline, some of which has been corroded by albite. Quartz occurs as small irregular masses interstitial to the microcline, and locally as spindles and rod-shaped masses within the potash feldspar to form a crude graphic granite. Garnet and fluorite occur as small crystals near the borders of the dike. A little mica is also present along the walls. It is yellowish green, soft, and badly broken. The deposit is of little commercial interest.

PENO BLANCO DEPOSIT

The Peno Blanco deposit (67, Plate 1), which occupies a well-defined ridge at the east edge of the SE¼ sec. 32, T.26N., R.9E., can be reached over 0.35 mile of very poor road that extends eastward from State Highway 111 at a point 0.85 mile north-northeast of the Globe road junction. The pegmatite, a dike that trends N. 70° - 80° W., is exposed in many outcrops, in several closely spaced shallow cuts, and in three deeper pits near its eastern end. It is 1 foot to 18 feet thick and dips south at steep angles. The workings are distributed over a distance of 300 feet along the strike.

The pegmatite is rich in medium- to coarse-grained deeply flesh-colored microcline. No quartz core is present, but the proportion of interstitial quartz is greater in the central parts of the dike than elsewhere. Moderate quantities of albite are present, especially near the margins of the body. The accessory minerals are fluorite, highly altered garnet, and minor columbite and monazite. No beryl was observed, but its occurrence has been reported.

Muscovite is present along the walls of the dike as well as in quartz-rich portions of its interior. It is light green and soft, and tends to occur in lumpy masses of wedged and tangled books. Those that are flat are small and are badly ruled, reeved, and broken. Several books a foot or more in diameter are exposed in the face of a short incline near the east end of the dike, but none are flat. The mica would be suitable for scrap only, and it is doubtful whether the concentrations are sufficiently rich for a profitable operation.

LAURA CRYSTAL DEPOSIT

The Laura Crystal deposit (68, Plate 1) is at the west edge of the NW¼ sec. 4, T.25N., R.9E. It lies near the bottom of a canyon 1.2 miles due west of Servilleta Plaza, and can be reached over 0.5 mile of poor road that extends southeast from a point on the La Madera-Petaca road south of the turn-off to the Peno Blanco deposit. The pegmatite, a dike that strikes N. 80° E. and dips 60° S., is exposed at intervals for a length of about 400 feet. At its west end, which is about 50 feet from the canyon bottom, a cut 20 feet long, 10 feet wide, and 6 feet deep exposes an 8-foot thickness of pegmatite. Eastward, however, the dike narrows to 3 feet. At its west end it wraps around a septum of country rock to form a small inverted trough that plunges moderately west. The quartzite adjacent to this trough has been selectively impregnated with pegmatitic material to form a thinly layered hybrid rock.

The dike contains a well-defined quartz core that is flanked by a wall zone of coarse-grained microcline-quartz pegmatite. A few large well-formed crystals of microcline are present in the core. A narrow, rather fine-grained microcline-quartz border zone is in sharp contact with the country rock except at the west end of the dike, where gradational contacts are exposed. Garnet crystals, some as much as 8 inches in diameter, are present in the outer zones.

The wall zone is moderately albitized, and distinct concentrations of albite and light to medium green book mica are present around the borders of the quartz core and adjacent to the walls of the dike. The mica is badly ruled, reeved, and bent. Much occurs in "A" books. Ribbons an inch or less wide are common. Neither the concentration of mica nor its quality offers promise for successful future operations.

QUARTZITE DEPOSIT

Several small pegmatite dikes, which crop out on a low hill near the center of sec. 5, T.25N., R.9E., constitute the Quartzite deposit (69, Plate 1). They are immediately east of the junction of State Highway 111 and the Globe road. The country rock, which has been quarried for road material, is typical platy micaceous quartzite. Two of the pegmatites are exposed in the quarry walls, where they trend N. 80° E. to N. 80° W. with steep dips. Others lie on the slopes to the north. All are microcline-rich and none is conspicuously zoned. Albite, mica, and garnet are widespread but minor constituents. The mica is light green, soft, and badly ruled, warped, and broken. Most of the books are small.

HIDDEN TREASURE AREA

HIDDEN TREASURE DEPOSIT

The Hidden Treasure mine (70, Plate 1) is on the south side of a small canyon 1 airline mile east of Ancones. It lies in the NW¼ SE¼ sec. 1, T.25N., R.8E., at an altitude of about 7,450 feet. A poor road approximately 3 miles long connects the deposit with State Highway 111 at the Alamos Canyon-Tusas River junction, which is 1.1 airline miles northeast of La Madera. The mineral rights have been owned by Manuel Griego and more recently by Alberto Trujillo of La Madera. The mine was last operated during the summer and fall of 1943, when several tons of scrap mica was produced.

The pegmatite body of chief interest is a somewhat sinuous dike 390 feet long and about 15 feet in average thickness (see Plate 24). Its general trend is due west, but a large central bulge that reaches a maximum thickness of about 40 feet trends south of west. Most of the workings are in this bulge. The most recent opening is a 50-foot footwall drift. A 25-foot incline from the surface connects with this drift at a point 27 feet from its portal. The hanging wall has been explored by at least three inclines that slope gently west and west-northwest for distances of 15 to 40 feet. All have been partially backfilled and are caved. The other workings comprise nine cuts and shallow pits. Several smaller pegmatites crop out in the immediate vicinity of the mine, but these have not been explored.

The country rock is micaceous quartzite with interlayered mica-impregnated schist. A series of platy quartzite beds forms bold outcrops north and southeast of the mine. The foliation in these rocks, which trends northwest and dips 40° - 55° SW., is much contorted near the margins of the pegmatite bodies. Pegmatite-country rock contacts are relatively sharp, but in most places are fringed by a narrow zone of mica-impregnated material. Quartz veins are abundant. One group consists chiefly of short thin lenses that are conformable with the schistosity of the country rock. A second group includes longer and thicker veins that trend west, dip very steeply, and locally merge into medium-grained microcline-quartz-albite pegmatite along their strike. One of these is well exposed about 70 feet north of the west end of the main dike, another 65 feet north of the east end. Dikes and irregular masses of coarse-grained microcline-quartz-albite pegmatite are also present.

The main pegmatite body dips about 50° N. along its central bulge. The dip steepens on either side of this bulge and passes through the vertical near the ends of the dike. At the ends the dip is steeply south. Relations at the east end, at several outcrops elsewhere along the dike, and in the underground workings show that the entire body, its broad bends, and the minor irregularities along its borders plunge west to west-northwest at angles of 20° -35°. This plunge is generally conformable in direction and degree with the plunge of minor fold axes and other linear elements in the country rock.

The main pegmatite body is sharply and regularly zoned, with a quartz core that occupies its entire length. Giant microcline crystals occur within the quartz at the bulge, and at the west end of the core are small flanking lenses of coarse blocky microcline. A well-defined wall zone once surrounded the core and these lenses, and consisted of microcline and quartz with minor garnet and fluorite. It has been so thoroughly replaced by albite, however, that only remnants of its original constituents remain, and thus it is an excellent example of a zonal pseudomorph. A thin border zone, clearly recognizable in most places, is very rich in biotite and fine-grained muscovite that appear to have been formed in part through reaction with the country rock.

Branches of quartz, which are locally fringed with fine- to medium-grained feldspathic pegmatite, extend from the main dike near its east end. Evidently these once connected with the quartz core, but much of the connecting quartz has been albitized. A layer of ilmenite-bearing quartz is present along at least 140 feet of the hanging-wall contact, and superficially resembles a quartz-rich border zone. Although most critical relations have been obscured by partial albitization of this unit and the adjacent wall zone, it appears to be a late-stage fracture-controlled feature, presumably the result of injection of quartz along the pegmatite contact. It is therefore interpreted as a correlative of the quartz prongs near the east end of the dike and the quartz veins in the country rock.

The albite-microcline ratio in the Hidden Treasure deposit is one of the highest in the district. Besides occurring in the wall zone, albite is present in the quartz core as a fracture-controlled network, and has completely replaced local masses of the quartz. It is white to deep flesh colored, and occurs both as fine-grained sugary aggregates and as coarse cleavelandite. Much of it is veined with films of thin, bright yellow to yellowish green muscovite flakes. The quartz is milky to light gray. The microcline is coarsely perthitic and is white to deep flesh-colored. Both cinnamon-colored garnet and pale green fluorite are common as remnants of the wall zone, and are cut and corroded by albite.

Muscovite, which occurs in the wall-zone pseudomorph, is particularly abundant along the margins of the quartz in the bulge of the dike. Well-defined shoots, which plunge west and west-northwest in accord with the other structures previously noted, are present along both the hanging wall and footwall. The hanging-wall shoot appears to be the richer. The mica is light to dark green, and occurs in books with cleavage faces averaging about 2 by 3 inches. It also occurs in wedged masses as large as 1 by 2 feet; these appear to consist of a number of smaller books interlayered with cleavelandite. Most of the mica is either "A" or has been ruled into narrow ribbons. Many books are reeved and hairlined, and do not split well. They are not stained, but many contain thin films of silica in their cleavage planes. Flattened garnet inclusions have been observed, but are not common.

The quartz in the old workings on the hanging-wall side of the bulge contains many impressions of closely spaced books 8 inches or more in diameter. This mica was nearly flat and little ruled. On the other hand, the footwall workings have yielded material of scrap grade only. Moreover, the appearance of the heading in the drift suggests that the west end of these workings lies above the main footwall shoot. The hanging-wall workings are so inaccessible that little can be foretold concerning the amount and quality of mica as yet unmined. The deposit might yield moderate quantities of scrap mica, especially from the hanging-wall shoot, but an appreciable amount of dead work would be necessary before mining could be resumed. The proportion of recoverable sheet and punch mica would be small.

