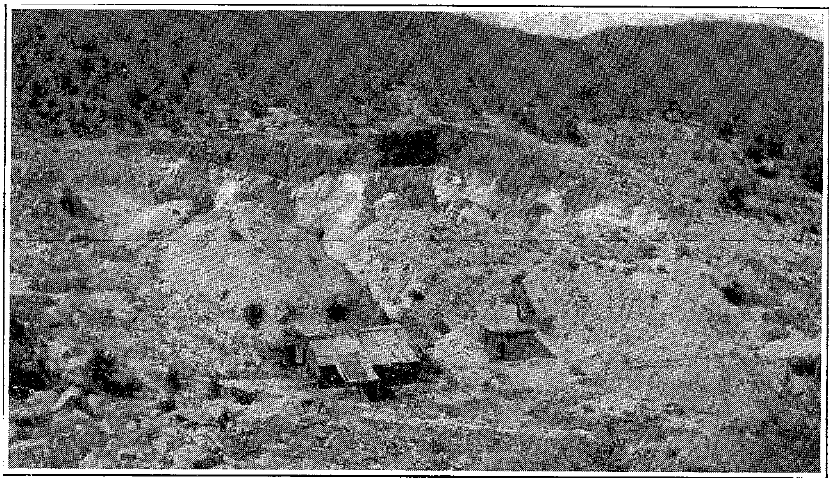
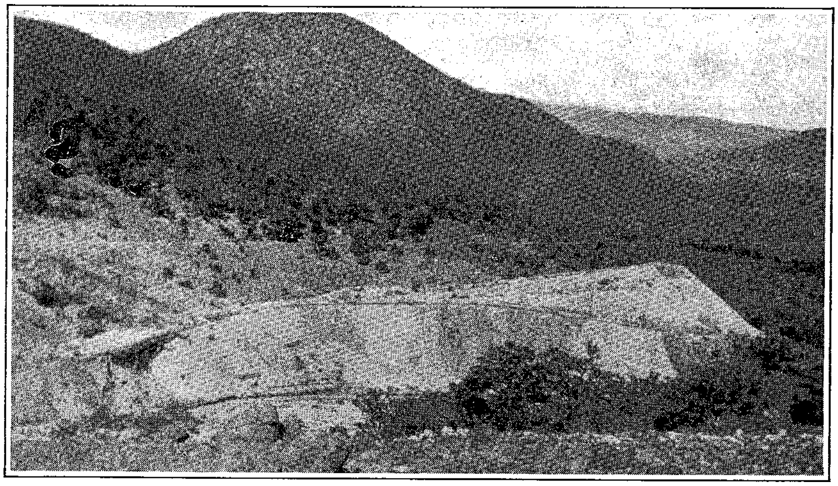
NEW MEXICO SCHOOL OF MINES
STATE BUREAU OF MINES AND MINERAL RESOURCES

BULLETIN 13
FRONTISPIECE



PIT AT HARDING MINE
(To left of dump)



DUMP AT HARDING MINE
(To right of pit)

NEW MEXICO SCHOOL OF MINES

STATE BUREAU OF MINES AND
MINERAL RESOURCES

E. H. WELLS
President and Director

BULLETIN NO. 13

Geology and Economic Features of the Pegmatites of Taos and Rio Arriba Counties, New Mexico

By
EVAN JUST

1889

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Bulletin No. 13. Geology and Economic Features of the Pegmatites of Taos and Rio Arriba Counties, New Mexico—Evan Just, 1937. (Price 50 cents.)
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Note—Bulletins 1, 2, and 3 were issued by the Mineral Resources Survey of the New Mexico School of Mines.

Geology and Economic Features of the Pegmatites of Taos and Rio Arriba Counties, New Mexico

By
EVAN JUST

PURPOSE AND SCOPE OF REPORT

In two areas in Taos and Rio Arriba Counties, pre-Cambrian rocks have yielded commercial quantities of non-metallic minerals. The Picuris area, a few miles southwest of Taos on the east side of the Rio Grande, includes what has been variously called the Embudo, Rinconada, Picuris, or Copper Hill district. In this district the rare lithium minerals, lepidolite and spodumene, have been produced at the Harding mine. The Petaca area, several miles west of the Rio Grande, includes the Bromide-Hopewell, La Madera and Petaca districts. Scrap and plate mica have been mined for many years from. a number of workings in the La Madera and Petaca districts.

Although both areas have been productive of metallic minerals, particularly the Bromide-Hopewell district, this report, except for furnishing some details of the regional geology, is concerned primarily with non-metallic minerals rather than with ore deposits. The areas and their geology are described, and some pertinent economic considerations are discussed, with a view to aiding operators already established as well as fostering new exploitation. Possibilities of new development that are considered include minerals as yet unexploited as well as minerals that have been mined.

Very little systematic study has been made of the pre-Cambrian rocks of this part of New Mexico, and practically no separation or naming of lithologic units has been attempted. In making a start in this direction and in presenting some details of pre-Cambrian structure and geologic history, it is hoped that a systematic beginning has been made in unraveling the complicated pre-Cambrian geology of this part of the State.

The writer wishes to acknowledge the cooperation and aid of the following people : Mr. J. J. Peyer and Mr. A. H. Gossett, owners of the Harding mine, who kindly permitted entrance to the property ; Mr. Mark Stallings, of Rinconada, who aided the writer in the Picuris area ; Mr. C. R. Fisher, of the United States Geological Survey, who furnished some data concerning the elevation of Picuris Peak and the drainage of the Picuris area ; Mr. J. T. Scopes, of Paducah, Ky., who kindly made available his samples and conclusions concerning the Harding mine and vicinity ; Mrs. Alma K. Hoyt, of Las Tablas, who gave pertinent in-

formation relative to mining the pegmatites of the Petaca area ; and Mr. Donald Brown of Petaca, whose information and field assistance aided the writer in the Petaca area. Dr. Frank Hess of the United States Bureau of Mines kindly furnished copies of notes made by him on visits to this region.

The analyses of the lithia content of minerals of the Harding pegmatite were made by Professor A. R. Ferguson, head of the department of chemistry of the New Mexlco School of Mines. The maps were drawn by H. E. Hellmann. The constructive suggestions and criticisms of President E. H. Wells and Professor Sterling B. Talmage of the New Mexico School of Mines have been of most valuable assistance, and are gratefully acknowledged.

PART I. GENERAL DESCRIPTION OF THE PICURIS AND PETACA AREAS

TOPOGRAPHY AND GEOGRAPHY

The Rio Grande in southern Taos County and eastern Rio Arriba County has a southerly course and has cut deeply into the broad, rather flat surface of a thick series of Quaternary (Pliocene?) basalt flows. The continuity of the basalt surface is broken only by the gorges of the Rio Grande and Taos Creek and a few minor groups of hills, including the pre-Cambrian inlier known as Blue Hill. To the east of the basalt plain are the high, north-south ranges of the Sangre de Cristo Mountains. The Picuris area includes a conspicuous, triangular group of mountains extending westward from the Sangre de Cristo ranges to the Rio Grande.

Between this great basaltic mass and a dissected plateau that lies about 25 miles west of the Rio Grande, the hills and mountains of the Petaca area rise above the plain of basalt and Tertiary sediments which surrounds them and buries their edges. The rocks of the Petaca area, consisting of resistant pre-Cambrian formations, are exposed from a point northwest of Hopewell southward to Ojo Caliente. Although this area includes mountains of magnitude similar to those of the Picuris area, they do not stand out so conspicuously when viewed from a distance, as they are more surrounded by rugged topography, particularly on the west, where the general plateau surface is as high as the general level of the pre-Cambrian rocks. The Picuris area drains westward into the Rio Grande, and the Petaca area drains south-ward into the Rio Chama.

The region is sparsely inhabited but is accessible by good roads. It is traversed by the narrow-gauge line of the Denver & Rio Grande Western railroad, which extends from Santa Fe to Alamosa, Colo., where it connects with a standard-gauge line of the same company. The climate is very agreeable in summer, and the winters are not severe enough to prevent mining operations.

SPECIAL FEATURES OF PRE-CAMBRIAN ROCKS

In most parts of North America where ancient rocks are exposed, the Cambrian and younger rocks overlie a platform of older rocks whose character indicates a tremendously long and eventful history, which by comparison dwarfs the several hundred million years of history since the beginning of the Cambrian period. Because of the characteristic complexity of structure and lithology of these rocks, correlation between separated exposures is still very indefinite. In New Mexico they have been grouped together as the "basement complex." Such studies as have been made of pre-Cambrian rocks indicate the deposition of great thicknesses of sediments, building of major mountain systems, periods of extensive vulcanism, and long stretches of time in which great mountain masses were leveled down to mere remnants. Much of the evidence suggests that every one of these processes of deposition, deformation, vulcanism, uplift and erosion, took place repeatedly and on a scale that has rarely been duplicated since. In view of the thousands of years necessary for an insignificant development in geologic history, and of the small likelihood that these processes were more rapidly effected in the dim past than at present, it is apparent that a vast extent of time is represented in known pre-Cambrian rocks.

As a result of the profound and long-continued geologic processes to which they have been subjected, most pre-Cambrian rocks have been considerably modified since their formation. Many of them, particularly the gneisses and schists, have been so changed that it is impossible to deduce their original natures. Others retain traces of their ancestries but are greatly altered lithologically. In the latter class are quartzites and quartz schists that once were sandstones, slates that once were shales, and certain amphibole or chlorite schists that once were extrusive basalts. A few of the more resistant rocks, such as some granites and rhyolites, when studied microscopically, show a good deal of modification not perceptible to the naked eye.

The rocks of the Picuris and Petaca areas have been de-formed to an extent that is not uncommon for pre-Cambrian rocks but is rare for younger rocks. any of the folds have been so intensely compressed that they are isoclinal, that is to say, all dips are approximately parallel, and the ordinary value of dip and strike observations in deciphering structure is considerably diminished. This difficulty is augmented by the fact that, where schistosity is developed in sedimentary rocks, their bedding is often obscured. The evidence of solid flow, apparent in nearly all the pre-Cambrian rocks of these areas, indicates that the rocks of sedimentary origin now exposed were once buried under many thousands of feet of overlying material, as solid flow can occur only in deeply buried rocks. The evidence of solid flow is chiefly the schistosity, but there are other effects, such as contorted folding, unusual thickening and thinning of formations, and conglomerate boulders, once roughly spherical, that have been pressed into elongated ellipsoids.

GEOLOGIC HISTORY AND GENERAL LITHOLOGY

PROTEROZOIC ERA

The oldest rocks exposed in these areas belong to the Hopewell series, a succession of metamorphosed igneous flows, with which are interspersed metamorphosed sediments. The flows were principally andesite, and basalt (Picuris basalts), most of which are now dark hornblende-chlorite schists. There are some flows of rhyolite and trachyte (Vallecitos rhyolites), most of which are but little changed. The sediments were principally sandstones, which have been changed to quartzites. There were also some shales and arkoses, which have become slates and arkosites. The series as exposed ranges up to a mile and a half in thickness, but it may be considerably thicker. It is possible that the Hopewell series eventually may be classed as Archeozoic, but its great thickness and that of overlying Proterozoic sediments suggest that all these rocks are part of a geosynclinal sequence and therefore probably are not separated by a major unconformity. No indication of a major unconformity was observed by the writer.

Above the Hopewell series are quartzites and quartz, schits, which were originally sandstones of various degrees of purity. This group of rocks is called the Ortega quartzite and apparently ranges from 2 to 4½ miles in thickness. It includes some of the basalts, particularly near the base, and in the Petaca area it includes several of the Vallecitos rhyolites The Ortega quartzite represents a long time of shallow-water deposition, accompanied by vulcanism. It is succeeded in the Picuris area by a black, carbonaceous slate series, the Hondo slate. This slate represents deposition of muds, presumably in deeper or quieter waters. The Hondo slate is about a mile thick. An indeterminate additional amount may have been removed by erosion.

A few minor basaltic masses, apparently intrusive, were noted in the pre-Cambrian rocks, and presumably a more detailed survey would reveal others. These rocks are not schistose, and are tentatively classed as Keweenawan, but may possibly be of any age younger than the Proterozoic rocks of sedimentary origin. They are not shown on the geologic maps. The Agua Caliente gabbro is the only one described..

The Archean rocks of the Grand Canyon in Arizona, known as the Vishnu schist, have been recently studied by Dr. Ian Campbell and Dr. John H. Maxson of the California Institute of Technology, and they kindly permitted the writer to inspect their samples. Striking similarities between the lithology of the Vishnu schists and of the rocks of the areas described in this report are apparent. In both general areas isoclinal folding is prominent and structural trends are somewhat similar. These features suggest the possibility that the Vishnu schist and the pre-Cambrian rocks of sedimentary origin described herein are of the same general age. For reasons stated elsewhere in this report, the writer has classed all the exposed pre-Cambrian rocks in the Picuris and Petaca areas as Proterozoic rather than

Archean, and he believes that possibly they were deformed in the Killarney Revolution. If the Vishnu schist is incontrovertibly established as Archean, the pre-Cambrian rocks described herein should be reconsidered as possibly of the same age.

PUEBLO (KILLARNEY?) REVOLUTION

Correlation of pre-Cambrian rocks is likely to be comparatively loose between distant points, being based on lithology and diastrophism, and lacking the fossils so useful in correlating younger rocks. The Proterozoic rocks described herein are so classed because they are similar in lithology and history to the Proterozoic rocks of the Great Lakes region.

Great thicknesses of sedimentary rocks similar to the Proterozoic series here under discussion appear to be deposited only in great troughs, called geosynclines, which subside at approximately the same rates at which they are filled. Thus, thousands of feet of sediments are deposited, laid down in waters that are probably never as deep as a thousand feet. When some tens of thousands of feet of material accumulate, the geosynclines, for reasons not well understood, become areas of active diastrophism and are laterally compressed. The surface rocks are folded and faulted, the deeper rocks yield by folding and solid flow, and vulcanism may become active. As a consequence, mountain systems arise on the sites of former geosynclines. The major mountain systems of the earth, past and present, have had geosynclinal ancestries, the ranges, folding and schistosity in each system being oriented parallel to the axes of the geosynclines.

In the Picuris and Petaca areas it seems reasonable to presume that the folding, rock flowage and granitic intrusion succeeded the Proterozoic geosynclinal deposition, and that the general east-west orientation of the present structural trends indicates the trend of the ancestral geosyncline (Pueblo geosyncline[1]) and of the mountain system. (Pueblo Mountains[1]) that succeeded it. This trend is similar to pre-Cambrian trends observed in Colorado.[2] Comparisons of lithology, structure and orientation of the Proterozoic rocks of these areas and of the Great Lakes region suggest the possibility that the Proterozoic sediments of New Mexico and Colorado may represent the westward extension of the Proterozoic geosyncline of the Great Lakes region, and that the Pueblo Revolution which folded the New Mexico rocks (and presumably the Colorado ones) was part of the great Killarney Revolution which disrupted that geosyncline. The magnitude of the folds in both regions indicates that the resultant mountains must have been comparable to the loftiest ranges in existence today. There is no evidence that the Killarney

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[1] Names initiated in this report.

[2] Stark, J. T., and Barnes, F. F., The structure of the Sawatch Range; Am. Jour. Sci., 5th ser., vol. 24, pp. 471-480, 1932.

TABLE I

Correlation of formations in Picuris and Petaca areas

			PICURIS AREA	PETACA AREA
POST-CAMBRIAN	QUATERNARY OR PLIOCENE	Igneous	Basalt flows	Basalt flows
	QUATERNARY	Sedimentary	Alluvium and talus	Alluvium and talus
	TERTIARY		Santa Fe formation	Santa Fe formation
				Carson conglomerate*
	PENN.		Magdalena formation	
PRE-CAMBRIAN	PROTEROZOIC	Igneous Origin	Minor basaltic intrusives (?) (non-schistose)	?
			Dixon granite* (intrusive; later than formations listed below)	Tusas granite* (intrudes all formations listed below)
				Vallecitos rhyolites* (flows in Ortega and Hopewell schists)
			Picuris basalts* (flows including Hopewell sediments and base of Ortega quartzite)	Picuris basalts* (interlayered with Hopewell and Ortega sediments)
		Sedimentary Origin	Hondo slate*	
			Ortega quartzite*, including Rinconada schist* (base includes top of Picuris basalts)	Ortega quartzite* including Petaca schist* (interspersed with Vallecitos rhyolites and top of Picuris basalts)
			Sediments of Hopewell series* including Badito quartzite* (interspersed with Picuris basalts)	Sediments of Hopewell series* including Cleveland Gulch quartzite* (interspersed with Picuris basalts and Vallecitos rhyolites)
	?		?	?

*Names initiated in this report.

Mountains died out to the west in Wisconsin, and having no exposures west of Wisconsin, paleogeographers assume that they must have continued some distance farther to the west or southwest. Considering the extent of some modern mountain systems, it seems possible that the Killarney Mountains may have extended into New Mexico, Colorado and Arizona. However, it must be realized that the evidence supporting such an interpretation is extremely meager, and does not warrant consideration as more than a possibility at the present time.

It is not to be concluded that the Pueblo geosyncline and the Pueblo Mountains that succeeded it were of any width yet defined. Folded pre-Cambrian rocks of sedimentary origin occur in various parts of New Mexico, and east-west trends have been observed in them near Socorro by the writer. The Pueblo geosyncline and Pueblo Mountains may possibly have been wide enough to extend from southern New Mexico to northern Colorado.

PALEOZOIC ERA

Rocks of Lower and Middle Paleozoic age are missing in northern New Mexico. In any places such an absence would be simply a lost interval, it being. unknown whether rocks of such age were deposited and eroded or simply never deposited. In this case the second alternative is correct. Lower and Middle Paleozoic marine deposits are found farther south in the State, the relationships indicating a sea that gradually advanced north-ward, presumably encroaching upon an elevated area to the north. In Pennsylvanian time the advancing sea submerged at least part of the areas under consideration, as the Magdalena (Pennsylvanian) formation occurs adjacent to the Picuris area, lying unconformably upon the pre-Cambrian rocks. It is apparent that in the interval from the Pueblo Revolution to Pennsylvanian time a considerable thickness of pre-Cambrian rocks was stripped away, as the crests of the Pueblo folds were removed. Moreover, the observable effects of solid flow developed in the Pueblo Revolution could have been produced only under heavy overburden, most of which was removed by Pennsylvanian time. A study of Plate II indicates that probably at least a 4-mile thickness of pre-Cambrian rocks was eroded before the deposition of the Magdalena formation, as in places the Magdalena lies upon the earliest part of the Proterozoic sequence.

The Magdalena formation is composed chiefly of limestone and shale, but in a number of exposures some of the lower members consist of quartzite conglomerate, quartz conglomerate, and arkose, which were apparently derived from nearby pre-Cambrian land masses. It is questionable whether the Pennsylvanian sediments ever completely buried the pre-Cambrian rocks in these areas. No Pennsylvanian rocks occur adjacent to the Petaca area, except as boulders in later conglomerates, and hence no such relationships can be deduced concerning that area.

Considering local rocks alone, from Pennsylvanian to Tertiary time is another lost interval. However, geologic relation-ships observable not far away indicate that the Pennsylvanian sea was succeeded by a Permian sea that occupied a basin centering in southeastern New Mexico and western Texas. This sea was only intermittently connected with the ocean, and in the cut-off intervals salt deposits were laid down. Apparently this basin sea did not submerge the Picuris and Petaca areas for any extended period, as Permian rocks are not known to be present. If deposited they were later removed by erosion.

MESOZOIC ERA

Southeast of the Picuris area Permian rocks are overlain by Triassic red beds, apparently deposited in desert basins. The ensuing Jurassic deposits were largely sands. Cretaceous time is represented by a thick series of marine shales, sandstones and some limestones, deposits of a new advance of the sea into a north-south geosyncline that was later to be disrupted to form the Rocky Mountains. Although it is doubtful if the Permian and early Mesozoic sediments were ever deposited over the Picuris and Petaca areas, it seems certain that these areas must have been buried by Cretaceous marine sediments, as the Cretaceous rocks in this region indicate an original thickness of several thousand feet.

