BULLETIN 72

# Mineral Deposits of Luna County, New Mexico

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# Abstract

Luna County mines have produced $8.64 million in minerals since the first recorded mining operations in 1876. The bulk of this production has been from lead-zinc-silver ores, but appreciable amounts of manganese, fluorspar, copper, and gold also have been mined. The principal producing districts of the past were the Cooks Peak (lead, zinc, silver), Victorio (lead, silver), Tres Hermanas (zinc, lead, copper), Little Florida (manganese, fluorspar), and Fluorite Ridge (fluorspar). Lesser districts include the Fremont, Florida, and Cedar-Carrizalillo.

Mining is now at a standstill in Luna County because of the lack of known deposits that can be operated profitably under present market conditions. The full mineral potential of Luna County cannot be appraised accurately, but many factors point to at least the possibility of moderate-sized metalliferous ore finds in the Victorio, Tres Hermanas, and Cooks Peak districts. The fluorspar and manganese deposits offer promise only on radical improvement in the respective market prices involved.

# *Introduction*

## PURPOSE AND SCOPE

The mineral deposits of Luna County were studied as part of a continuing effort by the New Mexico Bureau of Mines and Mineral Resources to provide individual reports on the mineral-producing counties of the State. All the known deposits of the county are described, with two important exceptions: the Cooks Peak district is only briefly mentioned, because Jicha (1954) has previously described this area; similarly, the manganese mines are given only short descriptions, inasmuch as the U. S. Bureau of Mines is now making a commodity study of manganese for the entire State.

The descriptions given herein are intended to provide some of the basic facts concerning the regional and local geology, ore controls, and type of mineralization occurring in the several mining districts. A brief estimate of the ore potentialities is given after the discussion of each important district. These estimates are necessarily brief, because accurate appraisals of ore potentialities must depend on actual exploratory work, such as drilling, trenching, and drifting, none of which lie within the province of the New Mexico Bureau of Mines and Mineral Resources.

## METHOD OF INVESTIGATION

Field work was started in May 1959 and continued through June of the following year. The Tres Hermanas, Victorio, and Fluorite Ridge mining districts were considered to be the most important areas in which detailed examinations had not been made, and thus consumed the majority of the time spent in the field. The Florida, Little Florida, Fremont, and Carrizalillo—Cedar districts were examined only in a reconnaissance fashion. Except for manganese mining, the mines of Luna County have been shut down for many years. This fact hampered the field investigations in several ways. First, it was difficult to find where many of the mines were located; in some areas the writer had to rely on the examination of aerial photographs to determine if mines even existed. The shortcomings of this method are obvious. Second, the openings of many of the mines have deteriorated, preventing the examination of some pertinent ore showings. Lastly, many of the mine owners, who almost certainly could have provided much useful information, could not be reached, either because of death or removal from the area. As a result, it is certain that some mines were missed completely during the field investigations. The writer regrets the necessity of such omissions.

## PREVIOUS WORK

Jones (1904), Lindgren et al. (1910), Lasky and Wootton (1933), and Anderson (1957) briefly described the important ore districts of Luna

County. Lindgren (1909) gave an excellent account of a portion of the Tres Hermanas district. Darton (1916, 1917) completed the first detailed investigation of the geology of the county and gave some additional information on the mineral deposits. Jicha (1954) described the geology of the Lake Valley quadrangle in detail, including the Cooks Peak mining district, which lies in that quadrangle. Holser (1953) gave the first detailed account of the tungsten-beryllium deposit in the Victorio district, and Dale and McKinney (1959) have provided additional information on the tungsten in this deposit. Strongin (1956) has mapped the Sierra Rica Hills in the extreme southwest part of Luna County, which aided the present writer's investigation of the Fremont district. The fluorspar deposits have been described in varying degrees of detail by Rothrock et al. (1946), Russell (1947), Johnston (1928), and Darton and Burchard (1911).

Many other investigations, although not directly related to mineral deposits, have provided valuable geologic data that aided the interpretation of the environment of the ore deposits. A listing of these publications will be found in the bibliography.

## ACKNOWLEDGMENTS

The writer was privileged to have the full cooperation of the resident mine owners of Luna County; the help received from these persons is gratefully acknowledged. Thomas E. Pearse was an excellent field assistant and companion during the summer of 1959, when the bulk of the field work was accomplished. Frank E. Kottlowski has helped the writer solve so many of the geologic problems encountered during the course of the field work that he deserves special mention. Roy W. Foster, Robert H. Weber, and Edmund H. Kase, Jr., read the report and made many helpful suggestions. Robert Price prepared the illustrations, and Mrs. Bessie Vigil typed the manuscript. Mrs. Glenda K. Niccum assisted in proofreading and in the preparation of the index.

# *Geography*

## LOCATION

Luna County is situated in the southwestern part of New Mexico. It is bounded on the south by Mexico and on the other three sides by Dona Ana, Sierra, Grant, and Hidalgo Counties. The county is almost square in shape and covers an area of 2,957 square miles. According to the preliminary 1960 census, the county population is 9,733, most of which is concentrated in Deming (pop. 6,710), the county seat.

Two rail lines operated by the Southern Pacific Co. pass in an east-west direction through the county, one passing through Deming and the other paralleling the Mexican border and passing through Columbus. In addition, the Atchison, Topeka & Santa Fe Railway Co. operates a branch line that connects Silver City with Hatch via Deming. The principal highway network consists of U. S. Highway 70-80, crossing east-west; U. S. Highway 260, leading from Deming to Silver City; State Highway 11, from Deming to Columbus; and State Highway 26, connecting Deming with Hatch (fig. 1).

## TOPOGRAPHY

Luna County lies in the Mexican Highlands section of the Basin and Range province. The principal mountain ranges are the Cooks Range, Florida Mountains, Tres Hermanas Mountains, and Cedar Mountain Range. All of these are isolated masses except for the Cooks Range, which is the southern extension of the Black Range. Smaller topographic features are the Victorio Mountains, Grandmother Mountains, Sierra Rica, Carrizalillo Hills, Goodsight Mountains, and Fluorite Ridge. Cooks Peak (8,404 feet) is the highest point in the county.

Between the mountain and hill groups is a bolson plain devoid of a major drainage network. The Mimbres River drains from Grant County across the northwest part of Luna County, until its flow is dissipated near Deming. The Luna County portion of this "river" contains water only during brief periods in the rainy season. The bolson plain slopes gently across the county, starting at an altitude of about 5,400 feet in the northwest corner and descending to the southeast, where it reaches a low of approximately 3,960 feet on the international border, south of Arena.

## CLIMATE AND VEGETATION

The climate of Luna County is similar to that found generally in the southwestern part of the United States. Th summers are hot, and the winters are very mild.[1] Mining operations would almost never be hampered by unfavorable weather conditions anywhere in the county.

**I. Columbus, situated near the U. S.—Mexico border, south of Deming, frequently has the highest recorded daily temperature in the State, both during the winter and summer months.**

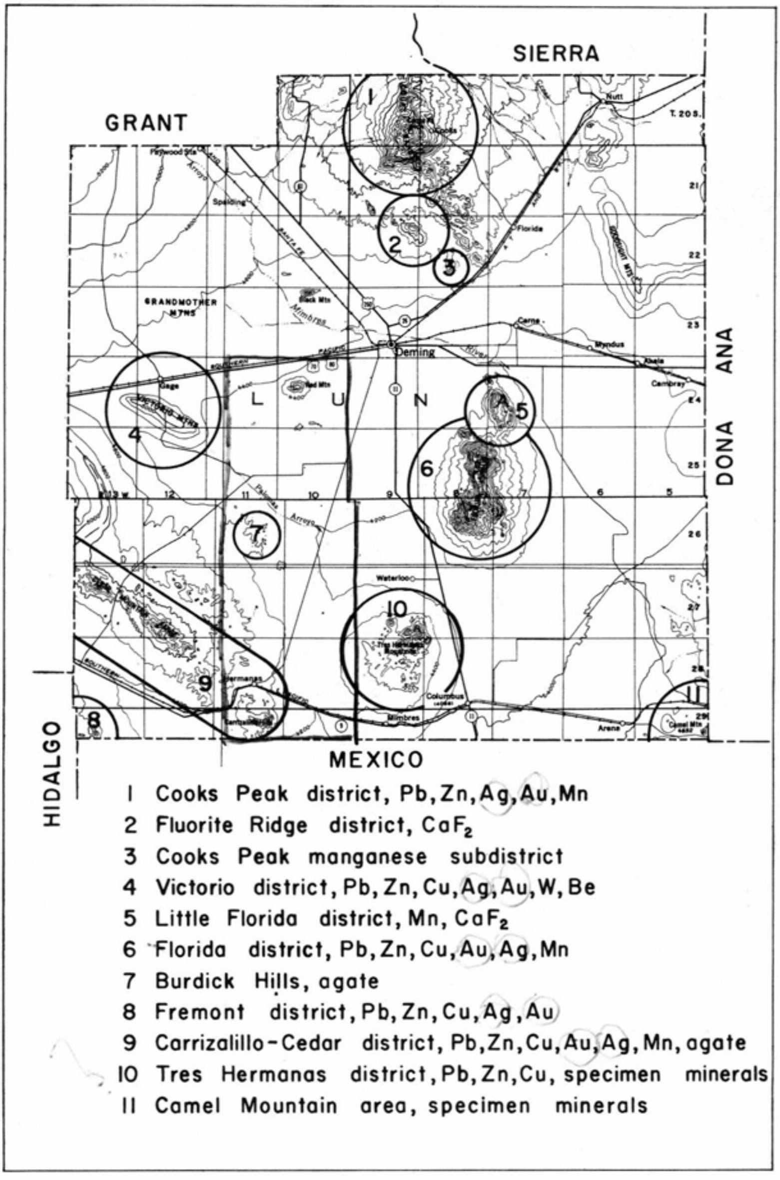



Figure 1. LOCATION OF MINING DISTRICTS IN LUNA COUNTY.

TABLE 1. CLIMATOLOGICAL DATA FOR LUNA COUNTY

(Data from *Climate and Man*, U. S. Department of Agriculture, 1941, p. 1,013.)

| | | TEMPERATURE (degrees Fahrenheit) | | | | PRECIPITATION (inches) | | |
|---|---|---|---|---|---|---|---|---|
| Station | Altitude (feet) | January average | July average | Maximum | Minimum | Wettest month | Dryest month | Annual average |
| Columbus | 4,058 | 42.5 | 82.5 | 111 | –6 | 2.19 (August) | 0.24 (April) | 9.59 |
| Deming | 4,336 | 41.6 | 78.8 | 110 | –7 | 1.85 (July) | 0.25 (April) | 9.20 |
| Gage | 4,489 | 41.2 | 79.6 | 111 | –9 | 2.05 (July) | 0.21 (April) | 9.93 |

Table 1 summarizes the pertinent climatological data for three stations in the area.

The bolson plains are sparsely covered with prairie grass, mesquite, creosote bush, yucca, and many varieties of cactus. The mountains have essentially the same growth except at the highest elevations, where juniper and pition appear. The land is used extensively for ranching. Near Deming, farms irrigated by ground water produce an abundance of cotton and other farm products.

## MAPS AND AERIAL PHOTOGRAPHS

An index of U. S. Geological Survey topographic maps is given in Plate 9. A planimetric map of Luna County is available from the State Highway Department at $1.00 per ozalid copy; this map 'shows the road network, principal drainage, and other important features. Complete aerial-photograph coverage of the county is available from the Soil Conservation Service, U. S. Department of Agriculture, Beltsville, Maryland. Semicontrolled aerial mosaics, however, are presently available only for that portion of Luna County which lies north of latitude 32°30' N.

# *Geology*

## INTRODUCTION

Only a brief description of the rock formations and structural features will be given here. More detailed information on the geology of each district is given later in the text, and an index of geologic maps available for Luna County is provided in Plate 9. The accounts of the various sedimentary rocks are based mainly on the work of others, notably Flower (1953a, 1953b, 1955, 1958), Kottlowski (1952, 1958, 1960), Armstrong (1960), Laudon and Bowsher (1949), Zeller (1960), Balk (1958), and Darton (1916, 1917), whose knowledge in this field exceeds that of the writer.

## STRATIGRAPHY

Columnar sections of four strategic areas in Luna County are presented in Plate 10.

### PRECAMBRIAN

Precambrian rocks crop out in five localities in Luna County: the Florida Mountains, Fluorite Ridge, Cooks Peak, Klondike Hills, and west of Cow Springs, in the extreme northwest corner of the county. By far the largest exposures are in the Florida Mountains, the bulk of this range being composed of pink to gray granite accompanied by sheets and dikelike bodies of diorite. The exposures in the Fluorite Ridge area are confined to an outcrop less than a square mile in area on the southeast flank of the ridge, and consist of pink coarse-grained granite and greenish-black diorite and amphibolite. Darton (1917) mapped several other smaller areas as Precambrian on the north flank of Fluorite Ridge, but the writer believes that these are simply boulders of Precambrian granite included within the Gila(?) conglomerate.

Precambrian granite forms the west slope of the northern portion of the Cooks Range. The outcrop is 4 miles long and one-half mile wide, but only the southern tip of the outcrop extends into Luna County.

Ballman (1960) has mapped a pedimented surface of Precambrian rock extending from the southern end of the Big Burro Mountains (in Grant County) to the Luna County boundary west of Cow Springs. This pediment is believed to extend a short distance across the county line into Luna County. The Precambrian here is pinkish-gray coarse-grained granite similar to outcrops in the Florida Mountains. The remaining Precambrian exposure, in the Klondike Hills, is a very small outcrop of pink granite overlain by Bliss sandstone.

To date little detailed mapping has been done in the Precambrian outcrop areas of Luna County, and the writer is unable to give much factual information concerning the history of Precambrian time for these areas. As described above, there are only two rock types of this age known in Luna County, granite and a basic rock ranging in composition from diorite to amphibolite. The relationship between these two rock types is not clear; in the Florida Mountains the diorite and amphibolite appear to be later than the granite, whereas in the Fluorite Ridge area the reverse may be true.

## CAMBRIAN-ORDOVICIAN

### Bliss Sandstone

The sandstone and quartzite beds that unconformably overlie Precambrian rocks in Luna County were originally correlated with the Bliss sandstone of the Franklin Mountains, and their age was assumed to be Cambrian (Darton, 1917). The lithologic correlation of the two is correct, but Flower (1953a) has shown that these beds range from Upper Cambrian to Lower Ordovician in age throughout most of southern New Mexico.

The Bliss sandstone is recognized easily because the formation weathers to a dark-brown color that contrasts sharply with the reddish Precambrian rocks below and the gray El Paso limestone above. Jicha (1954) and Elston (1957) measured thicknesses of 94 and 71 feet respectively for the Bliss at two localities in the Cooks Range, and Balk (1958) measured 50 to 185 feet for the same beds in the Florida Mountains.

## ORDOVICIAN

### El Paso Limestone

The El Paso limestone has been recognized in the Florida Mountains, Victorio Mountains, Snake Hills, Cooks Range, Klondike Hills, and Fluorite Ridge areas in Luna County. Although the El Paso was first defined as a formation by Richardson (1908), it was raised subsequently to group status by Kelley and Silver (1952).

Flower (1953a, 1955, 1958) has shown that the El Paso, together with the Ordovician part of the Bliss sandstone, represents an essentially continuous period of deposition that continued throughout Canadian time. The El Paso, as would be expected, lies conformably on the Bliss sandstone. The beds consist of gray to dark-gray, medium- to thick-bedded limestone. Red-weathering chert nodules are present at certain horizons. Thickness measurements for the group range from 831 feet in the Cooks Range (Jicha, 1954) to slightly over 1,000 feet in the Florida Mountains (Balk, 1958).

### Montoya Group

In Luna County, the El Paso group is overlain by massive, gray dolomite beds of late Middle and Upper Ordovician age; these beds have been correlated with the Montoya formation originally defined by Richardson (1908) in the Franklin Mountains. Kelley and Silver (1952) raised the sequence to group status in the Caballo Mountains by defining four formations within the Montoya; these are, starting with the lowermost, the Cable Canyon sandstone, Upham dolomite, Aleman formation, and Cutter formation. These same divisions have been recognized and measured in the Cooks Range and Victorio Mountains by Jicha (1954) and Kottlowski (1960), respectively. Montoya beds also are present in the Florida Mountains, Klondike Hills, Snake Hills, and Fluorite Ridge.

The Montoya is separated from the underlying El Paso by an erosional unconformity, but the contact may be conformable over small areas. The thicknesses of the group that have been reported in Luna County are as follows:

| Cooks Range (Jicha, 1954) | | Victorio Mountains (Kottlowski, personal communication) | |
|---|---|---|---|
| Cutter formation | 51 feet | Cutter formation | 50-120 feet |
| Aleman formation | 190 " | Aleman formation | 150 |
| Upham dolomite | 47 " | Upham dolomite | |
| Cable Canyon sandstone | 33 " | Cable Canyon sandstone | 70 |
| | 321 feet | | 270-340 feet |

A more detailed description of the lithology of the group, as exposed in the Victorio Mountains, is given on page 73.

SILURIAN

## Fusselman Dolomite

The Silurian period is represented in Luna County by massive to medium-bedded, gray dolomites, which overlie the Montoya group. This formation, also, was first described by Richardson (1908), in the Franklin Mountains.

Lack of abundant fauna in the formation has prevented detailing the exact age of deposition. Flower (1958, p. 72) states:

> There is some indication in south central New Mexico, of a zonation of the Fusselman, and it may be that it consisted originally of several discrete units of deposition, possibly ranging through a good part of Middle Silurian time. Certainly dolomitization has done much to produce the present general uniformity of lithology, and has destroyed most of the fossils, the few remaining being silicified.

The only complete section of the Fusselman exposed in Luna County is in the Cooks Range, where Jicha (1954) estimated the thickness to be from 200 to 225 feet. This estimate is believed to be low; the actual thickness approaches 400 feet. The formation thickens in the western portion of the county, for at least 900 feet is present at Mine Hill in the Victorio Mountains. The formation has been recognized also in the Florida Mountains and Klondike Hills, and near Camel Mountain.

The lithology of the formation is discussed more fully on pages 73-74.

## DEVONIAN

### Percha Shale

A shale sequence of Upper Devonian age unconformably overlies the Fusselman dolomite. The Percha shale was first defined as a formation by Gordon (1907) from exposures in Grant and Sierra Counties. Jicha (1954) and Elston (1957) divided the Percha shale into two members, Ready Pay (lower) and Box (upper), in the Cooks Range; these two members were first described by Stevenson (1945) from a section along Percha Creek near Hillsboro.

In the Cooks Range the Ready Pay member ranges from 150 to 220 feet thick and consists of black fissile shale, whereas the Box member is greenish-gray shale containing limestone nodules and is 50 to 100 feet thick. The Ready Pay and Box members are detectable in Fluorite Ridge, but complicated structure prevents an estimation of their thickness. The Percha also is present in the Florida Mountains and Klondike Hills.

## MISSISSIPPIAN

Mississippian limestones overlie the Devonian shales throughout Luna County. The paleontology and lithology are complex for these beds, and the reader is referred to the descriptions by Armstrong (1960) and Laudon and Bowsher (1949) for more complete details. The complexity has arisen in part from the use of formation names from Arizona, west Texas, and central New Mexico for describing essentially the same intervals of deposition. For example, the names Rancheria and Helms are used in the Franklin Mountains (near El Paso) to describe beds of Osage to Meramec and Chester age respectively, whereas in the Big Hatchet Mountains (in southern Hidalgo County) the names Escabrosa and Paradise are used for beds of approximately the same ages. Furthermore, the Lake Valley and Kelly formations are used in Sierra County (north of Luna County) for beds that belong to the Osage age and that correspond to the lower portion of the Escabrosa formation. This duplication of names is not entirely without reason; facies changes and slight differences in age in some cases make these separate formational distinctions desirable.

In this report, the term Lake Valley formation will be confined to the Mississippian beds in the Cooks Range and Fluorite Ridge, and the terms Escabrosa and Paradise formations will be applied to such outcrops located elsewhere in the county. The Rancheria and Helms names will not be used, because the outcrops in the Florida Mountains and Tres Hermanas Mountains (the easternmost outcrops in the county) are lithologically more similar to the Escabrosa and Paradise facies of the Mississippian.

## Lake Valley and Kelly Formations

In the Cooks Range, the Mississippian beds range from 300 to 450 feet in thickness. A summary of the section measured by Laudon and Bowsher (1949) in the Cooks Peak mining district is given below:

SUMMARY OF MISSISSIPPIAN STRATIGRAPHY
IN THE COOKS RANGE

| FORMATION | MEMBER | THICKNESS (in feet) | DESCRIPTION |
|---|---|---|---|
| Kelly | | 30 | Dark-gray to brown, finely crystalline, slightly crinoidal limestone carrying much chert. |
| Lake Valley | Tierra Blanca | 35 | Coarsely crystalline, gray to brown, crinoidal limestone containing abundant white chert. |
| | Nunn | 155 | Soft, gray, very shaly, crinoidal marls interbedded with dark-gray cherty limestones. |
| | Alamogordo | 50 | Massive, slightly crinoidal limestone at the base overlain by massive, black, cherty limestones. |
| | Andrecito | 130 | Black to gray, mostly thin-bedded, sparsely fossiliferous limestone with 30 feet of crinoidal marl at the top. |

Total Lake Valley formation, 370 feet.
Total Mississippian, 400 feet.

## Escabrosa and Paradise Formations

Armstrong (1960) has described a complete section of the Mississippian in the Klondike Hills, on the western boundary of Luna County. A summary of this section is given below:

SUMMARY OF MISSISSIPPIAN STRATIGRAPHY
IN THE KLONDIKE HILLS

| FORMATION | MEMBER | THICKNESS (in feet) | DESCRIPTION |
|---|---|---|---|
| Paradise | | 90 | Thin- to medium-bedded, dark-colored limestone with several shale lenses. |
| Esclbrosa | Upper* | 350 | White to light-gray, crinoidal limestone. Lower two-thirds almost void of bedding planes; upper one-third darker gray and more bedded. |
| | Lower* | 395 | Thin-bedded encrinites overlain by massive bioclastic limestone in the lower part of the member. Upper part is thin- to medium-bedded, gray, cherty limestone. |

Total Escabrosa limestone, 745 feet.
Total Mississippian, 835 feet.

**• Armstrong (1960) has proposed raising the Escabrosa formation to group status, and naming the Hachita and Keating formations to correspond respectively to the upper and lower members cited above.**

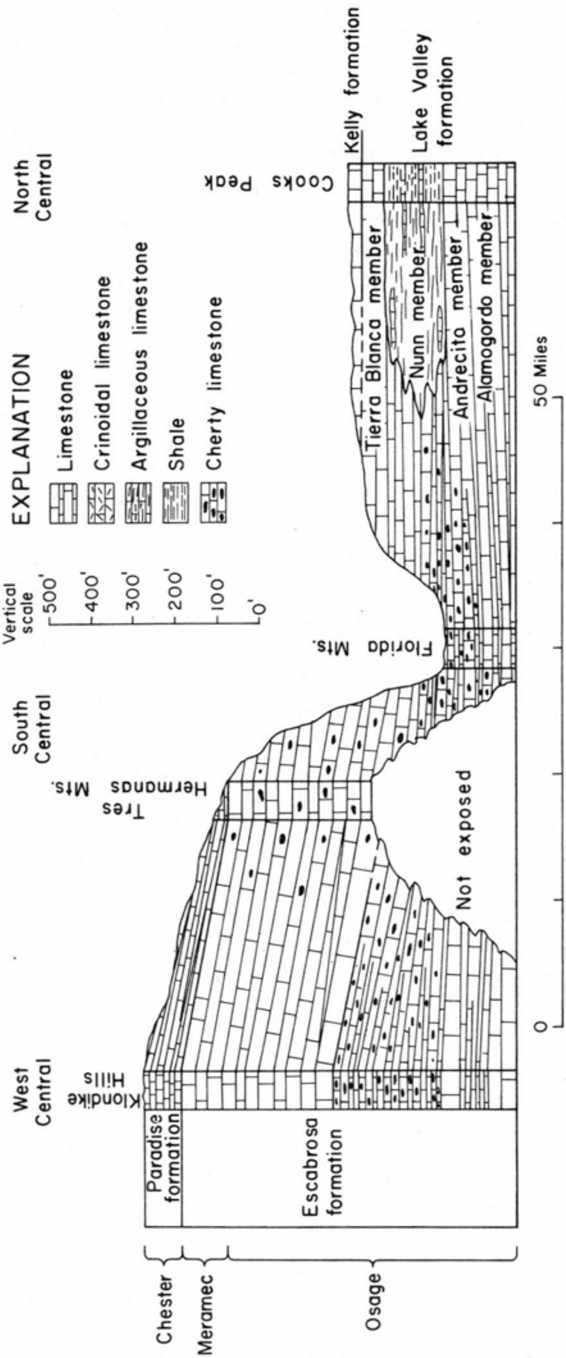



Figure 2. Schematic Correlation Diagram of Mississippian Sediments.

The correlation diagram (fig. 2) shows the relationship between the Kelly and Lake Valley formations in the Cooks Range and the thicker Paradise and Escabrosa sections in the Klondike Hills. Unfortunately, the Mississippian beds were removed by late Pennsylvanian to early Permian erosion in the Victorio Mountains, which lie between the Cooks Range and the Klondike Hills. If these beds were present, they would shed more light on this transition zone.

In the Tres Hermanas Mountains only the upper part of the Mississippian series is exposed. Here some 345 feet of typical Escabrosa crinoidal limestone overlain by 35 feet of Paradise formation was measured by Armstrong (1960). In the Florida Mountains only 170 feet of Mississippian, representing the lower part of the Escabrosa formation, survived late Pennsylvanian to early Permian erosion.

**PENNSYLVANIAN**

Pennsylvanian rocks are absent or very thin over the central portion of Luna County; in the surrounding area, however, the beds of this system measure thousands of feet in thickness. The thinning of the Pennsylvanian beds has been attributed by Kottlowski (1958, 1960) to two circumstances: first, a low landmass (Florida landmass) covered most of central Luna County during Pennsylvanian and early Permian times, thereby restricting the deposition of Pennsylvanian sediments to scattered lagoonal deposits; second, erosion during early Mesozoic time removed some of the marine deposits laid down west of this highland mass.

Pennsylvanian rocks are absent in the Florida Mountains, where Permian limestones directly overlie the Mississippian. This fact accords with the postulated presence of a low landmass in this locality during Pennsylvanian times. Thin intervals of Pennsylvanian sediments present in the Cooks Range to the north of the Floridas, and in the Tres Hermanas Mountains to the south, probably were deposited in shallow waters short distances from the Florida landmass. In both places, the thickness is variable, ranging from 40 to 200 feet in the Cooks Range, and from 350 to perhaps as much as 636 feet in the Tres Hermanas. The Cooks Peak section consists of limestone-chert-pebble conglomerates, laminated blackish calcilutites, and fossiliferous calcarenites. The sequence in the Tres Hermanas Mountains contains interbedded calcareous siltstone, black shale, cherty limestone, massive calcarenite, and sandstone, all of which have been strongly metamorphosed by the intrusion of a Tertiary quartz monzonite stock.

The Pennsylvanian in all probability thickens rapidly southwest of the Tres Hermanas—Florida Mountains area even though actual outcrops of rocks of this system are absent until the Big Hatchet Mountains are reached, in Hidalgo County. Zeller (1958) measured 2,450 feet of Pennsylvanian sediments in the Big Hatchets, consisting of, in ascending order: (1) 360 feet of dark-gray oolitic limestone, (2) 190 feet of aphanitic limestone alternating with crinoidal limestone, (3) 780 feet of cherty crinoidal limestone with some shale beds, and (4) 1,120 feet of partially dolomitized, massive limestone. The beds range in age from Morrowan or Derryan to Virgilian. It is plausible to assume that about 1,000 feet of sediments similar to those of the Big Hatchet Mountains underlies the southwestern corner of Luna County. It is likely, moreover, that a substantial thickness of Pennsylvanian rocks originally was deposited in the northwestern part of the county; early Mesozoic erosion then stripped away these beds, as evidenced by the unconformable overlap of Lower Cretaceous sediments onto Paleozoic and Precambrian rocks in the Burro and Victorio Mountains.

No outcrops of Pennsylvanian rocks are present in Luna County east of the Florida Mountains. The Pennsylvanian beds, however, probably do not thicken rapidly to the east. This assumption is based on the fact that Pennsylvanian beds are only 670 feet thick in the Robledo Mountains, near Las Cruces, approximately 50 miles to the east.

Formational names will not be used in this report for the Pennsylvanian rocks.

### PERMIAN

As in the case of the Pennsylvanian system, Permian beds where exposed in Luna County are thin in comparison with surrounding areas. The thinning is attributed to the continued presence of the low landmass that existed in Pennsylvanian time in the central portion of the county, and to early Mesozoic erosion.

In the Cooks Range, the Permian is represented by a sequence of basal limestone lenses and limestone-chert conglomerate grading upward into reddish-brown to yellowish sandstone, siltstone, and conglomerate; the entire sequence ranges in thickness from 80 to 150 feet. Jicha (1954) called these beds the Lobo formation after a formational name used by Darton (1916) for red beds occurring immediately below the Sarten (Lower Cretaceous) sandstone. Although Darton classed these beds as Triassic, the subsequent investigations by Jicha in the Cooks Range led to the conclusion that the beds were most probably Permian and related to the Abo formation.[2] These deposits represent the earliest known occurrence of terrestrial deposition in Luna County.