BIG BUG DEPOSIT

The Big Bug deposit (71, Plate 1) is in the SW¼ SE¼ sec. 1, T.25N., R.8E., and lies about 550 feet southeast of the Hidden Treasure mine. It can be reached over a short road that connects with the Hidden Treasure road. The pegmatite is a dike that trends N. 80° E. and dips north at moderate angles. It cuts quartzite and quartzitic schist whose foliation strikes N. 35° W. and dips about 30° WSW. The pegmatite is exposed at intervals over a strike distance of more than 200 feet, and ranges in outcrop breadth from 10 to 20 feet. It has been opened by means of two cuts, both near its west end. The larger, which is 15 feet long, 10 feet wide, and 7 feet deep, exposes the westward-plunging crest of the dike.

Although the pegmatite is not clearly zoned, a vaguely defined core of white to brick-red microcline and massive white quartz is present. It is flanked by coarse-grained microcline-quartz pegmatite that is moderately albitized. Some of the albite is fine-grained, and some is coarse cleavelandite. Garnet occurs near the walls of the dike as poorly formed crystals as much as 2 inches in diameter. A little fluorite is present, but no beryl or tantalum minerals were noted.

Mica occurs as rather widely scattered "A" books whose maximum diameter is about 8 inches. It is pale green and hard, but the books are severely ruled, cracked, and hairlined. Many are lightly spotted with iron and manganese oxides. None of the mica seen was of good quality, and the concentrations are relatively lean.

ANCON DEPOSIT

In a small canyon about 900 feet southeast of the Hidden Treasure mine and 300 feet northeast of the Hidden Treasure road are two pegmatite dikes that have been opened by means of shallow pits and cuts (72, Plate 1). They lie near the southeast corner of the SW¼ SE¼ sec. 1, T.25N., R.8E. The largest opening is a cut 40 feet long, 4 to 6 feet wide, and 6 to 10 feet deep. This was sunk along the hanging wall of a 10- to 15-foot pegmatite dike that trends N. 80° W. and dips very steeply north. The country rock is thinly foliated quartz-muscovite schist that strikes N. 10° - 20° W. and dips gently westward.

The dike contains a well-defined core of massive gray quartz and crystals of red microcline 3 to 5 feet in diameter. The surrounding wall zone is coarse-grained microcline-quartz pegmatite that has been thoroughly albitized along both its inner and outer edges. Lustrous white plagioclase has entered the potash-feldspar masses along a network of fractures and has replaced the host mineral in widely varying degrees. Excellent examples of partial to complete albitization can be seen in place and on the dumps. The accessory minerals are garnet and fluorite, which are moderately common in the wall zone, and monazite and samarskite, which occur chiefly in albite. A little pale blue-green beryl was found on the dump. The entire dike is transected by prominent vertical joints that trend N. 20° - 30° W.

A well-defined mica shoot is present along the hanging wall of the quartz core. It appears to plunge west at moderate angles. The books, which are 3 to 8 inches in diameter, include much wedge, "A", and tanglesheet material. Most are badly warped and broken. A few books of light green high-quality mica are said to have been recovered by A. C. Bohrnstedt of La Madera during the summer of 1943, when the cut was last worked, but nothing but scrap was seen at the time of the examination.

About 150 feet northwest of the cut is a dike that is 18 feet thick and trends N. 80° W. along the bottom of the canyon. It dips very steeply north. This deposit has been opened by means of two pits and several small shallow cuts. It consists of very coarse aggregates of microcline and subordinate quartz. The material in the central part of the dike is distinctly coarser than that near the edges, but a uniform gradation is present between the two extremes. Some of the microcline and quartz has been albitized along fractures. A little mica is present. The books are small, badly bent, and broken, and are scattered irregularly throughout the pegmatite.

DEPOSITS NORTHEAST OF LA MADERA

SALT LICK DEPOSIT

The Salt Lick deposit (73, Plate 1), which is 2.3 airline miles north-northeast of La Madera, is in the SW¼ SW¼ sec. 8, T.25N., R.9E. It lies immediately southwest of Salt Lick Spring, and is at the lower end of an alluviated valley whose bottom has been severely eroded to form miniature badlands. The deposit is 300 feet southeast of the La Madera-Petaca road. It consists of a pegmatite dike that is 15 to 20 feet thick, trends nearly due west, and dips very steeply south. It is exposed for a distance of about 200 feet along its strike, and has been opened along its footwall by means of five small cuts.

Although the pegmatite is not clearly zoned, its central parts are markedly coarser and richer in potash feldspar than its borders. The entire dike consists of coarse-grained microcline-quartz pegmatite in which small quantities of albite are present. Mica is sparsely distributed, and occurs in small badly ruled books.

PALOMA CANYON DEPOSIT

A pegmatite mass crops out prominently on the very steep east wall of lower Paloma Canyon in the NW¼ SW¼ sec. 17, T.25N., R.9E. (74, Plate 1). It is 1.7 airline miles northeast of La Madera and 0.2 mile east of the La Madera-Petaca road, from which it is clearly visible. The pegmatite, which has the outcrop plan of an elongate pod, strikes approximately N. 85° W., dips steeply south, and plunges west at moderate angles. Although somewhat obscured by volcanic-rich gravels at the top of the slope, its east end appears to be a blunt, quartz-rich keel. The adjacent country rock is dark greenish gray amphibole schist, but typical platy micaceous quartzite crops out not far to the southwest and northeast. Its foliation strikes N. 55° W. and dips 35° - 40° SW.

The pegmatite contains a prominent quartz core with flanking feldspathic material. Both core and wall zone have been extensively albitized. Rosettes and "bursts" of cleavelandite are common. A small pit has been dug in quartz-albite pegmatite near the east end of the dike. A second pit, 20 feet long, 20 feet wide, and 15 feet in maximum depth, is farther down the slope to the west, and exposes the thoroughly albitized wall zone. The dump from this pit obscures the down-slope relations, but no pegmatite is present near the canyon bottom. This may indicate that the plunge of the pegmatite mass is less steep than the slope of the canyon wall.

Garnet and fluorite are present in the replaced wall zone, and are corroded and cut by veinlets of albite. Monazite and columbite occur in the plagioclase as small well-formed tabular crystals. Light to medium yellowish muscovite occurs with the albite on both sides of the core. Much is soft and small, but a few books 8 by 10 inches on their cleavage faces are immediately adjacent to the massive quartz. Most of the mica is severely ruled, bent, and broken. Small quantities of acceptable punch material might be recovered from some of the books, but it would represent an almost negligible portion of the whole. Possibilities for future operation of this deposit are not considered good, chiefly because its bottom may lie not far below the present workings. Moreover, the mica concentrations do not appear to be sufficiently rich to support a scrap operation.

LOWER ALAMOS CANYON DEPOSITS

At the bottom of Alamos Canyon, less than 0.2 mile north of its confluence with the Tusas River Valley, is a small mica deposit that has been opened by means of a 30-foot incline, now partially caved. The deposit is on the east side of the old La Madera-Petaca road (Plate 1), and lies in the SW¼ SE¼ sec. 18, T.25N., R.9E. It is in a strong fault zone, and trends N. 75° E. and dips 75° - 80° N.

The hanging wall of the pegmatite body is in dark gray amphibole schist that strikes north and dips gently west. The footwall is a sill-like contact against schistose quartzite. Most of the contacts are slickensided and show other evidence of fault movement. One near the north side of the incline portal, however, appears to represent a normal irregular intrusion of amphibole schist by pegmatite.

The pegmatite is not perceptibly zoned. It is a medium-grained aggregate of red microcline, white albite, and quartz, with minor garnet, fluorite, and columbite. It is rich in pale green mica, all of which is broken, sheared, and locally even triturated. No sheet or punch material could be obtained from this deposit. Moreover, it occurs in an area that consists of many small fault blocks, hence mining would be difficult and the abrupt truncation of pegmatite by faults or shear zones would be an ever-present possibility.

Approximately 2,000 feet N. 10° E. of the shear-zone deposit, in the SE¼ NE¼ of the same section, are two small sill-like pegmatite bodies. They are exposed in west-draining gullies about 100 feet apart, and are 300 to 400 feet east of the old La Madera-Petaca road. The country rock is platy quartz-mica schist that strikes N. 25° W. and dips 25° - 35° WSW. It is surrounded and overlain by Tertiary volcanic rocks. The sill-like pegmatites, which are 1 foot to 4 feet thick, are medium to coarse aggregates of brick-red microcline, quartz, and lustrous white albite. Minor quantities of pale green fluorite, cinnamon-colored garnet, and yellowish green beryl are also present. A little mica is scattered through the pegmatite, but even the richest concentrations, as exposed in several shallow cuts, are too poor to warrant mining.

OTHER MINERAL DEPOSITS

Deposits of copper, silver, and gold, chiefly in quartz veins and as disseminations in amphibole schist and micaceous quartzite, have been worked in the Tusas River Canyon north and northwest of the Kiawa mine. These are in the extreme southeastern part of the Hopewell-Bromide district, the deposits of which were studied and described by Graton[26] and more recently were summarized by Lasky and Wootton.[27] Little mining has been done for many years.

Molybdenite occurs with pyrite and other sulfides in an albite-rich pegmatite exposed at the bottom of La Jarita Canyon about 0.2 mile south of Poso Spring. Quartz veins with irregularly disseminated small flakes of molybdenite have been prospected in the SE¼ sec. 26, T.27N., R.8E., where they crop out along both sides of an old wagon road (Plate 1) and at several places on the northeast slopes of Kiawa Mountain. None of these occurrences is of more than mineralogic interest.

Platy crystals of ilmenite are abundant in quartz veins and quartz-rich pegmatite in the De Aragon and Sunnyside deposits, as previously described. Attempts have been made to work similar occurrences between Persimmon Peak and the Las Tablas-Vallecitos trail in the east half of sec. 25, T.27N., R.8E.; in the rough country north of Apache Canyon, east of the Keystone-Western deposit, and south and west of Sawmill road; and on the steep east side of the Tusas River Canyon in the north half of sec. 9, T.26N., R.9E. The ilmenite forms plates ½ inch to 8 inches in diameter and 1/32 to 1 inch thick. They are scattered through the quartz without distinct orientation. Many contain columbium, probably in the form of minor intergrown columbite. Intergrowths of magnetite are present in others. None of the deposits examined is of current commercial interest.