LARAMIDE REVOLUTION

The geosyncline that during Cretaceous time occupied the present site of the Rocky Mountains met a characteristic fate at the end of the Mesozoic Era, being compressed into great folds, with attendant vulcanism. As a consequence of this deformational epoch, which is known as the Laramide Revolution, the Rocky Mountain system was formed.

How the Laramide folding deformed the pre-Cambrian rocks of the Picuris and Petaca areas is rather uncertain, as whatever north-south folding may have taken place was superimposed upon the old isoclinal folds developed in the Pueblo Revolution. The most obvious case of Laramide folding occurs along the east border of the Picuris area. Between Arroyo Miranda and the Rio Grande del Rancho, the Magdalena formation dips steeply east-ward, defining the eastern limb of a Laramide fold. The western limb of the fold is not expressed in any Paleozoic rocks, as they have been eroded away on the west, but this limb is defined by the upturning at its east end of the large syncline that includes most of the pre-Cambrian exposure. Possibly the westerly dips of the schistosity over a considerable part of the Petaca area express Laramide folding.

CENOZOIC ERA

It is a moot question whether the Laramide Revolution was restricted essentially to the beginning of the Cenozoic Era or continued through Cenozoic time up to the present. At any rate, no further encroachments of the sea occurred in this section during the Cenozoic. Erosion was active in the higher areas, and a large amount of detrital material was deposited in the valleys and basins. The distribution of this material indicates that the principal features of the present topography of the pre-Cambrian rocks were developed before its deposition. At least one upwarping of the region occurred, in or just preceding the Quaternary period. Volcanic activity continued intermittently throughout the era, pouring out flows of rhyolite, andesite, trachyte and basalt.

The earliest Tertiary deposit is a coarse, well-cemented conglomerate series of Eocene or Oligocene age, named the Carson conglomerate. It is abundant in the Petaca area and environs, and outcrops on some of the peaks to the east of the Picuris area. The boulders and pebbles consist of pre-Cambrian quartzite, granite and schist; of chert, presumably Pennsylvanian and of various extrusive rocks, such as andesite, trachyte and rhyolite, presumably Tertiary. The poorly stratified and coarse nature of this conglomerate, and the wide distribution of similar and approximately contemporaneous rocks, indicate rapid erosion from a major highland area, the lately-built Rocky Mountains. Certainly a good deal of erosion must have preceded the deposition of the conglomerate, as in the Petaca area it lies directly upon the pre-Cambrian rocks and east of the Picuris area it lies upon the Magdalena formation. In each area all of the Mesozoic rocks and a part of whatever Paleozoic rocks may have existed were eroded before the conglomerate was deposited.

The next series is the Santa Fe formation, consisting of sands, gravels and clays, which in most exposures are poorly consolidated. These rocks were deposited possibly in part during Miocene, but principally in Pliocene time; and at the end of Pliocene time the broader physiographic features of the region, with the exception of the great basalt plain along the Rio Grande, must have been quite similar to those of the present time. The formation is characteristic of the valley of the Rio Grande, so presumably that river was in existence at the time. The deposits are thickest and lowest near the river, and they are thinner and coarser on the higher levels near the mountains. The Santa Fe formation was not deposited north or west of the Petaca area nor east of the Picuris area, but it did accumulate against or over their other flanks. The pre-Cambrian rocks of the Picuris and Petaca areas are undoubtedly continuous under the Santa Fe and younger formations. Igneous extrusives, consisting of rhyolites, trachytes and agglomerates, occur in a few places within the

Santa Fe formation. Their distribution indicates that during its deposition intermittent volcanic activity occurred.

In Pliocene or Pleistocene time, vulcanism on a grand scale spread a series of basaltic lava flows over a good part of the region. These flows filled the valley of the Rio Grande, and in parts of both the pre-Cambrian areas basalt flowed over or against the ancient rocks. These flows have been trenched by the Rio Grande and a few tributaries, and the amount of erosion accomplished since their eruption suggests that they may be Pliocene rather than Quaternary, notwithstanding the fact that similar !flows in other parts of the State are unquestionably Quaternary. It seems quite possible that the uplift of the region, which followed or accompanied the eruptions and initiated the present cycle of erosion, may correlate with the break between Tertiary and Quaternary time. Some of the vents from which the eruptions came are indicated by volcanic cones, such as San Antonio Peak, Cerro Olla and Ute Peak, which project above the northern part of the basalt plain.

In this region the surface defined by the basalt flows and the Tertiary rocks is continued in the general level of the pre-Cambrian. areas. Obviously the late Tertiary surface upon which the basalt flowed was one of comparatively moderate relief. Erosion had reduced much of the upland areas approximately to the levels at which deposition was taking place, leaving elevated spots composed of the most resistant rocks. These high places remain the peaks of the present topography. The effect of Quaternary erosion has been to dissect the Tertiary surface and increase relief, but the general accordance in elevation of any of the summits clearly defines the position of the old surface. This surface is called the Santa Fe peneplain in this report. Evidence of it is observable in any parts of New Mexico.

Since the basalt eruptions the region has been subject to erosion. Signs of Pleistocene glaciation, recognizable in the Sangre de Cristo Mountains, were not observed in these areas. Probably some of the higher terraces of coarse material along the larger streams are Pleistocene. The Rio Grande and Taos Creek have cut deep canyons through the basalt flows and have ex-posed the underlying rocks. The valleys of the Vallecitos and Tusas rivers have been cut down approximately a thousand feet below the surfaces of the basalt flows. The Rio Pueblo has cut a scenic gorge of similar dimensions into the Dixon granite. Considerable erosive stripping has been accomplished over the entire region. Large alluvial fans have been built skirting the mountain slopes. Sands and gravels have been deposited along the stream courses.

GENERAL ECONOMIC POSSIBILITIES

Among the economic mineral substances known to occur in the pre-Cambrian rocks of the areas under consideration are the following:

I. Minerals that have been exploited: Mica, lepidolite and spodumene, and silver- and gold-bearing veins.

II. Unexploited minerals whose occurrences warrant consideration as possibly exploitable: Sillimanite, kyanite, feldspar, quartz-mica schist (presumably to be separated into ground mica and quartz), dimension stone (pink granite, black slate) , crushed stone (granite, quartzite, slate), wolframite, refractories (quartz, quartzite, mica schist), ilmenite, garnet, and placer gold.

III. Minerals that occur under conditions not encouraging for prospective exploitation: (a) Minerals that have been mined and sold, but whose recovery was distinctly accessory to exploitation of other minerals; monazite, tantalite-columbite, samarskite, and bismutite; and (b) unexploited minerals; copper, lead and zinc minerals, microlite, dumortierite, specularite, roscoelite, fluorite, molybdenite, and beryl.

Tertiary deposits in the vicinity of these areas contain fluorite, manganese minerals (not observed in exploitable quantities), and sands and gravels. The Tertiary deposits might reasonably be expected to contain workable clays. However, the Tertiary deposits are not considered in this report.

PART II. THE PICURIS AREA

TOPOGRAPHY AND GEOGRAPHY

The Picuris area consists of a triangular group of mountains situated west of the Sangre de Cristo ranges. The northeast corner of the triangle is about 7 miles southwest of Taos. From this point the east border extends south approximately 9 miles to the Rio Pueblo. Here the border follows the Rio Pueblo west to the Rio Embudo and that stream west to the Rio Grande. The remaining side of the triangle is roughly parallel to the Rio Grande, and the pre-Cambrian rocks outcrop in its canyon from Rinconada to Pilare. The mountain group is dominated by Picuris Peak, whose elevation is 10,770 feet. It is some distance southeast of the center of the area. All the prominent peaks of the area are connected by divides to Picuris Peak. As shown on Plate II, most of the area is occupied by a great syncline. This geologic structure is manifested by the two principal divides. One extends west from Picuris Peak and connects with Copper Mountain the other extends north from Picuris Peak to the east of Arroyo Hondo and swings westward in a great hook nearly to the mouth of Arroyo Hondo. The southern part of the area is drained by the Rio Embudo and tributaries, and the northwestern part by the streams occupying Arroyo Hondo, Piedras Lumbres, Tierra Amarilla, and Agua Caliente canyons. The northeastern part is drained by Rio Grande del Rancho, Arroyo Miranda, and some conspicuous but unnamed streams. All the drainage is tributary to the Rio Grande. The Rio Grande del Rancho, the first stream west of Arroyo Miranda, Arroyo Hondo, Piedras Lumbres, Tierra Amarilla, Agua Caliente, Picuris, and Telephone creeks, the Rio Pueblo, the Rio Embudo and the Rio Grande are all permanent streams. The other streams are intermittent.

The area is scantily populated and only along its borders. The villages of Talpa and Ranchos de Taos are near the northeast corner. Rinconada and Pilare (formerly Cieneguilla) are along the Rio Grande. Bordering the area on the south are Dixon, Peñasco, Chamizal, Badito, Rio Pueblo, and the Picuris Indian pueblo. All these villages are small, and with the exception of the Picuris pueblo are peopled mainly by descendants of colonists whose land grants originated in the days of Spanish or Mexican rule. They are a pastoral people, living essentially by irrigation of small tracts along the larger streams. Most of the area of pre-Cambrian rocks is too rugged or lacks the permanent streams to support a population. Although there are no roads that extend any distance into the heart of the area, its border on every side is followed by well-constructed highways. The nearest railroad point is Embudo, on the narrow-gauge line of the Denver & Rio Grande Western railroad.

GEOLOGIC STRUCTURE

The Picuris area is for the most part a large syncline. (See Plate II.) The southern limb of this syncline is approximately vertical and in places is slightly overturned. This limb extends from Copper Hill eastward through Copper Mountain to Picuris Peak. The syncline turns up rather abruptly on the east, the strike of the rocks swinging northward from Picuris Peak and then westward. The northern limb is approximately parallel to the Rio Grande. The strata dip about 75° W. at the east end of the fold and the dip of the northern limb varies between 75° and 45° SE. The axis of this syncline is marked by a belt of black slate extending from near Dixon northeast to a point about midway along Arroyo Hondo. Near Dixon a subordinate syncline, whose axis is also occupied by black slate, forks eastward from the main syncline, but it dies out before it reaches Picuris. The anticline that separates it from the main syncline is best observed at Copper Hill. Most of the strata composing the smaller syncline are approximately vertical. Presumably there is an anticlinal axis along the south border of the area, but it is obscured by granitic intrusions and overlap of younger formations.

As previously discussed in the section devoted to geologic history, the folds that strike approximately N. 70° E. through this area were developed in the pre-Cambrian revolution that built the Pueblo Mountains, and the present exposure is a mere remnant of a folded mountain system, most of which has long since been eroded away. The region was later affected by the Laramide Revolution, the trend of the Laramide folds being north-south. The upturning of the east end of the large syncline is presumably due to Laramide folding, as the Magdalena formation dips steeply eastward along the divide between Arroyo Miranda and Rio Grande del Rancho. The structure of the pre-Cambrian rocks must be understood as manifesting two periods of folding with a very long interval between, the folding of the later period being superimposed on and nearly at a right angle to the folding of the earlier period. No important faulting was observed in the Picuris area.

Unquestionably the pre-Cambrian folding of this area is contemporaneous with that of the Petaca area, and the folded series found in both areas would be continuous if the intervening younger rocks were stripped away. Undoubtedly an eastward continuation will be discovered in the pre-Cambrian rocks of the Sangre de Cristo Mountains.

PROTEROZOIC ROCKS

ROCKS OF SEDIMENTARY ORIGIN

HOPEWELL SERIES

The oldest group of Proterozoic rocks, the Hopewell series, is represented in this area by a group of dark schists, formed from a succession of basalt and andesite extrusives (Picuris basalts) with some quartzite members. The most conspicuous quartzite is mapped separately as the Badito quartzite member. Although some of the Picuris basalts are readily identifiable as such by having porphyritic or amygdaloidal texture, the series contains a good deal of black hornblende-chlorite schist for which an igneous origin is merely inferred. Such schists may be observed between the Harding mine and the Dixon granite to the south, where they are in part epidotized by contact metamorphism resulting from the intrusion of the granite. They may also be found in Picuris Canyon, on the south spurs of Picuris Peak, and west of the mouth of Arroyo Miranda. In all these places the Hopewell series, with the exception of the Badito quartzite, is composed of hornblende schist and basalt, both of which are considered as representing the Picuris basalts. In a belt north of the Harding mine is the only conspicuous part of the series in this area which is presumably of sedimentary origin. Here the schists are composed of biotite, muscovite and quartz, and grade into the Rinconada schist. The Badito quartzite is bluish-gray quartzite, unquestionably of sedimentary origin. It occurs along the north side of the Rio Pueblo gorge and in a long strip extending from the mouth of Picuris Canyon across the south and east spurs of Picuris Peak. At the mouth of Picuris Canyon it has been converted to quartz-muscovite schist, possibly by contact metamorphism.

The Hopewell series in this area ranges up to three-quarters of a mile in thickness. The intercalation of sedimentary and extrusive rocks suggests a period of diverse sedimentation, abundantly punctuated by volcanic activity. Some further description of the basaltic members of the series is given in the discussion of the Picuris basalts.

ORTEGA QUARTZITE

In most places the quartzite and quartz schist formation that succeeds the Hopewell series is divisible into quartzitic and schistose phases. However, there seems to be no stratigraphically consistent separation between these phases, so for correlation purposes the minor schistose phase is included under the general name, Ortega quartzite. It is quite apparent that the formation was originally sandstone those parts that contained impurities became schistose under pressure, while the purer parts, lacking the ingredients to form platy minerals, became quartzite. Thus the quartzite and schist are to be considered as lithologic phases having no separate stratigraphic significance in correlating with other areas. It is anticipated that the formation may exhibit either or both phases wherever it may be found, but that it is essentially quartzite, the schistose phase representing local departures from type due to impurity. Typically the quartzite is bluish gray. The schistose phase, called the Rinconada schist in this area, is gray to buff quartz muscovite schist, which in many places has interbedded quartzite members. Some of the quartzite members are quite thick; north of Copper Mountain quartzite composes about half the total mass of the Rinconada schist. Although most of the schist is more or less even in texture, in places it contains porphyroblasts of garnet ranging from pinhead to marble size, or of staurolite up to an inch long. Many of the staurolite crystals are twinned. Some of the schist is conglomeratic. Conglomeratic pebbles, flattened and drawn out by flowage, may be observed from, the Dixon-Peñasco road in a bare hill that is approximately on the north line of Sec. 30, T. 23 N., R. 11 E.

The non-schistose quartzite outcrops in a great curved strip extending east from Copper Hill to Picuris Peak, then swinging north and west to the mouth of' Arroyo Hondo, thence southwest along the Rio Grande to the mouth of the Rio Embudo. Near the base of the quartzite in Picuris Canyon, some of the Picuris basalts are included. At this location the quartzite contains conglomeratic pebbles of quartz which have been elongated by solid flow. Conglomeratic pebbles are also observable on the peak in the south half of Sec. 13, T. 23 N., R. 12 E. In the valley that cuts across the quartzite just west of Copper Hill the quartzite grades into sandstone. This is the only place found in either of the pre-Cambrian areas where the Proterozoic sediments have not been converted to metamorphic rocks.

The Rinconada schist occurs principally in a belt up to a mile in width extending parallel to and just inside of the curved strip of the quartzite. It also occurs in a broad east-west belt about 6 miles long between Copper Hill and Rio Pueblo. No quartzite intervenes between the Rinconada schist and the Hopewell series in this locality, although it does everywhere else in the area. Possibly the encroachment of the schistose phase is due to original difference of composition, but it seems more likely that emanations from the Dixon granite may have introduced enough material to facilitate the formation of platy minerals.

Over most of the area the Ortega quartzite has a thickness of about 2 miles. North of the Harding mine it is only a mile from the Hopewell series to the Hondo slate. Judging from observations made elsewhere in the two pre-Cambrian areas, this change in thickness might be due either to sedimentary thinning or to solid flow, or both.

HONDO SLATE

The Hondo slate marks the axes of the principal synclines of the area. The most conspicuous occurrence is a belt extending from near Dixon northeast to the central part of the drainage system of Arroyo Hondo. Another smaller belt extends east-west between the Harding mine and Copper Hill. Presumably the smaller belt diverges from the larger one under the Tertiary cover near Dixon. Some of the slate is exposed along the Dixon-Peñasco road a few miles east of Dixon, The Hondo slate is characteristically black and has well-developed schistosity. In places a rather high iron content causes it to weather to a rusty color. In a few spots, zones are exposed that resemble streaks of "iron formation" in the Proterozoic rocks of the Lake Superior region. The most conspicuous of these noted was just east of the exposure on the Dixon-Peñasco road. However, the ferruginous beds are scarcely well enough developed to warrant hopes of finding exploitable bodies of iron ore. In many places, particularly along Arroyo Hondo, the black slate grades into quartz-muscovite schist.

The black slate is not very rich in carbonaceous material, but it loses its color upon ignition, and chemical tests indicate carbon. The presence of carbon suggests that organisms existed in the Proterozoic geosynclinal sea. However, no forms even remotely suggestive of fossils were observed.

The Hondo slate ranges up to a mile in thickness, but there is no evidence to show that it may not have been thicker, as it is preserved only in the troughs of synclines.

ROCKS OF IGNEOUS ORIGIN

PICURIS BASALTS

The Picuris basalts comprise a series of basalt and andesite flows that occur principally interspersed with the sedimentary schists of the Hopewell series. The basalts could be grouped definitely as part of the Hopewell series, except that they persist up into the Ortega quartzite. The only such occurrence observed in the Picuris area is in Picuris Canyon, and there the basalts are close to the base of the quartzite and could readily be grouped with the Hopewell series. However, the occurrence in the Petaca area of basalt bodies in the Ortega quartzite makes it necessary to recognize that, although the usual position of the Picuris basalts is within the Hopewell series, the volcanic activity so prominent in Hopewell time persisted to a limited extent into Ortega time. Therefore the basalt extrusives have been given a distinctive name. It should be understood that most of the dark hornblende schists of the Hopewell series probably belong to the Picuris basalts, but the development of the schistosity has destroyed their original textures.

The most readily recognizable exposure of the Picuris basalts observed in the Picuris area is near the mouth of Picuris

Canyon. Here, although the basalts are schistose, their igneous nature is definitely established by the presence of lath-shaped phenocrysts of plagioclase. The phenocrysts are oriented parallel to the flows and show typical flow-banded structure. The basalt series in Picuris Canyon is half a mile thick, and near the mouth of the canyon it is intruded by numerous aplite dikes, presumably from the Dixon granite. Basalts, and dark hornblende schists, that were probably of igneous origin, were also observed at the foot of the mountain slope northeast of Picuris, in the vicinity of the Harding mine, on the spurs of Picuris Peak west of Telephone Canyon, and west of the mouth of Arroyo Miranda. In the first-named place the basalt is porphyritic. In part of the last-named exposure the hornblende schist contains many lit-par-lit stringers of feldspar, presumably formed by emanations from the Dixon granite. In many places rounded inclusions of white quartz may be discerned that are almost certainly amygdaloidal. South of the Harding mine, contact metamorphism from the Dixon granite has epidotized patches of the basalt and hornblende schist.

DIXON GRANITE

Much of the pre-Tertiary surface of the Dixon granite is covered by the Santa Fe formation and younger rocks. The dimensions of the igneous mass are unknown, but the distribution of its present outcrops indicates that it is batholithic in size. It is conspicuous in the hills to the west and south of the Harding mine and is exposed along the Rio Pueblo from Dixon almost to Picuris. Most of Rio Pueblo in this stretch occupies a scenic gorge cut several hundred feet deep into the granite. Granite occurs in hills south of the Rio Pueblo and in isolated outcrops from Las Trampas to Peñasco. Irregular aplite dikes, presumably from the granite, cut the Picuris basalts in Picuris Canyon. From Picuris to Badito the Rio Pueblo flows between two granite hills. The Dixon granite also occurs in a conspicuous belt extending from the foot of the mountain slope northeast of Picuris to the head of Telephone Canyon, thence north nearly to Talpa. Virtually all the watershed of Arroyo Miranda is underlain by this granite.