Permian marine limestones crop out in the Florida and Tres Hermanas Mountains, but the thicknesses are not great, being 360 feet in the former area and about 500 feet in the latter. Because these beds are similar in lithology and stratigraphic position to the Hueco formation (Wolfcampian) of south-central New Mexico, this name will be used in the remainder of the text, and the writer will deliberately sup-

2. Recent investigations also have shown that at the type locality (Florida Mountains) Darton's Lobo formation is neither Triassic nor Permian, but Lower Cretaceous or Tertiary.

press the name "Gym limestone," which Darton (1916, 1917) proposed for Permian sediments in Luna County. The suppression of this name is required by the work of Bogart (1953) and Kelley and Bogart (1952), who have shown that the type section of the Gym limestone, Gym Peak in the Florida Mountains, contains beds ranging from Silurian to Permian in age. In addition, beds that Darton (1916) described as Gym limestone in the Victorio Mountains, Tres Hermanas Mountains, and Cooks Range range from Mississippian to early Cretaceous.

The beds of the Hueco formation are thin- to thick-bedded, dark-gray, marine limestones, with lenses of chert-breccia conglomerate, siltstone, and sandstone at the base. Kelley and Bogart (1952) reported 744 feet as the thickness of Permian beds in the Florida Mountains, but Kottlowski (personal communication) believes the thickness to be only about 360 feet because some Pennsylvanian and early Cretaceous beds had been included by Kelley and Bogart in their measurement. A complete section of the Hueco is not exposed in the Tres Hermanas Mountains, but Kottlowski (personal communication) states that at least 510 feet is present on the north slopes of North Sister Peak.

Significant outcrops of Permian beds in Luna County are limited to the areas discussed above. Outcrops to the east and west of the county, however, indicate that considerable deposition occurred during Permian times away from the Florida landmass, which occupied only the central part of the county. Zeller (1958) reported more than 5,000 feet of Permian strata in the Big Hatchet Mountain's. These beds are correlative with the Permian portion of the Naco group in Arizona. To the east, near Las Cruces, 1,725 feet of the Hueco formation, plus a minor amount of the Bursum formation, is present in the Robledo Mountains. It is fairly certain that any deep borings in the far eastern or far western parts of Luna County would penetrate a considerable thickness of Permian strata; an exception would be the area extending northwestward from the Victorio Mountains, where early Mesozoic erosion stripped away Permian, Pennsylvanian, and a large portion of lower Paleozoic beds.

To summarize, during the Permian period in Luna County a low landmass in the central part of the county extended northward into a much larger highland area in the central part of the State. Terrestrial sediments (Abo formation) were deposited on this highland in the vicinity of the present Cooks Range, whereas to the east, south, and west marine deposits, mostly limestone, were laid down. The Permian limestones of the Florida and Tres Hermanas Mountains represent shallow-water deposits immediately to the south of the landmass, but extensive deposition took place farther to the east and west. Both the terrestrial and marine deposits were limited to Lower (Wolfcampian) Permian time in the central and eastern parts of the county, but deposition probably extended into Middle Permian time in the western part.

## CRETACEOUS

Sedimentary rocks ranging from Lower to Upper Cretaceous are present in Luna County; however, extreme variances in lithology, the lack of complete faunal dating, and the scattering of outcrops have prevented a detailed study of the system. This is also true for much of the surrounding area. The work of Zeller (1958) is probably the most comprehensive study of the Cretaceous system in southwest New Mexico to date, and future publications by this worker will certainly lead to a better understanding of the Cretaceous in this area. Lasky (1947), Cobban and Reeside (1952), Darton (1916, 1917), and several others have also made important contributions to the knowledge of the Cretaceous strata of the area.

Four formational names are used later in this report: Sarten sandstone, Colorado shale, Lobo formation, and Howells Ridge formation. Use of the Colorado and Sarten names will be restricted to the Cooks Range, whereas the Howells Ridge and Lobo formational names will be employed only in the Sierra Rica and Florida Mountains, respectively. Cretaceous strata crop out elsewhere, but formational names will not be used for these outcrops because of the lack of adequate correlations, whether lithologic or faunal.

### Sarten Sandstone

The formation was named by Darton (1916, 1917) for a sandstone horizon that crops out on Sarten Ridge, on the southern end of the Florida Mountains. The formation also crops out on Fluorite Ridge and Goat Ridge in the same general area. At the type locality, the sequence consists of 300 feet of light-gray to buff, thin-bedded to massive sandstone. The formation typically weathers into yellow and brown rectangular blocks, some of which have concentric rings of hematitic stains.

Fossils collected by Darton (1916, 1917) and Jicha (1954) from limy beds near the middle of the formation have established the age as Commanchean. Darton originally correlated the Sarten with the Beartooth quartzite common to the Silver City area. The U. S. Geological Survey, however, now favors an Upper Cretaceous age for the Beartooth quartzite; therefore, the correlation by Darton is not compatible with current knowledge. Kottlowski et al. (1956) measured 95 feet of Sartentype beds beneath the Dakota(?) (Upper Cretaceous) sandstone in the southern part of the San Andres Mountains. If the Beartooth is Upper Cretaceous, it must be correlative with the Dakota(?) sandstone, and an overlap between the Beartooth and Sarten is possible in northern Luna County.

### Colorado Shale

In the Cooks Range a shale sequence overlies the Sarten sandstone with apparent conformity; fossil evidence, however, indicates that the shales are of Bentonian age, suggesting a hiatus in sedimentation between the two formations. On the basis of fossil evidence and lithology, Darton (1916, 1917) correlated the shale sequence with the Colorado shale. The beds are roughly equivalent to the Mancos and Eagle Ford shales in other parts of New Mexico.

Postdepositional erosion has stripped away most of the Colorado shale from outcrops in the Cooks Range; only occasional remnants now remain. Darton (1916, 1917) estimated 300 feet of mostly dark-gray to black, blocky shale interbedded with buff sandstone and blue-gray limestone.

### Howells Ridge Formation

The Sierra Rica, in the extreme southwest corner of the county, is composed of a thick sequence of interbedded limestone, limestone conglomerate, and red beds, all of Lower Cretaceous age. Strongin (1956) has correlated these beds with the Howells Ridge formation. The Howells Ridge formation is part of an immense thickness (about 15,000 feet) of Lower Cretaceous beds first described by Lasky (1947) in the Little Hatchet Mountains. Zeller (1958) has discussed the stratigraphy and paleontology of the Lower Cretaceous of the same area in considerable detail, substantially revising Lasky's work.

The total thickness of Lower Cretaceous beds present in the southwest corner of Luna County is not known, but it must be of the order of several thousand feet. The lithology of these beds is quite variable, sandstones and shales of the red-bed type alternating with thick sequences of oyster-rich limestone. Limestone conglomerate beds occur throughout the section.

### Lobo Formation

Darton (1916, 1917) designated a sequence of maroon-red shales, siltstones, sandstones, and chert conglomerates in the Florida Mountains as the Lobo formation. He tentatively assigned the formation to the Triassic. Although fossils have never been found in the beds, the age now is believed to be Lower Cretaceous, because Triassic rocks are unknown in southwestern New Mexico. The lithology, moreover, is similar to that of Lower Cretaceous beds exposed in the Victorio and Tres Hermanas Mountains. Darton used the same name for beds in the Cooks Range that are Permian in age. To avoid confusion, the writer will limit the use of the name to the Florida Mountains. The thickness of the formation is 250-300 feet.

### Other Cretaceous Sediments

Cretaceous rocks crop out in several other localities in Luna County. In these areas, the rocks consist essentially of interbedded limestone conglomerate, dark-gray limestone, and red sandstone and shale. Where faunal evidence is present, the age is consistently Lower Cretaceous.

Known thicknesses are as follows: Tres Hermanas Mountains, ± 1,000 feet; Victorio Mountains, 600-800 feet. Outcrops of similar beds occur in the Cedar Range, but their total thickness has not been estimated. These beds will be termed "Lower or early Cretaceous" sediments in this study.

## TERTIARY

Two types of Tertiary sedimentary deposits have been recognized in Luna County: the Gila(?) conglomerate, of late Tertiary age, formed after the major period of volcanism; and an older class of sediments, interbedded with the volcanic rocks. The latter type has been recognized by the writer only in the vicinity of Fluorite Ridge.

### Intervolcanic Sediments

A variable thickness of poorly cemented sediments containing some volcanic material is present between the lower andesitic and middle rhyolitic groups of volcanic rocks in the southern part of the Cooks Range, east of Fluorite Ridge. These sediments are lithologically similar to the Gila(?) conglomerate, but deposition must have occurred much earlier, because the beds are overlain by a rhyolite flow. Similar deposits are common throughout southwestern New Mexico, being sandwiched between various volcanic units. A more complete description of the sequence as exposed near Fluorite Ridge, together with comments pertaining to age, is given on page 103.

### Gila(?) Conglomerate

The close of the Tertiary period in southwestern New Mexico was marked by the retarding of the intense volcanic activity, but continued erosion of the irregular land surface caused the deposition of great thicknesses of fanglomerate deposits in the various valleys and basins. Deposits of this type have been correlated either with the Santa Fe formation or the Gila conglomerate, whose type localities are located in north-central New Mexico and southeastern Arizona respectively. The writer prefers the name Gila conglomerate because the type locality of this formation is closer to Luna County, but the name will be queried to indicate that a direct correlation has not been made.

The principal outcrops of the Gila(?) conglomerate are on the flanks of the major mountain ranges: Tres Hermanas Mountains, Cedar Mountains, Cooks Range, and possibly the east slopes of the Little Florida Mountains. The deposits typically consist of poorly to well sorted gravel, sand, and silt, all of which are weakly cemented. Exposed thicknesses of the formation do not exceed a few hundred feet, but far greater thicknesses may be present under the bolson plains.

## QUATERNARY

The normal variety of alluvial deposits are present in Luna County, ranging from Pleistocene to "yesterday" in age. The flanks of the mountain ranges are composed of great alluvial fans, which at depth almost certainly must grade into deposits of the Gila(?) conglomerate type. The vast plains between the ranges contain typical bolson deposits of finer sized material washed down from the mountains and blown about by the wind. The thickness of Quaternary alluvium beneath some of the broad valleys may be immense.

## IGNEOUS ROCKS

### GENERAL

Apart from the Precambrian, igneous rocks in Luna County are limited to an interval of time extending from Cretaceous to Quaternary. The earliest evidence of volcanic eruption is given by the presence of lenses of volcanic conglomerate occurring at the base of early Cretaceous sediments in the Victorio Mountains. After a considerable time lapse, igneous activity was renewed, causing the outpouring of a vast amount of volcanic material and the formation of several plutons. For the sake of simplicity, the writer has assigned this major igneous episode to the Tertiary period. It must be realized, however, that the earliest events of this episode probably occurred in late Cretaceous time; that is, some of the lower units of the volcanic sequence, and certain of the intrusive bodies, may represent events that took place in late Cretaceous time, whereas rocks of similar composition in another locality may have been erupted or intruded in early Tertiary time. In late Tertiary and Quaternary time, sediments comprising the Gila(?) conglomerate were deposited, followed by brief outpourings of basaltic lava over small areas.

As is to be expected, the long and intense period of volcanism was accompanied by the formation of plutons below the surface. These intrusive bodies are believed to have been the source of the various ore-forming fluids; hence, the locations and compositions of such bodies are of very special interest. The Cooks Peak and Tres Hermanas stocks are the largest exposed bodies of Tertiary granitic rocks in the county. Smaller intrusions occurred at Fluorite Ridge and Eagle Nest, and near Camel Mountain. In addition, intrusive bodies of stock size are inferred to be present at depth in the Victorio and Florida Mountains and under the bolson plain north of Myndus.

As geologic mapping proceeds in southwestern New Mexico, and as techniques are improved for the dating of igneous rocks, it will be possible to divide and distinguish between the various igneous rocks more accurately than is now feasible. Significant inroads into the problem have already been made by Jicha (1954) and Elston (1957) for northern Luna County, and basic information concerning surrounding areas has been reported by Elston (1960), Jones (1956), Kottlowski (1960b), Lasky (1938, 1937), and Zeller (1958). In addition, reconnaissance geologic mapping in southwestern New Mexico by staff members of the New Mexico Bureau of Mines and Mineral Resources for the new

State geologic map has provided an abundance of additional information concerning the volcanic rocks; summaries of this work have been given by Callaghan (1953) and Willard (1960).

TABLE 2. CHEMICAL ANALYSIS OF SOME IGNEOUS ROCKS FROM LUNA COUNTY

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 62.95 | 68.74 | 55.69 | 61.28 | 59.37 | 66.07 | 72.86 | 51.17 | 56.41 |
| $A1,0_2$ | 15.91 | 15.12 | 17.48 | 16.58 | 16.17 | 16.11 | 13.70 | 14.43 | 16.22 |
| $Fe_20_2$ | 3.30 | 1.69 | 0.56 | 2.49 | 4.49 | 2.96 | 0.75 | 4.49 | 2.37 |
| Fe0 | 1.37 | 1.36 | 5.83 | 1.58 | 1.20 | 0.29 | 1.08 | 5.90 | 5.47 |
| $M_20$ | 2.18 | 0.57 | 3.75 | 1.76 | 3.00 | 0.92 | 0.59 | 6.43 | 3.00 |
| Ca0 | 4.46 | 1.41 | 5.70 | 5.42 | 5.12 | 3.50 | 0.65 | 8.33 | 5.81 |
| $Na_20$ | 4.05 | 4.15 | 4.34 | 4.10 | 3.46 | 3.21 | 1.24 | 3.05 | 4.28 |
| $K_20$ | 2.95 | 4.77 | 2.64 | 3.47 | 2.81 | 4.24 | 5.18 | 1.62 | 2.85 |
| I-20+ | 1.91 | 0.87 | 2.15 | 1.09 | 0.86 | 1.11 | 2.89 | 0.19 | 0.89 |
| $H_2O$- | | 0.25 | 0.41 | 1.36 | 1.80 | 1.38 | 0.49 | 1.68 | 0.23 |
| $TiO_2$ | 0.67 | 0.49 | 0.90 | 0.51 | 1.01 | 0.48 | 0.28 | 2.00 | 1.52 |
| $P_20_5$ | 0.18 | 0.04 | 0.05 | 0.25 | 0.36 | 0.20 | 0.10 | 0.55 | 0.36 |
| Mn0 | 0.08 | 0.10 | 0.10 | 0.06 | 0.07 | 0.07 | 0.02 | 0.17 | 0.16 |
| Total | 100.01 | 99.56 | 99.60 | 99.95 | 99.72 | 100.54 | 99.83 | 100.01 | 99.57 |
| Alkaline/lime | 1.6 | 6.3 | 1.2 | 1.4 | 1.2 | 2.1 | 9.9 | 0.6 | 1.2 |
| $K_20/Na_20$ | 0.7 | 1.1 | 0.6 | 0.8 | 0.8 | 1.3 | 4.2 | 0.5 | 0.7 |

1. Cooks Peak granodiorite porphyry (Lindgren, 1910, p. 39). Analyst: George Steiger.
2. Tres Hermanas quartz monzonite (5E1/4 sec. 33, T. 27 S., R. 9 W.). Analyst: H. B. Wiik.
3. Tres Hermanas intrusive andesite (NE1/4 sec. 25, T. 27 S., R. 9 W.). Analyst: H. B. Wiik.
4. Lower extrusive andesite from the Cooks Range; called Macho formation by Jicha (1954, p. 50) (SEV4SW1/4 sec. 20, T. 19 S., R. 7 W.). Analyst: H. B. Wiik.
5. Extrusive andesite younger than the lower andesite group, yet older than the middle rhyolite-latite group; called Rubio Peak formation by. Jicha (1954, p. 50) (NWV4NWV4 sec. 16, T. 19 S., R. 8 W.). Analyst: H. B. Wiik.
6. Extrusive quartz latite from the Cooks Range; part of the middle rhyolite-latite group; called the Pollack formation by Jicha (1954, p. 50) (sec. 28, T. 18 S., R. 8 W.). Analyst: H. B. Wiik.
7. Rhyolite flow from the Tres Hermanas Mountains; part of the middle rhyolite-latite group (NEV4 sec. 22, T. 28 S., R. 9 W.). Analyst: H. B. Wiik.
8. Late Tertiary basalt flow from the Cooks Range; called Bear Springs formation by Jicha (1954, p. 50) (3E1/6E1/4 sec. 22, T. 18 S., R. 10 W.). Analyst: H. B. Wiik.
9. Late Tertiary or Quaternary basalt dike from the Tres Hermanas Mountains (NE1/4 sec. 5, T. 28 S., R. 9 W.). Analyst: H. B. Wiik.

## EXTRUSIVE ROCKS

### Early Cretaceous Extrusive Rocks

Lenses of andesitic volcanic conglomerate occur at the base of Lower Cretaceous sediments in the Victorio Mountains. These conglomerates testify to the occurrence of a nearby volcanic eruption at some time immediately preceding the deposition of the Lower Cretaceous strata. Although the outcrops in the Victorio Mountains provide the only conclusive evidence of volcanic activity of early Cretaceous age in Luna County, eruptions also occurred in Hidalgo County at about the same time (Lasky, 1938, 1947; and Zeller, 1958).

## Tertiary Extrusive Rocks

The Tertiary volcanic sequence is divisible into three broad groups: lower andesite, middle rhyolite-latite, and upper basalt. A cessation of volcanic activity followed by an erosional interval is assumed between each of the groups; certain areas, however, indicate some degree of overlap.

*Lower andesite.* The lowest volcanic rocks belonging to the Tertiary period are a group of andesite breccias, agglomerates, tuffs, and flows. The lithology of a typical section of these rocks, as exposed in the Victorio Mountains, is discussed on pages 74-75. Rocks of similar lithology and age crop out extensively in the Tres Hermanas Mountains, Cedar Mountain Range, and Cooks Range. These are the volcanic rocks that may extend from Upper Cretaceous to Lower Tertiary time.

In the Tres Hermanas Mountains the andesite has been invaded by a quartz monzonite stock, indicating what seems to be a characteristic relationship in southwestern New Mexico; i. e., the majority of the intrusive rocks are later in age than the extrusive andesites. Another interesting relationship is shown in the Tres Hermanas by andesite breccia overlying a sequence of latite flows and flow breccias. These older latites probably are an integral part of the andesitic sequence, for the contact between the two appears to be gradational. There is, however, a remote possibility that the latite is of Lower Cretaceous age. The strongest argument against the latter conclusion is the absence of volcanic fragments in the conglomerate lenses that make up a large portion of Lower Cretaceous sediments exposed in close proximity to the volcanic sequence.

The lower andesite group of volcanic rocks appears to be consistently present in the mountain ranges of the southern and western parts of the county. This is not true, however, for the Florida Mountains, where rocks of this type are completely absent, or in the Cooks Range, where the andesites appear only in certain areas. The absence of the andesites may be explained by erosion or simply by lack of deposition on topographical highs.

*Middle rhyolite-latite sequence.* Capping the lower andesite group is a rhyolite-latite sequence of extrusive rocks. The two groups are believed to have been separated by a considerable time and erosional break (Jicha, 1954; Jones, 1956; Willard, 1959). The contact is easily recognizable in the Tres Hermanas Mountains and Cedar Range because of an abrupt change in the physical and chemical properties of the rocks between the two groups. The andesite is characterized by rounded hills having a distinct greenish-gray cast, whereas the rhyolite-latite group tends to produce much more rugged forms on the outcrop and possesses a reddish to tan coloration. An exception to this general form can be noted where pyroclastic rocks make up a large portion of the rhyolitelatite sequence, causing them to be easily stripped away by erosion, so that only occasional remnants are left, resting on the lower andesites.

The middle rhyolite-latite group is composed of an almost infinite variety of intercalated flows, breccias, agglomerates, welded tuffs, and tuffs. Although the sequence is composed mostly of rhyolite and latites, it may contain lenses of andesite. In the Cooks Range, a thick sequence of andesite forms the basal part of the group; these particular andesites were described by Jicha (1954) as the Rubio Peak formation. The thick sequence of agglomerate, mostly of rhyolitic composition, that forms a large portion of the Florida and Little Florida Mountains is believed to be an integral part of the rhyolite-latite group.

*Upper basalt group.* The Cedar Mountain Range and Goodsight Mountains contain thick flows of basalt and basaltic andesite and related pyroclastic rocks. In both ranges the basalts are separated from the underlying rhyolite-latite group by an erosion surface. The basalts are believed to be late Tertiary and should not be confused with the Quaternary basalts mentioned below. The Tertiary basalt group is not so widely distributed as the rhyolite-latite group. This is due in part to Quaternary erosion, and in part to a less intense period of volcanism than the older periods.

### Quaternary Basalt

The most conspicuous evidence of Quaternary eruption in the area is the volcanic field that forms the West Potrillo Mountains, lying just across the east boundary of Luna County between U. S. Highway 70-80 and the Mexican border. Almost perfectly shaped cinder cones, scarcely touched by erosion, testify to the recent age of the basalts. Although the volcanic field is located mostly in Dona Ana County, several cones lie near Eagle Nest Mountain, and one thin flow extends westward into Luna County near Camel Mountain. Two smaller basalt flows are present south of the Tres Hermanas Mountains, and Black Mountain, located northwest of Deming, is a cinder cone composed of basaltic material. In the latter two areas, the age is assumed to be Quaternary, but the activity may have started in late Tertiary (Pliocene) and then have continued into Quaternary time. Small outcrops of basalt are known in the Cedar Mountains, Burdick Hills, and other areas, which are probably of the same age.

## INTRUSIVE ROCKS

### Cooks Peak Granodiorite Porphyry

The southern end of the Cooks Range contains an intrusive complex composed of three closely grouped masses of granodiorite porphyry plus numerous small apophyses that extend into the surrounding sediments. The compositions of the three masses are so similar that a common source magma is certain, and the amount of sedimentary rock separating the three is so trivial as to postulate a common body at a shallow depth.

The largest of the three masses forms Cooks Peak, being oval shaped and covering a 6-square-mile area on the outcrop. The Cretaceous and Paleozoic sediments appear to have been arched by the intrusion, and Darton (1916) assumed the shape to be laccolithic. There is no evidence, however, of a flooring to the body, and in certain places the intrusion was discordant with the bedding. The two smaller bodies crop out southwest of the main Cooks Peak "stock." Each is separated from the others by narrow bands of Cretaceous and Paleozoic sediments. Jicha (1954, p. 38) described the granodiorite porphyry as follows:

> The intrusive rock is a massive porphyry of gray color with prominent phenocrysts of andesine and lesser amounts of hornblende and biotite. The phenocrysts show well-developed flow structure. The groundmass is microcrystalline granular and consists of the same minerals with the addition of quartz, orthoclase, and lesser amounts of apatite and chlorite.

The analysis of the rock is given in Table 2.

Mapping by Jicha (1954) and Darton (1916) has shown that the granodiorite plutons were intruded after the deposition of the Colorado shale, which is Upper Cretaceous (Bentonian) in age. The age of the granodiorite relative to the Tertiary volcanic sequence is unknown because the only exposures of such rocks near Cooks Peak are separated from the granodiorite by a large northwest-striking fault. Jicha (1954, p. 59) concluded that the intrusion may have occurred prior to volcanism, basing his judgment on the finding of granodiorite pebbles in conglomerate lenses at the base of the oldest volcanic sequence, and the absence of hypabyssal equivalents of the granodiorite cutting any volcanic rock. This conclusion is contrary to the writer's view (p. 22) that the intrusive episode in Luna County most likely occurred after the outpouring of the lower andesite group. A few clarifying remarks are therefore necessary to substantiate the writer's viewpoint. First, Jicha has mapped two andesite groups in the Cooks Range, naming the lowermost the Macho formation and the upper the Rubio Peak formation. The Macho formation contains lead-zinc veins in the Old Hadley mining district, located a short distance east of the Cooks Peak stock. Moreover, the Macho formation is kaolinized and silicified in the same area. The writer believes that the solutions that caused the alteration and that formed the lead-zinc veins in the Old Hadley district were derived from deeper portions of the Cooks Peak granodiorite complex. Therefore, either the Macho formation was already present at the time of the granodiorite intrusion or it followed so closely as to suggest contemporaneity. The Rubio Peak formation did escape hydrothermal action; hence those andesites are probably postgranodiorite in age. Second, the granodiorite pebbles reportedly discovered at the base of the Macho formation may be altered Precambrian gray granite fragments. Jicha failed to note the exact area where the pebbles occur, so that his assumption could not be verified by the present writer.

### Fluorite Ridge Granodiorite Porphyry

Fluorite Ridge was formed by an elongate intrusion of granodiorite porphyry into Paleozoic and Cretaceous sediments. The rock differs from the Cooks Peak granodiorite by a greater abundance of hornblende and biotite, which impart a distinct greenish cast to the rock. The rock, however, is otherwise very similar to the Cooks Peak plutons, and the two are probably genetically related. The Fluorite Ridge granodiorite porphyry is discussed more fully later in the text. (p. 102).

### Tres Hermanas Quartz Monzonite

A circular stock of quartz monzonite, covering approximately 10 square miles, forms the core of the Tres Hermanas Mountains. The stock invaded Paleozoic and Lower Cretaceous sediments and Tertiary andesite breccia. The sedimentary rocks were intensely metamorphosed (marbleization, silication, and silicification) adjacent to the stock; this alteration is in contrast to the simple silicification associated with the intrusion of the granodiorite porphyry in the Cooks Range and Fluorite Ridge.

A small arc-shaped body of hornblende-rich intrusive andesite crops out on the northeast slope of North Sister Peak. The andesite is probably older than the quartz monzonite, being related to the same episode that caused the formation of the andesite breccias and flows that surround the southern end of the mountain group (fig. 5). The chemical analysis of both the quartz monzonite and andesite is given in Table 2.

### Other Intrusive Bodies

A small, circular body of diorite(?) forms a group of low hills midway between Arena and Camel Mountain in the extreme southeast corner of the county. More particular information concerning this small pluton will be found on page 147.

A tiny outcrop, scarcely more than 100 feet in diameter, of granitic rock stands boldly above the bolson plain a few miles north of Myndus, in sec. 14, T. 23 S., R. 6 W. The rock is a gray, granular igneous rock containing predominantly plagioclase feldspar accompanied by quartz and a considerable amount of dark minerals. The rock is identified tentatively as diorite. Evidence of the intrusive nature of the rock is provided by the granitic texture and the blocky shape, typical of most large intrusive bodies, to which the outcrop has weathered. The immediate area surrounding the knoll is devoid of other outcrops.

The Victorio Mountains do not contain large intrusive bodies near the surface. The presence, however, of granite dikes and intense silica-don of carbonate rocks suggest the probable existence of a pluton buried nearby. An analogous situation is required in the Florida Mountains to explain the presence of rhyolite dikes and to provide a source for the lead-zinc mineralization.

# STRUCTURAL FEATURES

## GENERAL

A detailed analysis of the major structural features of Luna County is hampered by the presence of the great bolson plain that covers the greater part of the land surface. An analysis of structure, therefore, must be limited to the several isolated mountain ranges that rise above the plain, resembling islands rising out of a sea. The obvious manner to attack the problem would be to couple geologic mapping of the ranges with geophysical surveys (gravity, magnetic, and seismic) of the entire region. By so doing, the known structural elements exposed in the mountains could be extrapolated beneath the bolson plains. In addition, entirely hidden features, lying off the mountain ranges, could be detected and correlated into the structural framework. Unfortunately, geologic mapping is not complete, and geophysical information, apart from confidential surveys of private companies, is entirely absent.

The description below is based on observations made by the writer during the entire period of field investigation. The geologic maps of Darton (1916, 1917), Jicha (1954), and Elston (1957) also were studied to gain additional information concerning areas of which the writer has no special knowledge.

## SUMMARY OF TECTONIC HISTORY

The entire Paleozoic era was one of relative quiescence in Luna County, being a period of marine deposition punctuated by only a few hiatuses. The formation of the Florida landmass during Pennsylvanian times undoubtedly was accompanied by faulting and folding, but subsequent erosion and renewed deposition have obliterated these structures.

Triassic and Jurassic sediments are unknown in southwestern New Mexico, causing an appreciable time gap in the geologic history. In the Victorio Mountains, early Cretaceous sediments contain basal lenses of volcanic conglomerate, testifying to a nearby eruption, and the outcrops at Fluorite Ridge hazily suggest considerable deformation prior to the deposition of the Lower Cretaceous Sarten sandstone. The extent and mode, however, of tectonic activity occurring at the beginning of the Cretaceous period cannot be appraised with present knowledge.

The disturbances mentioned above were dwarfed by the orogeny that started at the close of the Cretaceous period and continued through most of Tertiary time. Essentially all the structures mentioned below were fu: med during this orogeny.

## FOLDS

There is little evidence of large flexures in the stratified rocks; most of the failure, instead, occurred by faulting. Darton (1916, p. 73) postulated that the Florida Mountains may represent the eastern limb of a large north-trending anticlinal fold. There is little evidence to substantiate that belief; the western escarpment of the range suggests a north-trending fault.

The Goodsight Mountains form the western limb of a broad syncline, the axis of which approximately follows the east boundary of Luna County. The mountains consist of a sequence of latite flows and breccias overlain by basalt, all of which dip to the east and pass under an alluvium-filled valley. The same sequence then rises again to form the east limb of the syncline in Dona Ana County.