Masses of mica-rich schist like those of the Veseley and Sunnyside deposits and those near the Queen, Sandoval, and Apache deposits are abundant in the area between the Lonesome mine and Russian Ranch, as well as in the vicinity of Big Rock. The material consists of mica in small white to pale green flakes and minor intergrown quartz. Irregular veins and pod-like masses of quartz 3 inches to 20 feet in maximum dimension are present in and adjacent to the mica-rich masses. The richest bodies, which consist almost wholly of mica, could be crushed and marketed directly as scrap. Few, however, would yield more

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[26] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 124-133, 1910.

[27] Lasky, S. G., and Wootton, T. P., The metal resources of New Mexico and their economic features: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 7, pp. 87-89, 1933.

than 25 tons of material that could be so simply handled. Fine-grained quartz is an abundant constituent of the larger bodies, and its removal would be necessary. Many other deposits of mica-rich country rock are undoubtedly present in the district, and these will be discovered as prospecting is continued.

A deposit of kyanite near the base of Big Rock was worked by means of a shaft and open cuts in 1928 by Philip S. Hoyt of Van Horn, Texas. Shipments amounting to 1,500 tons were made to a St. Louis firm for calcining and use in high-grade refractories. According to Just[28] ". . . . veins of quartz and kyanite outcrop at this location and kyanite-bearing boulders occur some distance to the east and to the west. . . . Some of the kyanite is of light blue color and in long blades, corresponding to the best market grades. . . . It seems quite likely that more kyanite might be produced from this property." He further notes the occurrence of schist rich in fine-grained white mica. In describing the same deposit, Talmage and Wootton[29] mention the purity of the kyanite and its tendency to break free from the quartz fairly readily. They conclude that other promising areas on the property have not yet been developed.

Another quartz-kyanite deposit is exposed in the canyon of the Rio Vallecitos about a mile south of Vallecitos, but does not appear to be large enough to merit development. Numerous quartz veins on the steep west slope of La Madera Mountain contain specular hematite and fibrous blue to violet dumortierite. Most occur along the sides of two steep gulches near the base of the mountain and about half a mile southeast of La Madera. The deposits are too small to serve as sources of refractory-grade dumortierite, but the mineral might have value as semiprecious ornamental material.

Thin veins of fluorite, which are exposed on both sides of State Highway 111 in secs. 5 and 8, T.25N., R.9E., have been prospected by means of numerous shallow pits and a long tunnel. The fluorite appears to have been formed through hot-spring activity during relatively recent geologic time. Most of it is intimately associated with silica, and the amount of recoverable material is small.

FUTURE OF THE DISTRICT

Most mica mining in the Petaca district was done in accord with the more obvious exposed geologic features of the deposits. Mica shoots were followed downward from their outcrops until mined out or until it became all but impossible to handle the

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[28] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, p. 69, 1937.

[29] Talmage, S. B., and Wootton, T. P., The non-metallic mineral resources of New Mexico and their economic features: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 12, p. 138, 1937.

mined material through the narrow, tortuous workings developed. Not only was little waste rock moved, but much mica was left underground, either in muck or in unmined pegmatite. Recovery of merchantable mica from rock hauled to the portal was far from complete, and Just[30] remarks that "the average dump contains nearly as much mica as was marketed." A large proportion of the waste material was distributed in workings as backfill, much of which now prevents examination of significant faces. It is not entirely clear in most deposits whether past operations were halted because the mica shoot or the pegmatite itself was worked out, or merely because of a change in prices or a local variation in size or proportion of mica books in the shoot. In a summary analysis of this general mode of mining, Just[31] makes the following comments.

> . . . Mining that depends exclusively on exposed shoots is bound to come to an end without uncovering probable near-by reserves that could be easily exploited if their whereabouts could be ascertained. The "gophering" that has been practiced results in workings so tortuous and inconvenient that mining cannot be profitably carried to depths greater than approximately 100 feet below the entrances. Operations have been spasmodic and not consistently profitable. There have been temporary successes based on the mining of rich shoots, but the equivalents of the profits yielded have been expended in prospecting for similar shoots. It is not to be denied that a good deal of mica may yet be mined by methods that have prevailed in the past, but, given prices similar to those at present, the continuance of these methods would yield low wages and little profit, and would handicap the exploitation of the principal reserves that the area undoubtedly contains. Moreover, but few prospects at present offer reasonable encouragement to pursue such operations.

He concludes that some modification of mining methods is the best present hope for profitable exploitation of the pegmatites. Such modification presents attractive possibilities, as demonstrated by the recent stoping operations in the Cribbenville deposit.

Serious problems confront the operator who plans to reopen a mine or to start work on an unmined deposit. Few promising mica shoots are now exposed at the surface and few of the others can be inspected in mine workings. Even partial reopening of many mines would necessitate the removal of tons of backfill. Production records are so fragmentary and past recoveries of mica so low that it is difficult to make an accurate appraisal of future possibilities on the basis of existing operational data. An old map of the Apache mine represents the only known underground survey in the district made prior to the present investigations, and oral descriptions of distribution and dimensions of

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[30] Just, Evan, *op. cit.*, p. 60, 1937.
[31] Just, Evan, *idem*, 1937.

workings are incomplete at best. Additional difficulties arise from the informal and irregular nature of claim ownership. The Globe deposit is in the only patented claim in the district, and mining operations in other deposits have been interrupted from time to time by claim-jumping, violent title disputes, and time-consuming lawsuits, particularly during periods in which economic conditions have been propitious for mining. Such difficulties, which have been numerous and recurrent, have tended to discourage legitimate operators.

Most of these problems, however, are not incapable of solution, and other factors favorable to mining ventures are present as well. Few of the deposits appear to have been worked out, and definite reserves of mica-bearing pegmatite are known to be present in many. Most unfilled workings are in good condition, and the cleaning-out of others might involve relatively little net expense if mica were recovered from the backfill. Although some workings are flooded, most of the water has flowed in from the surface and no difficult pumping problems are to be expected. In the present detailed studies of the deposits, accessible workings have been mapped and data concerning distribution, size, and grade of mica shoots have been accumulated. Guides for prospecting, based on detailed studies of more than a hundred deposits, have been set forth to focus attention on the most promising parts of the most promising deposits. The mica shoots, though irregular and discontinuous in detail, tend to be rather consistent in position and orientation with respect to the shape and structure of the enclosing pegmatite bodies. Large parts of most pegmatites can be eliminated from early consideration as sources of commercial mica.

Most Petaca mica is light green and clear, and hence yields a product of excellent color when ground. In a few deposits mineral stain is present in the books as spots and lattice-like intergrowths, but does not seriously affect the merchantability of the mica as scrap. The proportion of recoverable sheet and punch material from mine-run books is only about 0.5 percent, owing chiefly to reeves, ruling, and tangled intergrowths, but the average proportion of recoverable book mica in the shoots that have been worked is rather high—probably between 9 percent and 12 percent. It is clear that operations must be based on the production of scrap mica, with recovery of clear sheet and punch material and electric mica as by-products. The average value of mined pegmatite probably has been slightly less than $3.00 per ton, although distinctly higher values have obtained for appreciable periods during the working of most large deposits. The average value of mine-run mica probably has been $35.00 per ton or less for all deposits that have been mined, but may have been as much as $65.00 for the largest and richest of these.

The great distance of the district from centers of demand has severely handicapped the shipment of mica for processing, and in general has permitted only the sale of high-quality material. Erection of a mill in or near the district for the separation of scrap mica from material that ordinarily would be discarded on the dump might increase the net value of the mined rock. Moreover, old dumps might be handled, as well as mica-rich backfill that now chokes many mine workings. A mill would further encourage the adoption of low-cost bulk methods of mining. A grinding plant might be operated in conjunction with the mill, and the mica shipped to market areas as fully prepared material. Neither a mill nor a grinding plant should be erected, however, in advance of analysis of all economic factors involved.

As pointed out by Just,[32] the monazite, tantalite-columbite, samarskite, and beryl are distinctly accessory and should not be considered as a basis for exploitation. Recovery as by-products, however, should appreciably increase returns from mining. Such recovery has been applied in the past to coarse material only, but smaller masses of monazite and tantalum minerals might be separated at low cost by mechanical means, possibly by the addition of a simple tabling circuit in a mica-recovery mill. These accessory materials are relatively abundant in the Globe, Fridlund, Alamos, Lonesome, and several other deposits.

The separation and marketing of large lots of feldspar have not been attempted in the district, despite the presence of substantial reserves of high-grade material. Distances to railroad loading points are said to be too great to permit competition with spar produced from Colorado and Arizona deposits. Just[33] has pointed out and discussed possibilities for a mill designed to handle the mica-bearing parts of the pegmatite bodies on a wall-to-wall basis, with recovery and sale of mica, feldspar, accessory minerals, and possibly even quartz. Such a mill is a distinct possibility, but more specific recommendations cannot be made in advance of careful testing and economic analysis. In the meantime it may become feasible to mine microcline feldspar from parts of deposits adjacent to mica shoots, improve its grade by hand cobbing, and ship it away for milling, particularly if demand and prices for such material continue to rise.

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[32] Just, Evan, *op. cit.*, p. 60, 1937.

[33] Just, Evan, *op. cit.*, pp. 61-62, 1937.

OJO CALIENTE DISTRICT

GENERAL FEATURES

The Ojo Caliente district, in Rio Arriba County about 4 miles south of La Madera, occupies an area of approximately 4 square miles in T.24N., R.8E. It lies at altitudes of 6,400 to 6,750 feet between Ojo Caliente Mountain on the west and the Caliente River on the east (Figure 25). Most of the mica deposits are in a small area about 1½ miles north of the hot springs at the village of Ojo Caliente, and are most easily reached over a poor road that extends west from U. S. Highway 285. The district was once served by a narrow-gauge branch line of the Denver and Rio Grande Western Railroad, but the line was abandoned in 1931.