The typical Dixon granite is fairly coarse grained, but it varies a good deal in both texture and composition from place to place. In the gorge of the Rio Pueblo it is mainly even-grained pink and gray biotite granite. In the hills near the Harding mine, in the vicinity of Telephone Canyon, and west of Arroyo Miranda, it is pink, almost lacking in ferromagnesian minerals, and the quartz grains are rounded. Probably the rounding of the grains is due mainly to resorption. At the east end of the Rio Pueblo gorge, between Picuris and Badito, near Peñasco, and east of Arroyo Miranda, the granite is dark colored from an abundance of biotite and contains large twinned orthoclase phenocrysts of light flesh tint. In the last-mentioned location the porphyritic phase is abundantly intruded by aplite dikes. In places flowage has converted the granite to schist. Schistose phases in the granite may be observed along Chamizal Creek and near the Rio Pueblo east of Picuris. Most specimens of the granite studied in thin section show extensive granulation not perceptible to the naked eye. Possibly some of the rounding of grains is due to granulation. Besides causing granulation and schistosity, solid flow has so modified the original texture of the granite in any exposures that the original paragenetic relationships are obscured.

The Dixon granite is younger than the Proterozoic rocks of sedimentary origin and is intrusive into them. Because the schistosity developed in the granite is parallel to that of the other pre-Cambrian rocks, and because intrusive activity commonly accompanies a diastrophic revolution, the intrusion of the Dixon granite is presumed to correlate with the Pueblo Revolution. Development of schistosity in the granite could have taken place only under heavy cover, which has since been removed. The schistosity of the granite apparently developed in pre-Cambrian time, as no rocks of the region bear evidence of solid flow during any later period. The intrusive nature of the granite is evident from the following features: (a) It truncates the other Proterozoic rocks west of the Harding mine and west of Arroyo Miranda; (b) aplite dikes, pegmatites and veins, which from. their composition and distribution apparently emanated from the granite, may be observed cutting Proterozoic rocks in the vicinity of the Harding mine, Copper Hill and Copper Mountain, in Picuris Canyon, along the westernmost tributary of Telephone Creek, in the road cut near Pilare, and at the contact with the Hopewell series west of the mouth of Arroyo Miranda; (c) feldspathic lit-par-lit bands in hornblende schist at the last-named outcrop presumably emanated from the granite; and (d) contact-metamorphic effects may be observed south of the Harding mine. These effects consist of sericitization and feldspathization of a zone up to some hundreds of feet in width, and epidotization of the adjacent hornblende schists. Where the contact zone is well developed, a complete gradation has been established between granite and country rock.

AGUA CALIENTE GABBRO

On one of the southern tributaries of Agua Caliente Creek, an exposure of gabbro was found. No definite evidence of an intrusive origin or of pre-Cambrian age was discovered. A diorite outcrop just northwest of the top of Picuris Peak is similarly doubtful. No time was spent in studying these rocks separately. Lacking more definite evidence it is merely suggested that these rocks may be intrusive and of Keweenawan age. They are not schistose, and were not mapped separately.

PEGMATITES AND VEINS

Several conspicuous pegmatites and hypothermal quartz veins, which undoubtedly emanated from the Dixon granite, crop out in the general vicinity of the Harding mine between the Rio Pueblo and Copper Mountain. The only pegmatite that has been exploited is at the Harding mine. The other pegmatites are composed of feldspar and quartz, with accessory muscovite, and the outcrops would be of economic significance only in case feldspar and quartz should become workable. Some pegmatites are exposed in the contact zone west of the mouth of Arroyo Miranda, and one crops out in the highway cut just south of Pilare where the roadway enters pre-Cambrian rocks. This last-mentioned outcrop suggests that unexposed intrusive granite must be fairly close at hand, either below or concealed under the younger rocks to the west.

The principal pegmatite at the Harding mine, which is in the NE. $^1/_4$ Sec. 31, T. 23 N., R. 11 E., crops out in a wide band across the slope, of a north-facing hillside. (See frontispiece.) The pegmatite dips southward. Roos[1] describes it as having a dip of 11° and being 70 feet thick, but observations made in the present quarry indicate less thickness and a steeper dip. The pegmatite is quite irregular in outline and is about 35 feet thick in the quarry. Roos' diagram indicates that a pegmatite outcrop on a knob north of the quarry is part of the same one that has been mined, having been isolated by erosion, but the characteristic irregularity of pegmatites warrants caution in such extrapolation.

A good deal of the original outcrop has been removed in mining, but apparently lithium minerals were not predominant at the outcrop. The entrance to the quarry is cut through a large mass of schist and microcline-quartz pegmatite. There are many other pegmatite outcrops on the three claims composing the property. (See figure 1.) Most of them are composed of common microcline-quartz pegmatite, but lithium minerals are present in the outcrops at several places in the vicinity of the quarry and along the hill to the northeast. The exposures do not indicate whether the outcrops are separate dikes or intersect underground, but the latter relationship seems more probable.

It is apparent that the pegmatite as a whole is composed principally of microcline and quartz, with some muscovite. The lithium minerals occur in shoots that are similar in irregularity to the ore shoots in a quartz vein. Considered roughly in order of their abundance, these shoots consist of the following principal minerals: lustrous white albite; pink, gray and lilac lepidolite; and white, and greenish-white spodumene. Rarer minerals in the shoots include blue apatite; green and dark gray _microcline; microlite; pink beryl (said to be cesium-bearing). Blue beryl

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[1] Roos, Alford, Mining lepidolite in New Mexico: Eng. and Min. Jour.-Press, vol. 121, pp. 1037-1042, 1926.

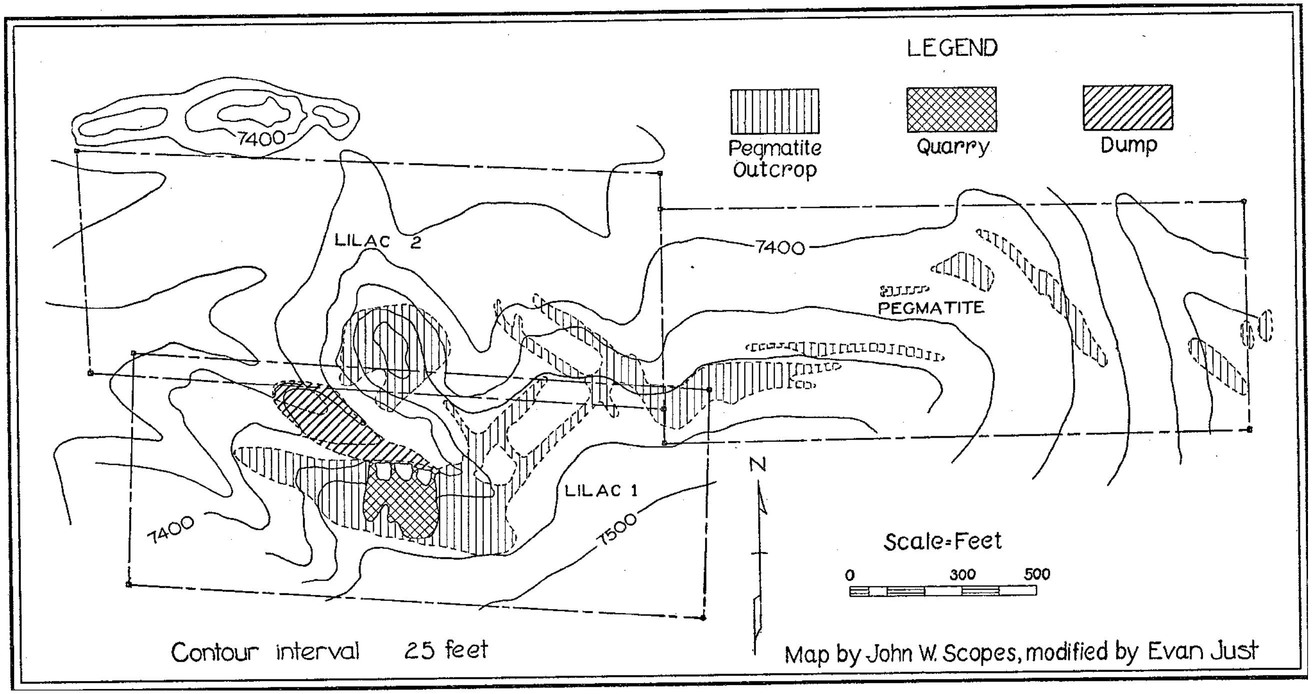

FIGURE 1.-Map of Harding mine

(aquamarine) is found in the schist immediately adjacent to the edge of the pegmatite. Pyrophyllite partly altered to kaolin is present, this mineral being probably a katamorphic product developed from some of the minerals already mentioned. Hess[2] identified columbite at the property. Schaller[3] mentions that amblygonite was reported from this mine, but none was found by the writer, nor is it mentioned by other investigators.

The mineralogy and field relationships of the Harding pegmatite confirm the general ideas expressed by Hess,[4] Landes[5] and Schaller.[6] These investigators conceive typical pegmatites as being originally dikes of potash feldspar and quartz injected as magma into the country rock. In many cases, particularly in the pegmatites carrying rare minerals, the original dikes are partly or wholly replaced and enlarged by metasomatic replacement. The replacement is accomplished by hot solutions emanating from the same igneous source—typically a granite batholith—as the dikes. The conception does not postulate that a dike necessarily antedates a pegmatite vein, as pegmatite veins may be formed directly in the country rock, or they may follow and replace or be replaced by quartz veins. The extreme heterogeneity of texture, composition and paragenesis characteristic of pegmatites is due to variations in temperature and composition of the solutions, which flow for a long period of time, continuously or in surges. Thus, some pegmatites are dikes, others are veins, some are dikes partly or wholly replaced by veins, and some are dikes grading longitudinally into veins.

The general mineral succession in the Harding pegmatite, subject to local variations, is: (1) quartz; (2) microcline, quartz and muscovite; (3) albite, lepidolite, spodumene, quartz, and rare minerals; and (4) quartz. Each successive wave of mineralization replaced earlier minerals, which were in part re-deposited locally, thus complicating the paragenesis.

The lithia content of the pegmatite is entirely in two minerals, spodumene and lepidolite. In the shoot that has been mined, lepidolite was the more abundant. Local parties have contended that some of the other minerals of the pegmatite, such as the feldspars, contain lithium, but analyses made of specimens collected by the writer failed to confirm this contention.

The accepted formula for spodumene is $LiAlSi_2O_6$. Accordingly, spodumene should contain about 8 per cent lithia (Li_2O), but comparatively few analyses show this much. The

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[2] Hess, Frank L., personal communication.

[3] Schaller, W. T., Lithium minerals: U. S. Geol. Survey Mineral Resources of the United States, 1916, pt. II, pp. 7-17, 1920.

[4] Hess, Frank L., The natural history of the pegmatites: Eng. and Min. Jour.-Press, vol. 120, pp. 289-298, 1925.

Pegmatites: Econ. Geology, vol. 28, pp. 447-462, 1933.

[5] Landes, Kenneth K., The paragenesis of the granite pegmatites of central Maine: Am. Mineralogist, vol. 10, pp. 355-411, 1925; Origin and classification of pegmatites: Am. Mineralogist, vol. 18, pp. 35-55, 95-103, 1933.

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

discrepancy is probably due to isomorphous replacement of lithium in the crystal structure by some other element. A specimen from the Harding pegmatite showed 7.61 per cent lithia. Lath-shaped crystals up to 2 feet long and 5 inches wide are not uncommon. The spodumene occurs with lepidolite and albite, but also is found in quartz. Hess[7] describes all the spodumene crystals in this mine as being oriented with their long axes within 45° of vertical, but observations made in the present workings do not corroborate this statement.

The lepidolite on the property is gray, pink and deep lilac. Occasional specimens are wine-red. A minor amount of the lepidolite occurs as small but comparatively very long prisms that have replaced and are enclosed in albite. The bulk of the lepidolite is massive and may be micaceous or in translucent blocks so fine grained that the micaceous character is not apparent. The massive lepidolite has replaced microcline, and all degrees of replacement may be found. Early stages of the replacement have lepidolite so finely disseminated through the microcline that it is apparent only because of the lilac tinge that it imparts to the microcline. Analysis shows a mere trace of lithia. Probably the impression that microcline, in this pegmatite carries lithia is due to analysis having been made of some of this partly replaced microcline. In more advanced stages of replacement, flakes of lepidolite are perceptible. Many specimens in which replacement is only partial may appear on cursory examination to consist entirely of lepidolite, and the observer is likely to be deceived at first, but careful examination will usually discover reflections from cleavage surfaces of the microcline. The pure lepidolite is usually recognizable by its micaceous character or, in the very fine-grained variety, by its translucency usually the pink lepidolite is micaceous, and the gray and lilac varieties are translucent.

Roos[8] gives nine analyses of lepidolites from this mine. One of these analyses shows 6.33 per cent lithia and undoubtedly represents spodumene. The remaining eight analyses show lithia ranging from 1.03 to 3.21 per cent, the average being 1.90 per cent. According to analyses of specimens collected by the writer, the translucent deep lilac variety is richest in lithia, usually containing 2.5 to 3.0 per cent. The gray and pink varieties are likely to contain about 1 per cent lithia, and specimens intermediate between these colors and deep lilac have a corresponding range in lithia content.

Superficial tests may suffice for recognition of the lilac and gray varieties of lepidolite as such, but may lead to the belief that the pink variety is muscovite. Even microscopic examination is likely to fail to distinguish between lepidolite and musco-

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[7] Hess, Frank L., Pegmatites ; Econ. Geology, vol. 28, pp. 447-462, 1933.

[8] Roos, Alford, op. cit.

vite, and thorough differentiation requires complete chemical analysis and X-ray analysis.

According to Winchell,[9] lepidolite is not a single mineral of constant composition, but is a triangular isomorphous system of octophyllite micas ranging between the following molecules: (1) Lepidolite, $H_4K_2Lti_3A1_5Si_6O_{24}$ (5.7 per cent lithia), or possibly $H_2K_2Li_2Al_6Si_6O_{24}$ (3.7 per cent lithia); (2) protolithionite, $H_4K_2LiFe_4A1_3Si_6O_{24}$ (1.6 per cent lithia, 23.6 per cent iron); (3) polylithionite, $H_2K_2Li_3Al_3Si_8O_{24}$ (5.7 per cent lithia). Zinnwaldite is an intermediate member fairly rich in iron. According to this conception, pure specimens of the lepidolite system should contain not less than 3.7 per cent lithia if they are iron-free, and any specimens approaching the minimum of 1.6 per cent lithia should show a corresponding increase of iron up to 23.6 per cent. Winchell states that these molecules do not fit all known analyses, but they are the best reconciliation of trustworthy analyses at present available. He states that some specimens show more fluorine and less lithia than these molecules would allow. Fluorine is conceived to replace hydroxyl in the crystal structure. Published analyses of lepidolite show as high as 7.0 per cent fluorine. The Harding lepidolites, according to analyses published by Roos, contain amounts ranging up to 3 per cent. The fluorine content of lepidolite undoubtedly adds to the fluxing quality, which is an important property for its use in glass manufacture.

The Harding lepidolites are not reconcilable with the lepidolite system as conceived by Winchell. They are essentially iron-free, but are too low in lithia to fit that part of the system ranging between lepidolite and polylithionite. Winchell states that some of the lepidolites which are lower in lithia than his diagrams would allow probably have aluminum replacing some of the lithium. This suggests that the system may contain another end-member, with more alumina and less lithia than lepidolite-polylithionite. Such an end-member would probably have optical and other physical properties so similar to muscovite that exhaustive tests would be required for differentiation. In this discussion the term muscovite does not apply simply to light-colored mica, but is a petrographic term, restricted to the compound $H_4K_2(Al, Fe)_6Si_6O_{24}$ and the muscovite-phengite system to which it belongs.

In this area the belt of hypothermal veins related to the pegmatites extends farther away from the granite than the pegmatites. The pegmatites do not extend north of the Dixon-Penasco road, but the veins extend to Copper Hill and Copper Mountain. Most of these veins are composed of barren quartz. Those on Copper Hill and Copper Mountain contain copper, tung-

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[9] Winchell, A. N., Studies in the mica group: Amer. Jour. Sci., 5th ser., vol. 9, pp. 309-327, 415-430, 1925.

The lepidolite system: Am. Mineralogist, vol. 17, pp. 551-553, 1932.

sten and precious metals, and fibrous, satiny brown tourmaline. They are described more fully on pages 35-37. A pegmatite-quartz vein, containing black tourmaline crystals up to 6 inches long, crops out on the granite hill about a mile and a half east of Picuris. Several of the veins on Copper Mountain contain kyanite.

POST-PROTEROZOIC ROCKS

SEDIMENTARY ROCKS

PENNSYLVANIAN SYSTEM

Magdalena Formation.—The Magdalena formation outcrops along the eastern border of the Picuris area and in a large part of the Sangre de Cristo Mountains. It may be observed in various attitudes at several places along the U. S. Hill road from Talpa to Pueblo. The best exposures of the unconformity between the Magdalena formation and the pre-Cambrian rocks are along the crest of the ridge between Arroyo Miranda and the Rio Grande del Rancho. There the lower members of the Magdalena are micaceous quartz conglomerate, arkose, shale and lime-stone. In a few places along the road, arkosic phases of the formation may be observed. In the outcrops somewhat removed from the pre-Cambrian contact, the formation is principally limestone and shale. Much of the southeastern margin of the pre-Cambrian rocks is well covered with soil and vegetation. On the spurs in the vicinity of Telephone Canyon the pre-Cambrian rocks are overlain by a quartz conglomerate with a brown matrix, similar to that which occurs in the Magdalena formation on the divide east of Arroyo Miranda. Inasmuch as it contains no chert or igneous rock pebbles such as are common in the Carson con-glomerate, this conglomerate is classed as Pennsylvanian. It occurs at levels too high to be part of the Santa Fe formation. Most of the pebbles are quartz, quartzite and schist.

TERTIARY SYSTEM

Carson Conglomerate.—The well-cemented conglomerate that borders part of the Petaca area and has been called the Carson conglomerate in this report is not prominent in the Picuris area. Some patches of early Tertiary conglomerate appear in the Sangre de Cristo Mountains to the east, as shown on Plate I. These conglomerates are coarse, with a cement-like matrix. Presumably they are equivalent to the Carson conglomerate, and more or less equivalent to the Raton formation of the northeastern part of the State. A similar conglomerate is ex-posed near the Peñasco-Chamizal road, but here it is closely associated with the Santa Fe formation and may be part of that formation. Most of the Carson conglomerate appears at distinctly higher levels than the Santa Fe formation.

Santa Fe Formation.—The Santa Fe formation borders and overlaps the Picuris area on its southern and western flanks, and also appears in Arroyo Miranda. Outcrops in the gorge of the Rio Grande indicate that it underlies the basalt flows in places along the northwestern part of the area. Although a good deal of the Santa Fe formation has been stripped away by Quaternary erosion, it covers much of the pre-Cambrian rocks in the south-western part of the area, and, except for some exposures of limited extent, obscures them south of the Rio Pueblo.

The Santa Fe formation consists chiefly of flat-lying unlithifled sands, silts, gravels and clays. Well-cemented outcrops, some of which have tilted bedding, are known, however. Along Agua Caliente Creek near Pilare the Santa Fe formation is in part composed of well-cemented sandstone and conglomerate dipping about 40° W. These rocks may possibly be part of the Carson conglomerate instead of the Santa Fe formation.

It is not unlikely that the Santa Fe formation contains de-posits of placer gold in this vicinity. Some gold was recovered from veins at Copper Hill, and it is not unreasonable to suppose that Tertiary erosion may have stripped away similar veins along with associated pre-Cambrian rocks. Prospectors have panned colors from the Santa Fe formation in this area, but the writer is not aware of any workable deposits having been discovered.