The invasion of granodiorite in the Cooks Range and Fluorite Ridge domed the sediments upward along the margins of the plutons. The intrusive complex at Cooks Peak, consisting of three separate bodies, appears to have been formed by a single intrusion of granodiorite, which spread laterally in many places along the strata, giving a laccolithic appearance to the entire body. The roof over the pluton was deformed in such a manner as to include downwarped projections into the granodiorite; erosion has not removed these projections, causing the granodiorite to crop out as three separate bodies. At Fluorite Ridge, the granodiorite apparently arched Cretaceous sediments upward along a northwest-trending axis; erosion then breached the elongated dome, exposing the underlying granodiorite. Goat Ridge, 3 miles to the northwest, appears to be a similarly formed structure, but erosion has not cut down far enough to expose the postulated igneous mass.

A synclinal fold and one small dome were formed in Cretaceous and Permian beds at the south end of Sarten Ridge, between Cooks Peak and Fluorite Ridge. These folds probably were formed during the invasion of the Cooks Peak granodiorite.

## FAULTS

The various fault patterns present in the several mining districts are discussed in detail later in the text. In order to avoid needless repetition, the discussion of faulting will be limited here to major structural belts. These belts are for the most part hidden beneath the bolson deposits, so that the interpretation given is highly speculative and subject to drastic revision as additional mapping is accomplished.

Most of the mountain ranges in Luna County are large fault blocks. The Florida Mountains, Cedar Mountain Range, Victorio Mountains, and Grandmother Mountains are all excellent examples. The trend of these ranges provides the key to the understanding of the major faulting within the area

### Northwest-Striking Fault Belts

The Cedar Mountains are an example of several northwest-trending structural zones present in Luna County. The range was formed by a system of faults striking N. 40°-60° W., which tilted a thick sequence of Tertiary volcanic rocks to the northeast. Subsequent erosion of the tilted block formed a system of ridges that parallel the fault direction. The Klondike Hills belong to the same structural trend, and the Burdick Hills, farther north, probably were formed by a parallel trend, which may extend into the Tres Hermanas Mountains.

Another northwest-striking structural zone extends from Fluorite Ridge through Goat Ridge. Fluorite Ridge, and probably Goat Ridge, were formed by the invasion of granodiorite along a northwest-trending zone of weakness.

Probably the strongest northwest-trending structural zone is the one that passes through the Cooks Range. Jicha (1954) mapped a large fault striking N. 30° W. along the east side of the range, where Cretaceous and Tertiary rocks on the east abut against Precambrian and Paleozoic rocks on the west. This same fault continues to the northwest, where it probably connects with a fault system that extends through Silver City. Northwest-striking faults are evident in the volcanic ridges in the southern part of the Cooks Range, but the main fault just mentioned swings to a due south direction, forming the east escarpment of Sarten Ridge.

To summarize, there are probably four northwest-striking fault belts: (1) the Cedar Mountain Range belt, (2) the Burdick Hills—Tres Hermanas belt, (3) the Fluorite Ridge—Goat Ridge belt, and (4) the Cooks Range belt. Post-Tertiary volcanic movement is indicated for each of the trends, but the trends are probably old lines of weakness along which movement has occurred periodically since late Cretaceous time. Activity along the Fluorite Ridge—Goat Ridge trend may extend back as far as the early Cretaceous period.

### North-Striking Fault Belts

The Florida Mountains are essentially an uplifted and east-tilted block containing rocks that range from Precambrian through Tertiary in age. It is the writer's opinion that the block rose along a north-trending fault zone that lies hidden under the gravel slopes on the west flank of the range. The same trend is assumed to continue southward, passing immediately east of the Tres Hermanas Mountains. The assumption of such a fault zone is based on the fairly straight west escarpment of the Florida Mountains and a definite beveling of the east side of the Tres Hermanas stock; the actual fault zone, however, is completely hidden. North-striking faults are clearly evident on the east end of Fluorite Ridge, and these faults may represent a continuation of the Tres Hermanas—Florida trend. Indeed, one could speculate that the trend extends into the Cooks Range, where it may join the large fault mentioned previously that forms the east escarpment of Sarten Ridge.

Another north-trending zone may be postulated as extending from the vicinity of Arena, on the Mexican border, northward past Eagle Nest Mountain. Evidence to substantiate the presence of the trend is admittedly vague: (1) the presence of three small, north-alined intrusive bodies, near Arena, at Eagle Nest Mountain, and north of Myndus respectively; (2) a north-trending escarpment, with sheet wash alluvium on the west and eolian sand on the east, which runs from Arena northward to U. S. Highway 70-80; (3) an indication of north-striking faults at Eagle Nest Mountain.

### Northeast-Striking Fault Belts

Numerous northeast-striking faults of small displacement are detectable in each of the mountain ranges, but large fault zones with this trend are either absent or completely hidden by the bolson plains.

### East-Striking Fault Belts and the Texas Lineament

Tectonic maps of the Western United States invariably show a major structural zone extending from trans-Pecos Texas on the east into southern California on the west. Although this prominent zone most certainly passes through Luna County, it is difficult to describe its course precisely. A logical course would run from the east through the gap between the Florida and Tres Hermanas Mountains, continue thence in a west-northwest direction, and pass just north of the Victorio Mountains before entering Grant County. The writer favors the passage through the gap between the Florida and Tres Hermanas Mountains because of the contrasting structural and lithologic features of the two ranges. Also, east-west faulting is present in the Florida Mountains, one of the faults being of considerable magnitude (fig. 14). The passage of the lineament near the Victorio Mountains is suggested by the alinement of the fault-formed ridges in a west-northwest direction. The Grandmother Mountains, lying immediately to the north have the same trend. Other west-striking fault zones may be present, but the absence of outcrops prevents the drawing of any definite conclusions.

## RELATIONSHIP OF ORE DISTRICTS TO STRUCTURAL TRENDS

Billingsly and Locke (1933, 1941), Mayo (1958), and many others have described the apparent tendency of large ore districts to occur near the intersection of major structural belts. Although Luna County does not possess a single known *major* ore district, it does appear that two of the districts, Cooks Peak and Tres Hermanas, occur at such intersections. In order to subscribe to the premise given here, it must first be assumed that the several structure belts, which have already been described, were zones along which movement periodically occurred throughout late Cretaceous to late Tertiary time. The assumption is plausible, but actual field evidence for the several structural belts is limited to those movements that occurred after the major igneous episode.

The Cooks Peak mining district is located near the intersection of northwest- and north-trending structural belts. The northwest-trending belt already has been described as extending from the Silver City region across the northern part of the Cooks Range. The north-trending belt is vague, being exposed only in Fluorite Ridge and the large fault that bounds the east edge of Sarten Ridge. The presence of this belt is substantiated, however, farther north by the prominent faults, possessing this same alinement, that form the east flank of the Black Range. Northeast-striking faults were noted in the Cooks Peak district by Jicha (1954); even though these particular faults are of relatively small displacement, they may represent minor movements along an older structural zone.

The Tres Hermanas district shows an interesting relationship to three structural trends. First, the Texas lineament, or at least a portion of that great belt, appears to pass along a west-northwestward course immediately north of the district. Second, a north-trending belt appears to pass immediately east of the mountains; one might speculate that the same trend continues farther north, past the Florida Mountains and Fluorite Ridge, into the Cooks Range. The third trend is the northwest-striking belts that formed the Cedar Mountains and Burdick Hills, and that pass across the south end of the Tres Hermanas Mountains. Why the Tres Hermanas district, lying at an intersection of strong structural elements and possessing a quartz-rich monzonite stock, has failed to yield a major ore discovery is a mystery.

The intersection of structural zones may have been important in localizing the other mining districts, particularly the Victorio district, which appears to lie on the Texas lineament. The discussions, however, of even the Cooks Peak and Tres Hermanas structural intersections, given above, are highly speculative, and the projection of trends into the other districts would be fantasy until such time as the regional structure is better understood.

# *Mining in Luna County*

## HISTORY

The history of each mining district is discussed later in the text; nevertheless, it will be appropriate to outline here a few of the important events relating to the development of mining in Luna Count' It is almost a certainty that Spanish explorers prospected the major mountain ranges in Luna County in he late 1700's and early 1800's, but their searches must have failed, for there was no evidence of large-scale mining when Americans began to settle the area in 1850.[3]

The first economic mineral discovery of record was made in 1876 by the finding of the lead-zinc-silver deposits at Cooks Peak. This district immediately flourished, producing a total of about $3 million by the turn of the century from such mines as the Desdemona, Graphic, Summit, Faywood, and Contention. Although the exact dates are not known to the writer, the Victorio, Tres Hermanas, and Florida districts are assumed to have been discovered in the early 1880's, soon after the Cooks Peak find.

After 1900, the production from these districts began gradually to decline because of the failure to develop new ore. The production had

Figure 3. American Smelting and Refining Co. flotation concentrator located northwest of Deming.

3. The Spaniards, however, did discover the now famous Chino copper mine located near Santa Rita, in Grant County.

TABLE 2. PRODUCTION OF METALS AND MINERALS FROM LUNA COUNTY

(Unless otherwise noted, production data from Mineral Resources of the United States [1902 to 1931] and Minerals Yearbook [1932 to 1958.)

| Year | Principal metals | | | | | | Other metals and minerals | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gold (oz) | Silver (oz) | Copper (lb) | Lead (lb) | Zinc (lb) | Total (dollars) | Manganese (tons) | Fluorspar (tons) | Total (dollars) | Total (dollars) |
| Pre-1902 | | * | | * | | 4,300,000t | - | - | - | 4,300,000 |
| 1902 | - | 10,382 | - | 711,825 | - | 34,400[1] | - | - | - | 34,400 |
| 1903 | - | 6,168 | - | 1,355,965 | - | 61,800t | - | - | - | 61,800 |
| 1904 | 85 | 8,549 | 16,000 | 671,772 | - | 37,605 | - | - | - | 37,605 |
| 1905 | - | 5,199 | - | 463,956 | 225,000 | 38,221 | - | - | - | 38,221 |
| 1906 | 21 | 11,265 | - | 831,193 | 103,836 | 61,673 | - | - | - | 61,673 |
| 1907 | 687 | 8,633 | - | 1,022,773 | - | 73,646 | - | - | - | 73,646 |
| 1908 | - | 1,077 | 5,934 | 127,535 | - | 6,713 | - | - | - | 6,713 |
| 1909 | 160 | 6,916 | 1,115 | 682,906 | - | 36,314 | - | 710 | 10,650[1] | 46,964 |
| 1910 | 1 | 2,484 | 47 | 298,112 | - | 14,490 | - | | | |
| 1911 | 5 | 1,278 | 1,814 | 98,888 | - | 5,458 | - | | | |
| 1912 | 284 | 24,265 | - | 827,556 | 458,594 | 89,493 | - | | | |
| 1913 | 554 | 41,664 | 1,453 | 1,158,682 | 702,028 | 126,771 | - | | | |
| 1914 | 11 | 2,975 | 2,181 | 416,923 | 793,588 | 58,694 | - | | | |
| 1915 | 25 | 2,795 | 4,080 | 148,766 | 861,218 | 116,405 | - | | | |
| 1916 | 177 | 18,077 | 2,663 | 868,724 | 2,725,582 | 441,255 | - | | | |
| 1917 | 261 | 15,142 | 319 | 721,117 | 1,635,500 | 246,612 | - | | | |
| 1918 | 411 | 16,442 | 3,150 | 490,493 | 463,445 | 102,432 | | | | |
| 1919 | 246 | 11,183 | 1,479 | 383,248 | 31,575 | 40,343 | - | | | |
| 1920 | 334 | 11,611 | 3,864 | 359,488 | 21,098 | 50,506 | | 16,400t | 530,000[1] | 1,987,665[1] |
| 1921 | 74 | 4,709 | - | 144,467 | - | 12,698 | - | | | |
| 1922 | 19 | 976 | 1,679 | 43,000 | 24,228 | 5,322 | - | | | |
| 1923 | 63 | 2,312 | 1,041 | 85,472 | - | 9,332 | 65 | | | |
| 1924 | 10 | 3,024 | 573 | 306,198 | - | 26,799 | 503 | | | |
| 1925 | 47 | 6,603 | 2,500 | 595,020 | 119,300 | 66,751 | 1,022 | | | |
| 1926 | 7 | 1,984 | 2,450 | 183,300 | 70,000 | 21,644 | 1,130 | | | |
| 1927 | 16 | 2,058 | 367 | 206,080 | - | 14,523 | 1,760 | | | |
| 1928 | 4 | 188 | - | 9,000 | - | 717 | 2,578 | | | |

* Production believed to have been made, but quantity and/or value not accurately known. t Estimated.

TABLE 2. PRODUCTION OF METALS AND MINERALS FROM LUNA COUNTY (continued)

| Year | Principal metals | | | | | | Other metals and minerals | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gold (az) | Silver (oz) | Copper (lb) | Lead (lb) | Zinc (lb) | Total (dollars) | Manga-nese (tons) | Fluor-spar (tons) | Total (dollars) | Total (dollars) |
| 1929 | 12 | 1,666 | 2,585 | 40,700 | | 4,151 | 1,961 | [ | | |
| 1930 | 15 | 904 | 500 | 51,000 | | 3,269 | 1,329 | | | |
| 1931 | | | | | | | 1,032 | | 21,700[1] | 21,700 |
| 1932 | | | | | | | | | | |
| 1933 | 0.2 | 143 | - | 20,000 | - | 796 | | * | * | 796 |
| 1934 | 1 | 1,245 | 200 | 49,100 | - | 2,670 | | 700 | 10,500* | 13,170 |
| 1935 | 6 | 380 | - | 7,400 | - | 786 | | 2,675 | 62,500[1] | 63,286 |
| 1936 | 4 | 745 | 250 | 16,700 | - | 1,515 | | | | 1,515 |
| 1937 | 94 | 3,722 | 3,000 | 74,400 | - | 10,908 | 856 | 13,044 j | | 59.098 |
| 1938 | 397 | 13,676 | 6,000 | 256,700 | - | 35,146 | | | | |
| 1939 | 455 | 17,397 | 9,500 | 332,800 | 9,000 | 44,832 | 339 | | 6,460[1]- | 51,292 |
| 1940 | 113 | 4,175 | 2,600 | 107,000 | 49,000 | 15,665 | | * | * | 15,665 |
| 1941 | 14 | 218 | 200 | 26,400 | - | 1,684 | | * | * | 1,684 |
| 1942 | - | 339 | - | 32,000 | - | 5,851 | 1,000* | * | 33,500t | 39,351 |
| 1943 | - | - | - | 6,000 | 22,000 | 2,826 | * | * | * | 2,826 |
| 1944 | | | | | | | | | | |
| 1945 | - | - | - | - | - | - | | | | |
| 1946 | - | 26 | - | - | - | 21 | | * | * | 21 |
| 1947 | 25 | 3,093 | 2,900 | 134,500 | 42,600 | 28,806 | | * | * | 28,806 |
| 1948 | 2 | 958 | - | 14,678 | - | 15,615 | | * | * | 15,615 |
| 1949 | - | 221 | | 38,000 | - | 6,204 | | 2,731 | 45,000t | 51,204 |
| 1950 | I | 336 | - | 10,000 | - | 1,689 | | 5,868 | 93,359* | 95,048 |
| 1951 | 10 | 2,970 | 6,000 | 464,000 | 552,000 | 179,766 | | 6,716* | 69,234* | 249,000 |
| 1952 | 3 | 1,222 | 2,000 | 190,000 | 188,000 | 63,493 | 1,431* | 2,964* | 60,867* | 124,360 |
| 1953 | - | 57 | - | 4,000 | - | 581 | 5,948* | 3,279* | 234,919* | 235,500 |
| 1954 | - | 19 | - | - | - | 17 | 7,176* | 5,025* | 273,838* | 273,855 |
| 1955 | 1 | 175 | - | 2,000 | - | 491 | 4,886* | - | 141,136* | 141,627 |
| 1956 | - | 227 | 2,100 | 9,300 | - | 2,558 | 1,076* | - | 81,950* | 84,508 |
| 1957 | - | 272 | - | 6,000 | 2,000 | 1,336 | 2,2001 | - | 200,0001 | 201,336 |
| 1958 | | | | | | | 2,500t | | 225,000[1] | 225,000 |
| Total | 4,655.2 | 282,145 | 90,544 | 15,105,137 | 9,099,592 | $6,531,293 | 38,882 | 47,068 | $2,113,657 | $8,644,950 |

* Production believed to have been made, but quantity and/or value not accurately known. t Estimated.
* Data from State Mine Inspector's Annual Reports. Fiscal years.

been mostly ores containing lead, zinc, and silver; only small amounts of gold and copper ore were mined. Fortunately, about the time that the older mines were being worked out, discoveries were made of important deposits of fluorspar and manganese. Fluorspar mining started in 1909 in the Fluorite Ridge district, and manganese production started in the Little Florida Mountains in 1918. In later years, these minerals accounted for the bulk of the county's mineral production.

The Deming vicinity is well situated for ore beneficiation plants because of abundant ground water, adequate tailing-disposal areas, and good transportation facilities. The Peru Mining Co. and the American Smelting and Refining Co., recognizing these factors, built flotation concentrators northwest of the town. These mills were built primarily to treat zinc ores mined from the Central district in Grant County. Both mills, however, have accepted other base metal ores on a custom basis, including some ore mined from Luna County itself. The Peru mill was built in 1928 and is now rated at 1,250 tons per day; the A. S. & R. mill was constructed in 1949 and is now rated at 650 tons per day. The La Purisima Fluorspar Co. also built a flotation mill in Deming, in 1931, to treat ores mined at Fluorite Ridge. The original capacity of the mill was 20 tons per day, but it was increased to 100 tons per day in 1937, when the General Chemical Co. bought La Purisima's holdings in the area.

In 1951, the Federal Government initiated an incentive buying program for domestically produced manganese ore. This program had a positive effect in Luna County. Manganese mines that had been closed for many years were reopened, and renewed exploration led to the discovery of several new deposits. In addition, several mills were built to treat the ore.

Economic conditions in the mineral industry have had, however, a damaging effect in Luna County in the past few years. Lead-zinc-copper-silver-gold mining has declined in recent years until the production value of these metals is of little significance. The reason for this is twofold: depletion of ore reserves, and low metal prices. Fluorspar mining came to a halt in 1954, caused by a flooding of the fluorspar market with cheaply produced foreign ore. Finally, the Federal Government terminated its manganese purchasing program in September 1959, which simultaneously forced the closing of every manganese mine in the county.

Whenever mineral prices again rise, Luna County certainly can be counted on to produce its share of mineral wealth. Just when this will occur depends on so many variables and uncertainties that the writer will not even hazard a guess.

## PRODUCTION

Table 3 summarizes the recorded production values from Luna County through 1958, the last year for which accurate production data are available. Unfortunately, the table is not so detailed as one might desire. There is no yearly breakdown of production prior to 1902; instead, a lump estimate is given, based on information from Jones (1904), Lindgren et al. (1910), and other sources. Also, there are some omissions, such as sand and gravel, building stone, and specimen minerals, for which production data are lacking. The table is divided into two divisions, one for gold-silver-copper-lead-zinc, and the other for manganese and fluorspar.

## GOLD, SILVER, COPPER, LEAD, AND ZINC

The total value of these metals produced prior to 1902 is estimated at $4.3 million. A breakdown of this estimate is not possible other than to state that the production values of these five metals probably ranked in the following order: lead, zinc, silver, gold, and copper. This same order has prevailed from 1902 to the present.

If it is assumed that substantial mine production started in 1880, the average annual production value, rounded to the nearest thousand, can be computed for several inclusive periods, as follows:

| | |
|---|---|
| 1880-1901 | $195,000 per year |
| 1902-1927 | $ 69,000 per year |
| 1927-1958 | $ 14,000 per year |
| Overall (1880-1958) | $ 83,000 per year |

The above figures illustrate the decline in metal mining in Luna County.

It is interesting to compare the value actually realized from the production of these metals with that which would be realized at current (July 1960) prices. In order to calculate this value, we must first assume that the relative production of the several metals was the same prior to 1902 as thereafter. On this assumption, the present-value calculation is as follows:

| METAL | WEIGHT | PRICE | VALUE |
|---|---|---|---|
| Gold | 13,600 oz | $35/oz | $476,000 |
| Silver | 826,000 oz | 91C/oz | 751,660 |
| Copper | 265,000 lb | 33¢/lb | 87,400 |
| Lead | 44,300,000 lb | 120/lb | 5,316,000 |
| Zinc | 26,650,000 lb | 1301) | 3,464,500 |
| | | | Total = $10,095,560 |

The current value thus represents a 55-percent increase over that which was actually realized.

## MANGANESE AND FLUORSPAR

The annual production data for manganese and fluorspar for Luna County have not been reported accurately, and the information given in Table 3 was derived from several sources, leading to the possibility of serious errors. Future publications by the U. S. Bureau of Mines are expected to give more complete and accurate production data than those available to the writer.[4]

4. The U. S. Bureau of Mines is now preparing commodity reports on manganese and fluorspar in New Mexico.

# *Mineral Deposits*

## GEOGRAPHIC DISTRIBUTION

Figure 1 shows the locations of the several mining districts in Luna County. Essentially every mountain group is classed as a mining district, for these are the areas of rock exposures. The possible effects of certain structural zones on the localization of the various ore districts have already been discussed; this structural control forms the only discernible geographic distribution pattern of the ore deposits in the county.

## CLASSIFICATION

The mineral deposits of Luna County fall into three broad classifications: pyrometasomatic replacement, meso—leptothermal, and epithermal. True pyrometasomatic conditions are exhibited by the helvitescheelite deposits in tactite in the Victorio district and by the small magnetite bodies adjacent to the quartz monzonite stock in the Tres Hermanas district. In addition, the lead-zinc replacement deposits of the latter district may be considered pyrometasomatic because they lie near an igneous contact, even though the actual conditions of deposition were probably in the mesothermal to leptothermal range.

The lead-zinc deposits of the Cooks Peak and Victorio districts are believed to be leptothermal because of their mineralogy and lack of intense wall-rock alteration, and because they are remote from intrusive bodies. The epithermal deposits are represented by the fluorspar and manganese deposits occurring in the Fluorite Ridge and Little Florida districts respectively.

As to be expected, several structural types are superimposed on the temperature-pressure classification. The lead-zinc deposits in the Tres Hermanas and Cooks Peak districts are limestone replacement mantos.[5] The lead-zinc deposits of the Victorio district occur as replacement veins in dolomite, having been controlled by minor preore faulting. The fluorspar and manganese deposits of the Fluorite Ridge and Little Florida districts are simple fissure veins representing open-space filling accompanied by very little replacement. Many of the smaller lead-zinc deposits also are fissure veins; the Cincinnati vein in the Tres Hermanas district is one example.

In addition to the temperature-pressure and structural classifications given above, the mineral deposits can be divided further on the basis of age. Most, if not all, of the deposits are of Tertiary age, the period of major igneous activity in Luna County. The deposits fall into two divisions within this period, one closely related to the intrusion of

5. The term manto, as used here, refers to blanketlike replacement bodies of irregular shape formed more or less parallel to the sedimentary bedding, but does not mean the tubular-shaped ore bodies so common in northern Mexico.

the granitic stocks during early Tertiary time and the other of late Tertiary origin, taking place at the very end of the period of igneous activity.

The lead-zinc-copper-silver-gold deposits of the Tres Hermanas and Cooks Peak districts are related genetically to the granitic stocks located in each of these areas. Furthermore, evidence of intense silication of sedimentary rocks in the Victorio district points toward the probable presence of a buried stock nearby, to which all the ore mineralization (including the tungsten-beryllium occurrence) could be attributed. The Florida and Carrizalillo—Cedar districts do not have Tertiary granitic stocks exposed, but the likelihood of their presence at depth in both areas is almost a certainty. It has already been stated that the major period of igneous intrusion was early Tertiary; hence, the accompanying mineralization period must also be credited to that time.

The fluorspar and manganese deposits of Luna County belong to a much later period of mineralization than the lead-zinc-copper-gold-silver deposits. In the Fluorite Ridge district, fluorspar veins are younger than basalt dikes, which in turn are younger than the Gila(?) conglomerate. A similar age relationship is evident in the Little Florida district, where the fluorspar and manganese deposits are younger at least than the Middle Tertiary agglomerate sequence.

The vein at the Stenson copper mine, located in the Florida district, may be of Precambrian age; the mineralogy (mostly copper sulfides) is unique for the district, and the vein is limited to Precambrian rocks. This vein is the only mineral deposit in Luna County for which the age has not been established as Tertiary.

## ORE MINERALS

Past mine production from Luna County has been mainly ores of lead, zinc, manganese, and fluorspar, but some copper, silver, and gold also has been produced. Table 4 summarizes the principal ore minerals

TABLE 4. ORE MINERALS OF LUNA COUNTY

| GOLD | SILVER | COPPER | LEAD |
|---|---|---|---|
| Native | Native | Chalcopyrite | Galena |
| Auriferous pyrite | Argentite | Bornite | Cerussite |
| | Tetrahedrite (freibergite) | Azurite | Anglesite |
| | Argentiferous galena | Malachite | Wulfenite |
| | Silver halides | Chrysocolla | Plumbojarosite |
| **ZINC** | **MANGANESE** | **FLUORINE** | **SPECIMENS** |
| Sphalerite | Psilomelane | Fluorite | Agate Onyx |
| Smithsonite | Pyrolusite | | Spurrite |
| Hydrozincite | Manganite | | Gehlenitc |
| Willemite | Wad | | Dumortierite |
| Calamine | | | |
| | **TUNGSTEN** | **BERYLLIUM** | |
| | Wolframite | Beryl | |
| | Scheelite | Helvite | |

found in these deposits, as well as some of the specimen minerals, which are collected solely for their rarity or ornamental value.

## FUTURE POSSIBILITIES

Testimony that Luna County never has had a truly large mineral discovery is given by the fact that the total production value to date of all minerals from all districts within the county is less than $9 million. Many individual mines in the State have exceeded this value; indeed, many of the porphyry copper mines of the Southwest can produce metal valued at $9 million in 2 or 3 months' time! To carry the point still farther, a mine that produces 100 tons per day (a very small mine by industry standards) of $15 ore will yield a gross return of $450,000 per year on a 6-day work-week basis; note that the average yearly production values given on page 35 range far below the capacity of this hypothetical small mine.

In the face of this past-performance record, it would be foolhardy to suggest that the future for Luna County's mineral industry is one of great promise. There are factors, however, that tend to indicate that there may be a satisfactory chance for significant ore finds if intensive exploration is carried out in the larger districts; namely, the Cooks Peak, Tres Hermanas, and Victorio districts. Such a program must be based on geophysical methods that have the ability to explore at depth; all the promising ore outcrops have been tested.

The ore potentialities are discussed further at the end of the descriptions of the principal districts.

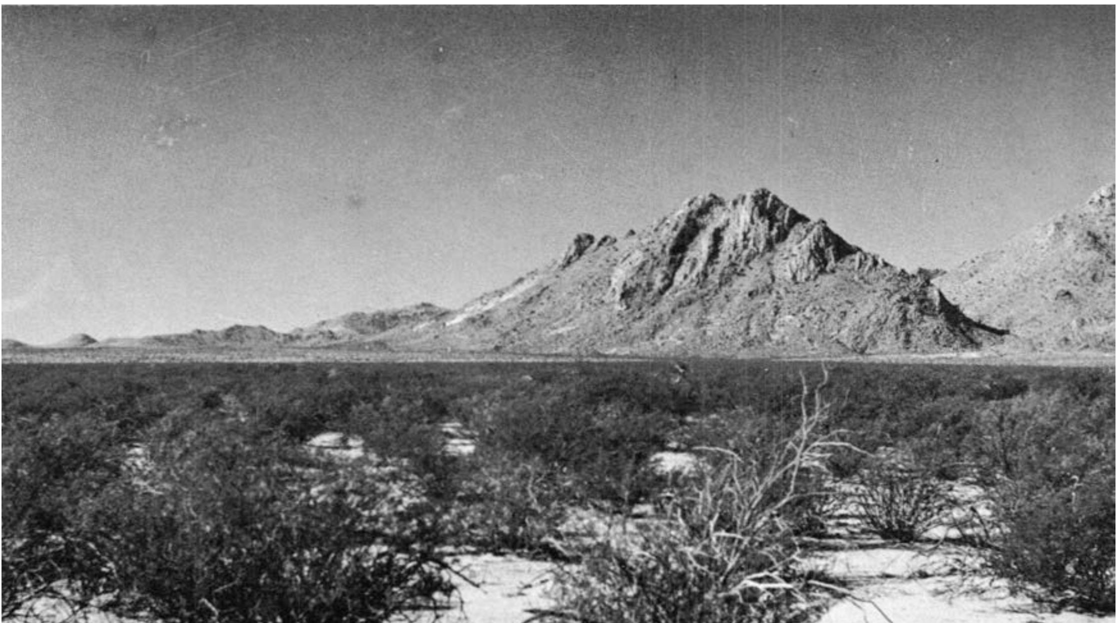
# *Description of Deposits*

## TRES HERMANAS MINING DISTRICT

### GENERAL

The Tres Hermanas district is located in a small group of mountains of the same name a few miles northwest of Columbus (fig. 1). The exact value of the minerals produced from this district is not known. A reasonable estimate is $500,000, and the area is believed to be the third-ranking metal-producing district of the county, excluding manganese. Ranked in accordance with past production, zinc and lead were the most important metals produced, but significant amounts of silver, gold, and copper also have been mined. Deposits of Mexican onyx, fluorescent calcite, spurrite, and dumortierite have been exploited for mineralogic specimens and semiprecious gem stones, but descriptions of these deposits are contained in a later section.