Ojo Caliente Mountain and several of the lower hills to the southeast are underlain by fine-grained gneissic granite. This rock is distinctly pinkish and consists of quartz, orthoclase, and microcline, with minor quantities of albite, muscovite, and biotite. The mica flakes are oriented in distinct foliation that in general trends northeast. In the north half of the district is an older complex of metamorphic rocks. Thinly foliated dark green to bluish black amphibole schist and pale greenish gray to buff quartz-mica schist are the principal rock types. Interlayered with them are vitreous quartzite, buff to dark gray quartz-staurolite and quartz-andalusite schists, and minor kyanite-bearing schist. The foliation of these rocks, much of which is markedly crenulated, trends northeast to east-northeast and dips steeply in the area immediately west of the Caliente River. Farther west its trend swings through north to west-northwest, and moderate to gentle north-northeast dips prevail in the western part of the district. Local variations in attitude are common.

A series of poorly consolidated tuffaceous sandstone and conglomerate beds, which are probably Tertiary in age, were laid down over an irregular surface truncating the igneous and metamorphic rocks. These soft sediments are exposed along the Caliente River and in a broad gullied flat that lies west and northwest of Ojo Caliente. In the area between the mica deposits and the river their base is marked by a series of dark greenish gray to black flows of amygdaloidal basalt. Typical fine-grained buff sands and silts of the Santa Fe formation are exposed on the east side of the river. The geology of these and the other sedimentary and volcanic rocks has been described by Smith[34] and that of the older rocks by Lindgren[35] and Just.[36]

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[34] Smith, H. T. U., Tertiary geology of the Abiquiu quadrangle, New Mexico: Jour. Geol., vol. 46, pp. 933-965, 1938.

[35] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 72, 1910.

[36] Just, Evan, Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 13, pp. 41-48, 1937.

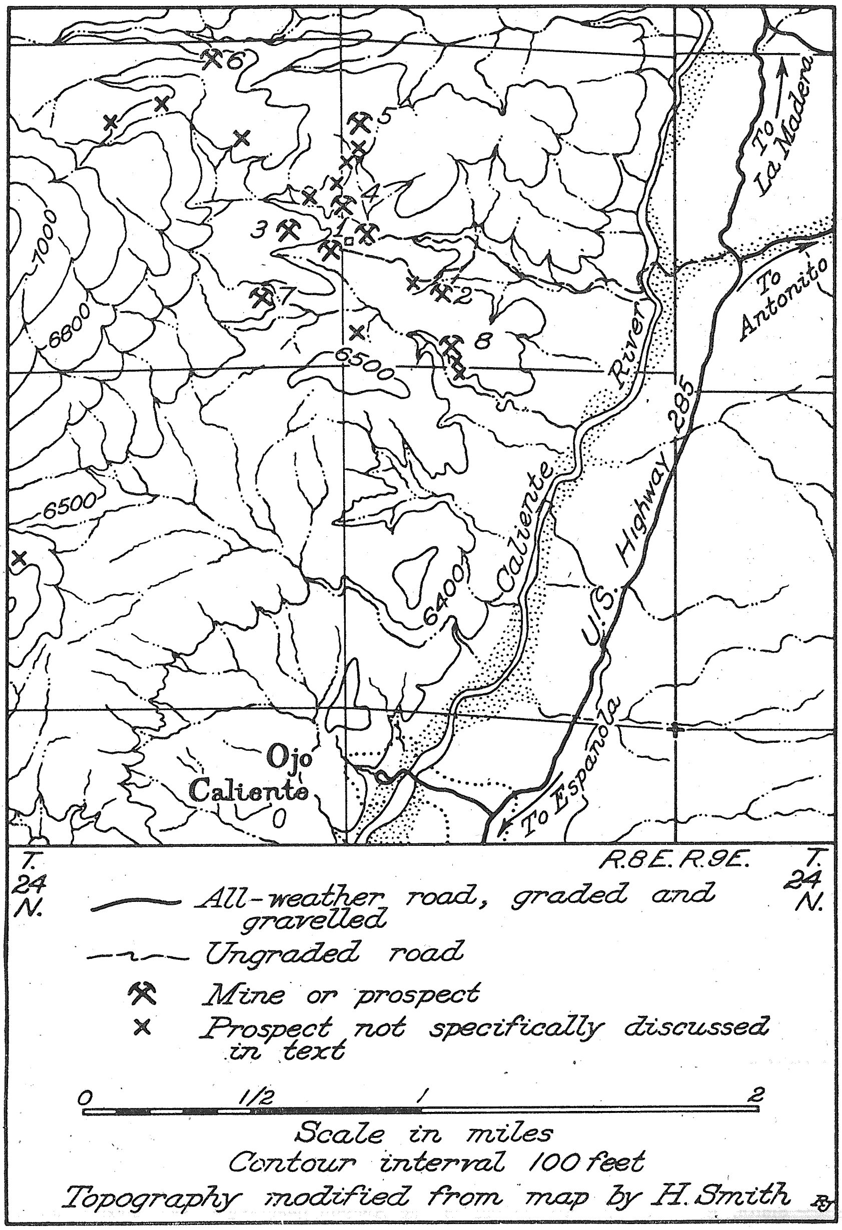

FIGURE 25. Map of the Ojo Caliente district showing locations of mines and prospects.

The pegmatites, most of which occur in the amphibole schist and associated metamorphic rocks, are tabular bodies 25 to 750 feet long and 3 to 65 feet in maximum outcrop breadth. Their ratio of length to thickness is distinctly greater than that of the Petaca pegmatites. Many of these bodies are sill-like. Their general trend is N. 70° W. to N. 70° E., with steep northerly dips. Zonal structure is characteristic. Cores of massive quartz, and intermediate zones of blocky microcline and of massive quartz with large well-formed microcline crystals, are common. The border and wall zones are rich in fine- to moderately coarse-grained feldspars that range from white through shades of flesh to dark brick red. Both microcline and albite are abundant and in some deposits cannot be readily distinguished. The microcline occurs as blocky masses in which perthitic structure is not prominent. The plagioclase, some of which is extremely sodic, also occurs as blocky masses, but each mass is generally an aggregate of thin sharply curving blades. Many of these are finely twinned.

Salmon-colored to wine-red spessartite, pale green to lemon-yellow fluorite, and blue-green to pale yellow beryl are minor but widespread constituents of the wall zones. Beryl also occurs in the cores and other inner zones of several deposits. Columbite and monazite are locally abundant in pegmatite that is rich in brick-red albite. Samarskite, bismutite, and sulfides are most common in quartz-albite pegmatite. As compared with the Petaca deposits, the relative proportions of samarskite and monazite in most of the Ojo Caliente pegmatites is lower, and that of columbite distinctly higher.

Most of the feldspar-rich inner zones contain numerous thin closely spaced layers of quartz and small mica crystals that are roughly conformable with the walls of the containing sills and dikes. They are $^1/_{32}$ to ½ inch thick, and appear to have been injected along fractures during final consolidation of the pegmatite bodies. They transect individual feldspar crystals and crystal boundaries, as well as some zone boundaries. None, however, extends outward far beyond the inner margins of wall zones. Some are composite and plainly demonstrate a recurrence of fracturing, with granulation of the quartz and buckling, ruling, and breaking of previously formed mica books, followed by deposition of additional quartz and mica. Concentrations of albite and large mica books also occur as elongate lenses or "streaks", some of which are as much as 50 feet long and 8 feet thick. Many were fracture-controlled, but the origin and age relations of others are not clear. They occur in all parts of the pegmatites and bear no consistent relation to zonal structures.

The mica is light green to brownish green. It is fairly hard and occurs in books 2 to 3 inches in average diameter and less than ½ inch in average thickness. In the larger pegmatites individual books almost 3 feet in diameter and a foot or more thick have been observed, and some aggregates of books are as much as 6 feet in diameter. "A" structure is less common than in the Petaca mica, but most of the books are so severely ruled, broken, and crushed that the proportion of recoverable sheet and punch material is extremely low. Much of the mica occurs as irregularly intergrown books and contains interlayered films of silica and albite. The proportion of clear material is lower than in the Petaca district, but the stain is rarely heavy.

JOSEPH DEPOSIT

The Joseph deposit (1, Figure 25), which is exposed on the east end of a prominent spur in the NE¼ SE¼ sec. 11, T.24N., R.8E., lies a mile west of the Caliente River at altitudes of 6,420 to 6,540 feet. It was prospected and opened by Antonio Joseph of Ojo Caliente about forty years ago, and was later worked on a large scale by Joseph A. Stanko of Los Angeles, California. Although the production is not accurately known, it must have amounted to several thousand tons of scrap mica. Operations were discontinued in 1932, when rail service from the district was no longer available.

The pegmatite is a large plug-like mass that trends N. 80° - 85° E., dips steeply north, and appears to plunge moderately east. It is 250 feet in exposed length and more than 80 feet in maximum width. From a point near its west end a short branch dike extends southwest. As traced eastward the south wall of the main pegmatite swings northeast and is truncated by a steeply dipping fault that trends north. On the east side of the fault are Tertiary andesite and basalt, but the amount of displacement is not known.

Mining in the east half of the pegmatite has developed a large irregular quarry more than 100 feet long, 50 feet wide, and at least 50 feet in maximum depth. The main opening is slot-like and gives access to drifts, crosscuts, and finger-like rooms that extend southward, westward, and downward. Many of these have caved or are in caving condition. The pegmatite is a very coarse aggregate of red microcline, white to red albite, quartz, and mica. There is little conspicuous zoning, but a crude streakiness is developed on a large scale. Most of the streaks are relatively rich in plagioclase and mica, others in quartz. Accessory minerals are garnet, fluorite, and minor beryl, columbite, samarskite, and bismutite.