QUATERNARY SYSTEM

Quaternary sediments in this region consist of alluvial gravels and silts washed out from highland areas .and deposited along the stream courses and in fans skirting the mountain slopes. The most extensive deposits of such outwash contiguous to the Picuris area flank it to the north, where .a fairly large part of the Quaternary basaltic flows has been covered with alluvial material.

No signs of Pleistocene glaciation were observed in this area. Typical glacial phenomena do occur in the higher parts of the Sangre de Cristo Mountains, however, and although there is no published classification separating Pleistocene from Recent sediments in this region, the writer believes that some of the higher stream terraces along streams draining from the Sangre de Cristo Mountains, such as the Rio Grande del Rancho and the Rio Pueblo, will eventually be correlated as glacial outwash.

IGNEOUS ROCKS

TERTIARY AGGLOMERATE

A few small hills near the hot-spring baths in Arroyo Miranda are capped with rhyolitic agglomerate that is undoubtedly Tertiary and is probably contemporaneous with the Santa Fe formation.

BASALT FLOWS

As mentioned in the discussion of geologic history on page 17 the deposition of the Santa Fe formation and development of the Santa Fe peneplain was followed by the outpouring of extensive basalt flows. These flows are prominent in the canyon of the

Rio Grande and Taos Creek, and a spectacular view of them may be obtained in the ascent out of the canyon on the road to Taos Junction. In this vicinity the Rio Grande has cut through a succession of basalt flows that is hundreds of feet in total thickness. A good section may be obtained along the road up Taos Creek toward Taos. These basalts extend along the west bank of the Rio Grande as far south as the mouth of the Rio Chama. They are of late Pliocene or Pleistocene age. Up to the present time they have commonly been accepted as the latter.

The basalts flowed against and over the northern and western margins of the Picuris area. Except in the canyons of the Rio Grande and tributaries, it is only in the southwestern part of the area that noteworthy amounts of basalt have been removed by erosion. Some small isolated exposures of the basalt occur along the Rio Pueblo near the southeast corner of the Picuris area. Inasmuch as they are rather remote from the flows near Dixon, it seems questionable whether or not they were ever connected to the basalts along the Rio Grande. However, they undoubtedly belong to the same epoch of volcanic activity.

ECONOMIC FEATURES

THE HARDING MINE

The Harding pegmatite, in the NE. ¼ Sec. 31, T. 23 N., R. 11 E., has been known at least since 1900, as in that year one of the present owners, J. J. Peyer, participated in locating a claim on it. At that time there was no recognition of its potentiality as a source of lithium minerals. The claim was allowed to lapse, and the pegmatite was located several times by various parties, presumably in the hope that it contained gold or silver. It was not until 1919 that the commercial possibilities of the lithium minerals were realized.[1] The property was then leased to Henry E. Wood, Inc., of New York City. Mining was begun in 1920 by the Mineral Mining Co. and Milling Co. after some exploration by shot-core drilling. The rock mined was shipped without any milling or concentrating, other than hand sorting, to the Wheeling Pulverizing Works, Wheeling, W. Va., where it was ground and sold to the glass trade. According to Roos, the price of ground lepidolite, f. o. b. Wheeling, varied from $30.00 to $45.00 per ton. Costs mentioned by Roos are: freight, Embudo to Wheeling, $14.00 per ton; haulage to Embudo, $2.50 per ton ; mining and stripping, up to $1.75 per ton delivered to stockpile.

According to information gathered by Hess[2] in 1924, the rock shipped was graded as follows:

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[1] Roos, Alford, Mining lepidolite in New Mexico: Eng. and Min. Jour.-Press, vol. 121, pp. 1037-1042, 1926.

[2] Hess, Frank L., personal communication.

Grades of Lithia Rock Shipped from the Harding Mine

1. Clean lepidolite plus 10 per cent spodumene—about 3 per cent lithia.
2. Thirty per cent spodumene, 60 per cent lepidolite, 10 per cent quartz—up to 3.5 per cent lithia.
3. Thirty per cent spodumene, 50 per cent lepidolite, 10 per cent quartz, 10 per cent feldspar—about 3 per cent lithia.
4. One-third each of lepidolite, spodumene and microcline; free from quartz—over 3 per cent lithia.
5. Mixed albite and spodumene, with about 10 per cent lepidolite; nearly free from quartz--about 3 per cent lithia.
6. Spodumene free from both quartz and lepidolite.
7. Spodumene with not over 10 per cent quartz and lepidolite.

All Grades, except and 7 (and probably 5) carried about 2 per cent fluorine; lumps were required to have diameters under 9 inches.

In 1927 a grinding plant was completed at Embudo, and mining operations were transferred to the Embudo Milling Co. whose mill is still intact (1934). It consists of a small jaw crusher arranged to feed a large quartzite-lined Abbe ball mill, which discharges to screens. The mill is powered with a large reciprocating steam engine. Several dozen sacks of ground rock are still stored in the mill. The property was transferred to the Pacific Minerals Co., Ltd., in 1928, but was turned back to the Embudo Milling Co. in 1930. Operations ceased in 1930. The mine is now in the hands of the parties who owned it during the entire period of exploitation, J. J. Peyer, A. H. Gossett, and Frank Gallup (estate of the latter, deceased).

Mining was done principally by quarrying, as the over-burden was thin. The south face of the quarry at the present time exposes a cover of up to 10 feet of schist and soil capping the pegmatite. (See frontispiece.) Presumably this cover would increase in thickness if the face were advanced, both because of the slope of the hill and the apparent dip of the pegmatite. Two small underground stopes have been cut into the south face of the quarry, and if operations should be continued in the same direction it probably would be desirable to continue mining by underground methods.

There are several small exploratory open cuts and tunnels scattered over the property, many of which have exposed lithium minerals, but the tenor of material exposed up to the present time in these cuts is scarcely rich enough to warrant development. Virtually all of the profitable exploitation was done in the principal quarry. The quarry at present is about 200 feet long east and west, and 60 feet wide. Judging from, the sizes of quarry and dump, the production was approximately as follows:

Estimated Production of the Harding Mine

	Tons
Total material mined	35,000
Overburden	5,000
Waste, excluding overburden	18,000
Estimate of rock shipped	12,000

Although the mine is usually considered as being primarily a lepidolite mine, comparison of the lithia percentages of the grades of material shipped with the lithia percentages of the lithia-bearing minerals makes it obvious that spodumene was necessary to bring the products up to marketable tenor. Remnants of shoots of lithium minerals indicate that characteristically the lepidolite was mixed with spodumene, so probably but little artificial compounding was necessary.

Except for two possibilities, the shoot of lithium minerals that was mined during the productive period seems to be mined out. The first possibility concerns a face of gray lepidolite and spodumene about 2 by 8 feet that shows in the face of the eastern-most stope. Development of this face might disclose a continuation of the shoot. The other possibility involves the floor of the quarry. It is concealed with debris, the removal of which might uncover workable lithium minerals. However, even if such work should fail to be encouraging, the abundance of lithia-bearing shoots on the property, plus the characteristic irregularity of pegmatites and of their contained shoots of metasomatically deposited minerals, warrant the belief that a well-conducted exploration program of drilling, supplemented with exploratory tunnels and cuts, would have an excellent chance of finding unexposed shoots of lithium minerals that would be exploitable.

Lepidolite is used chiefly in glass manufacture, in which it is employed as a flux. It also lessens the amount of froth developed. It is used particularly in the making of opal and white glass, heat-resisting glass and non-shattering glass. In clear glass the use of lepidolite makes the product more brilliant, tougher and harder. It lowers the coefficient of expansion and makes the glass more resistant to devitrification in moist air. In the making of opal glass, lepidolite used in place of cryolite reduces the corrosion of glass tanks. It is used in glazes and enamels. These and other uses are described by Ladoo[3] and Myers.[4] The use of lepidolite in glass batches is at present subject to a basic patent, U. S. Patent No. 1,261,015.

METALLIFEROUS VEINS

All the veins observed which offer any suggestion of being exploitable are near Copper Hill and on Copper Mountain. On Copper Hill, in the S. ½ Sec. 17, T. 23 N., R. 11 E., are the abandoned workings of the Champion Copper Co. where some small

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[3] Ladoo, Raymond B., Non-metallic minerals, pp. 319-322, 1925; McGraw-Hill Book Co., Inc., 1925.

[4] Myers, W. M., Mica: U. S. Bur. Mines Inf. Circ. 6205, pp. 29-32, 1929.

malachite-stained quartz veins cut the Ortega quartzite. It is apparent that several thousand dollars was spent in exploration and in construction of the mill, which has since burned. The work was obviously unsuccessful. The following description is quoted from Graton:[5]

> The Copper Hill district is situated in southern Taos County, between the Rio Grande and U. S. Mountain. It lies a little north of east from Embudo station, on the Denver and Rio Grande Railroad, and about northwest of the Indian pueblo of Picuris, by which name the district is often designated.
>
> Although the presence of copper-stained quartz veins in the region has been known for many years, little attempt was made to develop them until about 1900. In that year the Copper Hill Mining Company began development operations and erected a concentrating mill, which burned soon after completion. The company failed and the property is now held by New York capitalists. About two years later the Green Mountain Copper Company prosecuted development work in a small way. A little prospecting has been done by other parties. The district is credited with practically no production, and in 1905 no work was being done in it.
>
> The mineral deposits consist of veins of glassy quartz carrying copper, silver and gold. Quartz veins to the east of Copper Hill carry abundant black tourmaline prisms, but this mineral seems to be absent in the ore-bearing veins. Chalcocite, cuprite, malachite, and chrysocolla are present in the veins and it is said that argentite and tetrahedrite also occur. A little limonite is present in places and has probably resulted from the oxidation of pyrite In such material carrying iron stains gold values are sometimes encountered. Developments have not passed below the zone of partial oxidation and it is consequently impossible to decide what the exact character of the unaltered ore may be. In places, however, the extent of oxidation is so slight as to make it seem doubtful that the solid lumps of chalcocite there occurring can have been produced by enrichment of a previously existing ore. It appears more probable that the chalcocite is an original constituent of the vein. In fact, the resemblance is very close to pre-Cambrian quartz veins that carry bornite and chalcocite in the Virgilina district of Virginia, where the primary nature of these sulphides is plain.
>
> There is reason to believe that these deposits are of pre-Cambrian age, and it seems probable that they were formed immediately after the metamorphism of the inclosing rocks and were genetically dependent on the same agents.
>
> The property of the Copper Hill Mining Company is developed by a 180-foot and a 60-foot shaft and a 350-foot adit. The country rock, of alternating quartzite and poorly fissile schists, strikes slightly north of west and dips very steeply to the south. On the Champion claim an approximately vertical vein of northerly strike has been followed by an adit for 350 feet with a maximum attained depth of about 70 feet. The vein ranges in width from 8 inches to 3 feet. It splits and forks considerably, but produces no apparent alteration of the glassy quartzite wall rock. Chalcocite and derived cuprite in massive form are carried in the green-stained quartz, but the average value appears to be low. Near the breast of the adit, where a bunch of ore considerably better than the average was encountered, silver values were said to be very good and were attributed to argentite, but this mineral was not observed by the writer. Practically no stoping has been done on the vein. On the Oxide King claim, a short distance to the south, a 180-foot shaft has been sunk to explore a northward-striking vein that dips about 50º W. Some ore similar to that in the Champion claim was found, but no important development was done.

[5] Lindgren, W., Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 89-90, 1910.

The Champion Copper Co. continued the attempt to develop this property and operated in the district until about 1920. It is said that a pocket of gold-bearing quartz, which yielded $25,000, was found in a shaft about 100 feet deep, but the writer doubts the authenticity of the report. This company also operated a small mine near the west end of Copper Mountain, in Sec. 15, R. 23 N., R. 11 E., from which it is said that tungsten ore was produced under the stimulus of wartime prices. The shaft, which is small, is not now in condition to permit entrance. On the dump are quartzite and vein quartz, with malachite, wolframite, and fibrous, satiny brown tourmaline. The surface evidence does not suggest extensive mineralization, but no definite conclusion can be drawn on the basis of available data.

In the slate belt in Arroyo Hondo there are a few quartz veins containing argentiferous galena on which a small amount of work was done many years ago. Work on these veins apparently never progressed beyond the prospect stage.

The locality near Glenwoody bridge, on the Rio Grande between Rinconada and Pilare, is called the Glenwoody District. The observations made by the writer suggest that the locality does not merit consideration as a mining district. The ruins of an old mill may still be observed. The following description is quoted from Graton:[6]

> A camp called Glenwoody was established in 1902 on the Rio Grande almost west of the Copper Hill district and a few miles above Rinconada. A wide band of quartzite, intercalated with other greatly metamorphosed pre-Cambrian sediments, was said to carry $1.40 to $3 a ton in gold and to yield satisfactorily to cyanide treatment. A water-power plant was installed and a mill built, but the amount of gold actually recovered was far too little to pay. The most favorable account is that the mill return was 40 cents a ton, although some people in the region have never been convinced that the quartzite contains any gold.

PLACER GOLD

The gravels of the Rio Grande and the Santa Fe formation contain placer gold. For any years various hydraulic and dredging operations along the Rio Grande have attempted to extract this gold, but up to the present time none have been profitable.

SILLIMANITE AND KYANITE

Along the south side of Arroyo Hondo, in the N. ½ Sec. 25, T. 24 N., R. 11 E., the Ortega quartzite contains some seams of schist in which sillimanite occurs. These seams strike approximately east and dip about 45° S. The schist is brick red, with gray streaks, and seems to be a product of dynamic metamorphism of impure phases of the sandstones which became the quartzite series. The schist is composed of sillimanite, with variable amounts of quartz, some muscovite and talc, and a minor amount

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[6] Lindgren, W., Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S Geol. Survey Prof. Paper 68, p. 91, 1910.

of magnetite. The composition varies somewhat, but there are undoubtedly many thousand tons of material which would merit exploitation if the quartz could be separated from the sillimanite. The outcrops, which have a length of about a mile, have been staked as mining claims, but no development beyond assessment work has been done on the claims.

Sillimanite (Al_2SiO_5) and other minerals of similar composition, such as andalusite, kyanite and dumortierite, have become valuable in recent years for the making of high-grade porcelain and refractories.[7] In the firing of ceramic products, mullite ($Al_8Si_2O_{13}$) and quartz are produced. Mullite is an artificial mineral that is hard and strong, and whose fibrous structure binds and strengthens the whole mass. Typical ceramic products from clay are essentially mixtures of mullite and quartz. The quartz acts as a filler, and for most uses the amount of mullite produced by the firing of clay is sufficient to afford all necessary strength. However, quartz has a greater coefficient of expansion than mullite, and inverts from the alpha to the beta state at high temperatures. When a ceramic product is subjected to great variations in temperature, it is weakened by the differential changes in volume of its components. Thus porcelain and brick, used for such purposes as spark plug cores, crucibles and furnace linings, are a good deal more durable when the quartz content is reduced in favor of mullite. Mullite can be synthesized by combining clay and alumina, but the necessary treatment is elaborate and expensive. Accordingly, a demand has developed for natural minerals that are similar to mullite in composition. Because they contain more silica than mullite, sillimanite and similar minerals, if used in place of clay, invert to mullite and quartz, but the quartz is proportionately less than when clay is used, and not abundant enough to impair the durability of the mullite.

The sillimanite schist in Arroyo Hondo in general contains two undesirable minerals, magnetite and quartz. Removal of the magnetite should be entirely practicable by magnetic separation after grinding. If detailed examination should show the existence of other ferruginous minerals, they would probably be susceptible to magnetic separation after roasting. These procedures are common practice in treating minerals of this group and should be no particular deterrent to exploitation here. The critical problem to be solved in order to exploit this schist is the separation of quartz from sillimanite. Most of the quartz would have to be removed, otherwise the fired products would contain as much quartz as those from clays. The Vitrefax Corporation uses a process[8] of separating quartz from kyanite by crushing, heating, quenching and screening, that might possibly apply to quartz and sillimanite. Possibly some combination of grinding,

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[7] Riddle, F. H., Mining, treatment and use of the sillimanite minerals: Am. Inst. Min. Met. Eng. Trans., vol. 102, pp. 131-154, 1932.

[8] Riddle, F. H., op. cit.

and classification or flotation would separate the quartz. The feasibility of gravity separation or flotation is impossible to predict without experimental checking. Sillimanite is denser than quartz, which quality would make it tend to sink more rapidly when suspended in a fluid. On the other hand, the acicular shapes of the sillimanite particles would tend to make them sink more slowly than the quartz. It remains for a practical test to determine which of the two minerals would sink faster, and if their settling rates would be different enough to be of value in separation. The problem of separation could probably be solved by experimentation.

West of the sillimanite claims, in Sec. 26, is a hypothermal quartz-kyanite vein that has been prospected. Similar veins occur on Copper Mountain. No bodies of kyanite have yet been found that are large enough to be exploitable, but the occurrences suggest the possibility of such bodies.

MISCELLANEOUS NON-METALLIC MINERALS

The pegmatites in the vicinity of the Harding mine are large enough to be exploited for feldspar or quartz, should prices be raised or freight charges lowered enough to warrant development.

Mica schist has been ground and sold in other states,[9] but apparently the product has not been processed to meet specifications for the higher priced types of ground mica. There seems to be no reason why mica cannot be separated from quartz in mica schists to make a product suitable to the demands of a good part of the ground-mica market. Mica schists are characteristic of the Rinconada schist, and many of them should be susceptible to exploitation in this way if prices of ground mica remain attractive.

Rocks similar to the Dixon granite, the Hondo slate and the Rinconada schist have been used elsewhere for building stone. Given a market, it should be possible to quarry these rocks profitably. All these rocks and the abundant quartzites of the area could be used as crushed stone for road construction and other purposes.

Mica schist, quartzite and quartz are used elsewhere for furnace linings. Ground quartz and feldspar are employed as fillers. Ground quartz is used in boiler-scale compounds. Quartz, feldspar and garnet are used as abrasives. Many of the Rinconada schists contain abundant garnets that could be separated by mechanical methods, should likelihood of profit arise. The garnets observed were not clear enough to be used as semi-precious stones, but clear varieties might occur locally. Some of the pegmatites might possibly be found to carry precious or semi-precious stones. Aquamarine occurs associated with the Harding pegmatite.

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[9] Myers, W. M., op. cit.

PART III. THE PETACA AREA

TOPOGRAPHY AND GEOGRAPHY

The Petaca area is considerably larger than the Picuris area. It consists essentially of a belt of pre-Cambrian rocks, which extends from Ojo Caliente northwestward about 40 miles to the west end of Jawbone Mountain and which has a maximum width of 9 miles. For the most part the area parallels the Rio Vallecitos. It is quite rugged and includes the Ortega Mountains, as well as, several conspicuous summits, some of which are Jawbone, Ojo Caliente, La Madera, Kiawa, Tusas and Burned mountains. These peaks project above the level of the old Santa Fe peneplain, which is clearly defined by the general accordance of the lower summits. The altitude of the area in general increases from south to north. Nearly all the drainage goes into the Rio Vallecitos and its principal tributary, the Tusas River, and enters the Rio Grande via the Rio Chama. Some of the drainage of the eastern part of the area goes directly to the Rio Grande. Precipitation is heavier than in the Picuris area. As a consequence this area is well forested; and most of the valleys of any size contain permanent streams. Nearly all the area is in the Carson National Forest.

Like the Picuris area, the Petaca area is sparsely settled. The inhabitants, most of whom are descendants of the early Mexican colonists, live almost exclusively in hamlets along the Rio Vallecitos and the Tusas River. The villages of Ojo Caliente, La Madera, Ancones, Vallecitos, Canon Plaza, Servilleta Plaza, Petaca, Las Tablas, and Tusas, are in or immediately adjacent to the area. Tres Piedras, Servilleta and Taos Junction, all on the Denver & Rio Grande Western narrow-gauge line, are within a few miles of its east border. Highways suitable for automobile traffic extend from Taos Junction north through Servilleta and Tres Piedras, from Taos Junction to Ojo Caliente, and from Ojo Caliente to Tres Piedras via La Madera, Ancones, Vallecitos, Canon Plaza, and Tusas. Most of the .mica-bearing pegmatites are near roads and trails passable to automobiles and light trucks.