The early history of the Tres Hermanas district is vague. According to Lindgren (1909), several mines were operating in the area in 1905, the Cincinnati, Hancock, and Mahoney (Thurman & Lindauer) mines being the most active. The Mahoney mine (actually a group of several mines)



operated fairly continuously until 1920. Only sporadic production has been effected since that time. During the fall of 1959, a copper prospect was being investigated in the southern part of the district; this constituted the only mining activity in the district at that time.

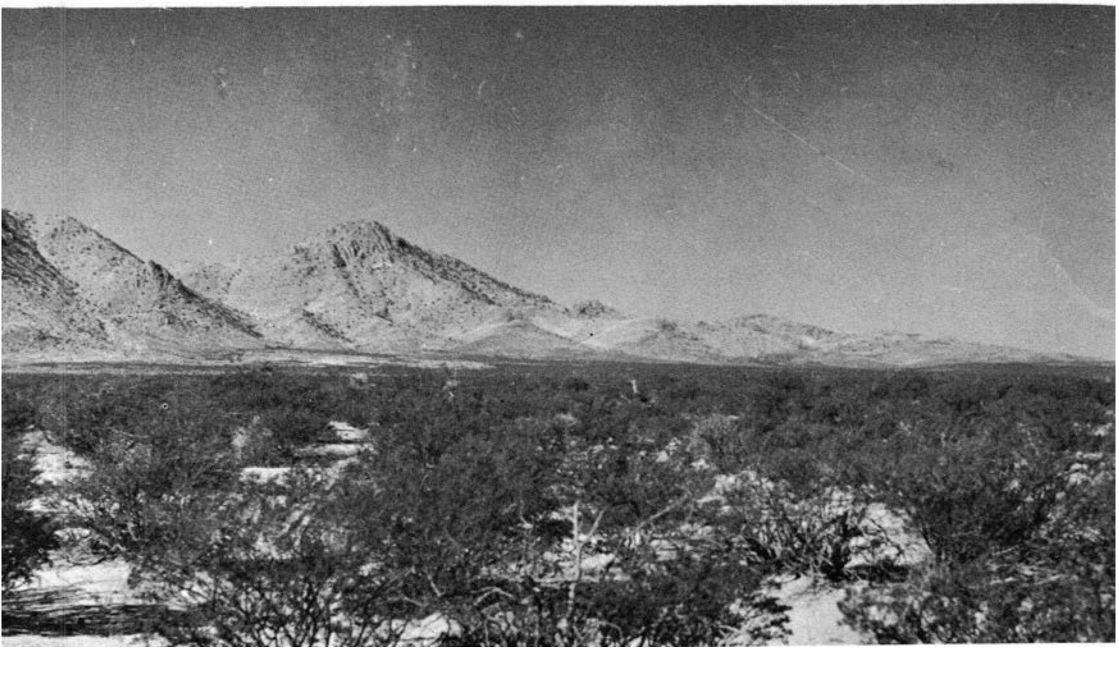
## GEOLOGY

Figure 5 is a generalized geologic map of the area, taken from several unfinished maps of the late Robert Balk. Balk had studied the geology of the Tres Hermanas Mountains in great detail; unfortunately, his untimely death prevented completion of that work. Nevertheless, the notes and field maps of Balk greatly aided the writer during the present investigation.

### Sedimentary Rocks

*Paleozoic rocks.* The bulk of the Tres Hermanas Mountains is composed of a quartz monzonite stock that intruded Paleozoic and Cre-

Figure 4. TRES HERMANAS MOUNTAINS.
Viewed from the east.



taceous sediments, and several types of Tertiary volcanic rocks. The Paleozoic sequence exposed ranges from Silurian to Permian, including the following formations: Silurian, Fusselman dolomite; Mississippian, Lake Valley (Escab`rosa) limestone; Pennsylvanian, undifferentiated limestones; Permian, Hueco formation.

The principal outcrop of Paleozoic rocks is along two adjacent ridges extending northward from North Sister Peak. In this locality the beds dip from 10 to 60 degrees east. A fairly complete section is exposed, starting with the Fusselman dolomite at the base of the west ridge, and continuing through to the Hueco formation on the crest of the east ridge. The only depositional period not represented is that of the Devonian Percha shale; this formation is not exposed because of faulting.

Paleozoic rocks are exposed elsewhere along the northern half of the periphery of the quartz monzonite stock; contact metamorphism, however, has so completely altered the sediments as to prevent accurate age correlations. Marbleization and silicification are the principal types of alteration, but considerable amounts of magnesium and calcium silicates also have been formed in certain areas.

*Cretaceous rocks.* A low northwest-trending ridge in the western part of the district is composed of Lower Cretaceous sediments, the only Mesozoic rocks exposed in the area. The sequence exposed here is similar to that exposed in the Victorio Mountains. Medium-bedded, gray to dark-gray limestones are interbedded with cobble conglomerates, shale, and sandstone. The conglomerates contain well-rounded cobbles of limestone and dolomite believed to have been derived from the erosion of Paleozoic rocks. The matrix cementing the conglomerates is practically all calcite, little quartz being visible in the unaltered beds.

## Tertiary Igneous Rocks

*Early latite.* The earliest evidence of igneous activity in the Tres Hermanas Mountains is a sequence of latite breccias, tuffs, and subordinate flows. The main exposure of these rocks is in the western part of the district (fig. 5 and pl. 1). Here approximately 3 square miles is covered with light-grayish-tan to gray quartz latite, most of which is volcanic breccia and tuff, but a porphyritic to aphanitic variety of light-gray latite is exposed in the immediate vicinity of the Cincinnati mine.

The age relationship between the Lower Cretaceous sediments and the early latite sequence is not clear. A northwest-striking fault appears to form the contact between the two rocks in the western part of the district (pl. 1); nevertheless, the latite is believed to be Tertiary. This is substantiated by the fact that igneous rock fragments are absent in the Cretaceous conglomerate beds. The latite directly overlies Paleozoic rocks northwest of the Marie vein; thus, there must have been consider-

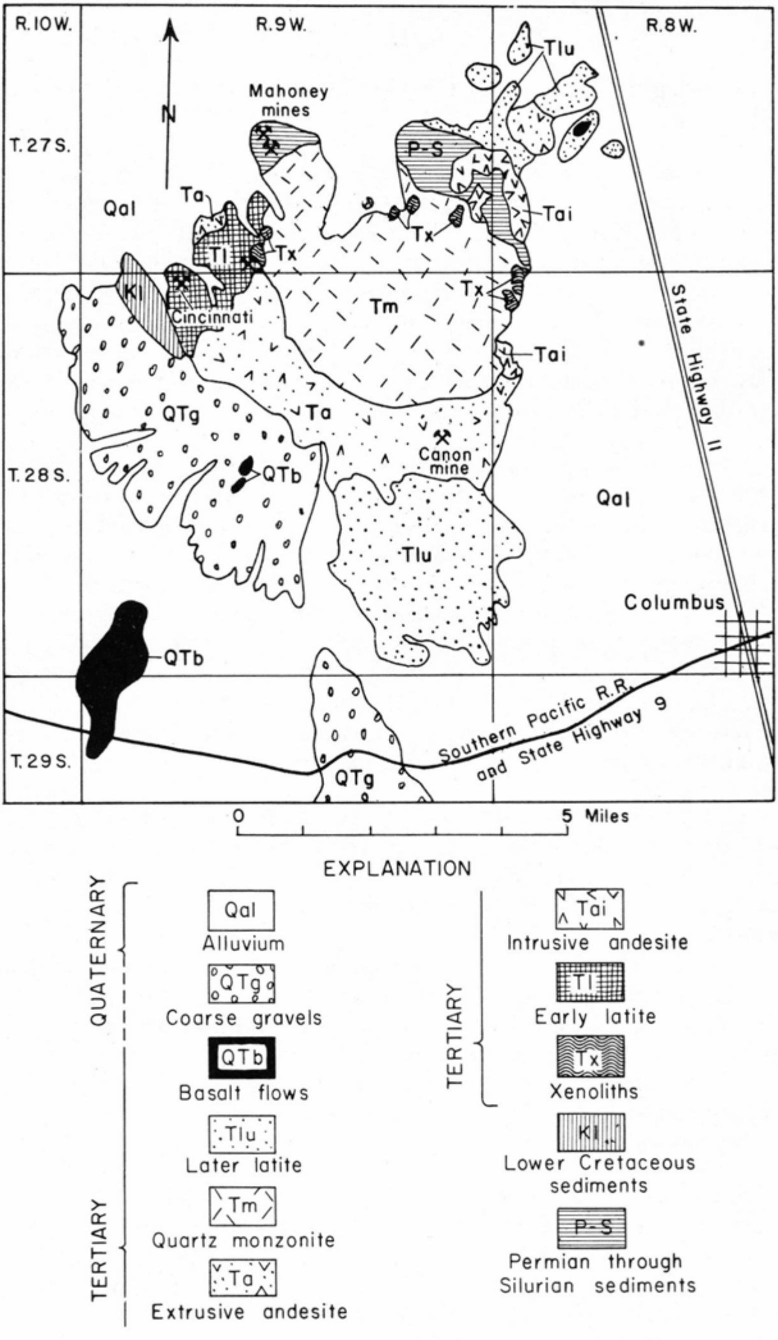



Figure 5. Geologic sketch map of the Tres Hermanas Mountains.
Adapted from maps and field notes of Robert Balk.

able faulting and erosion of the Cretaceous surface prior to eruption of the latite.

*Andesite.* Almost the entire southern edge of the Tres Hermanas Mountains is surrounded by a group of rounded hills composed of andesite flows, breccias, and tuffs. The rock is purplish gray and is layered to massive. Along the northeastern margin of the mountain, an arc-shaped body of intrusive hornblende andesite porphyry has invaded the Paleozoic rocks. This intrusion, though closely related in age, is considered to be later than the extrusive andesite. The general appearance of the contact between the early latite sequence and the extrusive andesite indicates that the latter is the younger; i.e., it overlies the latite.

*Quartz monzonite.* An almost circular stock of quartz monzonite, covering in excess of 10 square miles, forms the central portion of the Tres Hermanas Mountains. Erosion of this stock has formed numerous almost conical peaks, three of which are so similar that the name Tres Hermanas (Spanish for "Three Sisters") was given to the range.

The stock is composed of medium- to fine-grained, equigranular to slightly porphyritic, pinkish-gray to brownish-gray quartz monzonite. The rock has invaded the andesite sequence along the southern edge of the stock, and Paleozoic sediments along the northern boundary. These contacts are definitely intrusive, numerous dikes and small apophyses extending outward from the central mass into the older rocks.

*Later latite.* A series of latite breccias, tuffs, and flows, similar to the early lathe sequence, but definitely younger than the andesite; is exposed at the southern end of the mountains (fig. 5). The sequence is, on the whole, more acidic than the earlier latite, and probably includes some rhyolite.

A small body of the later latite appears to have invaded both the andesite and earlier latite in the southwest corner of sec. 4, T. 28 S., R. 9 W. (pl. 1). The later latite is almost indistinguishable from the earlier latite, except that the former is of lighter color and more compact. Two prongs of latite extend into the andesite along the eastern margin of this small body, indicating that the lathe is definitely later than the andesite.

*Monzonite, latite, and rhyolite dikes.* The emplacement of the quartz monzonite stock was accompanied by the formation of numerous dikes, which extended outward from the stock along fractures formed during the intrusion. The composition of these dikes is identical with that of the main stock; however, they vary from aphanitic to porphyritic in texture, owing to the more rapid cooling conditions that prevailed away from the stock. Several of these monzonite-latite dikes are shown in the south-central portion of Plate 1. This type of dike is probably present throughout much of the early latite sequence, but similarity between the latite and the monzonitic dike rock makes the field identification of these dikes difficult.

The quartz monzonite stock itself is cut by several latite to rhyolite dikes. These dikes are necessarily younger than those aforementioned. They may represent a later magmatic stage of the stock itself, or the dikes may be related to the later latite series.

### Basalt Dikes

Several basalt dikes cut all the known Tertiary rocks. These dikes, probably of late-Tertiary or early-Quaternary age, are related to the scattered basalt flows present around the flanks of the Tres Hermanas Mountains. Additional age correlations, however, will be necessary before these basaltic dikes can be dated accurately.

### Quaternary Rocks

The mountain group is surrounded by a bolson plain. Superimposed on this are numerous recent alluvial fans, which extend outward from the mountains along the principal arroyos. Several small, isolated olivine basalt flows appear to rest on older layers of alluvium, pointing to the probable existence of some Tertiary alluvium underneath the more recent deposits. This assumption is substantiated by the presence of Gila(?) conglomerate in a railroad cut 7 miles west of Columbus.

## DESCRIPTION OF MINES AND PROSPECTS

### General

The Tres Hermanas Mountains are virtually covered with small prospect pits, but the principal producing mines of the past are located in the northwestern part of the range. Lead-zinc limestone replacement deposits occur at the Mahoney and Lindy Ann mines, and vein deposits occur along the Marie—Cincinnati—Hancock—Black Hawk vein system.

In the southeastern part of the district, near South Peak, several small zinc deposits occur in some of the limestone outcrops adjacent to the quartz monzonite stock. A few copper prospects are located in the andesite breccia belt that surrounds the southern end of the mountain group. Minor lead-zinc-copper deposits also have been prospected east of North Peak and in the Lower Cretaceous sediments west of the Black Hawk mine.

### Mahoney Mining Area

*Location and access.* The Mahoney mining area is located in the southern part of sec. 21 and the northern half of sec. 28, T. 27 S., R. 9 W. (pl. 1). The area is reached by traveling 10 miles due south on a dirt road that leaves State Highway 11 approximately 13 miles south of Deming.

*History*. The early history of the area is not known in detail, but the deposits are thought to have been discovered around 1885. The first operators of record were in 1905, when Thurman, Lindauer, and Swope, all of Deming, were operating several mines in the area (Lindgren et al., 1910). Fairly continuous production, mostly of oxidized zinc ore with some lead, was maintained from the time of discovery until 1920; only sporadic production ensued thereafter (table 5).

TABLE 5. LEAD AND ZINC ORE SHIPMENTS FROM THE MAHONEY MINING AREA, 1915-1959
(Data from smelter returns in the possession of John W. Clark.)

| YEAR | WEIGHT (tons) | ZINC ORE Zinc (percent) | 165. | LEAD-SILVER ORE Lead (percent) | | Silver (oz/ton) | |
|---|---|---|---|---|---|---|---|
| 1915 | 169 | 32.6 | 110,188 | —— | | —— | |
| 1916 | 640 | 33.7 | 431,360 | —— | | —— | |
| | 10 | —— | | 42.0 | 8,400 | 5.4 | 54 |
| 1917 | 383 | 36.7 | 281,122 | —— | | —— | |
| | 29 | —— | | 26.8 | 15,544 | 6.7 | 194 |
| 1918 | 107 | 34.9 | 74,687 | —— | | —— | |
| | 30 | —— | | 45.7 | 27,420 | 6.0 | 180 |
| 1919 | —— | —— | | —— | | —— | |
| 1920 | 41 | —— | | 42.2 | 34,604 | 9.3 | 381 |
| 1921-25 | —— | —— | | —— | | —— | |
| 1926 | 19 | —— | | 38.6 | 14,668 | 7.1 | 135 |
| 1927-42 | —— | —— | | —— | | —— | |
| 1943 | 62 | —— | | 22.8 | 28,272 | 6.9 | 428 |
| 1944-47 | —— | —— | | —— | | —— | |
| 1948 | 76 | —— | | 9.2 | 13,984 | 2.8 | 213 |
| 1949-59 | —— | —— | | —— | | —— | |
| | 1,566 | | 897,356 | | 142,892 | | 1,585 |

TABLE 6. PATENTED MINING CLAIM DATA FOR THE MAHONEY MINING AREA
(Data from Bureau of Land Management, U. S. Dept. of the Interior.)

| CLAIM NO. | NAME OF CLAIM | PATENT NO. | DATE OF PATENT | ORIGINAL CLAIMANT | PRESENT OWNER* |
|---|---|---|---|---|---|
| 155 | Contention | 8025 | 8/1883 | J. D. Bail, U. C. Garrison, H. C. McComas, and T. M. Hall | Clarke Realty & Investment Co., J. A. Mahoney, Inc., and Mary Mahoney Carney |
| 2168 | Dona Susan<br>Mildred<br>Minnie Helen<br>Watch Dog<br>New Years Gift<br>Comfort<br>Flat Foot<br>Homestead | 1172896 | 6/24/57 | Clarke Realty & Investment Co., J. A. Mahoney, Inc., and Mary Mahoney Carney | Clarke Realty & Investment Co., J. A. Mahoney, Inc., and Mary Mahoney Carney |

* Present ownership determined from the Luna County tax records.

Plate 2 shows the locations of the claims covering the deposits. The ownership of the patented claims is listed in Table 6.

*Geologic setting.* The deposits are localized in a semi-isolated outcrop of Mississippian and Pennsylvanian limestones, about one-half square mile in area, located at the northwest end of the Tres Hermanas quartz monzonite stock (pl. 1). The stock forms the southern boundary of the limestone outcrop, and alluvium surrounds the east, north, and west sides.

Plate 2 is a geologic and topographic map of the mine area. The sedimentary sequence is here divided, somewhat arbitrarily, into five lithic units (table 7).

TABLE 7. GENERALIZED SECTION OF SEDIMENTARY ROCKS EXPOSED IN THE MAHONEY MINING AREA

| AGE | UNIT | DESCRIPTION | THICKNESS (feet) |
|---|---|---|---|
| ? | "Red limestone" | Grayish-pink, moderately recrystallized limestone. | Unknown |
| Pennsylvanian | "Upper impure limestone" | Intercalated light-brown and dark bluish-gray limestones; thin- to medium-bedded. | 150+ |
| | "Upper marble" | Highly recrystallized pure limestone; white to brownish gray. | 30 |
| | "Lower impure limestone" | Intercalated light-brown, gray, and dark bluish-gray limestones; thin- to medium-bedded. Altered to hornfels and garnet near the quartz monzonite contact. | 70 |
| Mississippian | "Lower marble" | Highly recrystallized pure limestone; white to grayish white. Contains some chert nodules near the quartz monzonite contact. | 110+ |

The sedimentary sequence was examined by Frank E. Kottlowski, New Mexico Bureau of Mines and Mineral Resources, in order to ascertain as accurately as possible the age of the sediments. Owing to the presence of fusulinidae in the two impure units, Kottlowski tentatively designated all units above the "lower marble" unit as Pennsylvanian. The "lower marble" unit is believed to be of Mississippian age (Escabrosa formation), based on its stratigraphic position and lithologic features.[6]

The "lower marble" unit covers the largest portion of the area and contains most of the known ore bodies. The unit is estimated to be at least 110 feet thick; the base not being exposed, the total thickness is not known. The "upper marble" unit is very similar to the lower one

6. The Paradise formation, which in the normal stratigraphic sequence overlies the Escabrosa formation, is not present in the Mahoney mining area. Apparently the former was eroded away prior to Pennsylvanian deposition in this particular portion of the Tres Hermanas Mountains.

except for a slight color variation. These two units are believed to have been very pure, medium- to thick-bedded crinoidal limestones prior to marbleization. The beds have been so highly recrystallized that indications of the original bedding planes are almost absent.

The two "impure limestone" units are identical in appearance; a distinction between the two would not have been necessary except for the presence of the "upper marble" unit, which separates them. The "upper impure" unit is exposed on the Dona Susan claim, whereas the lower unit covers most of the remaining northern slopes of the area, as well as several isolated outcrops in the central part, principally as erosional remnants capping the higher crests. These latter outcrops are generally only a few feet thick. The impure limestone beds that are near the intrusive contact have been transformed by alteration into hornfels and garnet.

The "red limestone" unit, so called because of its pinkish coloration, is exposed in several small patches immediately west of the two northwest-trending faults running through the New Years Gift and Forgotten No. I claims. The two faults are believed to be normal faults with the downthrown sides on the west; hence the "red limestone" unit tentatively is assumed to be the youngest sediment exposed in the area. The outcrops of this unit are too small to provide the basis for an accurate

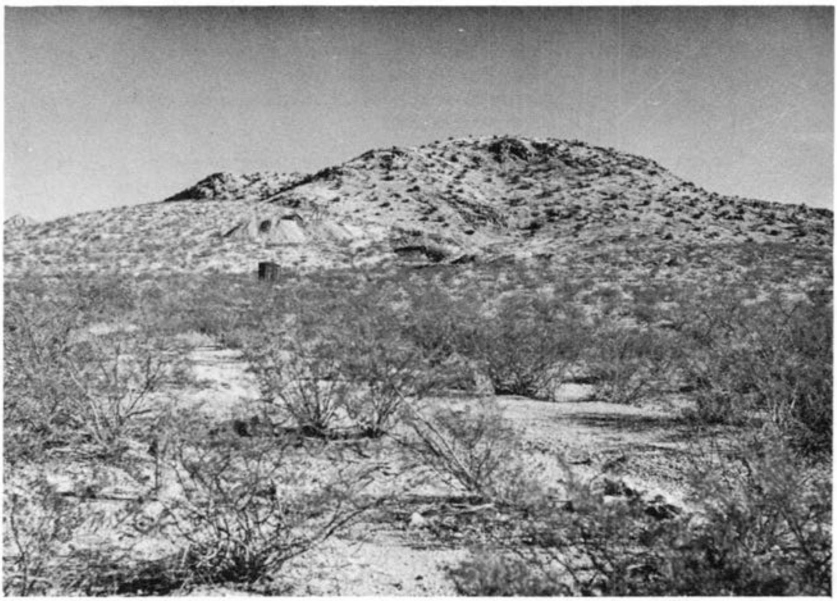


Figure 6. COMFORT SHAFT.

Viewed from the northwest. The rugged hill mass in the background is composed of quartz monzonite; the rounded hills in the middle foreground are Mississippian limestone.

description, but where observed, the rock is moderately recrystallized pinkish-gray limestone. The color and degree of recrystallization set the unit apart from either of the marble units.

The contact of the quartz monzonite with the sediments is irregular, but its general course is northeast. An extremely irregular dikelike apophysis, connected at both ends to the main intrusive body, was injected roughly parallel to the main contact. Thus an isolated block of limestone, some 1,500 feet long in an easterly direction, is surrounded by quartz monzonite.

The quartz monzonite is a brownish-gray, equigranular rock, and its texture varies from a true granitic type to a more fine-grained equivalent, almost a quartz latite, particularly near the limestone contact zone. The alkaline feldspars slightly predominate over the plagioclase, making the classification of the rock as a quartz monzonite somewhat doubtful. Biotite, with minor amounts of hornblende, is the most common dark mineral present in the rock. The stock and the dikelike extension weather into reddish-brown blocks and cobbles, which generally spread out over the softer sedimentary rocks, making accurate location of the limestone-quartz monzonite contact difficult in many areas.

Several outcrops of a white monzonite porphyry, almost devoid of dark minerals, are present in the limestone, in the quartz monzonite, and along the contact between the two. In the limestone areas, the white monzonite porphyry occurs as isolated patches and appears to have replaced the limestone along the bedding planes. A disconnected east-west dike of white monzonite porphyry about 5 feet wide is exposed in the quartz monzonite a few hundred feet south of the limestone contact, and three almost circular masses of the material occur along the main quartz monzonite-limestone contact.

One small outcrop of diabase, scarcely more than 100 square feet in area, was observed in the northwest part of the Good Hope claim. The exposure is too small to enable one to ascertain the form of this body. It is reported that a narrow diabase dike was cut in the north-trending adit on the Comfort claim, but this dike was not detected on the surface.

The intrusion of the quartz monzonite profoundly altered most of the limestone sequence. The more pure limestones (viz., the two marble units) were strongly recrystallized to marble. The rock is now composed of an aggregate of calcite crystals up to 2 cm in length, giving a brilliant, almost blinding, appearance to the rock in sunlight. Marbleization• is evident in these two units in exposures over 2,000 feet from the quartz monzonite contact.

The two impure limestone units were not marbleized to a marked degree. Instead, these became hornfels and garnet beds under intense metamorphic conditions, presumably as a result of the presence of original clay minerals. Farther away from the intrusive contact, the beds are somewhat silicified, but otherwise they do not appear to have been metamorphosed to a high degree.

In the southeastern part of the area where the limestone is enclosed by quartz monzonite, numerous chert nodules are present in the "lower marble" unit. Such chert nodules are common in Mississippian limestones of this region. Later silicification, presumed to have been related to the quartz monzonite intrusion, has formed halos of silica around the original chert nodules; apparently the chert formed the nucleus for the later silica deposition. Commonly the chert is gray, and the later silica halo is white.

Several other zones of intense silicification are present in the lime-, stone sequence: two small patches in the northwest part of the Good Hope claim, an elliptical zone near the center of the east line of the Bulldog No. I claim, and another zone near the center of the Homestead claim. In these localities the limestone is almost entirely replaced by compact, massive, gray to white silica.

In general the sediments dip outward from the intrusive contact, particularly in the northern outcrops. The dip ranges from 10° to 40° N. Several dip reversals, however, were noted; for example, on the Dona Leslie and Comfort claims.

Five faults were mapped in the mining area (pl. 2). Undoubtedly many others exist, but the recognition of faults was difficult because the "lower marble" unit, which is void of horizon markers, covers most of the area. The same statement holds true for the area within the quartz monzonite stock.

As mapped, the faults fall into two groups: an east-west, probably preore set; and a northwest-striking zone, which is postore. There are three faults in the first group (east-west), each having only minor displacements, the throw being less than 50 feet on each. Two of these faults contain ore mineralization and are, therefore, considered to be preore breaks. The third fault, the most southerly of the east-west group, does not contain known ore mineralization; inasmuch, however, as its strike is parallel to that of the others, it too is assumed to be preore.

The second set is composed of two distinct northwest-trending faults in the southern part of the area, but the two faults appear to join near the middle of the New Years Gift claim. These two faults are believed to be members of a northwest-striking fault zone that can be traced to the southeast for more than a mile (pl. 1). Both faults dip steeply to the southwest. The wedge between the faults is a grayish-black limestone, probably the "upper impure" limestone unit. If this is true, the more easterly fault has a throw of more than 200 feet, for the hanging wall lies against the lowest exposed part of the "lower marble" unit. The westernmost fault has a hanging wall of "red limestone" against a footwall of impure limestone; therefore, the total throw across both faults is in excess of 350 feet.

*Ore bodies.* Only a few of the mine workings were accessible at the time of the writer's visit to the area (see the section on mining and milling methods). Because only a few ore exposures were examined, the description of the deposits necessarily will be brief.

The ore bodies of the Mahoney area are of two types: (1) limestone replacements parallel to the bedding, and (2) nearly vertical vein deposits controlled by fractures and (or) faults. The bedding replacements, or "mantos," appear to have been the more productive type.

The ore mineral assemblage found in the Mahoney mining area is summarized in tabular form in Table 8.

TABLE 8. ORE MINERAL ASSEMBLAGE IN THE MAHONEY MINING AREA

| PRIMARY ZONE | | OXIDIZED ZONE | |
|---|---|---|---|
| ORE | GANGUE | ORE | GANGUE |
| Sphalerite | Calcite | Willemite | Calcite |
| Galena | Pyrite | Calamine | Limonite |
| Chalcopyrite(?) | Wollastonite | Smithsonite | Manganese oxides |
| Willemite(?) | Garnet | Hydrozincite | Quartz |
| | Epidote | Cerussite | |
| | Magnetite | Anglesite | |
| | Quartz | Azurite | |
| | | Malachite | |
| | | Cerargyrite(?) | |

As previously mentioned, zinc and lead are the principal economic metals contained in the deposits. There is a minute amount of copper "oxide" staining in the oxidized zone, which is assumed to have been derived from the oxidation of chalcopyrite. Similarly, the amount of silver contained in the deposits is minor (table 5). Silver minerals were too scarce to detect, but the metal may have been contained within the galena, which upon oxidation yielded cerargyrite.

The main economic minerals in the primary stage were sphalerite, galena, and perhaps willemite. The deposits were oxidized so thoroughly near the surface that only occasional sulfide remnants now remain. The galena was transformed to cerussite and anglesite, and sphalerite yielded a variety of minerals, such as smithsonite, hydrozincite, calamine, and willemite.

Lindgren (1909, p. 127) believed that the willemite was derived from the oxidation of sphalerite. It is also possible that the willemite was formed as a primary constituent of the deposits, which then resisted oxidation except for the formation of a minor amount of calamine.

The deepest excavation in the area, the vertical shaft near the center of the Comfort claim, extends only 200 feet below the surface. The zone of oxidation extends at least to this depth (4,320 ft elev.), for no water was encountered in the shaft. The ground-water table is assumed to be at an elevation of approximately 4,090 feet in the vicinity of the mines based on the fact that the water level in the well located on the

Mildred claim is 320 feet below the surface (Thelma Inmon, personal communication). If the present water table represents the surface of transition from oxide to sulfide ore, the Comfort shaft bottom is still 230 feet above the sulfide zone.

As stated previously, the most productive ore bodies were the limestone replacement bodies that conformed to the bedding. Known deposits of this type are limited to the "lower marble" unit, which is believed to be Mississippian (Escabrosa formation). The largest mantos occur on the Comfort and Contention claims. On the Comfort, a near-surface manto of oxidized zinc-lead ore, approximately 150 feet long in an east-west direction and from 10 to 50 feet wide, occurs in sediments that dip about 15 degrees to the south. The thickness of the manto is as much as 10 feet, but the average is about 4 feet.