Mica occurs throughout the pegmatite, but the largest books are in poorly defined shoots 5 to 8 feet thick and 5 feet to several tens of feet in length. Most of these shoots are approximately conformable with the walls of the pegmatite, but some trend northeast with moderate to steep dips and others are nearly flat.

Their mica content varies widely from place to place, but much of the material mined probably contained at least 12 percent recoverable books. The proportion of mica in the entire pegmatite may be as much as 5 percent. The average diameter of the books is about 6 inches, but many are 24 by 36 inches or larger, and some rosette-like aggregates of large, crumpled books are 4 to 6 feet in diameter. The average thickness of all books is probably an inch or less. The mica is olive green to brownish green and fairly hard. Much of it contains a cloudy brownish stain and some is lightly specked with brown to black iron oxides. "A" structure is present, but the chief defects are ruling, wedging, crumpling, and intergrowths with quartz and albite. A little flat sheet and punch mica of good quality could be obtained through careful preparation, but the proportionate yield would be very low.

Underground operations were conducted through an adit driven west-southwest in Tertiary volcanic rocks from a point near the bottom of the adjacent canyon. About 380 feet from the portal is a moderately dipping depositional contact of andesite and basalt on coarse pegmatite, and at a point 40 feet beyond this contact is the beginning of the mine workings (Figure 26). Branch tunnels extend to the west, west-southwest, and south, and apparently were driven along rich concentrations of mica. The pegmatite footwall was encountered in the two southerly branches (Figure 26), and further mining was done along and near this wall in at least one overhead stope. The dike is more than 80 feet thick at the adit level, and much unmined mica-bearing material probably remains between the underground workings and the surface openings above.

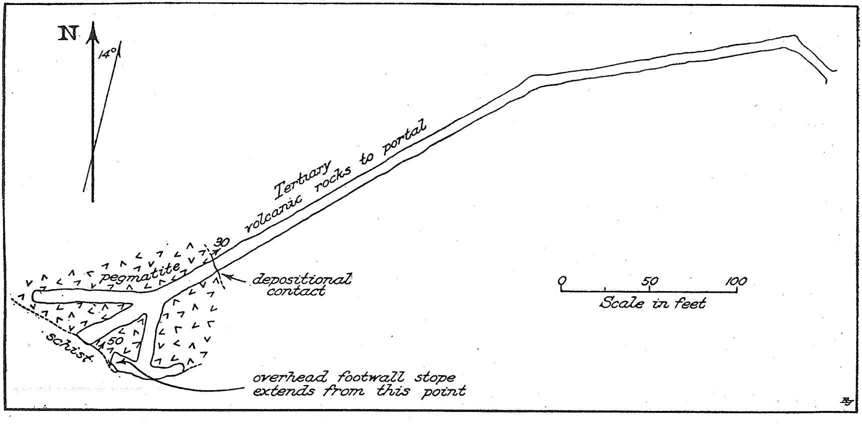

FIGURE 26. Geologic sketch map of main underground workings, Joseph mine.

In the canyon bottom near the portal of the adit there is a 10-foot pegmatite that is rich in red feldspar. It strikes N. 75° - 80° E., dips steeply north, and appears to plunge east-northeast. Small books of mica occur near the walls and along the margins of irregular quartz masses that may represent the pegmatite core. Immediately east of the dike the Tertiary volcanic rocks overlie the country-rock schist.

STAR DEPOSIT

The Star mine (2, Figure 25), which was reopened and operated briefly during the spring of 1944 by A. C. Bohrnstedt of La Madera, lies 0.6 mile west of the Caliente River in the NE¼ SW¼ sec. 12, T.24N., R.8E. It is in a pegmatite dike that trends slightly north of east, dips 55° - 70° north, and crops out high on a steep north slope. The main workings comprise three open cuts, an adit that extends west-southwest and south from a point near the base of the slope and intersects the pegmatite at depth, and small stopes. The highest cut, which is 50 feet long, 8 to 18 feet wide, and 15 feet in maximum depth, exposes a 10-foot thickness of pegmatite. The contacts diverge downward, and inasmuch as the west end of the dike is only a few feet beyond the cut, their attitude may indicate a gentle westward plunge for this part of the body. A second, smaller cut, which lies below and immediately to the north, is choked with muck but appears to have been excavated in schist that overlies the pegmatite. Adjacent on the east is the third cut, which is 20 feet in maximum depth. In it the dike is about 20 feet thick and appears to strike northeast with a gentle northwest dip.

The country rock is interlayered amphibole schist and quartz-mica schist. Garnet and staurolite are abundant in some of the layers. The foliation of these rocks is highly contorted, but it generally strikes east-northeast and dips steeply south-southeast. Local reversals of dip occur near the pegmatite. At the mouth of the adit the metamorphic rocks are overlain by amygdaloidal basalt, above which are conglomerate and tuffaceous sandstone.

The pegmatite body contains a poorly defined core of massive quartz and scattered large microcline crystals. The surrounding wall-zone material consists chiefly of pink to dark brick-red albite, which appears to have partially replaced a coarse-grained aggregate of microcline and quartz. The plagioclase also occurs along fractures in the core. Fluorite and garnet are abundant in the outer parts of the dike, and are commonly corroded by blades of plagioclase. Other accessory minerals are columbite, samarskite, monazite, and beryl. Thin flakes of late-stage, yellowish green mica are present along fractures in these minerals.

Book mica occurs as aggregates of closely spaced, much are an inch in average diameter, are badly ruled, bent, and broken. Other defects are "A" structure, albite intergrowths, and scattered black spots. The mineral is light to medium green in color and is said to yield a product of excellent color when sheared books along the walls of the dike and along the margins of the core. The richest and most extensive concentrations lie along the north or footwall side of the core. The books, which ground. The deposit probably is a potential source of scrap mica, although it might not support large-scale operations.

OTHER DEPOSITS

On the top of a ridge about 700 feet west-northwest of the Joseph quarry there is a quartz-rich pegmatite dike (3, Figure 25) that has been prospected by means of several cuts, the largest of which is 15 feet long, 8 to 12 feet wide, and 8 feet in maximum depth. In general this dike trends east-northeast, dips steeply north-northwest, and plunges east. It contains a prominent core of massive quartz that is flanked by a 1- to 4-foot zone of coarse microcline-albite-quartz pegmatite. From the main cut, which is near the west end of the dike, a quartz-poor branch dike extends northeast with steep southeast dip. The country rock is quartz-mica-andalusite schist, with minor interlayered amphibole- and staurolite-bearing schists. The foliation is locally contorted, especially near the pegmatite, but in general it strikes northeast and dips southeast at moderate angles.

As exposed in the main cut the footwall of the pegmatite dips gently east-northeast, in contrast to its general attitude farther east. A well-defined mica concentration is present along the lower contact of the quartz core. The books are 1½ by 2 inches in average size. They are much broken, warped, and reeved. The mineral is bright green but many of the books are partially clouded by thin films of albite and silica. The concentrations are limited in extent and would yield material of scrap grade only.

Several openings have been made in an irregularly anastomosing group of pegmatites exposed on the north side of the canyon bottom about 700 feet north of the Joseph workings (4, Figure 25). A dike of brick-red feldspar-rich pegmatite that strikes N. 10° W. and dips gently east has been worked during recent months by means of a short tunnel. It appears to occur in a fault zone in amphibole schist, and its walls are very irregular in detail. Immediately east of the tunnel portal the foliation of the country rock strikes N. 65° W. and dips 20° NNE. Elsewhere, however, it trends east-northeast and dips steeply south-southeast. The pegmatite, which is about 8 to 12 feet thick, can be traced north for a distance of 50 feet, whence its strike shifts abruptly to the west. A short distance beyond this bend, it disappears beneath a cover of Tertiary sedimentary rocks. Several thin projections branch east-northeast from its exposed portion.

The pegmatite is a medium-grained aggregate of red microcline, albite, and quartz, with scattered pods of massive quartz in its central part. These pods are probably a discontinuous core, but no other zoning is apparent. Garnet, fluorite, and columbite are minor accessories. Pale green books of mica about 2 inches in average diameter are scattered throughout the rock, but are most abundant along the margins of the quartz masses. They are fairly flat and hard, but are badly ruled, broken, and warped. Most contain scattered black and red spots of iron oxide and intergrown films of silica and albite. Little material other than scrap could be recovered from the mica concentrations.

Sixty feet northeast of the tunnel is an old, long cut in a 3- to 6-foot pegmatite dike that trends N. 80° E. and dips 70° N. At the west end of this opening a thinner branch dike trends N. 50° E. and dips gently north. These pegmatites are probably connected with the dike exposed in the workings to the southwest. They rejoin northeast of the cut to form a large mass 16 feet in outcrop breadth. Both consist of medium- to coarse-grained microcline-albite-quartz pegmatite in which mica books are irregularly scattered. The proportion of mica appears to be less than that in the pegmatite most recently worked.

On the crest of a sharp ridge 0.4 mile north of the Joseph quarry, there is a pegmatite sill (5, Figure 25) that trends N. 75° - 85° W. and dips 65° - 75° N. in thinly foliated quartz-mica schist. It is at least 550 feet long and thickens uniformly westward from a knife edge to a maximum of 12 feet near its end. Several shallow cuts have been sunk along the margins of a well-defined quartz core in the east half of this sill, but little mining has been done except in a cut that lies at the bottom of a gulch near the east end of the sill. This opening is 30 feet long, 10 to 25 feet wide, and 25 feet in maximum depth, and from its face a 20-foot drift extends west-northwest.