The summer climate of this area is very pleasant, with warm days and cool nights. Although the winters are fairly cold, and usually bring heavy snows, at no time of the year should climatic conditions materially hamper mining and operations accessory thereto.

STRUCTURE

The geologic structure of the pre-Cambrian rocks in most of the Petaca area is complicated and difficult to decipher. Mapping the structure in exact detail would require months of study. The plunging synclinal structure of Jawbone Mountain is quite apparent, and the granite of Tusas Mountain and Ojo Caliente Mountain roughly marks anticlinal axes, from which the other Proterozoic rocks that it intrudes, where exposed, dip away in all directions. The southward dip at Blue Hill, in T. 24 N., R. 10 E., apparently represents the southern limb of the Ojo Caliente anticline. In the entire locality between Tusas and La Madera mountains the apparent dips vary between southwestward and southward, ranging in inclination from about 20° to vertical. The only conspicuous exceptions are in T. 27 R. 7 E., where the dips are northward and northeastward; also on the east side of the Mesa la Jarita and in the northwestern extension of the Ortega Mountains, where the apparent dips are as low as 10° SW. Presumably a good many of these southwestward and southward apparent dips are false, being so because of tight isoclinal folding, coupled with a regional tilt. The cross-sections of this locality shown on Plate III should be considered as suggestive rather than substantiated. Interpretation of the upper sides of beds by observing cross-bedding, which was useful in checking the structure of the Picuris area, was inconclusive in this area. The difficulty was probably due to distortion of the bedding by solid flow and to minor folding. No diagnostic fracture cleavage or minor drag folding was observed in the quartzites, and no places were found where schistosity deviated appreciably from bedding. The discontinuity of the pre-Cambrian exposures added to the difficulty of structural diagnosis. The time available for field work permitted only an approximate analysis of structure, which is shown on the cross sections of Plate III.

Considering the isoclinal nature of the folding, structural trends show unusual variations in this area. The strike of the formations at Ojo Caliente and La Madera mountains is east-west, showing only a slight change from the northeasterly strikes of the formations at Blue Hill and in the Picuris area. From the Ortega Mountains to Kiawa Mountain the strike is in general northwest, with minor variations. North of Kiawa Mountain the formations trend east-west, but to the west the strike changes to northwest. From Hopewell to Jawbone Mountain the strike changes from northwest through north to northeast, then back through north to northwest. Considering both the Picuris and Petaca areas, trends of large-scale folds may be found corresponding to all directions of the compass, but the general trend seems to be roughly east-west. In each area it is quite apparent that the present exposures of pre-Cambrian rocks are remnants left by erosion of a major mountain system, which was built by the intense deformation of thick geosynclinal sediments and associated extrusives.

In some quarters the overturning of the folds that is common in the area of northwesterly strikes would be interpreted to indicate that a deformative thrust came from the southwest. It does not seem advisable to come to such a conclusion on the basis of the limited knowledge in hand concerning the history of these Proterozoic rocks. Furthermore, although there are no formations in this area that would give a clue to Laramide folding, it seems likely that this area was subjected to Laramide folding and- that the departure of the schistosity from the vertical might be due to that cause.

PROTEROZOIC ROCKS

ROCKS OF SEDIMENTARY ORIGIN

HOPEWELL SERIES

Although the Hopewell series is composed principally of schists that were originally igneous extrusives, it is here described among rocks of sedimentary origin because it apparently represents early deposits of the Pueblo geosyncline, and it contains rocks of sedimentary origin interspersed with the volcanic rocks.

The Hopewell series in the Petaca area is exposed in two belts. The larger belt extends from Jawbone Mountain southward through Hopewell, thence southeastward between Tusas and Kiawa mountains nearly to the Tusas River. The other exposure extends eastward across the north end of Ojo Caliente Mountain. The series consists principally of dark hornblende-chlorite schist, commonly feldspathic, developed from the metamorphism of basalt and andesite flows, which are described as the Picuris basalts. (See pages 23 and 44.) South of Hopewell and on the north end of Ojo Caliente Mountain some of the Vallecitos rhyolite flows are included in the series.

A small part of the Hopewell series is composed of quartzite and quartz-mica schist of sedimentary origin. The Cleveland Gulch quartzite is a particularly prominent member that is exposed between Tusas and Kiawa mountains. Its position in the series suggests that it may correlate with the Badito quartzite of ;the Picuris area.

The characteristic features developed in the series by contact metamorphism are epidotization and silicification. Aplite dikes and quartz veins are common in the contact zone. These features may be observed at all the contacts with the Tusas granite. Typically, the contact is sharp, but at Ojo Caliente it is marked by a belt of cross-bedded rock that strongly resembles arkosite. This rock is composed of small grains of feldspar and quartz and larger, rounded quartz grains, and is here interpreted as a sediment feldspathized by emanations from the granite. Except for the rounded quartz grains, it is very similar to the rock developed in the contact zone near Las Tablas.

The average thickness of the Hopewell series as exposed in this area is about 1 mile. The maximum thickness, exposed between Tusas and Kiawa mountains, is about 2 miles, but half a mile of this thickness is occupied by a large quartz monzonite intrusion, which has apparently wedged the series apart. These figures are not to be considered as indicating the total thickness of the series, as in no case has a contact with an older formation been observed.

ORTEGA QUARTZITE

The Ortega quartzite is the most widely exposed pre-Cambrian formation in this area. With the exception of Ojo Caliente Mountain, all of the numerous pre-Cambrian exposures west of the Rio Vallecitos, including the Ortega Mountains, consist of this rock, as do La Madera Mountain, Mesa la Jarita, Kiawa Mountain, several peaks west of Tusas Mountain, and Jawbone Mountain. The Ortega quartzite also appears at Blue Hill, between the Petaca and Picuris areas. Typically, it is white to bluish-gray quartzite. As in the Picuris area it contains a minor quartz muscovite schist phase, which is here named the Petaca schist. The Petaca schist is nearly restricted to the Mesa la Jarita. Locally the schist contains quartzite members, and in places it is conglomeratic. Along the strike it grades into typical Ortega quartzite. In places the schist is quite feldspathic. The schistosity obscures the original textures, and the feldspars may have been introduced by solutions emanating from the Tusas granite, or they may have been deposited as original components of the sediments. 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, which is described with the Tusas granite. (See pages 44 to 46.) The Petaca schist should not be regarded as a separate member of the Ortega quartzite for purposes of correlation with other areas.

Conglomeratic phases of the Ortega quartzite occur on the eastern end of Jawbone Mountain, in the narrows 3 miles north of Ojo Caliente, along the ridge in the north half of Sec. 15, T. 26 N., R. 8 E., and in the ravine that drains into the Rio Vallecitos just northwest of Burned Mountain. The pebbles consist of white quartz, jasper, and black chert. In several places the formation contains igneous masses. Several of the Vallecitos rhyolite flows are distributed through it, as shown on Plate III, and there are several places where the formation contains patches of hornblende-chlorite schist, which are discussed with the Picuris basalts. The thickness of the Ortega quartzite in this area is apparently between 4 and 5 miles. Such a thickness, however, is merely suggested, time not being available to muster conclusive evidence.

ROCKS OF IGNEOUS ORIGIN

PICURIS BASALTS

Most of the Hopewell series in the Petaca area consists of dark hornblende-chlorite schists that are metamorphic derivatives from basalt and andesite flows. In the Petaca area the schists derived from andesite are predominant. In a few places amygdules are recognizable in the less schistose phases. Plagioclase phenocrysts are abundant in the andesites, but most of them have been elongated beyond recognition by solid flow. The plagioclase phenocrysts are commonly saussuritized.

In places on the Mesa la Jarita, in the canyon south of Kiawa Mountain, and on the south slope of Kiawa Mountain, are patches of the hornblende-chlorite schist which are presumably related to the Picuris basalts, as some of the schist shows traces of amygdules. These occurrences indicate the persistence of basaltic igneous activity well into Ortega time, and furnish the reason for giving the basalts a particular name instead of grouping them as an element of the Hopewell series.

VALLECITOS RHYOLITES

The volcanic activity that persisted during the deposition of the Proterozoic sediments did not produce basalt and andesite exclusively. The Hopewell series and the Ortega quartzite contain a number of flows of rhyolite and. trachyte, which are here named the Vallecitos rhyolites. These flows range in thickness up to three-quarters of a mile. It is presumed that such thicknesses represent aggregates of flows, rather than single flows. In places the flows are somewhat schistose, but characteristically their original textures have been well-preserved, and flow banding is well developed. They range in color from deep pink to brick-red, and all contain distinct phenocrysts, which range up to a quarter of an inch in diameter. Trachyte is subordinate to rhyolite in amount. None of these flows were observed in the Picuris area. The following features support the classification of the Vallecitos rhyolites as extrusive rocks: (a) Flow-banded structure is well-developed; (b) the aphanitic ground masses are too fine for intrusive bodies of such size; (c) the long axes of the outcrops and the flow-banding strike consistently parallel to the sediments; (d) in the NE. $^1/_4$ Sec. 15, T. 26 N., R. 8 E., the flows are interbedded with conglomeratic quartzite; (e) the masses are elongated and lenticular; (f) the phenocrysts of quartz and orthoclase indicate an order of crystallization common in acidic extrusive rocks but rare in intrusive rocks of similar composition, such as granites.

TUSAS GRANITE

The Tusas granite, which is intrusive into the other pre-Cambrian rocks, is exposed along the east side of the area from Jawbone Mountain to Servilleta Plaza and in scattered inliers near Tres Piedras. It also outcrops at Ojo Caliente Mountain and in some of the adjacent hills. A quartz monzonite dike is wedged into the Hopewell series between Tusas and Kiawa mountains. It is an offshoot from the granite and is exposed for a length of 5 miles and a width up to half a mile. In most of its exposures the granite is stratigraphically low, most of its contacts being with the Hopewell series. This condition suggests that the Hopewell series was reactive with the intruding magma and permitted easy stoping, whereas the Ortega quartzite was unreactive and acted as a barrier.

The intrusive nature of the Tusas. granite and its position with reference to the pegmatites and veins indicate that the pegmatites and veins emanated from the granite intrusion. The granite is considered to be contemporaneous and possibly identical with the Dixon granite of the Picuris area, and likewise was probably intruded during the Pueblo Revolution. In both the Picuris and Petaca areas the development of schistosity in parts of the granites paralleling the schistosity of the other pre-Cambrian rocks indicates that the granites were not wholly antedated by the diastrophism that disrupted the Pueblo geosyncline. On the other hand, the granites are not sufficiently schistose to indicate that they underwent the full effects of that diastrophism. The dissimilarity of the trends of pre-Cambrian and later folding indicates that the schistosity in the granite was developed entirely before Paleozoic time.

The Tusas granite varies greatly in composition and texture. In general it is composed of medium-sized grains and is non-porphyritic. With the exception of the large dike north of Kiawa Mountain, the granite south of Tusas Mountain is pink and noticeably lacking in ferromagnesian minerals. In the dike and north of Tusas Mountain the rock is gray, contains a good deal of biotite, and varies from monzonite to quartz monzonite in composition. That part which is northeast of Hopewell contains numerous dark inclusions of the Hopewell series. The relationships between intrusion and host rock are intimate and complicated in this vicinity. It seems likely that the monzonitic phases of the intrusion are offshoots from the main mass, and that they are richer in ferromagnesian minerals because they contain much material derived from the Hopewell series. It is noteworthy that the pegmatites occur near the pink granite and that the precious-metal veins occur adjacent to the monozonitic phase.

Aplite dikes and quartz veins are present wherever the contact of the granite with the other Proterozoic rocks is exposed. Although the contact of the granite with the Hopewell series is typically sharp, most of the exposed contact between the granite and the Petaca schist is marked by a gradational zone ranging up to a mile in width. This unusual width possibly may be due to the granite being underneath the schist as well as to the east of it

The zone is feldspathized and exhibits a gradation in texture, composition and appearance from the schist on the west to the granite on the east. In many places small grains of magnetite are fairly abundant. The probability has already been mentioned, in describing the Ortega quartzite, that the entire mass of Petaca schist may have developed by contact metamorphism. The contact effects produced in the Hopewell series have been noted in the description of that series.

The pink phase of the granite exhibits unusual textural features. Locally the quartz grains are rounded. There has been enough alteration by solid flow to obscure the paragenetic relationships between minerals. Partly developed schistosity is common. Under the microscope, feldspar and quartz grains that appear whole to the naked eye show marked granulation. The characteristic texture of granite is the exception rather than the rule in the Tusas granite as exposed.

PEGMATITES AND VEINS

The pegmatites in the Petaca area occur adjacent to the Tusas granite in a belt that extends from the east side of Kiawa Mountain southward nearly to Ojo Caliente. Near Ojo Caliente the pegmatites are in the Hopewell series, but elsewhere they are in the Petaca schist. Most of the pegmatites are on Mesa la Jarita. The precious-metal veins of the Bromide-Hopewell District extend from Kiawa Mountain north to Jawbone Mountain. There seem to be no pegmatites north of Kiawa Mountain and no precious-metal veins south of it. The distribution of the pegmatites and veins with reference to the Tusas granite indicates that the granite is genetically related to both the pegmatites and veins.

The pegmatites are of various sizes, up to 100 feet wide and several hundred feet long. They do not have a uniform trend, either with reference to points of the compass or to schistosity of the host rocks. They are composed principally of white albite, pink, brick-red, white or green microcline, quartz, dark gray perthite, and muscovite. Accessory minerals include monazite, columbite-tantalite, samarskite, green or violet fluorite, garnet, ilmenite, bismutite, green beryl, uraninite, roscoelite, pyrite, and molybdenite. These minerals are named approximately in the order of their general abundance. Products of alteration, such as talc, kaolin and gummite, are developed locally. As a rule the monazite, columbite-tantalite, and samarskite are associated with brick-red microcline such as is common at the Fridlund and Miller mines. The principal minerals are characteristically coarse-grained, particularly the microcline crystals, many of which are more than a foot in diameter. Books of muscovite as large as 3 feet in diameter are reported, but most of the mica books that have been mined are less than 8 inches in diameter and 3 inches in thickness. Most of the pegmatites contain abundant smaller crystals of muscovite, and many of the feldspars contain fine-grained mica disseminated through them, much of which is distributed along cleavage planes. The book mica, large feldspar crystals and rare minerals are mainly scattered through shoots in the larger pegmatites.

A general survey of the district makes it apparent that no simple mineral succession prevails in the pegmatites. They must have been formed by solutions which were variable in character, as albite, muscovite, microcline and quartz may all be found replacing each other. It seems likely that these minerals were in part deposited by successive surges of different solutions, and that they were in part deposited contemporaneously. The book mica shoots are more abundant in border zones of the pegmatites, and the larger microcline and perthite crystals usually occur in interior zones, but these generalizations are subject to numerous exceptions. It is apparent that the mineralizing solutions followed zones of least resistance, which in various cases were border zones, interior zones or completely new courses in the country rock. The rare minerals commonly occupy interior zones of the pegmatites and seem to have been deposited by comparatively late surges of the mineralizing solutions. A good deal of the quartz and most of the large microcline and perthite crystals are paragenetically late. Many of the pegmatites grade longitudinally into quartz veins, so probably some of the later quartz represents a telescoping of quartz veins over the pegmatites in the later stages of mineralization. These pegmatites confirm the ideas expressed by Hess[1] and other investigators that pegmatites are deposited from hot solutions that were varied in character and flowed in successive surges over a long period of time.

The pegmatites of the Petaca, area are of the replacement type and are to be considered wholly as veins rather than veins telescoped over dikes. If dikes of common pegmatite preceded the formation of these pegmatite veins, they have been completely obscured by the veins. Some branches from the principal pegmatite at the Hoyt-Seward prospect illustrate various stages of growth. The beginning stages show albite in separated nuclei strung along contorted bedding planes of the schist. The more developed stages indicate that nuclei grew together into thin veins by progressive replacement of the intervening schist, and that these veins widened by replacement of the wall rock until the typical large pegmatites were formed. The wall contacts of the pegmatites are usually quite sharp, and but little alteration of the wall rock is apparent. The pegmatite at the Pinos Altos prospect exhibits maximum wall-rock alteration. The typical coarse pegmatite is bordered with a selvage of finer-grained pegmatite up to a few inches wide, which in turn is succeeded by a zone up

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[1] Hess, Frank L., Pegmatites: Econ. Geology, vol. 28, pp. 447-462, 1932 ; see also foot note, p. 28.

to 2 feet wide of muscovite and feldspar of coarser grain than the host rock, in which the schistosity of the host rock is preserved. This zone grades into the host rock, which is typical of the gradational contact belt between the Tusas granite and the Petaca schist. It is a tan fine-grained feldspathic quartz-muscovite schist, containing small, sparsely disseminated magnetite grains.

Hess and Wells[2] have analyzed samarskite from the pegmatite at the Fridlund mine, and by calculating the ratios of lead, uranium and thorium have computed the age of the mineral. According to their computations, the samarskite occurs in two separate generations in the same specimen and these generations are about 150,000,000 and 300,000,000 years old. However, current estimates of geologic time would place two such generations of samarskite in Paleozoic and Mesozoic time, instead of in pre-Cambrian time as the field relations indicate. The problem of dating contains so many unknown and variable factors that the best that can be done at this time is to point out the discrepancy and leave decision to the future.

The pegmatites exhibit fewer effects of dynamic metamorphism than the other pre-Cambrian rocks. No schistosity is developed in them. Such similarities of orientation of mica scales as exist are due to replacement along cleavage planes of the host rocks. The feldspars and quartz are not perceptibly granulated. Some of the mica books are bent into curved shapes, and "ruling" developed by pressure is common. On the whole, conditions suggest that the diastrophic effects of the Pueblo Revolution were accomplished before the end of the epoch of mineralization.

POST-PROTEROZOIC ROCKS

SEDIMENTARY ROCKS

TERTIARY SYSTEM

Carson Conglomerate.--Along the western, northern, and northeastern borders of the Petaca area the pre-Cambrian rocks are overlapped by an extensive early Tertiary conglomerate and sandstone formation which is here named the Carson conglomerate. This formation conceals patches of pre-Cambrian rocks within the area, and it is quite apparent that during Tertiary time a large part of the pre-Cambrian rocks now exposed was covered by this conglomerate. The surface of this formation on the west is higher than the general level of the pre-Cambrian rocks, but it is lower on the east. Probably most of the Carson conglomerate was derived from rock exposures to the west of the Petaca area, and the mountains of the area served as barriers which to a large extent prevented the conglomerate from being deposited farther eastward. Apparently this conglomerate

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[2] Hess, Frank L., and Wells, R. C., Samarskite from Petaca, New Mexico : Amer. Jour. Sci., 5th ser, vol. 29, pp. 17-26, 1930.

was derived from the rapid erosion of the Rocky Mountains, which were relatively young at that time. The distribution of the formation indicates that it was deposited over a surface having approximately as much relief as the present topography.

The conglomerate is characteristically coarse, containing many boulders over a foot in diameter. The matrix is typically light gray and resembles concrete. The cement is silica. The boulders, cobbles and pebbles consist of rhyolites, trachytes and andesites, unquestionably of Tertiary age black chert, presumably weathered from the Magdalena formation and various pre-Cambrian rocks, principally quartzites. The conglomerate is too coarse to have been derived from far-distant sources, and its composition indicates that the Magdalena formation once covered or occurred near the Petaca area and that the early Tertiary was a time of local volcanic activity. The conglomerate is usually well cemented and evidently is quite resistant to processes of denudation.

The Carson conglomerate is considered to be roughly equivalent to the Raton formation in the northeastern part of the State, and to the early Tertiary deposits of the San Juan basin. No direct correlation has been made between the early Tertiary deposits of the northeastern and northwestern parts of the State, and for lack of a means of correlating this conglomerate with a definite horizon in either region the formation is here given a separate name.