The ore is thoroughly oxidized for the most part, only occasional sulfide remnants being found. In this particular area, the lead and zinc percentages are about equal. Deeper ore bodies developed from the vertical shaft are said to contain a greater abundance of zinc than lead.

On the Contention claim, another manto of oxidized zinc-lead ore was developed near the surface in the vicinity of the mine shaft. The ore occurs in the "lower marble" unit immediately below the contact with the overlying "lower impure limestone." The manto appears to have been controlled by a small east-trending anticlinal fold. The south limb of the fold dips from 2° to 5° S., but the north limb is steeper, the dips being 10°-20° N. Farther north, away from the ore zone, the dips steepen to as high as 30° N., and the strike changes from east-west to northwest. The ore body is approximately 150 feet long parallel to the fold axis (east-west), 50 feet wide, and 5 feet thick. Stoping has removed most of the ore; small pillars are all that now remain.

Both of the mantos described above are associated with some silication of the "lower marble" unit in the vicinity of the ore. Wollastonite is the most abundant gangue silicate mineral present, but some garnet was also observed. It may be possible that the ore preferentially replaced previously existing silicate zones within the marble zone; this possibility is strongly suggested in certain parts of the manto on the Comfort claim.

Another characteristic feature of the manto ore bodies is the presence of a thin veneer of cellular calcite which occurs between the ore and the marble over certain parts of the mantos. This cellular calcite band ranges from 1 foot to the vanishing point in thickness and is very similar to gypsite in appearance. This odd feature probably was caused by further recrystallization of the marbleized limestone during the ore-deposition period. Later, the acid solutions generated by the oxidation of the ore leached these contact zones to form the cellular structure.

Several smaller mantos have been developed in addition to the two described above. The southern half of the Comfort claim and the central part of the Homestead claim contain several such deposits. The mantotype deposits appear to be limited to the upper part of the "lower marble" unit; those on the Contention and Homestead claims are located just below the base of the "lower impure limestone."

The vein deposits are also limestone replacements to a large degree, but instead of having been controlled by bedding they were controlled by minor faults and fractures. The vein deposits fall into two groups, an east-trending set and a north-trending set.

Numerous prospect pits were sunk on a minor vertical fault striking N. 77° E. on the Minnie Helen and Dona Susan claims. The "upper marble" unit forms the north wall, and the "lower impure limestone" forms the south wall. The character of the ore is similar to that of the manto deposits, but its occurrence is much more irregular. The width of the mineralized zone is as much as 4 feet in places. A similar vein, though much weaker, occurs along a fault striking S. 82° E. on the southwest part of the Lottie claim. The fault dips 60 degrees to the north. Only a minor amount of ore was mined from this vein.

A north-trending vertical vein was explored on the Comfort claim. The vein passes through the main vertical shaft near the center of the claim, just east of the manto deposit. The vein was developed for about 100 feet south from the shaft on the 40-ft level, and a small tonnage of ore was extracted. Unfortunately, the shaft is not accessible below that level, and the character of the vein at depth was not ascertained. The vein, which is contained in the "lower marble" unit, is probably controlled by minor north-trending fractures, for evidence of faulting is lacking.

Several prospect pits have been sunk on the two northwest-trending faults located on the New Years Gift and Forgotten No. 1 claims. An examination of the dumps of these pits failed to reveal substantial ore mineralization. The fault zones are much silicified, but the silicification probably was not related to the ore-deposition period.

Two adits, one trending north in the southern part of the Comfort claim, and the other driven to the south on the Bull Dog No. 4 claim, were not examined, because of the poor condition of the openings. These adits may have been driven on north-trending veins.

*Mining and milling methods.* The deposits have been developed through several shafts and adits and countless prospect pits. The vertical shaft in the center of the Comfort claim is reported to be 198 feet deep, with levels cut at 24, 43, 120, and 198 feet. The lower part of the shaft has been stripped of timber. The three shafts located in the southern part of the Comfort claim are not accessible, because of the poor condition of the timber, but they are believed to be shallow, each less than 50 feet.

There are two principal adits in the area, one on the Comfort claim and the other on the Bull Dog No. 4 claim. The projected outline of the adit on the Comfort claim is shown in Plate 2; the outline was taken from a map belonging to Mr. John W. Clark, the claim owner. The extent of the workings on the Bull Dog No. 4 claim is not known.

A vertical shaft reported to be 96 feet deep is located on the Contention claim; the shaft is now in poor condition. The near-surface manto located immediately south of the shaft was mined by open-pitting the outcrop and by room-and-pillar methods on the downdip extension.

The manto deposits were mined in general by room-and-pillar methods. The "lower marble" unit, in which these deposits occur, is strong and stands well over wide spans. Little caving is evident in stopes that are many decades old. The same general conditions existed in the vein deposits, but the vein material itself, being thoroughly oxidized, may have required timbering in a few areas.

To the writer's knowledge all the ores mined from this area were shipped directly to the smelters without the benefit of concentration other than handsorting. The lack of milling facilities undoubtedly can be attributed to the fact that a profitable method of concentrating oxidized zinc ores, such as those found in these deposits, has never been devised. The soft, "vuggy" nature of the ore would cause the formation of considerable fines and slimes during crushing and grinding, thus preventing the efficient use of gravity concentrating methods. Furthermore, a satisfactory flotation reagent has never been found for floating zinc silicates or carbonates. Leaching the zinc is theoretically possible, but the limestone gangue is so reactive that the acid consumption would be too high to be practical. On the other hand, the oxidized lead minerals could be concentrated by flotation if the ore were first subjected to a sulfidization treatment. Also, if primary ores are ever found below the oxidation zone, the zinc as well as the lead could be concentrated by a flotation process.

## Lindy Ann Claims

*Location and access.* A lead-zinc deposit in Paleozoic sediments is known in the E1/2 sec. 26, T. 27 S., R. 9 W., approximately 2 miles east of the Mahoney mining area (pl. 1). Access to the deposit is from the same road that leads to the Mahoney mining area; a truck trail turns off toward the southeast about 1 mile north of that area and leads to the prospect, which is about 2 miles from the turnoff.

*History.* Little is known of the history of the development of the deposit. The topographic map of Columbus quadrangle, surveyed by the U. S. Geological Survey in 1917, shows a road leading to the deposit and several buildings in the immediate vicinity. This indicates that the deposit was discovered previous to 1917, but more definite information is not known. The most recent work on the property, other than assessment, is believed to have been done by John M. Crump, who worked the deposit during the 1930's. The amount of ore shipped from these claims is believed to have been small.

*Geology of the deposit.* The claims are located on the west slope of a north-trending ridge of Paleozoic sediments extending outward from the quartz monzonite stock (pl. 1). The lower part of the ridge is gray, massive to thick-bedded Fusselman dolomite. The formation strikes almost due north with steep to moderate east dips. On the northwestern part of the ridge a thrust fault has displaced the Permian Hueco formation, so that it rests directly on the Fusselman dolomite of Silurian age, the Devonian rocks having been removed by the fault. The approximate strike of this thrust fault is north-northwest, with a moderate dip to the east. If the fault is interpreted correctly, the overthrust was to the west-southwest.

The southern edge of the ridge terminates against the Tres Hermanas quartz monzonite stock. The contact is very irregular, but the general trend is southeast. Several east-striking monzonite dikes cut the sediments, north of the main contact. One of these dikes appears to have been a controlling factor in the deposition of ore at the Lindy Ann.

The deposit consists of galena, sphalerite, pyrite, and possibly other sulfides occurring in irregular, small replacement bodies. Most of the mine workings, consisting of a shallow shaft and several short adits, are confined to the contacts of a 10- to 20-foot-thick east-striking monzonite dike located a few hundred feet north of the main sediment-quartz monzonite contact. The ore appears to have been controlled by postdike fractures and (or) minor faulting along the dike contacts.

About 500 feet northwest of the above mine workings, another shallow shaft was sunk, and some stoping was done on a vein structure striking N. 45° E. with a nearly vertical dip. The east wall of the vein is strongly recrystallized and partially silicated Fusselman dolomite. The west wall is a greenish-gray highly altered rock (composed mostly of sericite and chlorite) also believed to be Fusselman dolomite. The principal ore mineral is galena accompanied by minor amounts of sphalerite.

A shallow test pit was sunk on the Fusselman-quartz monzonite contact south of the main workings. At this place small amounts of magnetite and hematite occur as bedding replacements of the dolomite.

Numerous other prospect pits are located in the area surrounding the Lindy Ann prospect. Several test pits to the east and south show minor sulfide mineralization. Two prospects, located in a large xenolith of silicified carbonate rock in the quartz monzonite stock, about three-quarters of a mile to the south of the Lindy Ann, expose only a minor amount of galena and some barite. These occurrences are considered to be of minor importance.

## Cincinnati Vein System

*Location and access.* The Cincinnati vein system is composed of a group of several individual veins located approximately 1 1/2 miles south of the Mahoney mining area. Starting at the windmill near the Mahoney mines, the general area can be reached by traveling either of two roads leading to the south (pl. 1).

*History.* Several individual mines are located along the Cincinnati vein system. From east to west, the principal ones are the Marie, Cincinnati, Hancock, and Black Hawk mines. The Cincinnati and Hancock are probably the largest, to judge from the size of the present dumps.

Factual information is lacking concerning the early development of the mines. Lindgren (1909) examined the area briefly in 1905. Up to that time, the Golden Cross & Eagle Co. is said to have produced $100,000 in lead and gold from the Cincinnati mine. Lindgren also reported that the Hancock mine had been developed to a depth of 400 feet by a shaft, and that 1,000 tons of rich lead ore, with some gold, had been produced.

Since 1915 occasional shipments have been recorded from the mines, but the total of these later shipments probably has not been more than 1,000 tons. A reasonable estimate of the total value of the production from all the mines along the vein system since discovery is about $200,000. At the time of the writer's visit to the area (July 1959), most of the claims in the area were owned by, or under lease to, the Western Minerals Co., W. A. White, general manager. This company had reopened the Black Hawk shaft to a depth of 65 feet, and sampled the vein at that level. The company was also contemplating exploring the Cincinnati mine at depth by diamond drilling.

*Geology.* The Cincinnati vein system (pl. 1) extends in a N. 75° E. direction from the ridge of Lower Cretaceous sediments across the early latite breccias and flows, thence through a small outcrop of altered Paleozoic rocks, and finally into the main Tres Hermanas quartz monzonite stock. The total strike length of the system is over 10,000 feet.

The system is not one strong vein that is readily traceable. Instead it is a series of short, disconnected veins that have the same general alinement. The average strike of the veins is N. 75° E., but the dip varies from 75°-80° S. in the western part to 65°-80° N. in the eastern part of the vein system. The veins at the Black Hawk, Cincinnati, and Marie mines are alined, but the Hancock vein is offset some 500 feet to the south. The position of the Hancock vein could be explained by crossfaulting, or simply as a parallel vein to the main system. Direct evidence for either hypothesis is lacking.

Evidence that the vein system lies along a fault of at least moderate displacement is clearly shown near the Cincinnati mine. A latite porphyry dike striking N. 25° W. with nearly vertical dip is abruptly terminated on the north side of the vein. The extension of the dike was not found on the south side of the vein even though bedrock is fairly well exposed for 500 or more feet on either side of the aforementioned dike outcrop.

At the Marie mine, the contact between the quartz monzonite and the Paleozoic sediments appears to have been displaced in such a manner as

Figure 7. Black Hawk vein.

to indicate a left lateral movement of about 300 feet. Also, there is a radical change in dip of the sediments across the vein; on the north side the sediments dip 30° to 48° NE., whereas on the south side the dip is 45° SW. At first glance, one might assume a rotation of 90 degrees on the vein fault. The writer hardly believes this to be the case; instead the sediments were probably highly contorted by the intrusion of the quartz monzonite stock prior to the formation of the fault. Certainly some rotation is possible, but not of the magnitude indicated solely by the attitude of the sediments.

The veins are generally very narrow, 4 feet being about the widest observed width. Generally the vein is composed of numerous closely spaced veinlets instead of one main zone. Galena, sphalerite, and pyrite are the principal sulfides, accompanied by considerable quartz and calcite. Gold and silver are reported to be present in the veins, but the forms in which these metals occur is not known. Minor argillic alteration extends several inches to several feet outward from the vein into the wall rock.

The surface outcrops of the veins are highly oxidized, and only sparse sulfide minerals are found. In the oxidation zone the usual assemblage of oxidized lead and zinc minerals is present, accompanied by considerable limonite and manganese oxide. The depth to the present water table in the vicinity of the mines is not known; water, however, is not known to exist in the Hancock mine, which is said to be 400 feet deep.

The water level in the well southeast of the Marie mine is reported to be 560 feet below the surface.

The veins appear to be best developed in the latite flows and breccia. The veins are fairly well developed in the quartz monzonite, but the system is very weak, if indeed not absent, in the Paleozoic limestones. This may be attributed to the physical nature of the rocks during faulting and fracturing. The latite and quartz monzonite formed strong fractures, which were permeable to the ore-bearing solutions, whereas the fractures in the limestone may have been rehealed, thus causing that rock type to be relatively impermeable. Another and perhaps supplementary reason for the veins' being stronger in the igneous rocks is that they were nonreactive to the ore solutions; therefore, simple but regular fissure veins were formed. The limestone, on the other hand, being very reactive may have tended to form isolated and, as yet, hidden replacement deposits along the fault plane.

The structural features of the Cincinnati vein system enable the age of the vein mineralization relative to the other geologic events to be determined. The following facts are evident: (1) The vein is younger than the quartz-monzonite stock, which in turn is younger than the early latite sequence. (2) The latite porphyry dike near the Cincinnati mine is older than the vein, for it is truncated by the vein structure. This fact could be explained by postore faulting along the vein, but such major movement is not evident. (3) A northeast-striking basic dike, located between the Hancock and Black Hawk mines, appears to cut across the vein system without being displaced. Unfortunately, the outcrops of this dike are somewhat obscured in the vicinity of the vein, and the assumption that the dike is postore must be considered as probable but not conclusive.

From the evidence above, it is deduced that the ore deposition took place after the invasion of the Tres Hermanas quartz monzonite stock, but prior to the invasion of the basic dikes. Furthermore, the deposition probably took place immediately following the intrusion of the latite dikes. Unfortunately, the age relationship between the later latite volcanic sequence and ore deposition is not known; it would be plausible to assume them to be nearly contemporaneous.

The two northwest-striking faults on each side of the ridge composed of Lower Cretaceous sediments are believed to be much later than the faulting that localized the Cincinnati vein system; the vein system fault is not evident anywhere on the ridge, and the two fault scarps bounding the ridge are fairly sharp, indicative of a young age.

It is tempting to correlate the age of all the ore mineralization in the Tres Hermanas district with the same period as that of the Cincinnati vein system. Direct evidence for the assumption is lacking, however, and certainly some of the mineralization of the district (viz., the pyrometasomatic iron deposits) is believed to be contemporaneous with the emplacement of the quartz monzonite stock. The writer believes, however, that practically all the ore mineralization of the district originated from deep-seated differentiation products of the quartz monzonite stock. The ore solutions formed from this stock were then released over several different periods, ranging from the time of the emplacement of the stock to the period when the basic dikes were emplaced.

*Mining and milling methods.* To the writer's knowledge, the ores from the various mines along the Cincinnati vein system were never milled, being only handsorted and then shipped directly to the smelter. The discussion, therefore, will be limited to the method of mining the veins.

The veins have been developed by numerous shafts, pits, and trenches throughout their known strike lengths. The following shaft depths arc reported: Black Hawk mine, 65-foot inclined shaft; Hancock mine, 400-foot inclined shaft; Cincinnati mine, one vertical shaft, 300 feet deep, and another vertical shaft of unknown depth; Marie mine, one shaft at least 50 feet deep at the east end of the vein.

At present, only the Black Hawk shaft is accessible. Rotten timber in the other shafts prevented the writer from examining them; therefore, the shaft depths reported above for three of the mines could not be verified. Near the surface, the veins were mined by simple trenching methods, small windlasses being used to hoist the ore from the trenches. Stoping from the shaft probably was from levels placed at about 50-foot intervals, the operation involving a combination of shrinkage and over-hand-with-stulls stoping methods. Many of the stopes that connected to the surface are still accessible; their walls have stood fairly well, even though some of these openings are 50 or more years old.

## Section 35 Prospect

A lead-zinc prospect is located about 2 miles east of the Marie mine and near the center of the Tres Hermanas stock. The exact location of the mine is the SWIASE1/4 sec. 35, T. 27 S., R. 9 W. Attempts to find the original name of the prospect or of the claims covering the deposit were not successful. The writer, therefore, tentatively has named the deposit the "Section 35" prospect because it is located in that particular section of the township. The location can be reached now only on foot, as the old road leading to the mine has been washed out.

Two shafts of unknown depth and several pits constitute the principal development work done at the prospect. Rotten timber in the shafts prevented an examination of the underground openings; the description here is thus limited to the surface exposures.

One of the shafts is in an arroyo, and the other is about 300 feet to the east on the side of a hill. The shaft in the arroyo is vertical and must be in excess of 50 feet deep, to judge from the falling time of a rock dropped down the shaft. Alluvium covers the outcrops in the immediate vicinity of this shaft, but the dump contains abundant pyrite and arsenopyrite in a highly altered quartz monzonite. The feldspars of the original rock have been completely destroyed by the formation of sericite and kaolin. Sparse blebs and crystals of sphalerite and galena also accompany the pyrites.

The shaft located on the hillside is inclined steeply to the south, and it too is probably in excess of 50 feet deep. The shaft dump contains highly pyritized and altered quartz monzonite similar to that on the dump of the shaft in the arroyo. At the time the prospect was examined, several hundred pounds of excellent lead-zinc ore was piled near the shaft collar. This ore was probably handsorted; therefore, it is not expected to be representative of the average tenor of that in place. Immediately east of the shaft, what appears to be an east-striking vein is exposed. Dump material and alluvium prevented tracing the vein back to the west. It may be that the vein continues to the shaft in the arroyo, some 300 feet to the west, but this cannot be stated conclusively without examining the underground workings.

The quartz monzonite exposed on the hill immediately east of the easternmost shaft is fresh; that is, not hydrothermally altered. On the other hand, the few outcrops of this rock exposed near the west shaft show moderate alteration at least 200 feet north and probably south of that shaft. Therefore, it appears that the deposit is restricted to a triangular zone of alteration, the apex of the triangle being located at the east shaft and the base extending in a north-south direction through the west shaft.

The Eagle-Picher Co. drilled a churn drill hole 465 feet deep in the vicinity of this mine in 1937 as part of the exploration undertaken by that company in the Tres Hermanas district (see p. 66). The exact location of the hole relative to the two shafts is not known. The log of the cuttings from this hole indicated oxidation to a depth of 130 feet, then a heavily pyritized zone from 130 to 290 feet, and finally barren quartz monzonite from 290 feet to the bottom of the hole. The pyritized zone contained small, but far from economic, amounts of galena and sphalerite. The cuttings were also assayed for copper, but only traces of this metal were present.

Several other, though smaller, prospects are located farther to the east, between the Section 35 prospect and Middle Sister Peak. The dumps of the shallow excavations at the prospects generally contain highly pyritized quartz monzonite. The alteration, however, is limited to small vein structures, and the total amount of alteration present in the area is minor. The only ore minerals identified by the writer were galena and sphalerite, but it is reported that the original prospecting was done in the hope of discovering gold.

### Prospects in Cretaceous Sediments West of the Black Hawk Mine

Several prospects are located on the northwest-trending ridge of Lower Cretaceous sediments about one-half mile west of the Black Hawk mine (p1. 1). The area can be reached from this mine by following a truck road that crosses an arroyo northwest of the mine and then continues westward to the base of the ridge.

The ridge is bounded on the northeast and southwest by faults striking N. 40°-50° W. and is completely surrounded by alluvium. The interpretation of the movement along these two faults is difficult. Although the relative movement shown on these faults in Plate 1 appears to be the most logical, it may be in error.

The Lower Cretaceous sediments exposed here consist of alternating beds of massive cobble conglomerates, shale, and gray to dark-gray medium-bedded limestones. The conglomerates are composed of well-rounded cobbles, as much as 8 inches in diameter, of varying types of carbonate rocks, presumably derived from the erosion of earlier Cretaceous and Paleozoic limestone units. In the unaltered beds the interstitial material cementing the cobbles is composed almost entirely of calcite; little quartz is present.

The sediments, particularly the conglomerates, have been strongly silicified in many areas. The silicification appears to have been related to the northwest faulting, as the alteration zones are generally elongated parallel to the fault direction. There is also considerable evidence of recrystallization of the limestone beds.

The general attitude of the sediments strikes northwest with dips ranging from 30 to 60 degrees to the southwest. Numerous dip reversals are present along the ridge, particularly on the southwest side. More detailed examination of the area is required to explain these reversals.

The known ore mineralization within the Cretaceous rocks is limited to deposits of the vein type. Most of the veins strike east to northeast, but one vein, located on the west end of the ridge, strikes north. The veins commonly contain abundant iron and manganese oxides, calcite, and quartz, accompanied by only minor amounts of "oxidized" lead, zinc, and copper minerals. The veins have been prospected to only shallow depths, and the nature of the primary ores is not known.

Probably the best ore was developed from the north-trending vein on the west end of the ridge. The dumps of the shaft at this prospect have a moderate amount of porous, highly oxidized vein material containing some cerussite and smithsonite.

At depth, some of the veins may yield workable deposits, but the exposures now visible give little promise of economic exploitation.

### Prospects East of North Sister Peak

A few prospects are located in an arroyo leading east from North Sister Peak. This peak is defined as the northwesternmost of the group of three peaks for which the Tres Hermanas Mountains are named. The prospects are located near the center of the S1/2 sec. 25, T. 27 S., R. 9 W. The area can be reached by a dirt road branching off to the west from State Highway 11 approximately 51/2 miles north of Columbus. The dirt road leads west to the base of South Sister Peak, and thence northward to the prospects; the total distance from the highway is approximately 4 miles.

The prospects are located in a narrow belt of east-dipping Permian(?) limestones bounded on the southwest by the Tres Hermanas quartz monzonite stock and on the northeast by intrusive andesite porphyry. The limestones were strongly metamorphosed by both of these intrusions of igneous rock.

The first prospect reached in going up the arroyo to the area is on the north side. Here a short adit was driven in a northerly direction along a faulted contact between andesite porphyry on the west and Permian(?) limestones on the east. Little important mineralization was developed by this excavation; the fault zone contains only moderate amounts of iron and manganese oxides, without detectable amounts of any ore minerals. Immediately south, on the other side of the arroyo, steeply east-dipping limestones are exposed. One bed within this sequence has been highly silicated by the formation of garnet, epidote, and probably other silicate minerals. This bed contains scattered grains of magnetite and a few cubes of galena.

The several other prospects are located to the west about a quarter of a mile farther up the arroyo. Three closely spaced shafts, one timbered, but all considered unsafe to enter, are located where two smaller arroyos join to form the main channel. Outcrops are poor, but the shafts appear to be located along a northeast-striking contact between intrusive andesite porphyry to the north and east-dipping limestones to the south. The limestones are strongly marbleized and silicated. The shaft dumps contain only a few ore samples; these were highly oxidized specimens containing some cerussite.

Two other prospects are located nearby, one about 500 feet south and another about the same distance southeast from the shafts. The latter consists of several pits made along an east-striking contact between Permian(?) limestone on the north and intrusive andesite on the south. Considerable magnetite has replaced the limestone near this contact. The other prospect is within the andesite and does not offer visible signs of ore mineralization.

## Canon Mine

*Location and access.* A copper prospect is located in the NE1/4 sec. 14, T. 28 S., R. 9 W. The deposit can be reached by traveling 5 miles west-northwest of Columbus on a road leading to the old Rascon ranch and thence one-half mile to the northwest.

*History.* T4le early history of the deposit is not known. The Western Minerals Co. now leases a group of 19 claims covering the deposit from Mr. Boyce Cook, of Columbus. This company, of which Mr. W. A. White is general manager, was developing the deposit in the hope of installing a copper leaching plant at the time of the writer's visit to the area in July 1959.

*Geology of the deposit.* The deposit is located in the northwest-trending belt of Tertiary extrusive andesite that surrounds the southwestern side of the Tres Hermanas quartz monzonite stock (fig. 5). The volcanic rocks consist of andesite breccias, tuffs, and minor flows. Two sets of latite porphyry dikes, one trending northeast and the other northwest, cut the andesite series. These dikes are believed to be later than, though closely related to, the intrusion of the Tres Hermanas stock. Two parallel dikes, only about 200 feet apart and belonging to the northeast-trending set, are located about one-eighth mile north of the prospect.

The most important showing of copper is in a vein striking N. 20° W. and dipping about 75 degrees to the northeast (fig. 8). This vein has been developed by two bulldozer cuts, one inclined shaft on the vein, and one vertical shaft on the northeast (hanging wall) side of the vein. The inclined shaft is about 70 feet deep along the plane of the vein. The vertical shaft is 65 feet deep and has a crosscut to the vein on that level.

The vein is exposed over a strike length of more than 300 feet, but the structure could not be traced farther to the northwest or southeast because of poor exposures. Where observed, the vein consists of a fractured and brecciated zone from 1 to 10 feet wide containing malachite and azurite as a coating on the fractures. Little calcite or quartz accompanies the copper minerals, nor is there more than a minor amount of limonite present. Assays of vein samples taken by Mr. Jim Patterson, engineer with the Western Minerals Co., are reported to range from 12 to less than 1 percent copper, the average being slightly less than 2 percent.

At the time of the writer's visit to the mine, a crosscut had been driven to the vein from the bottom (65-foot level) of the vertical shaft. The copper-stained zone was about 10 feet wide at this level. A slight seepage of water was coming into the crosscut, but the vein was still thoroughly oxidized.

Another copper vein occurs about one-quarter mile east of the vein described above. A shallow shaft was sunk on this vein, which trends northeast and dips 80 degrees to the east. This vein lies within the same andesite sequence as the Canon mine but is much narrower and weaker.

## Prospects in the Vicinity of South and Middle Sister Peaks

Several prospects are located on the south and east slopes of South and Middle Sister Peaks. These peaks are defined as the southeasternmost and center peaks of the group of three similar peaks that form the Tres Hermanas group. The prospects are limited to highly metamorphosed and contorted Paleozoic sediments near the contact of the Tres Hermanas quartz monzonite stock. Large areas of the sedimentary outcrops have been converted into tactite, and even the less intensely altered

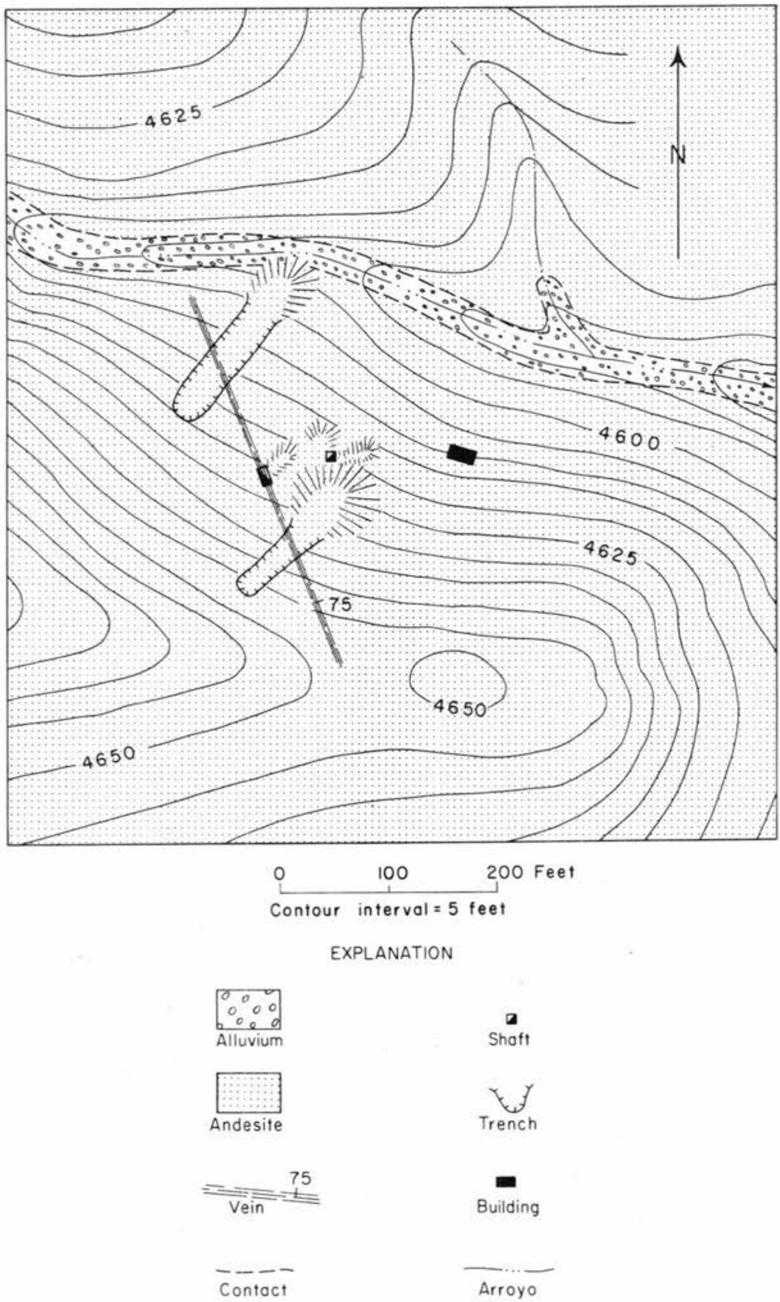



Figure 8. SKETCH MAP OF THE CANON MINE AREA.

exposures are highly marbleized and silicified. It is in this general area that the fairly rare carbonate—silicate mineral spurrite is found; a more detailed description of this occurrence is given on pages 146-147.