The pegmatite wall zone is a coarse aggregate of flesh-colored microcline, white to red albite, and quartz, with scattered small irregular masses of garnet, fluorite, and beryl. Tantalum minerals have been reported. Mica is concentrated chiefly along the quartz core, and to a lesser degree along the walls of the sill. The books are hard and flat, but in general are fairly small. The average size of cleavage pieces is 1½ by 2½ inches. Although ruling and breaks are common, some high-quality punch material could be recovered. Much of the mica, however, is lightly spotted. The deposit might yield satisfactory quantities of scrap material if worked on a small scale near its east end.

A pegmatite dike crops out boldly on a steep south slope about 0.7 mile north-northwest of the Joseph mine (6, Figure 25). It lies at altitudes of 6,660 to 6,730 feet in the NW¼ NE¼ sec. 11, T.24N., R.8E. It trends N. 70° - 80° E., dips 65° - 75° N., and can be traced for several hundred feet along its strike. The country rock, which forms large, cliff-like outcrops, is quartz-mica schist with kyanite-, andalusite-, amphibole-, and local staurolite-bearing layers. Its foliation strikes northwest and dips 45° NE. The pegmatite is best exposed in an irregular cut about 40 feet long and 5 to 20 feet deep, and in several smaller cuts to the west. It is 15 to 20 feet thick in these workings.

The eastern part of the dike contains a quartz core that is flanked by 6 inches to 3 feet of feldspathic wall-zone material. About 150 feet east of the main cut the wall zone tapers out and the core continues as a thin quartz vein. A second, nearly parallel dike lies en echelon and can be traced eastward from a point lower on the slope. The pegmatite in the main cut is quartz-rich, with abundant white, pink, and red albite and microcline. Its central portion is distinctly layered, with thin platy aggregates of quartz and fine-grained mica that apparently were emplaced along fractures. Farther west the pegmatite is thicker and distinctly richer in microcline.

Fluorite is an unusually abundant constituent and occurs near the walls as large masses without crystal form. Many of these are 15 inches or more in maximum dimension. Garnet, samarskite, columbite, monazite, and minor yellowish green beryl are also present. Two small white beryl crystals with pale pink cores were found on the dump. Mica concentrations occur along the walls and in the central part of the dike. Some of the books are very large, having diameters of 14 to 22 inches, but the average diameter of all books is probably not more than 5 inches. Cleavage pieces are light to medium green, hard, and relatively flat. Much of the mica is lightly stained with red to black spots and lattice-like intergrowths of hematite. Other defects are ruling and intergrowths of quartz and albite. Little "A" structure is present. Some sheet material of small size could be obtained from the deposit.

On a low ridge about a quarter of a mile southwest of the Joseph quarry there is a series of quartz pods that trends N. 10° E. (7, Figure 25). Individual pods are 10 to 12 feet long and 6 to 8 feet in maximum thickness. They appear to be pipe-like, with nearly vertical plunges. At their borders are small scattered crystals of feldspar and mica. A thin, relatively continuous pegmatite dike is exposed about 150 feet to the northwest. It strikes N. 45° E. and dips very steeply southeast in approximate conformity with the foliation of the enclosing amphibole schist. A quartz core 6 to 15 inches thick is flanked by 2 to 5 inches of albite-quartz-mica pegmatite. This wall-zone material disappears to the northeast, but the quartz core can be traced farther along its strike as a quartz vein. None of these bodies contains commercially recoverable quantities of mica.

A pegmatite dike that crops out in the canyon bottom about half a mile southeast of the Joseph mine has been worked on a small scale for mica and beryl (8, Figure 25). It trends east-northeast and dips steeply north-northwest. In the walls of a small cut that lies adjacent to the stream bed are large well-formed crystals of microcline and beryl in massive quartz. These three minerals form the core of the dike. The beryl is glassy, and yellowish green to amber in color. It occurs as hexagonal prisms 8 to 78 inches long and ½ inch to 9 inches in diameter. Many are transected by veinlets of quartz and corroded by albite.

Surrounding the core is a wall zone of coarse microcline-quartz pegmatite that has been partially albitized. In this unit are crystals of columbite, samarskite, garnet, fluorite, and beryl. A little mica is present. As traced east-northeast up the hill, the wall zone becomes richer in mica, most of which occurs as relatively small books that are badly ruled and broken. A few shallow pits represent the only attempts to recover this mineral.

Many other pegmatites in the district have been prospected for mica, but no appreciable production has been obtained. Most are long but relatively thin dikes and sills that consist chiefly of quartz and flesh-colored to red microcline and albite. The mica shoots are small and most of the books would yield material of scrap grade only.

ELK MOUNTAIN DISTRICT

GENERAL FEATURES

The Elk Mountain district is in the southern part of the Sangre de Cristo Range near the northwest corner of San Miguel County (Figure 1). It embraces an area of about 30 square miles between the valley of the upper Pecos River and the rugged country at the headwaters of the Gallinas River to the east (Figure 27). Altitudes range from approximately 8,000 feet at the west edge of the district near Terrero to more than 11,500 feet on Elk Mountain at the crest of the range. The district lies entirely within the Santa Fe National Forest and is most easily reached over good gravel roads that extend north from Pecos and west-northwest from Las Vegas. Automobile travel within the district, particularly in its higher parts, is impossible during most winter months, owing to heavy snow.

The core of the range consists of pre-Cambrian crystalline rocks, chiefly quartz-mica schist, amphibole schist, quartzite, granite, diorite, diabase, and pegmatite. These older rocks are exposed in an irregular belt that extends from a point east of Taos to the valley of the Pecos River southwest of Las Vegas, an airline distance of nearly 70 miles. Flanking the belt are calcareous sedimentary rocks of Pennsylvanian age. In general they occur as a thin cover over the crystalline rocks, but relations are complicated by folding and faulting.[37] Most of the pegmatites crop out in the rough, broken country east of the range crest. West of the crest is a widespread cover of younger rocks, although some pegmatites appear in small areas where erosion has exposed the pre-Cambrian crystallines along the Pecos River, as well as along Willow Creek and other west-flowing tributary streams. Other outlying pegmatite occurrences are east of Cow Creek in an area several miles south of that shown in Figure 27.

The pegmatite bodies generally occur in schist rather than granite or diorite. They range in shape from long, thin, sinuous dikes to thick pods that crosscut the country-rock structure. They trend north-northwest to north-northeast, and most dip steeply. Several structural and mineralogic types are present, but too few occurrences have been examined to permit classification. All the deposits contain quartz and white to flesh-colored

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[37] For descriptions of the general geology, see:
Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., *op. cit.*, pp. 68, 108-109, 1910.
Lee, W. T., Building of the southern Rocky Mountains: Bull. Geol. Soc. America, vol. 34, pp. 285-300, 1923.
Darton, N. H., "Red beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, 1928.
Harley, G. T., The geology and ore deposits of northeastern New Mexico: N. Mex. School of Mines, State Bur. Mines and Min. Res. Bull. 15, pp. 18-20, 28-30, 46-50, 1940.

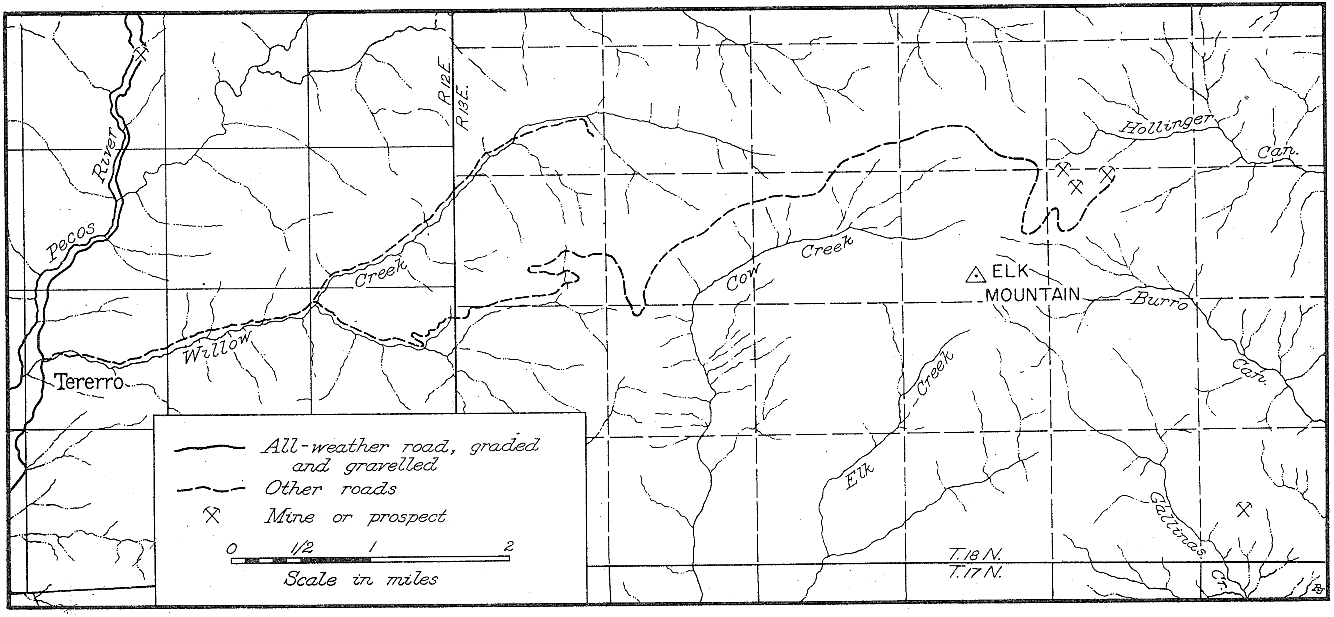

FIGURE 27. Map of a part of the Elk Mountain district showing locations of several mines and prospects.

microcline and albite, and these minerals tend to occur in distinct lithologic units. Spessartite, fluorite, and columbite are common accessory constituents. Tourmaline and beryl are rare.