Santa Fe Formation (Miocene-Pliocene).—The Santa Fe formation overlaps the pre-Cambrian rocks of the Petaca area on those flanks that are not bordered by the Carson conglomerate, namely the southeastern and southern flanks. A more detailed mapping of the Tertiary and Quaternary formations than was accomplished for this report would probably class patches of what is here called Carson conglomerate as Santa Fe formation and a part of each of them. as Quaternary.

The Santa Fe formation bordering this area is composed exclusively of unconsolidated sands, gravels and silts, deposits derived from, areas to the west and north and transported by streams tributary to the Rio Grande. As mentioned in Part I, this formation represents a time of long-continued erosion and crustal stability, and its upper surface is continuous with a peneplain that may be observed at many places in the State. No evidence of deformation of this formation was observed in the vicinity of the Petaca area. The rejuvenation that initiated the present cycle of erosion occurred after the basalt flows were erupted. Erosion since that time has dissected the Santa Fe formation and the correlated peneplain.

Sulphur springs on the southwestern flank of La Madera Mountain have deposited enough tufa in the Santa Fe formation to form the bluff known as Owl Cliff. The alignment of these springs with the hot spring at Ojo Caliente to the south and the fluorite-psilomelane spring deposits to the north suggests the presence of a concealed fault along which magmatic solutions have ascended in Recent time and along which they may still be ascending.

QUATERNARY SYSTEM

Alluvial Gravels and Silts.—It is evident that the Petaca area has been undergoing active erosion since early Quaternary time, and only a small amount of sediment has been deposited. Naturally, all the water-courses contain Recent deposits, but outside of numerous stream terraces the only significant areas of Quaternary sediments in the area are near Tusas and from Vallecitos to Canon Plaza. In both these areas alluvium has accumulated because narrows downstream have checked the streams sufficiently to allow deposition. These two areas of alluvial deposits comprise most of the cultivated land in the area. The writer believes that many of the stream terraces, which include large, assorted boulders, will eventually be classed as Pleistocene.

IGNEOUS ROCKS

TERTIARY AGGLOMERATE

The rhyolite and agglomerate that occur in this region interbedded with the Santa Fe formation are not prominent in the vicinity of the Petaca area. The only exposures of any consequence that were observed are along the road from La Madera to Servilleta Plaza, where agglomerate and flow breccia contain small surface spring deposits of fluorite and psilomelane.

BASALT

The Petaca area is along the western margin of the great series of basalt flows of Pliocene or early Pleistocene age that were poured out over the Santa Fe peneplain in the Rio Grande valley. The height of this area, which enabled it to act as a barrier to retain the Carson conglomerate to the west, performed a similar function in limiting the westward spread of the basalt flows. The basalt laps against the area on its northern extremity and composes the Petaca Mesa, which borders the area near Petaca and Las Tablas. The remnant of a basalt flow, which probably was once connected to the Petaca Mesa, covers a large area on the Mesa la Jarita. The topography indicates that when this flow was erupted the present valleys of the Rio Vallecitos and Tusas River were nonexistent, the Santa Fe peneplain coinciding with the present level of the Mesa la Jarita. Basalt outliers also border the area along the La Madera-Servilleta Plaza road and near Ojo Caliente. Geodes in the basalt near La Madera contain calcite of optical grade.

PROPERTIES, USES AND PREPARATION OF MICA

The following description of the properties of mica is quoted from Sterrett,[1] whose report also contains some excellent illustrations of these properties:

> The first prominent characteristic of the minerals of the mica group is cleavage. All the micas have a pronounced basal cleavage, generally almost perfect, by which they can be split into thin sheets. The true micas yield cleavage sheets that are tough, flexible, and elastic. Other properties possessed in common by the micas are similarity in crystallization, other cleavages or partings called "rulings," brilliancy or high luster, transparency in some varieties, color, comparative softness, and relatively great resistance to the conduction of electricity and heat.
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> Several of these properties, such as toughness, flexibility, and elasticity of the cleavage sheets combined with transparency in some varieties, non-conductivity of electricity and heat, and brilliancy of the cleavage faces make mica valuable.
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> Muscovite is transparent and light-colored when split into thin sheets, but sheets one-sixteenth of an inch or more thick may be colorless, gray, yellow inclining to amber, red, brown, or green. Thin sheets are called "white" mica, but sheets of sufficient thickness to show strong color are spoken of, according to color, as "rum," "ruby," "smoked," or "green" mica. Muscovite occurs both in the form of small scales as a common constituent of many rocks and as large crystals of less widespread but still rather common occurrence.
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> Mica mined for commercial use is commonly found in rough blocks, some of which have irregularly developed crystal faces. The faces are not usually as many as would be required to complete the simplest figure, and their surfaces are generally very rough. A large part if not all of a block of mica usually has a ragged outline and is without plane surfaces, but fairly well developed hexagonal or rhombic prisms have been observed in crystals of mica weighing hundreds of pounds.
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> Rough crystals of mica, or "books," as they are called in the Western States, do not split perfectly until the outer shell of etched and sometimes partly crushed mica has been removed by rough splitting or cleaving the large book into sheets an eighth of an inch thick or less and trimming the edges with a knife held at a small angle with the cleavage. After the tangled outside edges of the sheets have been removed, further splitting is easy, because the cleavage of mica is nearly perfect. By grinding a wedge-like edge on the sheets and using a thin, sharp knife mica can be readily split into sheets less than a thousandth of an inch thick, and some of the thin splittings prepared in India measure only about a sixteen-hundredth of an inch.
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> Mica has a number of physical peculiarities due to crystal structure, color, and inclusions, to which miners and dealers have applied certain descriptive terms. Structural peculiarities give "ruled" or "ribbon," "A," "hair-lined," "fishbone" or "herring-bone," "feather," "horsetail," "tangle-sheet" and "wedge" mica; the different colors give "rum," "ruby," "amber," "white," and "black" mica, though brown, green, and greenish-brown colors are also seen; and inclusions. give "specked," "black," and "clay-stained" mica.
>
> Ruled or ribbon mica is formed by more or less clean, sharp parting planes that cut through the crystals at an angle of nearly 67° with the base or cleavage surface. This, parting passes entirely through some crystals and extends only part way across the face of others or does not cut through their

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[1] Sterrett, Douglas B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, pp. 14-18, 1923.

entire thickness. The trace of the ruling planes corresponds in direction to the rays of the pressure figure in mica. Though a cleavage resembling ruling may be produced by making a series of percussion figures along the line of one of the rays, it is evident that ruling. planes do not correspond to the lines of weakness represented by the percussion figure, for the two make angles of 25° to 35°' with each other. On the other hand, the ruling planes fall in the same directions as the rays of the pressure figure and probably occur along the lines of weakness represented by them. * * * Ruling lines occur more commonly in one series of parallel lines in mica. In some specimens these parting planes extend in two or even in three directions, and their traces on the cleavage planes make angles of about 60º with each other, dividing the mica sheets into small triangular plates. Some large blocks or crystals of mica that are otherwise of excellent quality have been made practically worthless, by extensive ruling. Ruling is so extensive in some mica that it has cut the mineral into thin strips and slivers of hair-like fineness.

In "A" mica two series of lines or striations cross the sheets of mica at an angle of about 60º, generally forming a "V." * * * The third striation necessary to complete the letter "A" is absent, but the miners have nevertheless called this variety "A" mica. In some pieces these striations are caused by wedge structure in the crystals, and the sheets that have wedged out may or may not be replaced by detached, swordblade-like strips. In other pieces the striations are caused by small folds or crenulations in the sheets of mica. The "A" striations have the same orientation in the sheets as the ruling lines—that is, their position corresponds to the rays of the pressure figure. Ruling is seen in some "A" mica. If the striations are caused by small folds the mica may split across them and the. sheets may have some commercial value, though not so high as that of perfect plates; if they are due to the wedging out of sheets, only plates between the "A" lines can be used commercially, and the value of large crystals is thus materially reduced. A crystal of mica in which the striations extend in one direction only is called "hairlined."

In the "fishbone" or "herringbone" structure, striations with or without ruling and apparently identical with the "A" lines of mica make angles of about 120° with each other and join at a center line or spine. This forms a structure resembling a feather or the skeleton of a fish. * * * The same variety has been called "horsetail" mica by the miners in Alabama. Mica with fishbone structure has no commercial value as sheet mica but is used as scrap for grinding.

In "tangle-sheet" mica, a name little used, the laminae split well in some places but tear in others. This imperfection is caused by the inter-growth of parts of one sheet with another, and may extend half an inch or more through some crystals, making apparently sound material valueless or nearly valueless as sheet mica.

In "wedge" mica the crystals are thicker on one side than on the other. Wedge structure is common in "A" and fishbone or horsetail mica and occurs also in plate mica. In plate mica the difference in thickness on opposite edges may be greater than half an inch in a crystal 3 inches in diameter. In "A" and fishbone mica the angles of the wedge may be as large as 30°. * * * Wedge structure is due to an unequal development in the width of the laminae. Some of the laminae extend across the entire width of the crystal, but others do not, and generally these short laminae are not matched by similar laminae extending from the opposite edge, so that the crystal is thicker on one side than on the other, and not uncommonly wedge-shaped sheets of quartz are included between the laminae of such a crystal.

The words describing the color of mica are self-explanatory, but the miners and dealers ordinarily consider the color of sheets a sixteenth of an inch or more in thickness. Such colors as rum, ruby and green seen in the thicker sheets practically disappear after the mica has been split into thin sheets. The material is then called "white" mica to distinguish it from Canadian phlogopite or amber mica. By black mica the miners generally mean muscovite specked with magnetite as described below, but by some miners dark brown to black biotite is, also called "black" mica. Rum, ruby, green, and the lighter-colored micas make the best grades of white mica for glazing. Dark brown and brownish-green has to be split much thinner than rum and light-green mica to gain the desired transparency and is therefore generally classed as "No. 2," even when flawless and clear.

Some muscovite shows variations in color that accord with crystal structure. The variations generally appear in bands that follow the outline of the crystal. Thus, in looking through the mica one may see a dark rum-colored center surrounded by a fringe of light rum or yellow having a hexagonal rhombic outline; or the center may be light and the border zone dark. * * * In some sheets there are alternating bands of varying color.

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The pleochroism of muscovite and other transparent micas is strong and may be well observed in small crystals that have prism planes sufficiently smooth to transmit light. Crystals of such mica viewed edgewise are far more transparent than sheets of the same thickness. The color is also very different in these two directions. Some specimens of muscovite show a dark rum-color perpendicular to the cleavage and yellowish to greenish-yellow parallel with the cleavage.

Muscovite containing inclusions of spots or particles of different-colored minerals between the laminae is called specked or sometimes black mica. Magnetite is the most common inclusion, and occurs as black to brown dendritic tufts arranged in definite lines or patterns corresponding to the crystal structure of the mica or scattered irregularly through the sheets. * * * These tufts of magnetite are very thin and rarely penetrate far into a sheet of mica. The dark-brownish color of many of these spots is due to the translucency of the thin films of magnetic iron. Some of the streaks in the mica are parallel to the rays, of the percussion figure and others are apparently parallel to the rays of the pressure figure. * * *

Each spot owes its dendritic appearance to the arrangement in lines of small particles. of magnetite, some of which follow the rays of the percussion figure. From these lines of particles other particles branch off at more or less definite angles. * * * That the black dendrites are generally magnetite can be proved by cutting out thin films of mica containing them and testing with a magnet. By decomposition the magnetite is, partly or entirely altered to hematite or limonite and the specks become red or yellowish brown. In this way striking patterns in color are produced, which were once thought to be inscriptions made by the aborigines, and which gave rise to the name "hieroglyphic" mica. Still more delicate markings due to the other inclusions also resemble hieroglyphics.

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In the zone of surface weathering, especially within a few feet of the surface, mica crystals may be clay stained by the penetration of muddy water between the laminae. The solutions penetrate large areas of crystals and work in between many of the laminae, greatly damaging the value of the mica. The clay staining is generally less marked in mica obtained at some distance from the surface and is absent where mining reaches hard unaltered vein matter.

USES OF MICA

The following description of the uses and preparation of mica is quoted from Myers.[2]

By far the most important function of mica is as an insulator in the electrical industry, particularly where noninflammability or extraordinary resistivity is essential. Quantities of sheet mica are used in various household electrical appliances. Mica washers of different sizes formed into hol-

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[2] Myers, W. M.,-Micas U. S. Bur. Mines Inf. Circ. 6205, pp. 7-8, 14-18, 1929.

low rods or tubes and bonded with shellac are used as insulating sleeves and bushings of electrical machinery and X-ray apparatus. Mica tubes are also made of mica splittings cemented by shellac or glyptol and rolled to the proper thickness. Ground mica cemented by means of lead borate is also employed for insulation.

Natural sheet mica is used principally in flat insulation, the larger sizes being employed in a wide range of shapes. Various heater shapes, upon which the resistance elements of electrical appliances such as flat irons are wound, are made from "pattern mica." Small articles, such as commutator segments, disks, washers, and sundry small shapes used in the electrical industry, are made from "punch mica." It is estimated that nearly 90 per cent of the world's production of sheet mica, including punch mica, is utilized in electrical insulation.[3]

Mica windows in house-heating stoves constitute a use that is well known, though of declining importance. Substantial quantities of sheet mica are used, however, as glazing material in lamp chimneys, lanterns, projection lantern slides, canopies and shields, eye protectors, peepholes for furnaces and ovens, and similar transparent articles exposed to heat. Phonograph diaphragms were formerly made of mica but have now been almost wholly displaced by a new type of metal diaphragm.

Mica splittings, which are thin films of mica, are used with suitable cement in the manufacture of built-up mica board and other forms of electrical insulation. Tapes, cloth, and paper faced with mica splittings are also used for insulating.

Both sheet and built-up mica are used to some extent for decorative purposes, notably in lamp shades, and coarsely ground mica is extensively employed as "Christmas tree snow" during the holidays and for decorative purposes on post cards, wall paper, stucco, and plasters.

Ground mica is used in great quantities in dusting automobile tires, rolled roofing, and asphalt shingles and as a filler in rubber goods, particularly soft rubber articles and plastic wall finishes. It also has a variety of miscellaneous uses, for example, in heat insulating, annealing steel, and lubricating, in paints, and in ceramics.

* * *

TRIMMING AND CUTTING

The sorting, cleaning, grading, trimming, and cutting of mica are essentially hand processes, and little progress has been made in developing machines capable of doing this work. The sorting and trimming of mica require constant use of judgment on the part of the operator, so that a maximum of the most valuable material may be recovered. It is therefore necessary to use hand labor, and for this reason producing localities with an abundant supply of cheap labor, have a very decided advantage over regions where labor costs are higher.

ROUGH TRIMMING OR "LOBBING"

The masses of mica as taken from the mine may be roughly hexagonal in shape but are more commonly in the form of irregular masses. These masses are termed "mine-run," "run-of-mine," "book mica," or "block mica." The term "block mica" is unfortunate, however, because it is also applied to imported sheet mica. The mica is first "cobbed" to remove all adhering rock, and ruled, wrinkled or otherwise defective blocks are discarded as scrap. The blocks are rapped with hammers to separate adhering dirt. Rough mica is commonly passed over a $^1/_2$-inch screen to remove dirt and small fragments. The small pieces are later utilized as scrap.

Trimming sheds are provided at some mines, but most of the small miners sell their rough-cobbed mica to firms that sort, trim, and manufacture the product into forms desired by electrical companies and other consumers.

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[3] Spence, Hugh S., Mineral industry: Vol. 37, pp. 414, 1 28.

RIFTING

Cobbed mica of good quality is split into sheets $^1/_8$ inch thick or less. Workmen who perform this operation are known locally as "rifters." Where imperfections are present at intervals between the laminae skill and judgment are required so to split the blocks that the imperfections may be removed. The increased percentage of high-grade mica that may be obtained by proper splitting certainly justifies the employment of skilled rifters.

In handling amber mica the masses, which may be several inches thick, are first split into plates about $^1/_4$ inch thick. The edges of these plates are then hammered to loosen the laminae, so that the splitting knife may be easily inserted. A double-edge 3-inch blade with a V point is used. The sheets are split to about 1/16 inch, and all edge imperfections are cut away.

THUMB-TRIMMING AND KNIFE-TRIMMING

After rifting, the sheets may be "thumb-trimmed" by breaking off with the fingers all inferior material around edges, or they may be "knife-trimmed." The removal of the zone of etched, crushed, or tangled mica from the outer edges greatly facilitates further splitting. "Sickle-trimmed" or "Indian-trimmed" imported mica is closely "knife-trimmed," practically all flaws and cracks being removed. In this respect it differs from domestic "knife-trimmed," much of which is marred by cracks and flaws. The "sickle-trimmed" sheets are irregular rounded rectangles cut with beveled edges. . "Madras-trimmed" mica is that obtained from Madras, India. It is cut into approximately square patterns and is known as. "shear-trimmed," for it is cut with shears, and the edges are not beveled but are cut normal to the cleavage plane. Trimmed mica is known as "uncut" or "unmanufactured." It is graded according to size and quality. It may be sold to the consumer uncut, or it may be cut into any desired final size or shape.

MANUFACTURE OF SHEET MICA

Many standard shapes and sizes of sheet mica may be kept in stock, but no manufacturer who is unfamiliar with the requirements of the trade and the relative demand for various sizes and shapes should attempt to cut mica to final form. Some companies have been almost if not quite bankrupted by stocking up with unpopular sizes that would not sell. Unless thoroughly familiar with the consumer's requirements a manufacturer either should sell his mica uncut or should cut only on contract.

Uncut mica is split into thin films and cut into various rectangles, circles, or more complex forms. The smaller masses are either made into splittings, as described later, or manufactured into disks, washers, and various small forms. Washers and related forms are made with power machines fitted with compound dies, cutting outside and center hole at one operation. Washers vary in size from. $^5/_8$ inch to 2 inches in diameter, and the center holes from $^1/_4$ inch to 1 inch. Washers may be built up with shellac to any thickness desired. Aside from the die machines practically all trimming is done by hand, though an electrically operated rotary trimmer has been used in Canada.

Most of the trimming and cutting, including the operation of die machines, is done by girls. The tools employed in mica trimming and splitting are very simple and consist of hammers, splitting knives, scissors, and heavy hinged knives like paper cutters. A thin-bladed hardwood splitting knife is sometimes used, for wood is less liable than metal to scratch the soft surface of the mica. A rasp may be fastened to the bench in a convenient position to rub the edge of the block of mica so as to open up the sheets for splitting. Trimmers are provided with a set of wood, metal, or composition blocks or templets of the various standard shapes and sizes. Cutters become skilled in judging instantly the maximum standard size that any given sheet will provide. The proper templet is placed on the sheet, and the latter is trimmed to size with the scissors. The hinged blade is used chiefly to trim the larger sheets of stove mica.

The finished sheets are carefully sorted according to size and quality and placed in packages containing a specified number or weight. They may be rectangular, circular, or curved, or may be of more complex design. It is imperative that the sheets in a package be uniform in quality and color. Canadian records show that each trimmer of amber mica produces 40 to 45 pounds of medium-size sheet mica per day.

Considerable improvement is possible in the trimming and grading of mica, and such improvements would assist greatly in popularizing domestic mica. Mica users prefer India mica in many instances, not because of superior quality, but because it is so carefully graded and trimmed that little waste results from manufacturing processes. Much of the domestic mica is not so closely trimmed or carefully graded; therefore a much higher percentage of loss results, and the consumer is prejudiced against the American product.

There is a very high percentage of waste in the trimming and cutting processes. Usually 90 per cent or more of the original block is cut away and can be used only as scrap for grinding. The small proportion of finished sheet mica obtainable renders many mica enterprises unprofitable. A. careful inquiry by the United States Geological Survey indicated that from 1916 to 1918 block mica as obtained from a number of important mines yielded only 9 per cent of uncut sheet and 26 per cent of uncut punch. The final yield of cut mica was 3 per cent of sheet and 8 per cent of washers, while the remaining 89 per cent was scrap.