The prospects consist of scattered shallow pits, trenches, and bulldozer cuts, but none of these excavations are extensive enough to permit an accurate appraisal of the area. A few occurrences of lead-zinc mineralization were found, but large ore bodies apparently were never discovered. The writer doubts that more than a hundred tons of ore have been shipped from this area.

Galena and sphalerite are the principal ore minerals, accompanied by moderate amounts of pyrite. Copper minerals are rare. Where observed, the sulfide mineralization occurs as a replacement of the silicated sedimentary rocks. Oxidation seems to have been slight in this area, for sulfide minerals are found just a few feet below the surface. •

Scheelite is reported to be present in the tactite zones near South Sister Peak (Dale and McKinney, 1959). Unfortunately, the writer was not successful in his attempts to identify this mineral in the outcrops examined. The presence, however, of strong zones of silication in the carbonate rocks of this area make it a likely place for the occurrence of tungsten.

### Zones of Disseminated Sulfide Mineralization in the Tres Hermanas Stock

Interest is always aroused as to the possible presence of a large disseminated ("porphyry") type of mineralization whenever an intrusive body such as the Tres Hermanas stock is studied. The stock is composed of quartz monzonite similar to the host rock of many of the large disseminated copper deposits of the southwestern part of the United States. Furthermore, the stock is located near the intersection of several strong structural zones (see p. 29-30 for more details). Intrusive bodies located near such intersections are considered to be favorable loci for large ore deposits by Mayo (1958), Billingsley and Locke (1941), and others.

For the most part, the Tres Hermanas stock is not hydrothermally altered. This is particularly true of the numerous peaks and knobs that protrude above the other parts of the stock. The quartz monzonite is hydrothermally altered, at least in isolated patches, in several of the valleys and plains within the stock. Prominent among these areas are the broad valley south of the Marie mine and another valley located in the NE1/4 sec. 34, T. 27 S., R. 9 W. Areas that show the effects of hydrothermal alteration are indicated by stippling in Plate 1. Zones of alteration are also present in the andesite, but they do not appear to be extensive.

Because the alteration zones generally lie in valleys, outcrops are poor, owing to thin soil cover or the presence of talus derived from unaltered quartz monzonite on the higher slopes. One can be certain, therefore, that a given area is underlain by the stock and map it as such, but he cannot be certain as to whether the alteration in that area is spotty or continuous.

Probably the most intensely altered portions of the stock are located south of the Marie mine. Just north of the windmill in that area, a shallow prospect pit exposed strongly sericitized, kaolinized, and pyritized quartz monzonite. On the dump accompanying a vertical shaft about one-half mile southwest of the windmill, there is similarly altered quartz monzonite containing approximately 5 percent of combined pyrite and arsenopyrite. Three closely spaced prospect shafts in the NE1/$_4$ sec. 10,

TABLE 9. RECORD OF CHURN DRILL HOLES DRILLED IN THE TRES HERMANAS MINING DISTRICT
(Data from records of the Eagle-Picher Co.)

| HOLE NUMBER | LOCATION | COLLAR ELEV. (feet) | TOTAL DEPTH (feet) | DESCRIPTION |
|---|---|---|---|---|
| CDH-2 | NWIANWI/4 sec. 3, T. 28 S. R. 9 W. | 4,630* | 478 | Oxidized to 415 ft. Moderate amounts of iron oxides in the oxidized zone. Minor amounts of pyrite from 415 to 478 ft. Average combined assay of lead and zinc from 30 to 285 feet was ± 0.5 percent. |
| CDH-3 | SEV$_I$NWIA sec. 3, T. 28 S. R. 9 W. | 4,650* | 620 | Oxidized to 65 ft. Abundant pyrite (one or more percent) from 65 to 235 feet; thereafter spotty to the bottom of the hole. Water table reached at 560 ft. Minor amounts of lead and zinc (± 0.5 percent combined) from 113 to 215 ft. |
| CDH-4 | SW% sec. 3, T. 28 S. R. 9 W. | 4,660* | 285 | Oxidized to 65 ft. Much pyrite from 65 to 230 ft; only traces of sulfides thereafter. |
| CDH- J44 | SE% sec. 35, T. 27 S. R. 8 W. | 4,900* | 465 | Oxidized to approximately 130 ft. Moderate amounts of pyrite from 175 to 290 ft, and only traces from 290 to the bottom of the hole. This hole averaged ± 0.8 percent combined lead and *zinc*. |

* Approximate.

T. 28 S., R. 9 W., about 11/4 mile southeast of the windmill, are located in a highly altered zone; here the alteration, though less intense, continues to the southeast throughout a circular area more than 1,000 feet in diameter.

The important question is whether these scattered outcrops are part of a single large zone of alteration, or are simply individual zones of small extent. Several things tend to indicate that a large zone may exist under the thin layer of alluvium that covers this valley. First, three additional outcrops, located in the southern portion of sec. 3, T. 28 S., R. 9 W., contain moderately altered quartz monzonite. Second, three churn drill holes were drilled in the area, each of which encountered pyritized zones containing from minute amounts to almost 1 percent of lead and zinc combined. These churn drill holes were drilled in 1937 by the Eagle-Picher Co.. in the hope of discovering a disseminated ore body of copper, lead, and (or) zinc. The locations of these holes are shown in Plate 1. Three were drilled in the W1/2 sec. 3, T. 28 S., R. 9 W.; one additional hole was drilled near the "Section 35" prospect in SE1A sec. 35, T. 27 S., R. 9 W. A highly abbreviated log of the four holes is given in Table 9. As stated previously, minor amounts of galena and sphalerite were detected in the pyritized zones of these holes, but even the combined assay of lead and zinc is extremely low, the average combined assay being about 0.5 percent. Only traces of copper were detected.

The mode of occurrence of the minor amounts of lead and zinc minerals is not known. It may be a true disseminated type composed of tiny veinlets and discrete grains; or instead, the churn drill holes may have intersected veins of similar character to those within the Cincinnati vein system, though much weaker.

The broad valley in the NEVI sec. 34, T. 27 S., R. 9 W., is altered hydrothermally along the margins of stock outcrops. Several prospects in the southern part expose sericitized and pyritized quartz monzonite. The total zone of alteration exposed covers an area of approximately 200 acres. The degree of alteration appears to be rather mild; strong alteration is limited to small zones that may be related to veins of the Cincinnati vein system. Unfortunately, prospect churn drill holes were not drilled in this area, so that little can be said as to the depth to which the alteration may extend.

The alteration zone in the vicinity of the "Section 35" prospect has been described on page 60. This zone is very small, covering only a few acres. The vein at this prospect may yield a workable deposit, but the altered zone is far too small to yield a large low-grade deposit.

In summary of the known alteration zones in the Tres Hermanas stock, the following statements can be made: (1) Although small zones exhibit an intense degree of hydrothermal alteration, the alteration of the larger areas must be classified as mild. Sericitization, kaolinization, and pyritization are the prevalent types of alteration present. (2) Copper minerals are rare in the-known altered zones, and only minor amounts of galena and sphalerite are present. (3) Although the present water table is deep, 560 feet below the collar of Churn Drill Hole No. 2, oxidation has extended to only a shallow depth; therefore, little secondary enrichment may be expected if an ore zone should be discovered. (4) The results of the churn drilling by the Eagle-Picher Co. virtually eliminate the possibility of a shallow disseminated ore zone south of the Marie mine and in the vicinity of the "Section 35" prospect. (5) Other alteration zones may be more favorable, but the surface exposures of the known areas do not indicate the presence of copper or other valuable metals.

(6) The application of geophysical and geochemical prospecting methods may delineate new and more favorable zones for test drilling.

## Recommendations for Future Prospecting in the Tres Hermanas Mining District

The discussion will be limited to the high-grade lode deposits of lead-zinc-copper ores; the potentialities for large disseminated ore bodies have been adequately described above.

*Mahoney mining area.* The deposits in the Mahoney mining area were explored to only shallow depths; the deepest shaft is just 198 feet deep. There is a good possibility that additional mantos of oxidized ore exist in the area, which have escaped detection because of the lack of outcrops. Limestone-replacement ore bodies formed near igneous contacts, such as those of the Mahoney area, are noted for their irregularity in shape, size, and distribution. There is seldom a halo of alteration or low-grade ore surrounding the ore zones; instead, the ore-marble contact is knife edge thin.

Structure is often a major factor in controlling the emplacement of the ore mantos, as illustrated by the localization of the Contention ore body along an anticlinal fold. Another control for the Mahoney ores is stratigraphic; the habit of the larger ore bodies appears to be to form in the "lower marble" unit just below the "lower impure" unit. Future prospecting in the Mahoney mining area should be keyed to these two controls. The ridge extending east from the Contention mine appears to offer promise of ore discovery because the "lower marble" unit lies under a relatively thin veneer of "lower impure limestone."

It is highly possible that mantos exist at other horizons within the "lower marble" unit or, indeed, even in entirely different beds. Prospecting for these deposits would be extremely difficult. Geophysical methods, such as resistivity surveys, may be of some aid, but the targets are extremely small. The known vein deposits have been well prospected, but by far the most ore developed was limited to the mantos. This fact tends to discourage additional work on the veins.

It must be borne in mind that any additional ore discoveries made in the Mahoney area will in all probability be of the same type and grade as those mined in the past. Therefore, the metallurgical problem of how to treat oxidized zinc-lead ore will still be a major consideration.

*Ore possibilities east and west of the Mahoney mining area.* A broad alluvium-filled valley extends from the Mahoney area to the Lindy Ann mine located 1 1/2 miles to the east (pl. 1). The hidden contact between the Paleozoic sediments and the Tres Hermanas quartz monzonite stock is probably as favorable a zone for ore deposition as it is in the Mahoney and Lindy Ann areas. It is likely that a magnetometer survey would delineate the actual contact with a fair degree of precision. Other favorable factors are the presence of a nearby hydrothermal-alteration zone in the stock, and the possibility of finding primary ores that would be amenable to milling.

Prospecting the alluvium-filled valley is a long-chance gamble. The Mahoney mining area was never a prolific ore producer, and the Lindy Ann mine yielded even smaller amounts of ore. The obvious conclusion, therefore, is that any ore bodies found under the alluvium also will be small. Moreover, finding and delineating the ore bodies would require a large amount of essentially "blind" drilling, even if the location of the sedimentary-igneous contact were known.

The area to the west of the Mahoney mine cannot be appraised, because of the north-trending fault zone that forms the approximate boundary between the productive outcrops and the alluvium. The writer was unable to obtain a record of the formations penetrated by the water well drilled just west of the mines. The well appears to be still in the footwall of the fault zone (pl. 1). Until such time as the structure has been deciphered in this area, it will be foolhardy to recommend exploration.

*Cincinnati vein system.* This vein system has a long strike length; the prospect for continuance with depth is favorable. The principal deterent to further exploration is that the near-surface parts of the vein have been stoped except in areas covered by alluvium. Much costly development work would be required in order to exploit the deeper portions of the vein. The tendency of the ore shoots to occur in narrow lenses is still another deterring factor.

Perhaps the best opportunities for further ore development lie in exploring those parts of the vein that are covered by alluvium. To judge from the present exposures, the maximum amount of cover is only about 50 feet. It is unreasonable to assume, however, that a truly large deposit will ever be found along the Cincinnati vein system; the discoveries will sustain only small, efficient, and clean mining operations that use hand-sorting to upgrade the ore.

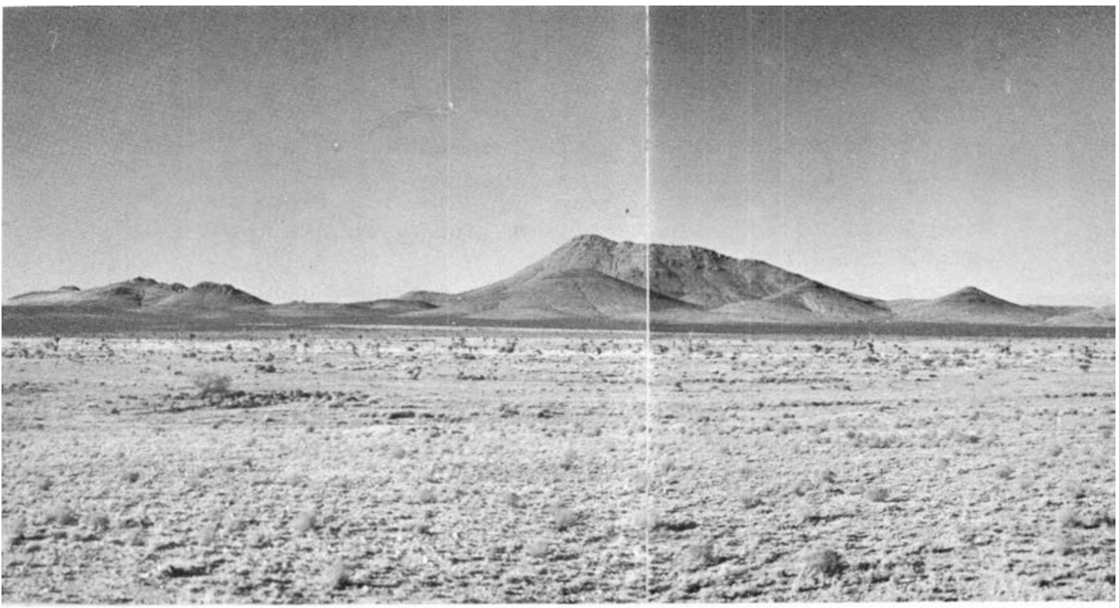
*Other areas.* The amount of exploratory work done on the numerous other ore showings in the Tres Hermanas mining district is insufficient for basing or projecting sound conclusions pertaining to favorable prospecting areas.

## VICTORIO MINING DISTRICT

### GENERAL

The Victorio district is an old lead, zinc, silver, and gold mining camp located in a group of low hills, known as the Victorio Mountains, which lie approximately 2 miles south of the village of Gage. A small deposit of tungsten and beryllium is also known in the area.

The early history of the district is not well known. Lindgren (1910,



p. 290) made the following comments pertaining to the early development of the area:

> The principal period of activity was from 1880 to 1886, when the big bodies of lead ore were being worked by Mr. Hearst, of San Francisco, under conditions which now would be considered very adverse. The Chance and the Jessie, the principal producers, are reported to have yielded $800,000 each in oxidized argentiferous lead ores. F. A. Jones gives $1,150,000 as the total production up to January 1, 1904. In recent years renewed prospecting by Wyman & Corbett and Lesdos has shown that the camp may yet reenter the ranks of producers. Smaller shipments of partly oxidized lead ores have been made at intervals during the last few years. In view of the total production the developments in the camp must be considered slight.

Lindgren's visit to the area was in 1905. Since that time, only an estimated $565,000 worth of ore has been produced from the district; thus, Lindgren's prophecy was partially fulfilled. The last significant ore shipment was made in 1947, when the Carlson & Sandberg Mining Corp. mined and shipped 1,509 tons of lead-zinc-silver-copper ore from the Mine Hill area. Table 10 summarizes the known production of the district.

The tungsten-beryllium deposit, located apart from the rest of the mines, has produced only a small amount of tungsten; exact data on this production are lacking. Although beryl is known to be present in the deposit, attempts have not been made to exploit the mineral economically.

## GEOLOGY

### General

The geology of the Victorio Mountains was investigated by F. E. Kottlowski during the summer of 1959. The geologic map and stratigraphic sections shown in Plate 3 are the results of that study. The

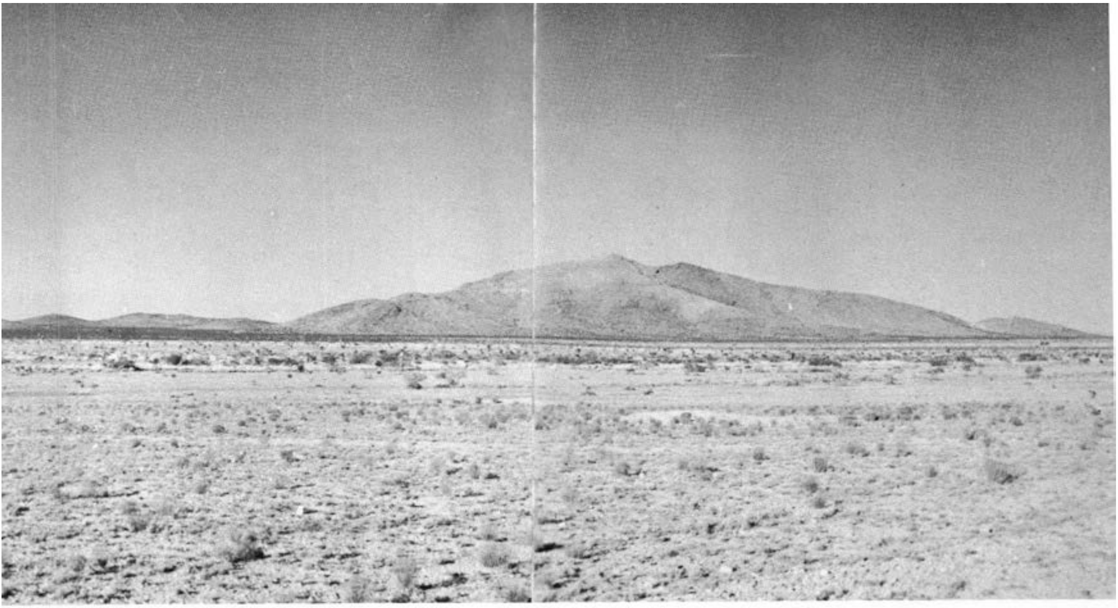


Figure 9. VICTORIO MOUNTAINS.
Viewed from the south. Mine Hill is located at the extreme right.

following description of the geology is based on several discussions with Kottlowski.

The Victorio Mountains are a group of ridges of volcanic and sedimentary rocks trending east-west and rising above the surrounding bolson plain. The elevation of Victorio (Cone) Peak, the highest in the range, is 5,260 feet above sea level, whereas the surrounding plain stands at about 4,500 feet. Therefore, the maximum relief is 760 feet. Drainage is limited to small arroyos, which drain outward from the hills and then quickly dissipate on the bolson plain.

For reasons of convenience the names "Main Ridge," "Middle Hills," "East Hills," and "Mine Hill" have been given to the principal ridges and hill groups that compose the Victorio Mountains (see pl. 3). The Main Ridge is composed of a thick sequence of Tertiary volcanic rocks. The Middle and East Hills are composed of Ordovician, Silurian, and Cretaceous sedimentary rocks, into which several small bodies of granite porphyry and andesite have intruded. Mine Hill, where most of the lead-silver-gold deposits occur, is composed of Fusselman dolomite, with small exposures of Montoya dolomite and El Paso limestone on the east slope of the hill.

## Sedimentary Rocks

The following sedimentary rocks are exposed in the Victorio Mountains, starting with the oldest: El Paso limestone (495 feet), Montoya dolomite (270-340 feet), Fusselman dolomite (900+ feet), and lower Cretaceous limestones and conglomerates (600-800 feet). Of the thickness measurements only the lower Cretaceous and Montoya sections represent

TABLE 10. PRODUCTION OF GOLD, SILVER, COPPER, LEAD, AND ZINC FROM THE VICTORIO MINING DISTRICT

(Sources: 'Prior to 1904: Jones, F. A., *New Mexico Mines and Minerals,* 1904, p. 184; 1904-1929: *Mineral Resources of the United States,* U. S. Geol. Survey, Metals, 1929, p. 752; 1930-1959: *Minerals Yearbook,* U. S. Bur. of Mines, annual volumes.)

| YEAR | ORE (tons) | GOLD (oz) | SILVER (oz) | ( (lb) | LEAD (lb) | ZINC (lb) | VALUE |
|---|---|---|---|---|---|---|---|
| Prior to 1904 | 1¯ | t | t | t | t | f | $1,150:0010 |
| 1904 | 274 | 85 | 2,047 | § | 76,465 | | 70* 6,170 |
| 1906 | 620 | 21 | 2,876 | § | 186,000 | § | 12,971 |
| 1907 | 1,200 | 50 | 3,600 | § | 408,000 | § | 24,992 |
| 1909 | 183•"-- | 15 | 2,460 | 1,069 | 85,418 | § | 5,3813,753 |
| 1910 | 22 | 0 | 267 | § | 21,318 | § | 51,382 |
| 1911 | 180x` | 5 | 883 | 1,598 | 66,250 | § | 75,227 |
| 1912 | 2,123 | 284. | 23,305 | § | 684,867 | 7,865 | 8 |
| 1913 | 3,895---- | 554 | 40,416 | 58 | 902,781 | § | 1,851 |
| 1914 • | 132 | 8 | 552 | § | 35,599 | § | |
| 1915 | 216 | 23 | 1,476 | 2 2,320 | 53,958 | § | |
| 1916 | 1,804 | 177 | 8,436 | § | 381,000 | § | |
| 1917 | 1,505 | 259 | 11,301 | 220 | 428,907 | § | |
| 1918 | 1,631 | 408 | 14,358 | § | 323,493 | § | |
| 1919 | 1,728 | 246 | 10,438 | 538 | 356,775 | § | |
| 1920 | 1,331 | 333 | 10,167 | 1,641 | 298,113 | § | |
| 1921 | 676 | 74 | 4,709 | § | 144,467 | § | |
| 1922 | 158 | 19 | 538 | § | 28,622 | § | |
| 1923 | 468 | 65 | 2,195 | 1,028 | 64,930 | § | |
| 1924 | 285 | 7 | 485 | § | 47,975 | § | |
| 1925 | 609 | 41 | 2,833 | 1,000 | 116,000 | § | |
| 1926 | 129 | 7 | 633 | § | 22,500 | § | |
| 1927 | 28 | 2 | 224 | § | 7,398 | § | |
| 1928 | 40 | 4 | 188 | § | 9,000 | § | |
| 1929 | 278 | 12 | 1,004 | 284 | 27,000 | § | |
| 1930 | 350 | t | t | t | t | t | 4,147 |
| 1931-35 | + | + | + | + | + | 4. | |
| 1936 | 40 | 6 | 259 | § | 4,900 | § | 578 |
| 1937 | 1,009 | 93 | 3,589 | 2,815 | 67,000 | § | 10,339 |
| 1938 | 3,595 | 398 | 13,283 | 6,000 | 210,000 | § | 32,744 |
| 1939 | 3,493 | 453 | 16,802 | 8,700 | 278,000 | § | 41,269 |
| 1940-46 | + | + | + | + | + | | |
| 1947 | 1,509 | 24 | 2,535 | 2,400 | 107,800 | 42,600 | 24,316 |
| 1948 | 119 | 1 | 347 | § | 18,000 | § | 3,571 |
| 1949 | § | § | § | § | § | § | |
| 1950 | 73 | 1 | 275 | § | 6,000 | § | 1,094 |
| 1951-56 | § | § | § | § | § | § | |
| 1957 | 53 | § | 239 | § | 4,800 | 2,000 | 1,134 |
| 1958-59 | § | § | § | § | § | § | |
| | 21756 | 3)05 | ig)')7)1) | 2-lib r( | | | $1,715,453 |

• *Estimated.* a ..12.35 () • I q 2-.' S)173, 33 l.
t Unknown. 0E/fon oaltow 1-20 7,
t Occasional small shipments; value unknown. § None reported.

complete stratigraphic sections. Complete sections of the El Paso and Fusselman beds are not exposed.

The El Paso limestone is best exposed on a steep hill in the East Hills group. At this place the beds strike slightly north of west, and the dips range from 17 to 28 degrees to the south. An east-trending reverse fault has displaced early Cretaceous sediments against the El Paso on the north side of the hill, and erosion has stripped away the upper portions of the group, to the south. A thickness of 495 feet of limestone was measured here. This partial section is believed to represent the lower part of the group, extending from near the base upward to the Oolite zone (Flower, 1958, p. 68).

The exposed section consists of gray to dark-gray, medium-bedded limestone and dolomitized limestone. Several limestone-pellet conglomerate beds occur near the middle of the measured section, and the lowermost beds are somewhat arenaceous. The oolitic limestone beds were found at the top of the measured section. Although the true thickness of the El Paso limestone is not known here, it may exceed the 836-foot thickness measured by Jicha (1954) near Cooks Peak. This assumption is based on the fact that equivalent units in the Victorio Mountains are slightly thicker (495 feet vs. 440 feet) than those near Cooks Peak.

El Paso limestone is exposed also in several small outcrops along the southern slopes of the Middle Hills and in one small area on the northeast slope of Mine Hill. At these places only the upper part of the group is exposed, being overlain by the Montoya dolomite.

The Montoya dolomite, which overlies the El Paso limestone, crops out in narrow belts along the southern slopes of the Middle Hills and the northeast side of Mine Hill. The group is divisible into three formations. Although these formations are not distinguished separately in Plate 3, they are, starting with the lowermost: Upham dolomite (70 feet), Aleman formation (150 feet), and Cutter formation (50 to 120 feet). The Upham is dark-gray, thick-bedded to massive, crinoidal dolomite, of which the lower 20 feet is arenaceous. The Aleman formation is composed of cherty, gray to dark-gray, thin- to medium-bedded dolomite. The Cutter formation consists of calcic dolomite to dolomitic limestone, which is light to medium gray in color. Laminae and lenses of limy shale are interbedded with the dolomite and limestone beds. The upper surface of the Cutter was eroded prior to deposition of the Fusselman dolomite (Silurian); therefore, the thickness of the former is variable, ranging from 50 to 120 feet where measured.

The Montoya is overlain by the Fusselman dolomite at Mine Hill, but Lower Cretaceous sediments directly overlie the Montoya in the Middle Hills area. A profound unconformity, therefore, exists between the Montoya dolomite and the Lower Cretaceous deposits. The Fusselman has been truncated from a thickness of at least 900 feet at Mine Hill to nothing in the Middle Hills, the truncation occurring in less than 1 mile. In addition, sediments of Devonian, Mississippian, Pennsylvanian, and Permian age were entirely removed prior to the deposition of early Cretaceous sediments.

Fusselman dolomite constitutes the bulk of Mine Hill. Here the sediments in general strike northwest and dip to the southwest, but dip reversals are common. Kottlowski measured a thickness of 900 feet at Mine Hill; some of the upper portion of the section has been removed, however, by recent erosion. The Fusselman is divisible into four lithic units, but because of the complex faulting present, these units could not be shown in Plate 3. The four units are:

| | |
|---|---|
| "UPPER BLACK" (90 feet) | Dark-gray, finely crystalline, massive dolomite. Weathers dark gray. |
| "UPPER CRAY" (340 feet) | Gray to dark-gray, finely crystalline, massive dolomite. Weathers to a light brownish-gray (tan) color. |
| "LOWER BLACK" (240 feet) | Dark-gray, finely crystalline to sugary dolomite. Weathers dark gray. Locally contains chert. Corals abundant, chiefly *Halysites*. |
| "LOWER CRAY" (230 feet) | Gray to dark-gray, finely crystalline, medium- to thick-bedded dolomite, which weathers brownish-gray (tan). Local arenaceous laminae; the upper half of the unit is cherty. |

The Middle Hills are capped by Lower Cretaceous sedimentary rocks. These sediments directly overlie the Montoya dolomite in this area. In the East Hills, thin lenses of what are believed to be early Cretaceous volcanic rocks occur at the base of the Lower Cretaceous sediments. As mentioned previously, the Lower Cretaceous sediments were deposited on a very unconformable surface.

The Lower Cretaceous sedimentary deposits are composed of interbedded conglomerates, siltstones, sandstones, and limestones. The sequence ranges from 600 to 800 feet thick, the clastic beds being very lenticular. *Trigonia* cf. *emoryi* and other pelecypods and gastropods of early Cretaceous age have been identified by S. A. Northrop, of the University of New Mexico, and R. H. Flower, New Mexico Bureau of Mines and Mineral Resources, from collections obtained from the upper part of this sequence.

Kottlowski divided the alluvial deposits surrounding the Victorio Mountains into three types: (1) high-level, poorly cemented gravels, which are older (perhaps even late Tertiary in part) than the other two types of alluvium; (2) alluvial fans of boulders, coarse gravel, and sand; and (3) stream, wind, and sheet-wash alluvium composed of sand and silt and subordinate amounts of gravel.

## Igneous Rocks

As previously mentioned, lenses of volcanic conglomerate, sandstone, and greenish tuff occur near the base of the Lower Cretaceous sedimentary rocks in the East Hills. The thicknesses of these volcanic lenses range from the vanishing point to 50 feet. This small exposure is the only known outcrop of Lower Cretaceous volcanic rocks in Luna County.

Overlying the Lower Cretaceous sediments and forming the bulk of the Victorio Mountains is a thick sequence of volcanic rocks. Although definite age criteria are lacking for these volcanic rocks, they are believed to be early Tertiary. The sequence was divided into three units for mapping purposes, as follows:

| | |
|---|---|
| "UPPER" (115 feet) | Gray to purple andesite breccias and flows. A white, banded felsite flow, ranging from 5 to 15 feet thick, occurs at the base. |
| "MIDDLE" (765-1170 feet) | Greenish-gray to purplish red-brown andesite flows, breccias, and welded tuffs. Lenses of volcanic sandstone and siltstones are also present. |
| "LOWER" (595-700 feet) | Purplish, green, and gray andesite agglomerate, welded tuff, lithic and crystal tuffs, and andesitic sandstones. The tuffs contain rounded pebbles and boulders of andesite; Montoya and Fusselman dolomite; Lower Cretaceous sediments; minor schist, granite, and pegmatite. |

Intrusive hornblende andesite porphyry, similar in general composition to the extrusive andesite, occurs in the Lower Cretaceous sediments. A sill and an irregular discordant mass of andesite are located northwest of the Irish Rose tungsten-beryllium mine. The discordant mass contains several xenoliths of Lower Cretaceous sediments along its outer margins; this mass may be a volcanic neck.