The pegmatites near the Pecos River and those northeast of Elk Mountain contain much book mica. Its color is very pale green to light brownish green. The books are hard, clear, and flat, but most are badly ruled and broken. Many occur in tangled intergrowths, but an appreciable proportion of sheet material, chiefly in the small-size range, is recoverable from others. Most of the pegmatites elsewhere in the district yield mica of scrap grade only. The books are wedged, tangled, warped, ruled, and reeved. Many are stained. Such deposits generally contain local concentrations of rare minerals, chief among which are monazite, columbite, uraninite, samarskite, hatchettolite, euxenite (?), fergusonite (?), gadolinite, and secondary uranium-bearing species.

ELK MOUNTAIN (KEPT MAN) DEPOSIT

The Elk Mountain or Kept Man deposit is on a steep thickly wooded north-facing slope about a mile northeast of Elk Mountain (Figure 27). It lies between Hollinger and Burro Canyons at an altitude of about 10,500 feet, and is near the north edge of sec. 23, T.18N., R.13E. The mine workings can be best reached over an 11-mile logging road that extends east from Terrero and crosses the range crest at an altitude of 11,480 feet. This route was improved by the Forest Service during 1944, but is impassable for most traffic during winter months. A new road said to be scheduled for construction will connect the mine with the west end of a good gravel road in the canyon of the Gallinas River.

The first mining in the deposit was done in 1942 by the International Minerals and Chemical Corporation. The No. 1 cut, which is 80 feet long, 10 to 20 feet wide, and 24 feet in maximum depth, was excavated in quartz-rich pegmatite, and small prospect openings were made to the south and south-southwest. During the summer and fall of 1943 Carl Frymire of Silver City worked the deposit for strategic mica, principally by open-cut methods. Production amounted to several hundred pounds of prepared mica, chiefly in the trimmed-punch size range, and about 20 tons of scrap. K. N. Garard of Pecos leased the mine during the summer of 1944, and obtained a little sheet mica and several tons of scrap from small-scale operations. At the present time the property is held under claim by Carl Frymire.

The No. 2 cut, which is down slope and 40 feet north of the older cut, is a bench-like working 90 feet long, 15 feet wide, and 20 feet deep along its south face. About 20 feet of its southeast end is cribbed and roofed, and a drift was being driven south-southeast when operations were suspended in November 1943.

The No. 3 cut is a shallow opening 70 feet south of No. 1. It is nearly circular in plan, with a maximum diameter of about 25 feet. The No. 4 cut exposes a small pegmatite mass on the hillside 150 feet south-southwest of No. 1. From its face a drift extends 11 feet south-southwest. Operations during 1944 were concentrated in the No. 3 cut, from whose floor a rich mica concentration was mined southward in a gently sloping slot-like room (Plate 4, top).

Pegmatite forms a bold knob in the east part of the mine area. The body trends almost due north (Plate 25), is 110 feet in maximum exposed width, and can be traced for at least 260 feet along the strike. It plunges gently beneath the hill slope immediately south of No. 3 cut. A smaller pegmatite body exposed in No. 4 cut is a dike that strikes north and dips 30° to 60° west. It appears to plunge gently south, but near the portal of the cut it plunges steeply in the opposite direction. Its maximum thickness is about 17 feet. Pegmatite is also present on the slope north of the workings, as shown by small outcrops and abundant float.

Glacial debris, consisting chiefly of dark gray compact pebbly calcareous till, forms a thin but nearly continuous blanket over much of the area. The country rock is quartz-mica schist with minor interlayered amphibole schist. Dark coarse-grained diorite, fine-grained diabase, and pink granite are present also, but are not exposed in the mapped area. The foliation of the metamorphic rocks trends northeast and dips moderately to steeply southeast. Concentrations of dark greenish to black tourmaline occur in the schist immediately adjacent to pegmatite. Typical contact relations are clearly exposed in the southeast face of the No. 2 cut. The schist also appears to have been impregnated with fine-grained mica at several places along the pegmatite, but there is no large-scale mechanical disturbance of the foliation.

Available exposures suggest that the main pegmatite is a large mass whose undulatory upper surface probably did not lie far above the present outcrop. This surface was complicated by many elongate protuberances 10 to 30 feet wide (see sections B-B′ and C-C′, Plate 25). Although the footwall is nowhere exposed, the shape of the body can be inferred from the general attitude of the hanging-wall contact and from the results of underground exploratory work done by the Federal Bureau of Mines in 1944. An adit driven 273 feet south-southwest from a point about 300 feet north-northeast of the No. 1 cut encountered the top of a small pegmatite dike 120 feet from the portal, but lies entirely beneath the main body. A crosscut extends 10 feet west from its heading, which is 115 feet below the surface of the quartz knob that lies between the No. 1 and No. 2 cuts. According to R. J. Holmquist, project engineer, preparations were being made to drill upward to intersect the pegmatite when severe winter storms forced abandonment of all work.

It seems likely that the pegmatite body is an undulatory dike that dips rather gently west. As exposed in the workings and in a road cut immediately southeast of the No. 3 opening, individual undulations trend north-northeast. On any horizontal surface, the south-plunging crest of each would appear farther north than the crest of the undulation adjoining it on the east, and hence the general trend of the entire dike is nearly due north. Its thickness is not known, but may be several tens of feet.

The massive quartz core of the main pegmatite is 160 feet and 50 feet in maximum outcrop length and breadth, respectively. It contains a few scattered aggregates of blocky microcline, one of which is exposed in the south wall of the No. 1 cut. Flanking the core is medium- to coarse-grained albite-microcline-quartz pegmatite. The plagioclase feldspar, most of which was formed by replacement of microcline and quartz, is the dominant constituent of this unit in all exposures except those immediately south and southwest of the No. 3 cut. Other minerals in this rock, which originally formed a wall zone, are mica and accessory green fluorite, black to green tourmaline, platy columbite, and pink spessartite garnet. A fine-grained border zone of sugary quartz and albite is present along the western edge of the dike.

An intermediate zone of coarse blocky microcline is the dominant unit in the small dike exposed in the No. 4 cut. A quartz core is present in its two-pronged eastern end, and a thin but continuous albitized wall zone encloses both inner zones. The border zone is a thin rind of fine-grained albite-rich pegmatite.

Most of the mica in the main dike occurs in coarse albite-rich pegmatite at the margins of the core. Individual shoots are 3 to 15 feet thick. Mica books are present locally in the sugary border zone (see section B-B′). In general the richest parts of the concentrations are in contact with the massive quartz, although in the upper pegmatite they lie between the wall zone and the microcline-rich intermediate zone. Except for minor shoots along the edges of cleavelandite "bursts" and pods, the central parts of both pegmatites are virtually barren of mica.

Although the proportion of mica in many of the richer shoots is locally as much as 55 percent, the general mica content is distinctly lower, as shown in Table 19. It is reported that the run-of-mine mica has yielded 1 to 1.5 percent trimmed sheet and punch material. This has been confirmed by Holmquist, who tested a 100-pound lot of mica taken from the No. 3 cut, as well as several larger lots obtained when the heading in the drift from the No. 2

TABLE 19. MICA IN FACES, ELK MOUNTAIN DEPOSIT

Location	Area of face (square feet)	% mica in face (by volume)
Mica shoots in south face of No. 1 cut	60	6[a]
Mica concentration in southwest face of No. 2 cut	60	8[a]
Heading of short drift from No. 2 cut	23	2
Working face in No. 3 cut (November 1943)	115	14
Working face in No. 3 cut (November 1944)	108	13
Heading of short drift from No. 4 cut	28	3
	Average	8
	Weighted average	11.5

[a] Represents material that cannot be mined without handling some barren rock; hence not included in averages.

cut was being advanced. The test drifting, which amounted to about 20 feet, was done by the Federal Bureau of Mines in 1944.

The mica is nearly colorless, with a faint greenish tint in plates ⅛ inch or more thick. It is hard, flat, and free-splitting, but most is severely ruled, broken, or marked by "A" structure. Most of the books are free from mineral stain, but clay staining was an objectionable feature in those mined to date. Many are 10 inches or more in diameter, but they yield trimmed mica of small size. It is estimated that less than 5 percent of the prepared sheet mica would be 2 by 2 inches or larger. The mica in the upper pegmatite is very hard, splits with some difficulty, and is light brownish green. In other respects it is like that in the main pegmatite.

Despite the obvious disadvantages of its location, the deposit appears to be a potential commercial source of scrap and small sheet mica. The concentration of books along the west side of the quartz core might be developed by extending the drift southward from the No. 2 cut. Substantial reserves of rich mica-bearing pegmatite are probably present beyond the face of the No. 3 cut, and a similar mica shoot may occur in the pegmatite roll exposed in the roadway about 20 feet southeast of this cut.