MICA SPLITTINGS

Large quantities of mica are consumed in the form of splittings for the manufacture of built-up mica board. These splittings consist of films 0.0007 to 0.001 inch thick and are made from pieces too small to use for sheet material, or, where a better quality is desired, from the small sizes of sheet stock. Splittings must be at least 1 square inch in area, must have no thick edge, and must be free from all inclusions of other minerals. Splittings produced in Canada from amber mica are known as "thin split mica," and in the United States the terms "skimmings" and "films" are sometimes used.

Practically all muscovite splittings come from India, where the splitting is done mostly by children. The children not only work cheaper, but they have a delicacy of touch that is an aid in the production of such thin films. Two classes of splittings are produced. Loose splittings made from irregular pieces of mica are small and characteristically irregular in outline. Pan-packed splittings are made from small sheet goods, generally sizes 4, 5, and 6. This material, having been prepared from trimmed sheets, has even outlines and greater area and is packed in pans to produce a laminated coherent mass. The price of pan-packed splittings is necessarily much greater than that of loose splittings.

MICA-SPLITTING DEVICES

In the United States the labor cost of splitting by the usual hand methods has proved prohibitive. A great deal of money has been spent in fruitless attempts to manufacture splittings mechanically. A promising device consists of a frame in which the block of mica can be gripped and then pierced on the edge by a point, a micrometer attachment being provided so that the thickness may be regulated accurately. It is necessary to complete the splitting by hand, however, and the machine has never proved a commercial success. A number of patents have been issued for other splitting devices, but their use has not become established in the mica industry.

Quite recently (1928) there was put into operation at Valparaiso, Ind., a splitting machine utilizing an entirely new principle. Small books of mica are fed between two belts which run over a number of pulleys. The bending action gradually separates the films of mica in the book, and the splittings are finally delivered to a trommel which removes the dust and small flakes. The splittings then drop in front of a suction drum from which they are delivered and laid flat, ready for the application of a liquid binder such as shellac or glyptol, for the manufacture of mica board.

SCRAP MICA

Scrap mica consists of material that, due to imperfections, cannot be manufactured into sheet goods. Scrap is classified according to the origin as mine scrap or shop scrap. The mine scrap consists of the folded, imperfect, or discolored mica which has been discarded at the mine during the sorting of mine-run ore. Mine scrap is contaminated by adhering impurities. Shop scrap is composed of the trimmings produced as a by-product during the manufacture of sheets or films. As this material is obtained from mica that has been subject to selection it is cleaner and has a better color than mine scrap. The flake mica recovered in clay-washing operations may also be classified as scrap, as it is utilized in the same manner. Scrap mica must be prepared for the market by grinding to the sizes required for industrial use.

The preparation of ground mica originated in the United States, and production has been limited almost entirely to this country. Operations were begun about 1890, and production has increased steadily in volume since that date. A few mines have been operated for scrap alone. In these properties the mica was found in large quantities but was either too small or imperfect for use as sheet. With an increased demand for scrap mica more attention has been paid to its recovery from other sources. Considerable mica associated with feldspar and kaolin is recovered as a by-product and sold for grinding.

GROUND MICA

Mica is ground both by wet and dry methods. In general, the tendency is to use dry grinding to produce coarse material and wet grinding for the finer sizes. The production of ground mica in the United States has grown so rapidly in recent years that it has commenced to assume the proportions of a separate and fairly substantial industry. For this reason it is being made the subject of a forthcoming information circular of the Bureau of Mines prepared by F. W. Horton, and will be treated quite briefly in the present paper.

The grinding of mica presents one of the most difficult problems in the milling of non-metallic ores. The peculiar combination of properties that mica displays, particularly its cohesion, toughness, flexibility, and smooth surfaces, makes it difficult for any type of mechanical equipment to grasp the mica so that it can be torn or reduced in size. Mica presents the unusual phenomenon of a soft mineral with a highly developed cleavage that makes it difficult to reduce to a ground condition. The results attained with mechanical beaters are somewhat similar to that obtained by hitting a feather with a sledge hammer, and the work accomplished is in no wise proportionate to the energy expended. A certain amount of secrecy surrounds mica-grinding mills, although the methods employed present nothing new other than the adaptation of well-known grinding methods to the problem in hand.

WET GRINDING

The first type of equipment employed in wet grinding consisted of simple tubs provided with impellers for stirring the charge. These tubs are upright cylinders constructed of wooden blocks with the end grain exposed to resist abrasion. The impeller is a wooden disk that fits loosely within the cylinder. The cylinder is filled with clean scrap mica, and enough water is added to permit free motion of the charge. The impeller is then pressed down on the mass so that the mica is constantly being split and abraded by the mutual impact and friction of one piece on another. The friction is so great that the water actually boils. Grinding is slow, eight hours being commonly required to grind a batch of three to four hundred pounds.

Edge runner mills of larger capacity have been installed in several plants. These likewise are constructed of wood. The pans vary in size up to 10 feet in diameter and 36 inches in depth, the wooden bottom being constructed of end-grain blocks. Four wooden rollers approximately 30 inches in diameter, with 24-inch faces, revolve around a central shaft. These rollers are so arranged that they can be raised and lowered, depending upon the height of the charge in the mill. Washed mica scrap is placed in the mill, water is added, and the rollers are lowered so that they are in contact with the charge. The rollers revolve at comparatively low speed and churn the mass until grinding is completed.

The wet ground mica is sluiced from the grinding mill to a settling tank, the supernatant water from one tank often being led to another in which the finest mica is recovered. From the settling tanks the wet mica is shoveled out and dried on steam tables, after which it is screened, generally on 160-mesh. Oversize material is returned for further grinding, and the undersize is sacked for shipment.

DRY GRINDING

A number of devices have been employed to grind dry mica, and many processes have been attempted that involve heating to promote its disintegration. Buhr mills and emery mills have been used with varying degrees of success. Hammer mills are used in some plants, the ground mica discharged through the mill screens being elevated to multiple-deck vibrating screens that produce the size required. This process has been described in detail.[4] In recent installations Marcy rod mills have been employed successfully.

ECONOMIC FEATURES OF THE PEGMATITES

In general the mica in the Petaca area is of unusually good color with the exception of that from the Red mine and the Conquistador and Beryl prospects, most of it falls into the class known as white mica. The proportion of mica found in well-formed books is comparatively large, but this advantage is offset by the common occurrence of ruled, A, fishbone, and wedge structures. Specked and hieroglyphic mica occur but are not particularly common. About 5 per cent of the mica produced in the area is suitable for plate and punch mica, the remainder being classed as scrap. However the scrap commands a good price because of its excellent color. Wet ground mica is much more costly to prepare than dry ground mica but obtains a higher price because it is ground finer, is more brilliantly white, and is less irregular in shape. Apparently, wet grinding produces lighter color because a good deal of the coloring matter slimes off in the process. Probably for certain uses where color is important; dry ground mica made from scrap from this area could be marketed in direct competition with wet ground mica.

The following quotation is from Jones :[5]

"The first mention of Mica in New Mexico was made by Lieutenant Pike in his Report of 1807. He says: `Near Santa Fe, in some mountains, a stratum of talc, which is so large and flexible as to render it capable of being subdivided into thin flakes, of which the greater portion of the houses in Santa Fe and all the villages to the north, have their window lights made.'

"This mica evidently came from Cribbensville mines, near Petaca, Rio Arriba county; from; Nambe, Santa Fe county; and from the little village Talco, in Mora county. It seems that the natives of New Mexico knew mica only as talco; hence, the name of the little village Talco, which is near the mica deposits in Mora county, as above mentioned. It also appears that

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[4] Antisell, T., Mica Mining and Milling Methods: Eng. and Min. Jour., vol. 122, pp. 894-896, 1926.

[5] Jones, F. A., New Mexico mines and minerals, pp. 260-261, 1904.

> these early people did not isolate the mineral *yeso* (gypsum) from the *talco* (mica). Since the selenite variety of gypsum occurs in divers, localities in large transparent plates, it was used indiscriminately with mica, whenever transparencies were needed.
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> "Down to a period of time as late as the American Occupation in 1846, there were no glass window lights in Santa Fe, excepting in the Old Palace. The most extensive deposits, of mica found in the territory, so far as known at the present time, lie two and one-half miles southwest of Petaca in Rio Arriba county and are known as the Cribbensville deposits."

The modern epoch of mica mining in the district dates from about 1870. Mica mining on a commercial scale was due to the use of mica in stoves. The old mining settlement in Sec. 18, T. 26 N,. R. 9 E. called Cribbensville, now deserted, was the center of early mining and was named after the maker of a popular brand of stoves. Only plate mica was produced in the earlier days. It was transported by pack animals to Pueblo, Colo. An early description of the district is given by Holmes.[6]

Mica mining of the "Cribbensville Period" languished somewhat in the early part of the present century, but under the stimulus of higher prices a revival occurred in the decade 1920-1930. A description of the district during that decade is given by Sterrett.[7] Production has declined since, and mining at present is confined to minor "gophering" whereby individuals make small earnings by hand mining. Most of this mining yields a very meager income to the owners of the properties, but the work serves to preserve title to the claims. The following statistics concerning mica production from this area are taken from several volumes of U. S. Geological Survey Mineral Resources of the United States :

Production of Mica from New Mexico, 1899-1934

YEARS	SCRAP		SHEET	
	Tons	*Value*	*Lbs.*	*Value*
1899	123	$ 2,500±	5,500	$4,000±
1900	258		9,620	
1901	146		3,100	
1902	1	40	500	300
*				
1923	898	16,417	30,300	8,489
1924	178	3,248	29,803	6,585
1925	920	14,580	34,486	7,531
1926	988	16,683	46,104	5,824
1927	776	12,741		
1928	1,328	23,426	1,822	2,266
1929	420	8,210	4,550	1,368
1930	768	12,004		
*				
1932	537	8,100		
*				
1934	602	7,957		
*				

*Production figures for these years not available.

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[6] Holmes, J. A., Mica deposits of the United States: U. S. Geol. Survey Twentieth Ann. Rept., pt. 6-cont., pp. 706-707, 1899.

[7] Sterrett, Douglas B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, pp. 159-164, 1925.

Scarcely any of the mining done in the past deserves a better name than "gophering." The cardinal principle of mining was to start on a mica-bearing shoot and follow it, regardless of the narrow or tortuous workings that often resulted. Virtually no waste rock was handled, little prospecting was done in barren pegmatite, and no supporting of ground was done except at the surface. Timbering was unnecessary, as the workings were hardly ever large enough to tax the capacity of the rock to support itself. A large fraction of the mining was hand mining. Only the book mica, which was recovered by hand operations, was marketed. As a consequence of the imperfect recovery of the book mica, plus the entire neglect of the finer-grained mica in the pegmatites, the average dump contains nearly as much mica as was marketed. The shoots that have been exploited in the past averaged about 15 per cent book mica. Although there was a good deal of variation from this average in places, it would be an unusual case where an operator would be warranted in anticipating more than 15 per cent as a basis for cost and profit calculations. An unusual type of occurrence is found in the Nambi mine and to a lesser extent in the Globe and Red mines. In the Nambi mine a massive intergrowth of medium-sized mica scales occurs, which is large enough to be minable in itself and would average over 80 per cent mica. Providing the unreplaced feldspar and quartz could be separated by milling, this mass would be an unusually rich source of scrap mica.

Mica from the Petaca area is shipped to industrial centers, particularly in the East, where it is able to compete with mica from more accessible regions because of its excellent color. Any reduction in shipping costs would be of very significant advantage to this area. The plate and punch mica are rifted and knife-trimmed locally. In the past one operator did some dry grinding and punching locally, but no such processing is done at present.

A general survey of past mining operations leads to the following conclusions: The rare minerals, such as monazite, tantalite-columbite, samarskite, and beryl are distinctly accessory, and should not be considered as a basis for exploitation. The mica-bearing shoots are almost certainly discontinuous, and mining that depends exclusively on exposed shoots is bound to come to an end without uncovering probable nearby 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.

In commenting on the crude methods that prevail in mica mining, writers have remarked that such methods are excusable considering the handicaps that Nature has imposed, such as the small size and irregularity characteristic of pegmatites, the discontinuity of shoots, and the uncertainty of grade. 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.

Obviously, advances in mining in this district must depend on new methods of discovery or modification of the common methods of mining. There is little reason to expect that any new prospecting methods applicable to mica deposits will be available in the near future. Profits to be expected do not warrant mining or drilling barren ground in search of profitable shoots. Only one geophysical method offers sufficient promise to justify a trial in this area, namely, the locating of radioactive minerals by electroscopes. This method would apply to those pegmatites which contain radioactive minerals, such as monazite, samarskite, uraninite, and gummite, and therefore probably would not be entirely trustworthy for many of the pegmatites, as the rare minerals are erratic in their distribution. Nevertheless, the method deserves a fair trial, and may prove to be valuable in the district.

Apparently the best present hope for profitable exploitation of the pegmatites depends on some modification of mining methods. In seeking improvement along these lines, consideration must be given to the typical pegmatites as a whole rather than to the scattered mica-rich shoots. By mining bulkier and more typical material the advantages of larger-scale and continuous operations could be obtained. If the more abundant components of the mica-bearing pegmatites could be mined without appreciable loss, geological conditions warrant the expectation that new mica-rich shoots would be uncovered, and it seems likely that the returns from, these shoots would justify the entire program. Thus, the search for a more logical exploitation program demands careful analysis of the chief components of the pegmatites and their marketability.

The writer's general observations in the area indicate that the better pegmatites contain approximately 4 per cent book mica, separable by hand; 30 per cent clean crude feldspar, separable by hand; 36 per cent mixed feldspar, mica and quartz, probably at present unusable; 30 per cent mixed feldspar and mica, which could be milled. About 95 per cent of the book mica would be scrap mica, and the remainder would be of plate and punch quality. Probably about one-sixth of the mixed feldspar and mica sent to the mill would be waste, one-sixth would be recovered as clean ground mica, and the remaining two-thirds would be recovered as ground feldspar. Presumably some minor revenue could be derived from the rare minerals, but it would be erratic and more or less unpredictable. These estimates are general, and should be carefully revised to accord with the special conditions of any actual exploitation program.

Larger-scale mining operations would logically involve the use of compressed air. They would also demand that shafts, adits or inclines be kept straight and convenient, and be driven underneath as much pegmatite as practicable. In pursuing such operations, however, it would be well to be extremely cautious in expecting any constancy of composition, size or orientation of the pegmatites. It is recommended that development in barren ground should be avoided unless the objective of such development is already known to exist. The possibility of rehandling old dumps is worthy of consideration.

. There are several possible alternatives in specifications for a mill. Hydraulic power sites occur locally. A steam or internal combustion plant might be located at Servilleta. Inasmuch as most of the mill feed would be composed of marketable components and crude materials would cost less to ship than processed products, it might be feasible to locate the mill at some distant point where power is cheap and markets are nearby. Preliminary grinding might logically be done with a jaw crusher feeding a ball mill having a non-metallic lining, the ball mill being in circuit with a vibrating screen which would recycle oversizes. The questions of economic separation of the ground mica from feldspar and quartz, and whether the best results could be attained by dry methods, tabling, classification or flotation, cannot be answered without adequate mill tests.

If the above conclusions are acceptable, obviously it is recommendable that operators test electroscopic prospecting, seek markets for the feldspar, and if possible the quartz, as well as the mica and rare minerals, undertake mining on a larger scale, and mill enough material to recover most of the mica that now goes to waste on the dumps. Prices for feldspar now quoted are encouraging for production.

DESCRIPTION OF PEGMATITE MINES AND PROSPECTS

CRIBBENSVILLE MINES

The old workings at Cribbensville are in the NW. $^1/_4$ SW. $^1/_4$ Sec. 18, T. 26 N., R. 9 E. They consist of several tunnels and open cuts in a number of pegmatites. The workings are badly caved. The pegmatites are composed mainly of albite, mica and quartz. The mica varies somewhat in color, but is mostly of good grade. Numerous molds of mined-out mica books as large as a foot in diameter are on the walls of the workings. The following description is quoted from Holmes.[1]

> At the Cribben mine, the best known of them all, a considerable amount of work was, done between 1884 and 1889, and on a smaller scale since that time. Openings were made on the property at several different locations: (1) I Excel tunnel, 300 feet long; (2) San Carlos tunnel, 40 feet long, where are also stopes and drifts under the crest of the hill; (3) an open; cut of 100 feet long and a tunnel 40 feet long, near the San Carlos; (4) El Capitan tunnel, shaft and open cut, some 1,000 or 1,200 feet northwest of Nos. 2 and 3; (5) Columbia tunnel, 40 feet long, with an open cut of 40 feet, in a dike 50 feet thick, located ,some 200 or 300 yards. east of the San Carlos; (6) the Rafugea tunnel, 20 feet long and an open cut, 30 feet long, located some 200 feet east of the last. The larger part of the work at the Cribben mine was done and most of the mica was obtained from the San Carlos and El Capitan openings, and it is in these also that there is the greatest promise of successful future operations. The mica from these openings is all of fairly good quality, generally free from specks, though in places, badly ruled.

A later description is quoted from Sterrett:[2]

> The several workings described by Holmes are not now readily recognized, as many of them have fallen in badly. The I Excell tunnel is blocked by a cave-in. The San Carlos workings are still open, in part at least, and mica can be obtained by continuing the stopes. The El Capitan workings are nearly all closed. Mr. Leichtle stated that the rich deposit of mica encountered in these workings was mined out. A quantity of mica that would yield scrap and small sheet remained around the workings.
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> During the last few years work has been concentrated on a deposit in a hill about 100 yards southwest of the camp and about 100 feet higher. A tunnel has been started in the hillside toward the "vein" and a shaft 25 feet deep and 12 feet across sunk near the summit of the hill. Massive coarse pegmatite containing crystals of feldspar 2 to 3 feet across was encountered. Most of the mica appears to come from a streak about 8 feet across, with a north strike and west dip. The mica is more plentiful along the sides of this streak, especially in shoots that pitch to the south. Rough crystals, of mica 12 inches across were seen in the shoots and larger ones are reported to have been found. The mica is of fair quality, and good sheets can be cut from many of the crystals- The thick sheets have a greenish color.

A quarter of a mile north of the main Cribbensville workings is the Fridlund mine in the NW. $^1/_4$ SW. $^1/_4$ NW. $^1/_4$ Sec. 18, T. 26 N., R. 9 E. The pegmatite is similar to those at the old Cribbensville workings in being principally albite, mica and quartz, but it contains more pink and brick-red microcline, with which are associated unusual amounts of the rarer minerals, monazite, colum-

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

[2] Sterrett, Douglas B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, pp. 160-161, 1923.

bite-tantalite, samarskite, and bismutite. Parts of the wall rock are epidotized.

The Nambi mine, just east of the old Cribbensville workings, is similar to the Cribbensville workings, but the pegmatite is notable for containing a large body of medium-grained mica that contains less than 20 per cent unreplaced feldspar and quartz. This mass would be of particular interest to anyone contemplating mechanical separation of mica from feldspar or quartz.

PORTER (APACHE) MINE

This property is in Canada los Apaches in the NW. 1/4 NW. ¼ Sec. 12, T. 26 N., R. 8 E., in a branching series of pegmatites that is exposed in the north wall of the canyon. The pegmatites are composed principally of albite, mica and quartz. This property was exploited principally in the decade 1920-1930, and has several tunnels up to 200 feet long. The work is said to have been highly profitable. A good deal of plate mica was produced. Prints of books up to a foot in diameter are common, and it is reported that books up to 3 by 4 feet were found. The mica is of excellent color.