Two dikes of light-gray to white alkalic granite porphyry, trending approximately north, are exposed west and northeast respectively of the Irish Rose mine. The one to the northeast leads into a small circular mass of the same rock, and another similar but entirely isolated body is located about 500 feet farther to the northeast. Under the microscope, the rocks appear to contain approximately 30 to 40 percent quartz and 25 percent combined orthoclase and albite in a microcrystalline matrix. Dark minerals are present only sparingly.

As the intrusive andesite is similar in composition to the main volcanic sequence, the two are believed to be closely related in age. On the other hand, the age of the intrusion of the granite porphyry is not accurately known. The event certainly took place after the deposition of the Lower Cretaceous sediments, but direct evidence is lacking for the age relative to the Tertiary andesite. Nevertheless, the granite porphyry has been assumed to be later than the andesite for the following reasons: there is evidence of hydrothermal mineralization in the Tertiary volcanic rocks; it is assumed that the hydrothermal solutions responsible for this mineralization were derived from some granitic body not yet uncovered by erosion; and the granite porphyry dikes are probably appendages from this ore-forming body.

### Structure

There is evidence that considerable folding and (or) faulting took place prior to the deposition of the early Cretaceous sediments. The Fusselman dolomite is 900 feet thick at Mine Hill, whereas this entire formation has been removed in the Middle Hills, less than a mile to the north. Unfortunately, little can be said as to the exact nature of this pre-Cretaceous disturbance because of the lack of suitable exposures.

Known faults fall into three general groups: (1) east-striking normal and reverse faults, (2) normal faults striking N. 30°-70° E., and (3) northwest-trending normal faults. The east-trending normal faults are present along the southern edges of the Middle and Mine Hills. A high-angle reverse fault of the same strike has uplifted the El Paso group against Lower Cretaceous sediments in the East Hills. The northeast group of faults is present in all four of the hill groups, and the northwest-striking faults occur on the east side of Mine Hill and in the Middle Hills.

On Mine Hill, both pre- and postore faulting is known. In the Middle Hills, an east-striking fault cuts one of the granite porphyry dikes, and northeast-striking faults displace the Tertiary andesite sequence east of Victorio Peak. Recent fault scarps are absent in the alluvial deposits. From the above evidence, it is believed that the known faulting in the Victorio Mountains is of Tertiary age, having occurred after the outflow of the andesite, and, in part at least, after the intrusion of the granite porphyry. Some of the faults may represent later movements along older (pre-Cretaceous) breaks.

Small flexures are present in the sedimentary rocks, but they are neither extensive nor persistent. The rocks generally failed by faulting rather than by folding. The Middle Hills and Mine Hill are homoclines with south to southwest dips. The Main Ridge and the Middle Hills are also homoclines, but the dips are to the north. The small band of Paleozoic rocks south of the east-trending fault on the southern edge of the Middle Hills dips to the south.

## MINES AT MINE HILL

### General

By far the largest quantity of ore from the Victorio mining district has been mined from deposits located on Mine Hill. Lead, silver, gold, zinc, and copper, listed in the relative order of importance, have been produced.

Plate 4 is a map of the western half of Mine Hill, showing the locations of the various claims, mines, and prospects, as well as more detailed geology for this particular locality than is given on the district map (pl. 3). Most of the mines are located on the west end of the hill, but a small quantity of ore is said to have been shipped from the shallow workings on the extreme southeast end of the hill.

### Geology of Mine Hill

As previously mentioned, Mine Hill is essentially a homocline dipping to the southwest at angles ranging from nearly horizontal to as much as 30 degrees; the attitude, however, reverses locally. The bulk of the hill is composed of Fusselman dolomite, but a northwest-striking band of Montoya dolomite and a small outcrop of El Paso limestone also are exposed on the east end of the hill (pl. 3).

A normal fault, here called the North fault, which strikes N. 50°-70° E. and dips steeply to the northwest, forms the northwest front of the hill. Underground workings on the Excess and Rambler claims expose, this fault well. Here the fault strikes N. 65° E. and dips 70 to 80 degrees to the north. The footwall is composed of Fusselman dolomite, whereas the hanging wall is Lower Cretaceous sandstones, conglomerates, and limestones (pl. 7). A dike of fine-grained, light-gray rock parallels this fault in the Rambler-Excess mine workings; the dike crops out only faintly on the surface. Under the microscope, the rock is composed of a quartz-rich groundmass containing small grains of highly altered albite and orthoclase. The rock is best described as aplite because of its fine-grained sugary texture. The overall composition is similar to that of the granite porphyry dikes in the Middle Hills.

Another normal fault, here called the South fault, strikes N. 75° E. and is located on the south slope of Mine Hill. The downthrown side on this fault is on the south, opposite to that on the North fault. The two faults, therefore, form a horst of Fusselman dolomite bounded on the north by Lower Cretaceous rocks and on the south by the upper part of the Fusselman.

The North fault shows clear evidence of postore movement in the Excess and Rambler mine workings. The South fault is also probably postore, even though positive evidence is lacking.

Numerous quartz-filled "veins" of N. 40°-80° E. strike and steep north dips are exposed on Mine Hill. The majority of these are believed to be preore faults and fractures that were filled with barren, massive quartz during the first stages of mineralization. There is no evidence of later movement along these breaks; apparently the zones were rehealed effectively by the quartz.

The Crest fault is the most prominent member of this preore group of faults, being traceable along the crest of Mine Hill for approximately 3,000 feet. On the southwest end of the hill, the fault splits into several branches, forming a "horsetail" pattern. This splitting is accompanied by a change in the strike from N. 80° E. on the east to N. 40° E. on the west. The Crest fault was not a zone of major movement. The exposed silicified slickensides indicate only dip-slip movement, and a projection of the offset of the contact between the lower and upper units of the Fusselman dolomite indicates less than 100 feet of total movement. The downthrown side is on the north, in the direction of the dip; the movement, therefore, was normal.

The Jackson fault, so named because it roughly parallels the northwest side of the Jackson claim, is believed to be a major branch off the Crest fault. The movement on this branch is similar to that of the Crest fault; that is, the northwest side is the downthrown block.

Several other preore faults or fractures that were resealed by quartz occur west of the Jessie adits. These breaks are parallel to the North fault.

## Characteristics of the Ore Bodies

The known ore bodies are replacement vein deposits. Two vein systems can be identified: (1) veins striking N. 30°-65° E. and dipping steeply to the northwest, and (2) veins striking almost due north with steep dips to the east.

The most productive veins in the past have been those striking northeast. The Chance, Jessie, Burke (on the Chance claim), Parole, Excess, and Rambler mines were on veins of this system. The north-trending veins were mined profitably only on the Excess and Rover claims, where several intersections of the north and northeast vein systems occur.

Veins of both systems cut across the Crest fault without noticeable displacement, indicating that the latter is preore. At first glance, one is tempted to say that the northeast vein system is parallel to the Crest fault; a close inspection of Plate 4 shows, however, that most of the veins of this system trend slightly more north of east than the fault zone. Apparently, the first stages of mineralization contributed only quartz, which resealed the early fissures and faults (e. g., the Crest and Jackson faults). This event was followed by renewed faulting and fracturing, into which the ore solution penetrated. These breaks did not follow the Crest or Jackson faults.

The breaks that formed the channelways for the two vein systems are probably complementary, having been formed at the same time and by the same tectonic forces. There is little evidence of postore movement on any of the veins except the small ore zones associated with the North fault.

The veins are thoroughly oxidized to the depths to which they presently have been developed. The principal ore minerals are cerussite and anglesite. Silver and gold are present in economically significant amounts, probably as silver halides and native gold. Gangue minerals are mainly quartz and calcite accompanied by various iron and manganese oxides. Smithsonite and oxidized copper minerals are found also, but the amounts are too small to contribute to the value of the ore. As no primary ore samples were found, little can be said as to the paragenesis of the various ore or gangue minerals.

The veins are not simple fissure veins; instead they are replacement veins. The width of the ore varies greatly along veins, pinching down into tight fractures in certain places and swelling to widths as great as 20 feet in others. Some of the veins that present "blind" outcrops on the surface have been very productive at depth. In certain areas of the Chance-Jessie vein, the ore has replaced the enclosing Fusselman dolomite parallel to the bedding for short distances outward from the main vein.

Although the writer had access to several old reports on the area, there is no accurate information available on the grade of the ore produced from the mines prior to 1904. The average of 19,515 tons of ore mined from the district in the years 1904 to 1929 is as follows: gold, 0.14 oz per ton; silver, 7.5 oz per ton; lead, 12.25 percent or 245 lb per ton.

The average gross dollar value of this ore when mined was $22.70 per ton. The value of such ore today (average 1959 prices)_ would be calculated as follows:

A • Fe;iis
foo-A

| | | | |
|---|---|---|---|
| Gold: | 0.14 oz/ton X $35.00 /oz =$ 4.90 | 14417 | 1..30 |
| Silver: | 7.5 oz/ton X $ 0.912/oz = 6.84 | I- JO | |
| Lead: | 245 lb/ton X $ 0.122/lb = 29.89 | Ot 045 | 11.03 |
| | Total gross value per ton =$41.63 | | 71,17 |

The above are gross values and do not include smelter deductions and freight charges. Also, the ore was undoubtedly handsorted prior to shipment. The ores carried small amounts of copper and zinc, but the percentages present were generally too small to be paid for by the smelter.

Several intensely silicified outcrops of dolomite occur on Mine Hill. These irregularly shaped zones probably were formed during the same stage of mineralization as that which deposited massive quartz in the preore fault zones. As a rule, the silicified zones are barren, but small amounts of galena and chalcocite and rare tetrahedrite occur in the dumbbell-shaped zone west of the Jessie adit. The presence of a primary type of ore here is probably due to the fact that the silicified zones were not permeable to the oxidizing environment that has so thoroughly oxidized the veins.

## Descriptions of the Individual Mines

*Chance and Jessie mines.* Probably the most productive zone in the district was a group of closely spaced veins that strike N. 50° E., dip steeply to the northwest, and pass through the center of the Chance claim and thence across the southern part of the Jessie claim. The vein group has been developed for over 1,000 feet along the strike.

Plate 5, taken from a map contained in an old report on the mines, is a sketch showing the mine workings in longitudinal section. The mines are only partially accessible at present. The lower and upper Jessie adits are open, but one cannot cross the stoped area into the Chance workings, at least without the aid of ladders. Similarly, ladders are needed to enter the southwestern part of the mine through the Boca de Mina on the Chance claim. The Chance shaft, reported to be 300 feet deep, is not timbered; therefore, access into the mine through that opening is not feasible.

It is unfortunate that the writer could not examine all these workings, because many additional facts concerning the characteristics of the ore bodies probably would have been learned thereby, particularly as to the effect the intersection between the Crest fault and the vein may have had on the ore.

Plan maps of the accessible portions of the upper and lower Jessie adits are shown in Plate 6. The two levels are 110 feet apart and are connected by two shafts. Shaft No. 1 extends from a stope at the surface to the lower adit. Shaft No. 2 (actually a winze) is reported to be 230 feet deep, extending down from the upper adit level through the lower level, and then continuing downward for another 120 feet. The absence of ladders prevents examination of openings leading from these shafts other than the main levels.

The Chance-Jessie vein group (pl. 4) consists of several short disconnected outcrops on the surface. Ore was present on the surface only in

TABLE 11. PATENTED MINING CLAIM DATA FOR THE VICTORIO MINING DISTRICT
(Data from Bureau of Land Management, U. S. Dept. of the Interior.)

| CLAIM NO. | NAME OF CLAIM | PATENT NO. | DATE OF PATENT | ORIGINAL CLAIMANT | PRESENT OWNER * |
|---|---|---|---|---|---|
| 773 | Virginia Lode | 18455 | 8/10/1891 | J. B. Haggin | Victor Smelting & Mining Co. |
| 774 | Rover Lode | 18457 | 8/10/1891 | J. B. Haggin | Victor Smelting & Mining Co. |
| 775 | Chance Lode | 18453 | 8/10/1891 | J. B. Haggin | Victor Smelting & Mining Co. |
| 776 | Jackson Lode | 18454 | 8/10/1891 | J. B. Haggin | Victor Smelting & Mining Co. |
| 777 | Star Lode | 18456 | 8/10/1891 | J. B. Haggin | Victor Smelting & Mining Co. |
| 779 | Parole Lode | 18452 | 8/10/1891 | J. B. Haggin | Victor Smelting & Mining Co. |
| 865 | Excess Lode | 24249 | 4/18/1894 | St. Louis & Plata Rey Gold & Silver Mining Co. | Russell W. McCandless |
| 928 | Tip Top Lode | 24502 | 6/18/1894 | Michael Burk | Jessie T. Kyle |
| 986 | Victorio Lode: Victorio & Southern Pacific Lodes | 30123 | 11/16/1898 | J. B. Haggin | Victor Smelting & Mining Co. |
| 1008 | Esperanza Lode | 30316 | 12/17/1898 | Michael Burk | Jessie T. Kyle |
| 1975 | Armistice Lode | 1033124 | 12/17/1929 | Victor Smelting & Mining Co. | Victor Smelting & Mining Co. |
| 1976 | Helen Group: Helen and Josephine Lodes | ? | ? | Martha Duryea, Helen Royce Morton, and Dorothy Pirnie | Estate of Jessie T. Duryea |
| 1977 | Jessie Group: Jessie, Laura, and May Lodes | 1034874 | 2/15/1930 | Martha Duryea, Helen Royce Morton, and Dorothy Pirnie | Estate of Jessie T. Duryea |

* As determined from the Luna County tax records.

the vicinity of the upper Jessie adit. Here the vein group consists of the main vein plus at least two, and possibly more, small parallel veins located to the southeast. Stoping indicates that the ore shoot exposed on the surface was continuous to a depth slightly below the lower Jessie adit level (pl. 5).

Stopes on the small parallel veins extend only short distances above and below the upper Jessie adit level. Also, on this level, it is clearly shown how the individual veins suddenly pinch out along their strikes. The crosscuts southeast of the vein fail to indicate the presence of veins that were stoped less than 50 feet away. These same crosscuts expose the Crest fault, which consists of a quartz-filled breccia zone ranging from 0.5 to 1.0 foot thick. Although this break is persistent along its strike, it does not carry ore mineralization; the early quartz stage completely sealed the break prior to the introduction of the ore-bearing solutions.

On the lower Jessie adit level, only the main vein was stoped, but a parallel vein and a vein striking N. 5° W. were explored for short distances. The stoping width on the main vein averages about 5 feet where observed. The stope pillars show highly oxidized vein material composed of quartz, calcite, various iron oxides, cerussite, anglesite, and smithsonite. In places the ore appears brecciated; the writer believes that these are solution breccias formed during the oxidation period and were not caused by postore movement along the vein.

It is interesting to note that the main ore shoot occurs near the intersection of the main vein with a vein trending N. 5° W. Unfortunately, it is not known whether this intersection effected the ore deposition or whether the ore occurred here because of some other control.

The crosscut to the southeast from the lower adit does not expose any parallel veins. Indeed, the main vein itself is represented here only by a tight fracture containing a small amount of iron oxide. The crosscut does not extend far enough south to intersect the Crest fault.

A small ore shoot that rakes to the southwest at about 30 degrees was mined between the first and second levels off the Chance shaft. This shaft is reported to be 300 feet deep, with levels at 100-foot intervals. Considerable drifting from the shaft was done, and several ore shoots were developed. Some stoping was done near the shaft collar on a vein that strikes N. 50° E. and dips steeply to the southeast. The extent of this stoping is not known; hence, it is not shown on Plate 5.

The workings of the Chance and Jessie mines are entirely within the "upper gray" unit of the Fusselman dolomite. This unit appears to have been a favorable zone for the formation of replacement veins, for most of the other productive veins of the district also are limited to this unit.

*Burke mine.* The Burke[7] mine developed a vein that strikes N. 50° to 60° E. and dips steeply to the northwest. The mine is entered through

7. Lindgren et al. (1910) refer to a Mr. Burke who worked this mine originally. Survey records of the U. S. Bureau of Land Management list a Michael *Burk* as the original claimant of two patented claims in the area. The two are believed to be the same person.

the Burke adit, located on the south slope of Mine Hill about 130 feet south of the Chance shaft. The vein is parallel to the Chance-Jessie vein, being located only a short distance within the footwall of the latter. Development has been limited to the south side of the Crest fault. There is no direct correlation between the Burke vein and the footwall veins exposed in the upper Jessie adit. Lindgren et al. (1910) credited a $100,000 production value to the mine.

The adit extends in a northeast direction for approximately 300 feet, following the vein. Considerable stoping has been done along the vein, and many of the adit's sill pillars have been stoped, leaving the adit unusable in some places. The stoping width was very narrow, ranging from I to 4 feet. The vein width, as determined from the stope pillars, averages only slightly more than a foot.

The Burke vein is reported to have been exceptionally high in gold, certain parts of the vein carrying several ounces of gold per ton. Assays of a few random samples taken by the writer did not verify these reports. The vein material is very similar to that of the other veins in the district, being a thoroughly oxidized lead ore containing cerussite, anglesite, iron and manganese oxides, quartz, and calcite. Small amounts of smithsonite are present but not in quantities that would justify its recovery.

*Mines and prospects located on the Rambler, Excess, Helen, and Rover claims.* Several shafts and shallow surface stopes explore veins on the west end of Mine Hill in the vicinity of the common boundaries of the Rambler, Excess, Helen, and Rover claims. Most of the ore mined from this area probably was derived from the shallow stopes located near the southwest corner of the Rover claim despite the fact that the most extensive underground workings are located on the Rambler and Excess claims. It will be pointed out later under the section dealing with the future possibilities that probably the most favorable zone in which to expect additional ore is under the Rover and Helen claims.

Veins on the Rover claim include northeast- and north-trending sets. The vein pattern forms a rude parallelogram, the corners of which are vein intersections. The average attitudes of the two vein systems are: (1) northeast system, N. 55° E., dipping 80° NW., and (2) north system, N. 5° W., dipping 70° E. Therefore, the vein intersections theoretically rake at an angle of 61 degrees in the N. 36° E. direction. Field observations verify this trend.

The location of existing stopes indicates that the vein intersections were a definite ore control. The veins and intersections were mined from the surface by underhand stoping methods. For the most part, the workings are inaccessible, but it is doubted that much mining was done to depths greater than 50 feet. At the vein intersections, widths of 5 feet are common, but away from these intersections, the veins narrow to widths averaging about 2 feet.

The mineralogy of the ore is typical of the district, containing cerussite, anglesite, smithsonite, iron and manganese oxides, quartz, and calcite. Water stands at a level 300 feet below the surface in the well on the Rambler claim. It is plausible to assume that sulfide ores would be encountered at a similar depth on the Rover claim.

Development on the Helen claim is limited to an inclined shaft sunk in the north-central part of the claim, plus numerous prospect pits. The intersecting vein systems described on the Rover claim extend into the northern part of this claim. The depth of the inclined shaft or the amount of lateral development is not known, because of the poor condition of the shaft timbers. The shaft was sunk on the projection of a "horsetail" split of the Crest fault. In the vicinity of the shaft, the fault split strikes N. 30° E. and dips 80° E.

The Excess and Rambler shafts are located on their respective claims. The Rambler shaft is known also as the Bradley shaft. Both shafts were sunk near the North fault zone. Plate 7 is a plan map of the 100-foot level of the Excess shaft; the level also connects with the Rambler shaft. The Excess shaft is 100 feet deep, being inclined so that it follows the contact between the Fusselman dolomite and the aplite dike. The shaft is equipped with ladders permitting entrance to the mine workings shown on the level map. The Rambler shaft is reported to be 300 feet deep. The shaft has caved at the collar, but it can be reached on the 100-foot level by the workings extending from the Excess shaft. The Rambler shaft is either bridged or filled to depth 25 feet below the 100-foot level. Another possibility is that the reported depth of 300 feet is erroneous, the actual depth being only 125 feet.

Horizontal development on the 100-foot level consists of two drifts and one crosscut, totaling 950 feet of workings. For the convenience of this description the names North drift, South drift, and Shaft crosscut will be used to distinguish these workings. The South drift is 660 feet long and was driven along the North fault zone, except in the vicinity of the Excess shaft, where it explores the aplite dike. The dike forms the footwall of the fault. The dike is 12 feet wide where exposed, and the North fault zone is approximately 25 feet wide. Both strike N. 65° E. and dip 65°-80° NW.

The dike footwall is the "upper gray" unit of the Fusselman dolomite, and the hanging wall of the North fault is composed of Lower Cretaceous sedimentary rocks (see pl. 7, sec. A-B). The Lower Cretaceous rocks are well exposed in the Shaft crosscut from the South drift through the Rambler shaft to the North drift. Here about 50 feet of coarse-grained arkosic sandstone overlain by at least 40 feet of red conglomerate containing sandstone and thin-bedded limestone lenses are exposed. A short crosscut from the North drift exposes medium-bedded gay limestone also believed to be of Lower Cretaceous age. Dips in the Lower Cretaceous rocks range from 40° to 65° NW., but these steep dips are due, in part at least, to drag against the North fault. The

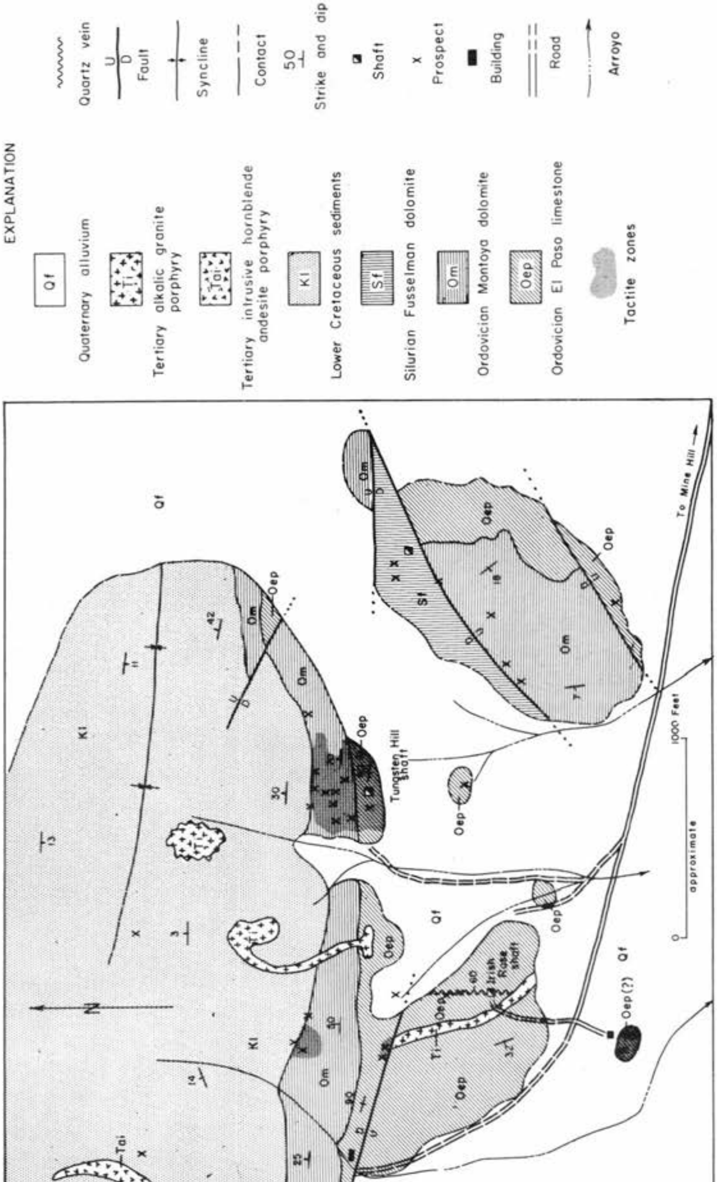



Figure 10. Sketch map of the tungsten-beryllium deposit, Victorio mining district.

attitude of the Fusselman dolomite could not be ascertained underground, but on the surface the outcrops strike N. 60° W. and dip 15° SW.

Information is not available as to the thickness of the Lower Cretaceous rocks in the vicinity of Mine Hill or even as to what formation they overlie. Hence, no estimate is possible of the total displacement of the movement along the North fault in spite of excellent exposures on the 100-foot level in the vicinity of the Rambler shaft. The minimum displacement would be about 200 feet if it is assumed that the Lower Cretaceous sediments overlie 900 feet of Fusslman dolomite, and if the Lower Cretaceous units exposed are near the base of that sequence.

Although considerable underground development was done from the Rambler and Excess shafts, the workings do not indicate much actual stoping of ore. Some stoping was done below the 100-foot level in the North fault zone south of the Rambler shaft. The ore mined here apparently occurred as a lens of oxidized low-grade lead ore, much brecciated, contained within the fault zone. The stope is not accessible, because of the poor ground conditions associated with the fault; little can be said, therefore, as to the dimensions of the ore shoot or its grade. A few tons of breccia ore also was mined from the same fault zone about 150 feet farther northwest. In the North drift, several minor ore lenses were developed in the small fault zone exposed along that drift.

The best ore occurrences on the 100-foot level are in the vicinity of the Excess shaft. Here several north-striking veins with steep east dips occur in the Fusselman dolomite. The veins are extensions of those exposed on the surface of the Rover claim; they terminate abruptly against the aplite dike, which shows a slight amount of postdike movement on its footwall side. These veins were explored only short distances south of the dike. A small amount of ore was stoped immediately south of the Excess shaft on a sublevel located 25 feet above the 100-foot level. The small stope extends 50 feet south of the shaft. The ore occurred at the intersection of small veins of the north and northeast systems.

The aplite dike contains a small amount of disseminated pyrite and chalcopyrite. This would tend to indicate that the dike is preore; on the other hand, the veins in the Fusselman dolomite abruptly terminate against the dike. The slight postdike movement may account for this termination, but lead veins or stringers were not found anywhere in the dike. If the dike is preore, its footwall may be a favorable prospecting area.

The reason why the mine operators of the Excess and Rambler mines failed to prospect more extensively southeast of the aplite dike is somewhat of a mystery. Certainly, the surface showing on the Rover claim is promising for the presence of ore at depth. A possible reason is that the Rover claim, which lies immediately southeast of the North fault, was owned by a separate company or group of individuals. If the Rambler shaft is 300 feet deep, its bottom is an ideal place from which to drive under the Rover claim veins.

*Parole mine.* The Parole mine is located at the base of the northern slope of Mine Hill (pl. 4). The workings are totally inaccessible; therefore, the description given here is based on surface observations alone. The main workings consist of the Parole shaft, which is at least 100 feet deep, and several shallow shafts and pits. The Parole shaft was sunk on a vein located about 300 feet south of, and parallel to, the North fault. The vein strikes N. 50°-55° E. with nearly vertical dip. The vein has been stoped through to the surface northeast of the shaft; it averages about 3 feet wide where it was stoped. A parallel vein that dips 70° NW. is located 100 feet to the southeast, but development has been limited to small prospect pits.

Several quartz veins with the same strike as the Parole veins are located to the southwest on the May and Rover claims. These veins have been shown as preore faults on Plate 4 because quartz was the only vein mineral noted.

*Other mines and prospects.* The mines described above produced the bulk of the ore mined from the district. Numerous smaller mines and prospects cover the hill. Little would be gained by giving separate accounts of each of these workings, inasmuch as the ore controls, vein mineralogy, and structure are similar to those already described.

## Mining and Milling Methods

The mines were developed by shafts with the single exception of the Jessie mine, which had two haulage adits. The following shaft depths are reported: Chance shaft, 300-foot vertical shaft; Rambler (Bradley) shaft, 300-foot vertical shaft; Excess shaft, 110-foot inclined shaft; Parole shaft, vertical shaft, at least 100-feet deep; Helen shaft, inclined shaft, depth unknown; Jessie No. 1 shaft, 110-foot vertical shaft connecting the two adit levels; Jessie No. 2 shaft, 230-foot winze sunk from the Upper Jessie adit level.

As mentioned previously, the Rambler shaft depth could not be verified.

The basic method of stoping appears to have been shrinkage, but some underhand mining also was done. The stoping width ranged from 1 to 20 feet, 4 feet being the average. The vein outcrops were extensively mined by simple trenching. The walls of the stopes were strong, little if any timber being required for support.

The foundations of an old mill can be seen north of the Rambler shaft. Although the milling equipment has been removed, it may be conjectured that the method of ore treatment was by gravity. The mill must have operated only briefly, as the amount of the tailing is small. It is reasonable to assume that the bulk of the ore mined from Mine Hill was simply handsorted and then shipped directly to custom smelters.

## TUNGSTEN-BERYLLIUM DEPOSITS IN THE MIDDLE HILLS

### History

A north-trending quartz vein containing tungsten was discovered in the Middle Hills during the early stages of development of the district. Jones (1904) mentioned the discovery, and Lindgren et al. (1910) reported that small shipments of handsorted tungsten ore were made from the deposit prior to 1905 by George T. Brinkman.