GUY NO. 1 DEPOSIT

The Guy No. 1 mica-tantalum-columbium-uranium deposit is 2.5 miles southeast of Elk Mountain in the SW¼ sec. 36, T.18N., R.13E. It lies at an altitude of about 9,500 feet near the crest of the high ridge between Burro and Gallinas canyons, and is accessible by trail only. From the end of State Route 65, a good gravel road that extends about 25 miles up the canyon of the Gallinas River from Las Vegas, the Elk Mountain trail can be followed

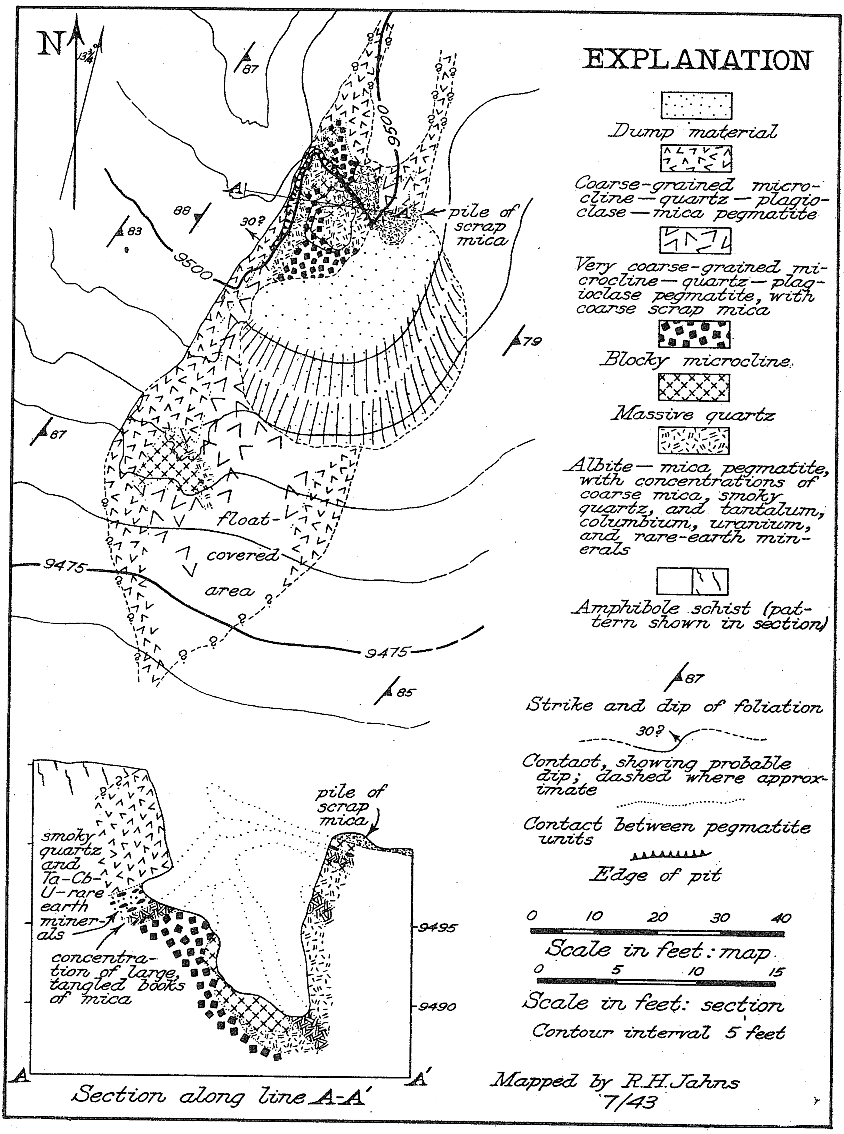

FIGURE 28. Geologic map and sketch section of the Guy No. 1 deposit.

for three miles to a point from which a poorly defined branch trail ascends the steep northeast wall of the canyon to the mine workings. The deposit lies on land held under claim by U. Leon Guy, Jay Stearn, and associates of Las Vegas. Production from small-scale mining operations during the past fifteen years amounts to several tons of scrap mica and more than 500 pounds of tantalum, uranium, and rare-earth minerals. A 350-pound lot of these minerals, obtained during the period 1940-1942, was shipped to the S. W. Shattuck Chemical Company in Denver, Colorado.

The main pegmatite is a pod-like body that trends north-northeast in approximate conformity with the strike of the foliation in the enclosing dark gray amphibole schist (Figure 28). It may dip west-northwest at relatively low angles, however, in contrast to the steep east-southeast dip of the country rock. At the principal opening, a pit 10 to 15 feet in diameter and 12 feet in maximum depth, the pegmatite is about 20 feet wide. As traced northward it splits into two thin prongs, but southward it widens to form a pronounced bulge about 40 feet from the pit and thence tapers abruptly. Although exposures are not continuous, particularly on the slope below the workings, a zonal structure is evident. The pegmatite units comprise a core of massive quartz; intermediate zones of flesh-colored blocky microcline and extremely coarse microcline—quartz—albite-oligoclase pegmatite with large mica books; a wall zone of coarse microcline—quartz—albite-oligoclase—mica pegmatite; and a very thin, discontinuous border zone similar in composition but much finer-grained than the wall-zone material.

The core is exposed near the north end of the pegmatite as an irregular pod about 25 feet long. Much of the quartz has been replaced along fractures by albite and mica. Stockworks of such material are exposed in the walls of the pit. Some aggregates of large tangled mica books occur in the core as vein-like bodies 6 inches to 2 feet thick (see section, Figure 28). Most of these extend from the core into other zones. All the mica books are badly ruled, tangled, broken, and stained, and hence are usable as scrap only.

Along the upper contact of a mica-rich "streak" that is exposed along the west and north sides of the pit is a thin layer of albite-mica pegmatite in which pockety masses of rare minerals and closely spaced veinlets of dark smoky quartz are present. Columbite is abundant, and occurs as rough, thickly tabular crystals and irregular masses with dull luster. Some of these are as much as 6 inches in maximum dimension. The specific gravity of the material ranges from 5.2 to 5.5, indicating a tantalum oxide content of less than 10 percent. The following partial analysis of a small shipment of clean-cobbed columbite was made by the S. W. Shattuck Chemical Company.

Cb_2O_5	71.9%
Ta_2O_5	7.8%
Fe_2O_3	16.1%

Globular masses of a lustrous brownish black to black tantalum-uranium mineral are numerous, and commonly are associated with large, poorly formed crystals of tan to mahogany monazite. These masses are ¼ inch to 5 inches in diameter, and according to analyses made by the Shattuck Chemical Company have a combined uranium oxide content of 12.6 to 14.1 percent. Calcium, iron, tantalum, and columbium are other abundant constituents. The mineral has an index of refraction of about 2.10, and probably is hatchettolite, a uranian microlite. A similar but more brownish mineral contains rare-earth elements, according to qualitative tests made in the laboratories of the Geological Survey by Charles Milton. It may be euxenite or fergusonite. Other, less common minerals are samarskite and uraninite in small irregular masses, yellow bismutite in small veinlets through monazite, and brownish gummite as crusts associated with the uranium-bearing minerals. The hatchettolite, uraninite, samarskite, and euxenite (or fergusonite) were found to affect a photographic film.

Although some masses as large as a man's head were obtained during past operations, little rare-mineral material is now visible in the workings. Additional quantities may be present in northward continuations of the pocket zone beyond the pit, but the reserves probably are small.

A small pit has been sunk on a very poorly exposed pegmatite body about 1,000 feet south-southeast and 300 feet below the Guy No. 1 deposit. This body is about 20 feet wide at the pit and consists of quartz, flesh-colored microcline, lustrous white albite-oligoclase, and coarse muscovite, with minor garnet and black tourmaline. The mica is in books as much as 5 inches in diameter, but their average maximum dimension is about 1½ inches. It is light green and badly ruled and tangled. Along the cleavage planes of many books are long thin crystals of tourmaline. A poorly defined mass of monazite-bearing pegmatite occurs near the bottom of the pit, but the total amount of this mineral is probably small.

OTHER DEPOSITS

The Thin Top mica deposit, which crops out on an extremely steep northwest slope about a quarter of a mile west-southwest of the Elk Mountain mine (Figure 27), was prospected during 1943 by Carl Frymire of Silver City. Further small-scale exploratory work was done by the Federal Bureau of Mines in 1944. Operations have been confined to a bold cliff-like outcrop of a 20-foot pegmatite dike that strikes north and dips west. Immediately below this outcrop the dike splits into two poorly exposed prongs. The pegmatite is not clearly zoned. It is a coarse-grained intergrowth of gray to white microcline, quartz, and white cleavelandite. Irregularly scattered through it are severely broken and ruled books of light green mica. Their average diameter is about 2 inches, and the largest observed book had a maximum diameter of 8 inches. According to R. J. Holmquist, Bureau of Mines engineer, sampling of the richest concentrations demonstrated that the mica content is low. The proportion of recoverable sheet material in all the mica is probably about 1 percent.

The Cold Bottom deposit, another of the Elk Mountain group, is on a steep slope 0.3 mile west of the Elk Mountain mine. It was not visited by the writer, but a description was kindly furnished by R. J. Holmquist. A pegmatite dike about 150 feet in exposed length and 8 feet in average thickness trends north, but curves to the northwest near its north end. It dips steeply west. Its lithology is similar to that of the Thin Top pegmatite, although it apparently contains a slightly higher proportion of mica.

Several mica-bearing pegmatites crop out along the lower part of Willow Creek and along the Pecos River to the north. One of these, the Betty Jean deposit, is 2.5 airline miles north-northeast of Terrero. It was worked by open-cut methods for a short time in 1943 by D. C. Mangum of Terrero, but production was very small. The dike, which trends N. 25° - 30° E. and dips 25° - 35° ESE., is exposed in the steep east wall of the canyon between the road and the Pecos River in the NE¼ sec. 15, T.18N., R.12E. (Figure 27). It is traceable for 500 feet along the strike and is 15 to 28 feet thick over much of this distance. It tapers to the south-southwest and disappears in a shear zone that is well exposed in a large road cut. The country rock is fine- to medium-grained diabase (?) that is much sheared, thoroughly chloritized, and deeply weathered. It is overlain higher on the canyon wall by Pennsylvanian limestone.

Although the pegmatite is not clearly zoned, it coarsens inward from its walls. The proportion of quartz also increases markedly inward. Most of the rock is a very coarse-grained intergrowth of gray to pink microcline, quartz, and minor mica and albite. Some of the largest microcline masses, which are as much as 4 feet in diameter, contain rude graphic intergrowths of quartz. Accessory minerals are spessartite garnet, fluorite, and rare monazite. The mica, which is scattered irregularly through the dike, is most abundant in the quartz-rich portions. It is pale green to yellowish green, and occurs as small badly broken books. The deposit holds little commercial promise.

The pegmatites that occur in the area east of Cow Creek and south of the area shown in Figure 27 are typical microcline-rich bodies in which monazite, spessartite garnet, and minor quantities of fluorite, columbite, and gadolinite are present. Mica occurs as small books near the pegmatite borders, but no workable concentrations are known.

INDEX

Figures in *italic* indicate main references.

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