GLOBE MINE

Located at the mouth of Alamos Canyon, in the SE. ¼ SE. ¼ SE. ¼ Sec. 25, T. 26 N., R. 8 E., this mine is one of the most important in the district, and offers one of the best possibilities for further operations in the area. The pegmatite is principally albite. Mica is abundant in good-sized books of excellent color. Pink microcline, quartz, green fluorspar, ilmenite, and pink muscovite (lepidolite?), also occur. The following description is quoted from Sterrett :[3]

> The Globe mica mine has been opened by three shafts—35, 30 and 25 feet deep—from which drifts have been run along the vein. The 30-foot shaft is about 200 feet S. 75° E. of the 35-foot shaft and the 25-foot shaft is about 50 feet farther away in the same direction. The 35-foot shaft has been equipped with a hoist, an air drill, and two 25-horsepower gasoline engines. From the bottom of the shaft 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 country rock is quartz-muscovite schist, which strikes, northwest and dips about 25° SW. The schist contains minor folds and crumplings that are visible in the mine workings as well as larger similar regional structural features. The pegmatite cuts. the schist with a strike of N. 75° W. and a vertical or high north dip. The full thickness of the pegmatite is not exposed but is at least 30 feet near the main workings. From the 35-foot shaft an irregular streak of mica, from 3 to 8 feet thick, was followed in the drifts, This streak lies near the north wall of the pegmatite and has an irregular dip of 85° N. The quartz-muscovite schist wall rock is exposed at some places in the drifts. The cross-cut tunnel from the end of the west drift follows a branch streak of mica. In parts of the main mica streak crystals, of mica are plentiful and form nearly solid masses 2 or 3 feet across. Blocks of mica nearly 2 feet in diameter were seen in the vein, but most of the mica is badly ruled and broken, so that only a small proportion of it could be cut into sheets. The feldspar

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[3] Sterrett, Douglas B., op. cit., pp. 162-163.

occurs in large masses and crystals and consists of both pink microcline and white albite. Some of the masses, of feldspar measure 10 feet across. The pink microcline occurs in the largest crystals. The streak of mica is separated from the north wall of the pegmatite by an irregular sheet of. massive feldspar. Irregular masses and sheets of quartz occur in massive feldspar on the south side of the streak of mica.

In the 30-foot and 25-foot shafts relations, similar to those in the main workings were found. A streak of mica 2 to 4 feet thick, with a high north dip, occurs in massive feldspar. Segregations of quartz, some of them 3 or 4 feet thick, lie along the south side of the streak. The mica is of about the same quality as that of the main workings.

JOSEPH MINE

An excellent description of the Joseph mine is given by Sterrett:[4]

Two prospects for mica have been opened by Antonio Joseph in the foot-hills of the mountains west of Caliente River. One of them is in the walls of a gulch about $1\frac{1}{2}$ miles north of Ojo Caliente and half a mile west of the river. It has been opened on each side of the gulch. The other prospect, which is the more promising of the two, is about half a mile northwest of this one, in the east end of a ridge between two draws tributary to the same gulch. Here several openings have been made in the hillside on the spur of the ridge and on the south side. The larger opening is a cut 15 feet long, from which an 18-foot tunnel has been carried and there is a 12-foot shaft at the end of the tunnel.

The country rock of the region consists of mica, cyanite, quartz, garnet, and hornblende schist and gneiss, granite, pegmatite, and basalt. The schist and gneiss have been much folded, and the axes of the larger folds are crossed by smaller flexures. The general strike near the mica deposits is N. 45°-60° E., with a vertical to west dip, but large variations from this attitude occur. Pegmatite is common in the gneiss and schist of this region.

At the best prospect a mass of pegmatite at least 100 feet wide crops out across the end of the ridge, with a probable northeast strike. This pegmatite shows the usual variations in composition and texture, part of it containing feldspar and quartz, with or without mica, granular mixtures and part containing segregations of these minerals. The feldspar is gray and pink to red and is chiefly of the potassium variety. The mica occurs in pockets and streaks as much as 20 feet thick in the pegmatite. The streaks have an approximate northeast strike and are richer in mica in some parts than in others. A large quantity of mica is exposed in the main working. Most of it is in small crystals, but some crystals 12 to 18 inches across and 4 to 12 inches thick were seen. Nearly all were so badly crushed and cut by "ruling" and irregular fractures that only small perfect sheets, not more than 2 or 3 inches across, could be obtained from them. The mica from this deposit would be valuable chiefly for grinding and for small sheets. The mica is in greenish sheets a sixteenth of an inch or more thick, and some of it contains specks of magnetite. From 50 to 100 tons of scrap and small sheet mica have accumulated on the dumps.

At the other locality a mass of pegmatite 8 to 15 feet thick crops out on each side of the gulch, with a strike of N. 40° E. and a nearly vertical dip. This pegmatite contains streaks of mica gneiss from 1 inch to 2 feet thick. The crystals of mica are more plentiful near these inclusions. Only small crystals of mica, 1 to 4 inches across, were seen, and many of these were crushed and ruled into small pieces.

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[4] Sterrett, Douglas B., op. cit., pp. 163-164.

PARKER MINE

This mine, located in the SW. 1/4 NW. 1/4 Sec. 25, T. 26 N., R. 9 E., on the southwestern side of Alamos Canyon, is also one of the most important and promising in the area. The workings are small irregular stopes. The pegmatite is mainly albite and pink microcline with abundant books of mica of excellent color. Quartz is relatively scarce.

LYONS MINE

The Lyons mine consists of a 60-foot tunnel and a small stope located on the crest of the ridge northeast of Alamos Canyon, in the SW. ¼ NE. ¼ Sec. 25, T. 26 N., R. 8 E. The pegmatite is composed of albite, pink microcline, quartz, and mica.

RED (PEACOCK) MINE

The Red mine, in the SW. ¼ NE. ¼ Sec. 25, T. 26 N., R. 8 E., is an incline about 60 feet long in a large dike of albite, microcline, book mica and quartz. There are patches of mica-aggregate similar to that in the Nambi mine, and some large garnet crystals are present. The primary minerals have been altered in part to kaolin and talc. The unusual feature of this mine is the red limonite stain, iridescent in places, which penetrates most of the minerals and destroys the merchantability of most of the mica. Probably the primary minerals were originally of ordinary color, and the stain is due to solutions from the surface. The red stain probably disappears with depth. Most of the coloring material would probably slime of in wet grinding.

MILLER MINE

The Miller mine is located on the hilltop just south of Canada la Jarita, in the NW. ¼ NW. ¼ Sec. 6, T. 26 N., R. 9 E. There are several old caved pits, shafts and stopes in an unusually large pegmatite. In addition to the typical minerals of the pegmatites of this area, there is an abundance of pink to brick-red microcline, with which are associated monazite, samarskite, tantalite-columbite, and green fluorspar.

QUEEN MINE

The Queen mine is in the NW. ¼ NE. ¼ Sec. 7, T. 26 N., R. 9 E., overlooking Petaca. The old workings, apparently of good size, are all badly caved. Apparently a considerable amount of mica has been produced. The mineralogy is typical, the minerals consisting of albite, microcline, mica, quartz and rare minerals.

COATS (AMERICAN) MINE

This mine, in the SE. ¼ NE. ¼ Sec. 7, T. 26 N., R. 9 E., overlooking Petaca, has apparently produced a moderate amount of mica in times past. The only openings permitting safe entrance are a small incline and a tunnel about 200 feet long. The minerals consist of albite, microcline, perthite, mica, quartz, and rare minerals. A description of this property is quoted from Sterrett :[5]

[6] Sterrett, Douglas B., op. cit., p. 161.

The American Mica mine, formerly owned by the American Mica Mining Co., is now reported to have become the property of Mr. Leichtle. The mine is on the brow of a hill facing east. It was first opened by irregular stoping from the surface to a depth of 25 feet and for 40 feet along the vein. Later a tunnel about 200 feet long and 40 feet lower than the outcrop was run into the hillside to the south of the workings and an air shaft raised to the stopes.

The country rock at the mine is fine-grained gneiss apparently coarser grained near the pegmatite. The pegmatite as exposed in the workings has a north strike and a dip of 20° W. The tunnel cuts through more than 30 feet of pegmatite, which, allowance being made for dip, would give a thickness of more than 10 feet. In texture the pegmatite ranges from moderately coarse rock to some that is very coarse, containing feldspar crystals as much as 2 feet thick. In the tunnel the mica was more plentiful near the footwall of the pegmatite, but some occurs in the interior of the mass. One crystal measured 15 inches in diameter. The crystals are irregularly distributed in the vein zone but are fairly numerous. Some crystals occur in pockets or bunches and others in streaks in the pegmatite. The greater part of the mica from the upper workings is suitable for grinding only. It is nearly all small and some of it occurs in mashed lenticular pieces as much as 3 inches across. This mica has been partly hydrated and has a soapy feel. It occurs in an irregular vein, 3 to 6 feet thick, in the pegmatite. It can be obtained easily in large quantities and some of it has been shipped to Denver for grinding.

KIAWA MINE

The Kiawa mine is located east of Kiawa Mountain, in the SW. $^1/_4$ NW. $^1/_4$ Sec. 11, T. 27 N., R. 8 E., It is a recently developed working, consisting of a small shaft, .a small adit and several pits. The pegmatite is mainly albite, quartz, and mica of good color. Outcrops of this pegmatite or its branches extend a quarter of a mile to the east.

HOYT-SEWARD PROSPECT

This pegmatite, in the SE. $^1/_4$ SE. $^1/_4$ Sec. 24, T. 27 N., R. 8 E., has been explored with several small shafts and a short tunnel. The pegmatite is large, has several branches, and consists of albite, white microcline, quartz, and mica. The mica as exposed is scarcely abundant enough to have yielded much profit. Presumably most of the workings were exploratory rather than productive.

CONQUISTADOR PROSPECT

This pegmatite is located in the NW. ¼ SE. ¼ Sec. 2, T. 26 N., R. 8 E. An incline about 70 feet long has been driven in it. Mica is abundant in books up to 10 inches in diameter, but is too dark to be marketable as white mica. The principal associated minerals are microcline, albite and quartz. Much of the feldspar contains fine-grained muscovite.

BERYL PROSPECT

The Beryl prospect is in the NE. ¼ NW. ¼ Sec. 1, T. 26 N., R. 8 E. It is in a fairly large pegmatite which has been explored by two small shafts and a small open cut. The pegmatite carries albite, green microcline, quartz, mica, perthite, green beryl, columbite-tantalite, samarskite, uraninite, gummite and monazite. Green microcline and beryl were not observed elsewhere in the area.

PINOS ALTOS PROSPECT

This prospect is located in the SE. $^1/_4$ SW. $^1/_4$ Sec. 6, T. 25 N., R. 9 E., on the hill overlooking Petaca. There are two open cuts and a short tunnel in a pegmatite consisting of albite, microcline, mica, and quartz. Much of the feldspar contains disseminated grains of mica. Wall-rock alteration is conspicuous.

ALMA PROSPECT

This prospect is located in the SE. $^1/_4$ NW. $^1/_4$ Sec. 26, T. 27 N., R. 8 E., one-half mile southwest of Big Rock. An open cut has been made in a pegmatite containing an abundance of large crystals of pink microcline and white microcline. The typical minerals of the pegmatites of the area also occur. Apparently not enough mica was found to make the work profitable.

MISCELLANEOUS MINES AND PROSPECTS

An old working in the SE. $^1/_4$ SW. $^1/_4$ Sec. 24, T. 27 N., R. 8 E., near the Las Tablas-Vallecitos trail, consists of several shafts and pits which are water-filled and impossible to enter. The dump indicates that a moderate amount of mica was produced. The pegmatite contains abundant quartz and seems to grade into a quartz vein. Albite, microcline and mica also occur in the pegmatite.

A mica mine, apparently of small size,. is situated near the La Madera-Petaca road in the S.E. ^{1}/4 SE. ^{1}/4 Sec. 18, T. 25 N., R. 9 E. The pegmatite is almost concealed by a basalt flow. The entrance to the mine is caved, and the dump has been washed away by the adjacent stream.

In the vicinity of the Joseph mine, in Sec. 11, T. 24 N., R 8 E., there are several pegmatite outcrops, a few of which have been prospected with small pits. These pegmatites contain more pink microcline than the typical pegmatites of the area.

On the southwest wall of Canada los Apaches, in the NW. ¼ NE. ¼ Sec. 11, T. 26 N., R. 8 E., are three short tunnels in mica-bearing pegmatite.

A new prospect in the NE. $^1/_4$ NE. $^1/_4$ Sec. 36, T. 27 N., R. 8 E., is now (1934) being developed in a small way. The working is only a small open cut, but gives some promise of justifying development.

A small prospect in a pegmatite in the SW. ¼ NW. ¼ Sec. 25, T. 27 N., R. 8 E., has exposed albite, microcline, quartz and mica.

In the SE. ¼ NE. ¼ Sec. 24, T. 27 N., R. 8 E., is a small prospect in a pegmatite whose exposed parts are not encouraging for mica mining.

A prospect in an albite-microcline-quartz pegmatite, containing ilmenite and specked mica, occurs in the SE. ¼ NE. ¼ Sec. 26, T. 27 N., R. 8 E.

In the NE. ¼ W. Sec. 25, T. 26 N., R. 8 E., in Alamos Canyon, is a small prospect. Another prospect is located in the NW. ¼ NW. ¼ of the same section.

A pegmatite prospect which contains a good deal of pink microcline has been developed a mile west of Servilleta Plaza, in the NW. ¼ Sec. 4, T. 25 N., R. 9 E., on a ridge of Petaca schist that protrudes up through the Santa Fe formation.

In the NE. ¼ SW. ¼ Sec. 6, T. 26 N., R. 9 E., is a prospect in a pegmatite that carries albite, microcline, quartz, mica arid garnet. A similar prospect has been opened about a quarter of a mile to the west in what possibly may be the same pegmatite.

On the east wall of the canyon of the Rio Vallecitos, up-strew from Ancones, in the SE. ¼ Sec. 35, T. 26 N., R. 8 E., is a large pegmatite composed principally of albite.

A pegmatite carrying massive albite, pyrite, and molybdenite occurs along La Jarita Creek, in the NE. ¼ NE. ¼ Sec. 27, T. 27 N., R. 8 E. .The molybdenite is in small hexagonal flakes, in quantities too small to be exploitable.

OTHER MINERAL DEPOSITS

In the Bromide-Hopewell District, veins consisting chiefly of quartz and carrying gold and silver occur in a long belt stretching from Kiawa Mountain to Jawbone Mountain. Several of the mines and prospects are shown on Plate III, but their economic aspects were not investigated for this report. Detailed descriptions of these mines and prospects are given by Graton.[6] Except for caving and other deterioration of the old workings, but little change has been effected in the district since the time of his description. A placer deposit near the mouth of Placer Creek has features that warrant an investigation of its commercial possibilities.

A prospect at the prominent rocks on the west side of Canada la Jarita, in the NW. $^{1}/_{4}$ SE. $^{1}/_{4}$ Sec. 27, T. 27 N., R. 8 E., harbors interesting possibilities for the development of kyanite veins and sericite schist. Hypothermal veins of quartz and kyanite outcrop at this location and kyanite-bearing boulders occur some distance to the east and to the west. A few carloads of kyanite were shipped from this prospect in 1925. Some of the kyanite is of light blue color and in long blades, corresponding to the best market grades. No further development has been done, but it seems quite likely that more kyanite might be produced from this property. At the same location is a seam of white sericite-quartz schist about 5 feet thick. This seam parallels the bedding of the Petaca schist, having a strike of N. 20º W., and a dip of 45° SW., and seems to be at least 500 feet long. Undoubtedly there is a minable tonnage. This schist is lustrous, white and slippery. It may be crumbled between the fingers. It should be marketable for some of the uses of ground mica, if crushed and the quartz removed. This mica may be hydrothermally altered, and it may contain some talc or pyrophyllite.

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[6] Lindgren, W., Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geo. Survey Prof. Paper 68, pp. 124-143, 1910.

A quartz vein carrying large blades of light-blue kyanite occurs in the small gorge of the Rio Vallecitos about a mile south of Vallecitos, in the SE. ¼ SE. ¼ Sec. 17, T.,26 N., R. 8 W. This vein as exposed is not rich enough in kyanite to be minable. A vein carrying roscoelite outcrops on the east side of La Madera Mountain, but here also the occurrence is non-commercial. Hypothermal veins carrying dumortierite and hematite outcrop on the west slope of La Madera Mountain, but there is probably too much hematite to warrant development. In the SE. ¼ NE. ¼ Sec. 26, T. 27 N., R. 8 E., at the foot of Big Rock, a quartz vein carries a good deal of ilmenite in large, platy crystals. This vein may merit development at some future date.

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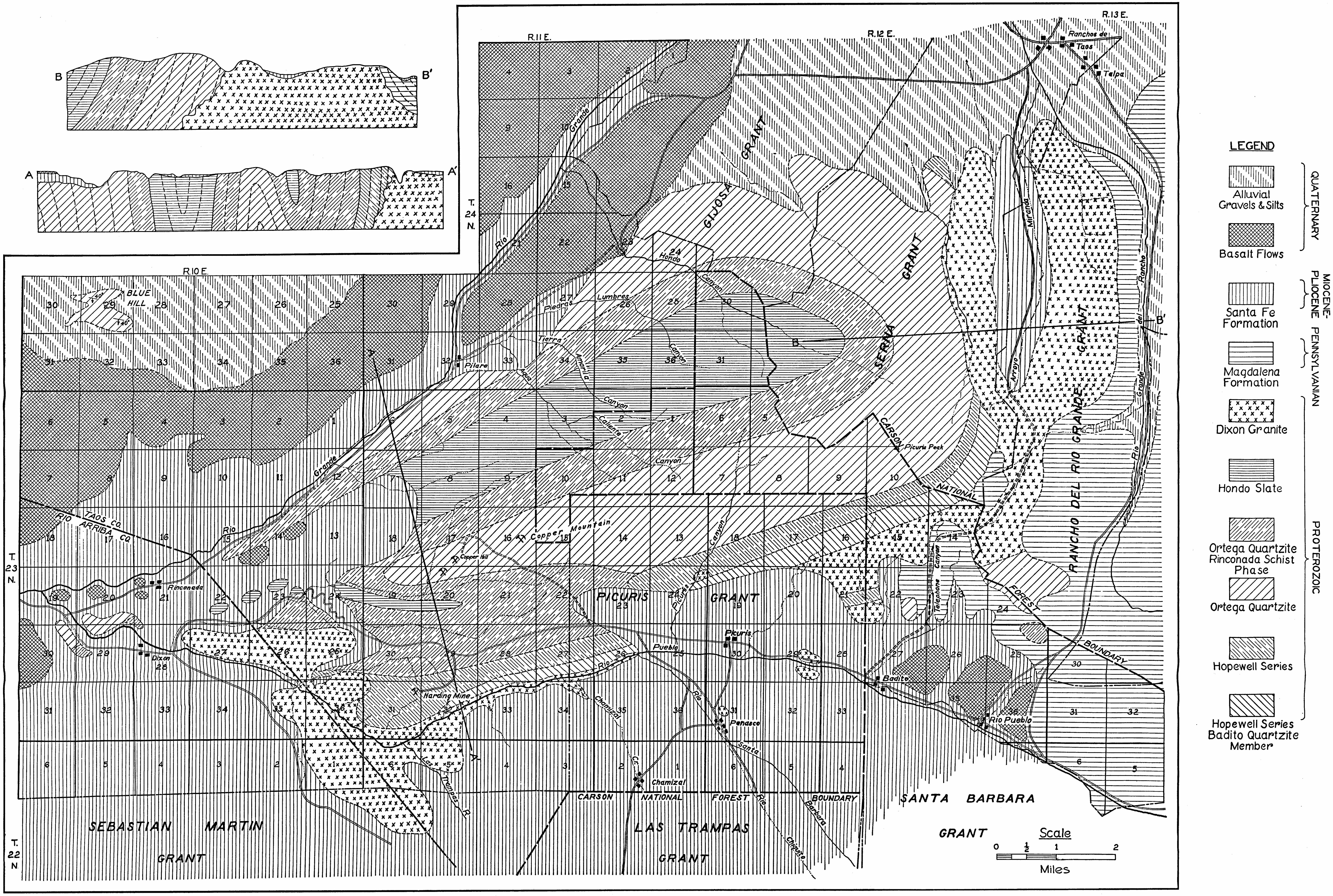

RECONNAISSANCE GEOLOGICAL MAP OF PICURIS AREA

RECONNAISSANCE GEOLOGICAL MAP OF PETACA AREA