Apparently, the deposit was then left dormant until World War II, at which time Y. E. Nichols, of Deming, obtained a lease on the mine and shipped several hundred tons of tungsten ore. Probably during this same time, scheelite was discovered in the small tactite zones in the immediate vicinity of the quartz vein. Nichols' shipments are believed to represent the last actual mining done on the deposit.

Beryl was recognized in the quartz vein by W. P. Johnston in 1948 (Holser, 1953). Unfortunately, only small quantities of this mineral are present in the vein, so that no attempt has been made to mine the vein for its beryllium content alone. In 1949, geologists of the U. S. Geological Survey examined the area and discovered the presence of helvite, another beryllium mineral, in the tactite zones.

Two excellent reports (Warner et al., 1959; and Holser, 1953) have been published on the beryllium-tungsten occurrences in the Victorio Mountains. Both descriptions are outgrowths of the U. S. Geological Survey investigations in the area during 1949. Dale and McKinney (1959) describe the tungsten occurrences briefly.

The quartz vein deposit has been called the Irish Rose, Morlock, Brinkman, Kimmic, and probably still other names. The name Irish Rose will be used here for this vein. The deposits in the tactite zones also have a variety of names. The name Tungsten Hill will be used in referring to the largest tactite zone, located northeast of the Irish Rose vein.

The deposits are covered by numerous unpatented claims, but the writer was not successful in finding a reliable map showing the locations of these claims. D. S. Tedford, H. R. Eaton, and V. C. Chrestman appear to be the major claim owners in the area.

### Geology

Figure 10 shows the geology of the immediate area of the deposits. As the geology of the general area has been described previously, only a few additional features concerning the local setting will be discussed here.

The quartz vein and the tactite zones occur on the south slope of the east-trending ridge that forms the Middle Hills. The east end of the ridge is formed by a small synclinal structure, the axis of which trends almost due east. The syncline dies out to the west. Along the southern limb of the structure, where the tungsten-beryllium deposits are located, the Montoya dolomite and El Paso limestone crop out with steep dips to the north.

There is an angular unconformity between the Montoya dolomite and the overlying Lower Cretaceous sedimentary rocks. The Fusselman dolomite is not present near the Tungsten Hill shaft, but a small wedge-shaped outcrop of this formation occurs on an isolated hill located to the southeast.

The Irish Rose vein cuts a block of El Paso limestone which strikes N. 5°-30° W. and dips 15°-40° W. The beds are strongly deformed in the vicinity of a fault, striking N. 73° W., located about 500 feet northwest of the Irish Rose shaft; the steep dips are probably due to drag along the fault.

Three separate bodies of intrusive alkalic granite porphyry are present: a northwest-striking dike west of the Irish Rose shaft; an isolated circular mass north of the Tungsten Hill shaft; and an oval mass with a dikelike appendage, located northwest of the Tungsten Hill shaft. Also, a sill of hornblende andesite porphyry was intruded into the Lower Cretaceous sequence northwest of the deposits; only the eastern extremity of this sill is shown in Figure 10.

### Irish Rose Vein

The Irish Rose vein strikes due north with dips ranging from 50° to 70° E. The vein probably terminates against the granite dike on the south and passes under the arroyo gravels to the north. The exposed strike length is approximately 500 feet. The vein was not found north of the arroyo, probably because of displacement along the N. 85° W. fault, which truncates the granite dike northwest of the Irish Rose shaft. A small quartz stringer occurs in one of the prospect pits located on the Montoya—Lower Cretaceous contact north of the fault, but there is no evidence that this stringer is a continuation of the main vein.

The vein is developed by an inclined shaft 125 feet deep, and by several pits and trenches. The writer was able to descend only about 60 feet into the shaft; ladders below this level were considered unsafe. On the 40-foot level, drifts were driven north and south along the vein (about 50 feet in each direction), and a small amount of stoping was performed. According to Y. E. Nichols (personal communication), lateral development also was done near the shaft bottom, at which level the vein frayed into several thin stringers.

The Irish Rose vein width ranges from 0.5 to 3 feet where observed, the mean width being about 1.5 feet. The vein is com osed of massive, milky to colorless quartz containing subordinate amou is of white to yellow muscovite, limonite, pyrite, wolframite, and ber . Wulfenite, cerussite, scheelite, and fluorite also are reported to be pres t, but these minerals were not detected by the writer.

The wolframite is dark brownish black and occul--,1,i_kol d masses up to 2 inches in diameter scattered irregularly through the quartz. The average $WO_3$ content of the vein is low; the writer's estimate is 0.1 percent. According to Nichols (personal communication), however, several pockets of ore averaging 1 percent or more of $WO_3$ were mined in the vicinity of the shaft. It is reasonable to assume that additional high-grade pockets occur in those parts of the vein that have not been thoroughly explored.

The beryl occurrences are erratic, but the mineral appears to be more abundant at the north end of the vein. Mineral collectors apparently have "high graded" most of the beryl from the outcrops and mine workings. The writer was able to find only a few scattered crystals. Holser (1953, p. 602) states:

> Prismatic crystals of beryl are oriented perpendicular to the wall in a hanging-wall selvage. The beryl crystals, as much as 5 cm. long and 1 cm. in diameter, are invariably bounded by (1010) and (0001) forms. The beryl is very pale green (5G9/2; Munsell Book of Color, Baltimore) to colorless. It has an ordinary refractive index of 1.5740+0.001, corresponding to a composition of about 13.5 per cent BeO.

Holser estimated the average grade of the vein as 0.06 percent BeO.

The emplacement of the quartz vein caused little alteration of the enclosing El Paso limestone. The beds show the same degree of recrystallization and silicification as in exposures hundreds of feet distant from the vein.

## Tactite Zones

Helvite and scheelite, minerals that contain beryllium and tungsten respectively, are present in minor amounts in the tactite zones located in the vicinity of the Irish Rose vein. The scheelite occurs as fine disseminations in the tactite and in the marbleized areas immediately adjacent. Helvite has been found only in the tactite.

The tactite zones are irregular lenses in the Montoya and El Paso groups. Grossularite, tresnolite, pyroxene, idocrase, and phlogopite are the dominant contact-silicate minerals present. Fluorite and quartz are also abundant.

The most strongly developed tactite zone is in the immediate vicinity of the Tungsten Hill shaft. A band of tactite approximately 20 feet wide and over 200 feet long has replaced vertical beds of El Paso limestone immediately below the contact with the overlying Montoya dolomite. The Tungsten Hill shaft was sunk on this tactite band.

Another band of intensely silicated limestone occurs in the Montoya dolomite immediately below the contact with Lower Cretaceous conglomerate, about 400 feet north of the Tungsten Hill shaft. The overlying Lower Cretaceous conglomerates and limestones are thoroughly silicified, but contact-silicate minerals are scarce. The tactite band in the Montoya dolomite averages 10 feet wide and is about 500 feet long.

The entire area around the Tungsten Hill shaft is altered to some extent; the limestone is recrystallized, and minor amounts of silicate minerals are present. True tactite, however, is limited to the two bands just described. It is not known if the tactite bands occurred at the El Paso—Montoya and Montoya—Lower Cretaceous contacts because of a chemical control (i. e., by reason of the composition of the original beds) or because of a structural control. Most likely the bands were controlled by both the steep attitude of the beds and their tendency to be easily transformed into silicate masses.

The Tungsten Hill shaft is not accessible, because of rotted timbers; the site of the (lump indicates, however, a probable depth of from 50 to 100 feet. The dump is composed of well-developed tactite in which small tetragonal crystals of helvite can be identified. The helvite is medium yellow and is difficult to distinguish from the grossularite. Analysis of the helvite showed a composition of 85 percent helvite and 15 percent Janalite (Holser, 1953, p. 603). Although the helvite probably is present in minor amounts everywhere in all the tactite zones, the writer was successful in identifying this mineral in hand specimens only from the Tungsten Hill shaft dump.

Four samples taken by geologists of the U. S. Geological Survey from the tactite zones around the Tungsten Hill shaft are summarized in Table 12.

TABLE 12. BERYLLIA AND TUNGSTEN IN SAMPLES FROM THE VICINITY OF THE TUNGSTEN HILL SHAFT (Data from Warner et al., 1959, p. 123.)

| SAMPLE NUMBER | DESCRIPTION | BeO (percent) | W (percent) |
|---|---|---|---|
| 329-408 | 6-ft. channel sample of tactite from pit on Tungsten Hill No. 3 claim (located just west of Tungsten Hill shaft). | 0.3 | 0.0X |
| 329-411 | Grab sample of garnet marble and tactite; average of dump at Tungsten Hill shaft. | 0.006 | 0.04 |
| 329-418 | Chip sample of green clay-sized material in altered limestone from pit on Tungsten Hill No. 2 claim (located on the Montoya—Lower Cretaceous contact north of Tungsten Hill shaft). | 0.008 | 0.01 |
| 329-420 | Grab sample of garnet tactite from dump of shaft on Tungsten Hill No. 2 claim (located a few hundred feet northeast of Tungsten Hill shaft). | 0.002 | 0.01 |

Two small tactite zones occur north of the Irish Rose shaft; one near the end of the granite porphyry dike, the other about 500 feet farther north, just below the contact of Montoya limestone with Lower Cretaceous conglomerate. At the latter location, considerable pyrite is present in the conglomerate. Sampling by the U. S. Geological Survey indicated the presence of minor amounts of beryllium and tungsten in these zones (Warner et al., 1959).

Boulders of tactite have been exposed in a small bulldozer pit located about 800 feet south of the Irish Rose shaft. The pit is not deep enough to ascertain whether these boulders were derived from a shallow pediment of tactite or were washed down from the known tactite zones located on the ridge. The boulders contain small amounts of scheelite and beryllium (presumably as helvite).

The prospects on the isolated hill located east of the Irish Rose shaft explored minor occurrences of lead-copper mineralization. Little, if any, actual ore was developed. Numerous other prospects dot the Middle Hills, but these, also, uncovered only minor lead-copper showings. The known tungsten-beryllium occurrences are limited to the Irish Rose—Tungsten Hill area.

## RECOMMENDATIONS FOR FUTURE PROSPECTING IN THE VICTORIO MINING DISTRICT

### Mine Hill Area

The lead-zinc-copper-silver-gold veins of the Mine Hill area were probably worked very profitably during the early part of the district's history. As mining progressed to deeper levels, the margin of profit probably became very small by reason of the increased difficulty in ore handling and the narrowing of the known ore shoots with depth.

The early miners have mined out all of the "in sight" ore blocks, but there is a possibility that additional ore shoots exist. *Will the money required to find and develop these new ore shoots exceed the profit that can be made in exploiting them?* No one can say. The existing mine workings may be suitable to conduct exploratory drilling or minor amounts of drifting and crosscutting, but new shafts and haulage adits will be needed to place a mine into production. The old shafts have caved in many places, and all of them were much out of plumb originally. Most of the haulageways are too narrow and sinuous to permit the entry of modern-sized haulage equipment; furthermore, the sill pillars were stoped in many places during the final stage of mining.

A glance at Plate 5 shows that the Chance—Jessie vein system was explored over 1,000 feet along its strike, but only 250 feet of this length constituted ore. This gives an idea of the amount of exploration and development required to find and then prepare individual ore shoots for mining.

If new ore shoots are found, most of them will probably be at depth, below the oxidized zone. The characteristics of the oxidized ore indicate that the primary ore will be composed of galena and sphalerite (probably in nearly equal proportions), accompanied by lesser amounts of pyrite and chalcopyrite. Some gold and silver will be mixed with the sulfide minerals. Such ore is seldom suitable for direct shipment to a smelter; it must be treated first by flotation methods to for m separate concentrates. Therefore, in appraising the potential of the Mine Hill area, one must consider not only the high exploration and development costs but the eventual capital cost of a flotation-type concentrator to treat the ore.

When dealing with vein deposits, the question of persistence of ore with depth always arises. Ore shoots should exist to at least moderate depths in the Mine Hill area for three reasons. First, although the individual ore shoots have small dimensions, the vein systems as a whole have long (± 1,000 feet) strike lengths. This tends to indicate that ore will persist with depth. Second, although the temperature conditions of the original ore deposition are not known, the temperature was probably in the leptothermal range; at least it was not in the epithermal class. Leptothermal deposits generally persist to moderate depths. Third, the measured thickness of the Fusselman dolomite, which is a favorable ore horizon, is in excess of 900 feet. The deepest workings in the Chance and Jessie mines probably bottom 300 feet or more above the base of this formation. The workings on the west end of the hill have penetrated the formation even less, the thickness of untested Fusselman under the Rover claim being probably in excess of 600 feet. In addition, the Montoya and El Paso groups, which successively underlie the Fusselman formation, may be favorable host rocks.

The Rover claim has not been thoroughly tested. The parallelogram pattern of intersecting veins that crop out east of the Excess shaft were mined to only shallow depths. A crosscut driven from the lowest level of the Rambler mine workings would reach these vein intersections below the point where they have been mined.

Prospecting on the footwall (southeast side) of the aplite dike may be fruitful in the vicinity of the Rambler shaft if the dike is preore. Unfortunately, age criteria for this dike are lacking. The veins in the dike footwall in the vicinity of the Excess shaft terminate abruptly, which hazily suggests that the dike may be postore. If this is the case, the dike footwall would not be a specifically favorable ore zone.

The hanging-wall area of the dike, including the North fault and the Lower Cretaceous limestone and conglomerate beds, is probably not a favorable zone for ore occurrence. Postore movement along the North fault probably diluted any ore shoots that may have existed in that plane. Also, the Lower Cretaceous sedimentary beds do not appear to be favorable ore hosts. The limestone beds are very thin, and the conglomerates are so permeable as. to have allowed any ore solutions to disperse without making high-grade deposits.

The Chance-Jessie vein group and the Burke vein have been prospected thoroughly on the upper levels. Further exploration at depth may be warranted, but the cost of such exploration is certain to be high. The writer was unable to examine all the underground workings; there is always the possibility that the development on the lower levels was not done properly and that obvious ore shoots were missed. This type of reasoning is seldom justified; the early miners had just as good "noses" for ore as those today.

Little can be said about other zones to explore in the Mine Hill area. The Parole and Helen shafts are not accessible; therefore, the writer has no personal knowledge of these areas.

### Tungsten-Beryllium Deposits

It is difficult to make concrete recommendations as to further prospecting for tungsten and beryllium in the Middle Hills. The Irish Rose vein has been fairly well developed, but the vein is narrow and the overall grade is low. It is reasonable to assume that additional small high-grade pockets exist, but the cost of finding and extracting these pockets may be prohibitive.

The same line of reasoning is applicable to the scheelite-helvite occurrences in the tactite zones. The known occurrences are small and of low grade. In addition, the tactite ores present a metallurgical problem. It is impossible to handsort this type of ore (as could be done in the vein deposit), because the economic minerals are finely disseminated throughout the rock. Considerable research would be necessary to find a feasible method of obtaining separate helvite and scheelite concentrates.

It is impossible to state what the possibilities are for the continuance of the tactite zones with depth. The type of silication present is most commonly associated with igneous intrusions into carbonate rocks. It is possible that such a body is buried nearby, in which case a much larger contact zone may exist. On the other hand, the tactite zones may have been formed in certain stratigraphic and structural environments by high-temperature hydrothermal solutions that were derived from a fairly remote intrusive body.

A magnetometer survey of the Middle Hills might reveal anomalies (most tactites are slightly magnetic) that would encourage prospecting. Such a survey would require careful interpretation because of the profusion of rock types present (namely, tactite, carbonate rocks, conglomerates, andesite flows, intrusive andesite, alkalic granite porphyry, and several types of alluvium).

The recent invention of the berylometer, a device used to detect beryllium minerals, should be of aid in detecting helvite in surface exposures and drill cores. Helvite is very similar in appearance to garnet, making field indentification difficult. This writer did not have access to a berylometer, but it is reported that several private surveys have been run over the area with such instruments. These surveys did not reveal any new helvite-bearing areas.

## COOKS PEAK MINING DISTRICT

### GENERAL

The Cooks Peak district has been the most productive mining area in Luna County; only a brief description, however, will be given here, inasmuch as detailed descriptions have already been published. Jicha (1954) has described the Cooks, Jose, and Old Hadley mining subdistricts, along with the general geologic setting of the area, and the reader is referred to that work for a fuller treatment of the Cooks Peak district. The U. S. Bureau of Mines is currently preparing a report that will describe the manganese deposits. The investigations of Darton (1916, 1917) and Elston (1957) also have added to the knowledge of the basic geology of the Cooks Range.

## COOKS AND JOSE SUBDISTRICTS

These two subdistricts comprise what has been the most prolific mineral-producing area in Luna County. Approximately $4 million worth of lead, zinc, and silver has been recovered here, representing almost one-half of the production value of the entire county.

Although the two subdistricts are essentially contiguous, the Cooks subdistrict being on the east slope of the Cooks range, and the Jose being on the west slope, they have separate access routes. The Cooks subdistrict can be reached from Deming by traveling 15 miles northeast on State Highway 26 to the Florida railroad siding, and thence 13 miles northwest over a dirt road leading to the abandoned mining camp of Cooks. The Jose subdistrict lies about 11/2 miles farther northwest and must be reached by a separate road leading northward from Deming.

The deposits consist of replacement mantos of sphalerite and galena in the upper part of the Fusselman dolomite, just below the Percha shale. The average grade of 25,148 tons shipped from the area during the period 1902-1947 was as follows: lead, 15.3 percent; zinc, 11.5 percent (actually the zinc content was higher, for zinc was not reported for many shipments); and silver, 2.51 oz per ton.

The first discovery in the area was made in 1876, and by 1900 approximately $3 million worth of ore had been extracted. Mining continued, though at a reduced rate, from 1900 until 1927, producing just short of $1 million. Since 1927, production has been meager.

## OLD HADLEY (GRAPHIC) SUBDISTRICT

The Old Hadley (Graphic) subdistrict is located in secs. 29 and 32, T. 20 S., R. 8 W., on the southeast slope of the Cooks Range. The area can be reached over the same road that leads to the Cooks subdistrict. Lead, zinc, and some copper were mined here from 1880 to 1929. The deposits occur as veins in altered andesite.

## MANGANESE DEPOSITS

The most productive area has been the Ruth patented claims in secs. 28 and 33, T. 22 S., R. 8 W. Narrow veins of psilomelane occur in latite(?) volcanic breccia, tuff, and agglomerate that form a group of low hills 3 miles southeast of Fluorite Ridge. The deposits were worked actively during the late 1950's, when the manganese stockpiling program of the Federal Government was in effect. It is interesting to note that a deposit of placer manganese occurs at the south end of the hills; this deposit was operated very profitably during 1959 by Q. M. Drunzer.

A small amount of manganese has been shipped from deposits located on the Nunn ranch, a few miles northeast of the abandoned village of Cooks.

## FLUORITE RIDGE MINING DISTRICT

### GENERAL

The Fluorite Ridge mining district lies northeast of Deming and just south of the Cooks Range (fig. 1). Access into the area is gained by traveling 6 miles northeast of Deming on State Highway 26, and thence another 6 miles in a north-northeast direction over a graveled road. The road terminates at the southeast base of Fluorite Ridge, whence narrow roads scatter to the various mines and prospects.

Fluorite Ridge is a striking topographic feature, being 31/2 miles long and as much as 2 miles wide, and rising approximately 1,000 feet above the surrounding bolson plains. Goat Ridge, a similar but smaller feature, lies to the northwest and, coupled with Fluorite Ridge, constitutes a northwest-trending belt of hills 6 miles long. The district is divisible into two fluorspar mining areas, one centered around the

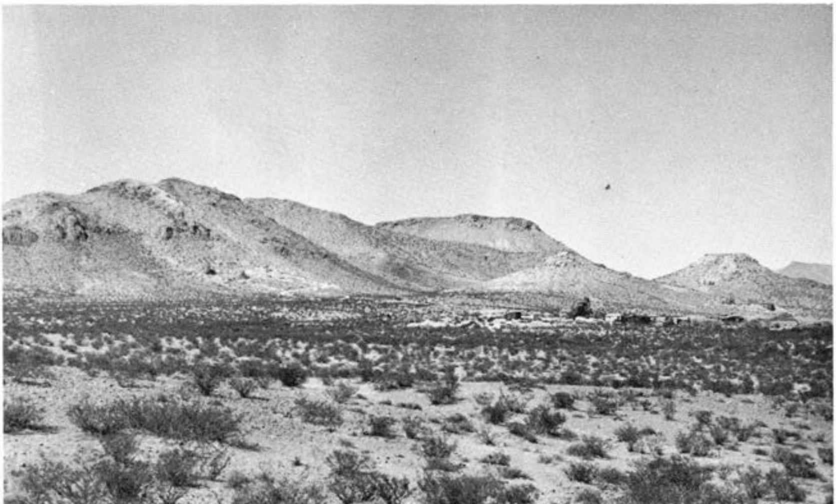


Figure 11. (A) "Lower Camp," Fluorite Ridge mining district.
The Sadler mine is located in the left background, and the Greenleaf mine in the right foreground.

southeast end of the ridge, and the other 11/2 miles to the northwest on the ridge crest. The northwest end of Fluorite Ridge and all of Goat Ridge appear to be devoid of productive fluorspar veins.

Fluorite is the only ore mineral that has been produced from the district, although important occurrences of manganese are known a short distance to the southeast. Mining started in the district at an early date. According to Darton and Burchard (1910, p. 533):

> The occurrence of fluorspar in southern New Mexico has been known for some time, several specimens of the mineral having been sent from Silver City to the mineralogical museum of the New Mexico School of Mines, at Socorro, within the last 10 years. Only recently, however, has fluorspar been found in sufficient quantities for exploitation. The American Fireman's Mining Co., of Kansas City, Mo., in prospecting for metallic ores on property situated 10 miles northeast of Deming, Luna County, N. Mex. has opened a number of veins of fluorspar which give promise of containing nearly if not quite enough spar to supply the western market for several years.

The same report described three active mines on Fluorite Ridge, which, to judge from the descriptions, must have been the mines now known as the Sadler, Grattan, and Lucky. The district shipped an estimated 5,000 tons of handsorted ore, averaging 92 percent $CaF_2$, between the summer of 1909 and the close of 1910.

G. M. Sadler succeeded the American Fireman's Mining Co. in the operation of the mines by the end of 1909. The district continued to produce ore in a sporadic manner until 1955. Numerous operators have

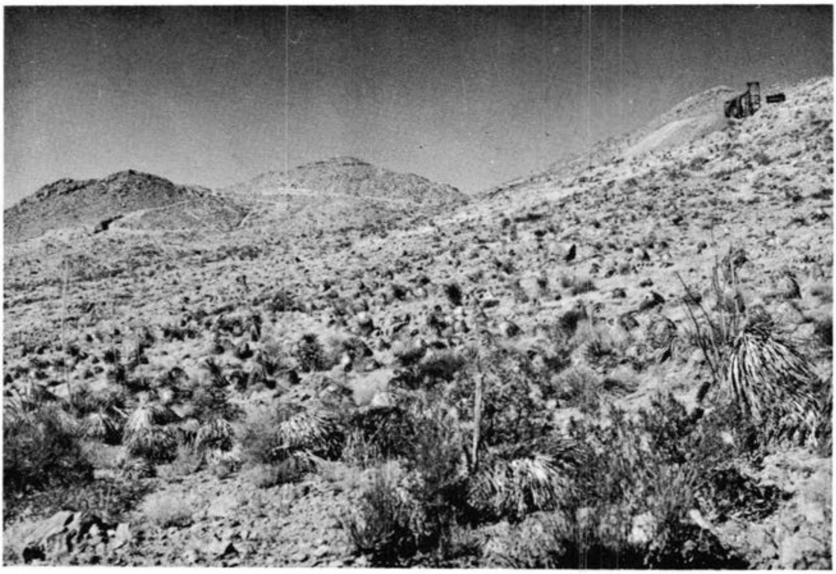


Figure 11. (B) "Upper Camp," Fluorite Ridge mining district. The Grattan mine is on the right, and the Green Spar mine on the left.

worked the deposits, but it is not possible to present a clear history of the district for the entire period.

The first mill to treat ore from the district was built in 1931-32 by the La Purisima Fluorspar Co. in Deming. The original capacity of the mill was only 20-30 tons per day, but this was increased to 100 tons per day in 1937, when the General Chemical Co. purchased the La Purisima Fluorspar Co. holdings in the area. The mill operated continuously from 1932 until 1954, when operations were terminated because of depressed prices of fluorspar. In later years, however, only a fraction of the mill feed was obtained from Luna County ores, the bulk coming from mines located outside the county. P. L. Grattan operated another small mill at Deming during World War II.

The total fluorspar production is not known, but a conservative estimate would fall in the 100- to 200-thousand-ton range. The most productive period was probably from 1932 to 1944. Annual reports of the State Mine Inspector indicate that approximately 25,000 tons of fluorspar ore was shipped from the district during the period 1949-1954.

## PREVIOUS INVESTIGATIONS

Darton (1916, 1917) mapped the geology of Fluorite Ridge in a reconnaissance fashion, and Darton and Burchard (1910) briefly described the fluorspar occurrences. Johnston (1928), Rothrock et al. (1946), and Russell (1947) described the individual mines in detail. The geology of the area was remapped by the present writer to provide more detail than was furnished by Darton's early work. Free use was made of the mine descriptions of Rothrock et al. in formulating the discussions that follow, because the majority of the mine openings are in poor condition, owing to prolonged shutdown.

## GEOLOGY

### General

A geologic map of the area is presented as Plate 8. Fluorite Ridge was invaded by an elongate mass of granodiorite porphyry that penetrated Paleozoic and Mesozoic strata at the close of the Cretaceous period or the beginning of the Tertiary. The intrusion appears to have taken place along a northwest-trending axis and to have spread laterally along the Permian-Cretaceous sedimentary contact, causing the Cretaceous rocks to be domed upwards. Preintrusion structures and late-Tertiary faulting modify the domal structure. For a descriptive summary of rocks exposed at Fluorite Ridge, see Table 13 (in pocket).

Great thicknesses of volcanic rocks surround Fluorite Ridge, but such rocks are not found on the ridge proper. A thick sequence of Gila(?) conglomerate crops out on the flanks of the ridge and has been cut by numerous basalt and basaltic andesite dikes. The fluorspar veins cross the basalt dikes, indicating that the mineralization was late Tertiary or possibly early Quaternary in age.

TABLE 13. SUMMARY OF ROCKS EXPOSED AT FLUORITE RIDGE

| SYSTEM | SERIES | GROUP | FORMATION | THICKNESS | DESCRIPTION |
|---|---|---|---|---|---|
| | | | Silt | 0-100 | Silt, sand, and minor amounts of gravel deposited in the flood plains of large arroyos. |
| Quaternary | | | Gravel | 0-500 | Coarse gravels that form alluvial fans surrounding Fluorite Ridge. |
| | | | Basalt dikes | | Black aphanatic basalt. |
| | | | Basaltic andesite dikes | | Dark-gray basaltic andesite. |
| | Late | | Gila(?) conglomerate | 1000? | Fanglomerate deposits of coarse gravel, sand, and silt, plus poorly cemented sandstone, siltstone, and marl. |
| Tertiary | | | Volcanic conglomerate | 500? | Coarse conglomerate of andesite and other rock types embedded in a matrix containing an appreciable amount of tuff; scant evidence of bedding. |
| | | | Rhyolite | 200? | Light-gray rhyolite tuff, welded tuff, and flow rock. |
| | Middle | | Andesite breccia | 10-300? | Angular to subrounded fragments of purplish andesite and gray latite embedded in a puplish tuff matrix. |
| | | | Granodiorite porphyry | | Greenish-gray granodiorite porphyry. Phenocrysts of oligoclase, hornblende, and biotite in a groundmass of the same minerals, plus quartz. |
| | Early | | Monolithic conglomerate | 0-150 | Coarse conglomerate composed of subrounded fragments of gneissic gray granite cemented by a red ferruginous matrix. |
| | Comanchean | | Sarten sandstone | 300± | Buff to gray, thin- to medium-bedded sandstone. Massive beds weather to dark-brown rectangular blocks. |

| | | | | | |
|---|---|---|---|---|---|
| Cretaceous | | | | | Concentric hematitic color banding common. Basal lens of conglomeratic sandstone. Minor beds of shale and limy sandstone. Believed to be overlain by Upper Cretaceous Colorado shale. |
| Permian | | | Abo formation | 100± | Limestone conglomerate; chert-breccia conglomerate; gray, medium-bedded limestone; and red shale and siltstone. Grouped with Pennsylvanian beds in Plate 8. |
| Pennsylvanian | | | Undifferentiated | 150± | Dark-gray, medium-bedded limestone and black fissile shale. Grouped with Permian in Plate 8. |
| Mississippian | Osagean | | Lake Valley formation | 400± | Medium-bedded, gray calcarenite and crinoidal limestone; may include a thin unit of Kelly limestone. |
| Devonian | Upper | | Percha shale | 200± | Black and greenish-gray shale interbedded with thin nodular limestone; includes both the Ready Pay and Box members. |
| Silurian | Middle | | Fusselman dolomite | 500± | Massive to medium-bedded, gray dolomite; minor chert. |
| Ordovician | Upper and Middle | Montoya dolomite | | 300± | Medium- to thick-bedded, dark-gray dolomite and dolomitic limestone; much chert; includes Cable Canyon sandstone. |
| | Lower (Canadian) | El Paso limestone | | 900± | Medium-bedded, gray limestone and dolomitic limestone. Weathers light brownish gray in contrast to thick-bedded, dark-gray beds of the Montoya. |
| Cambrian | Upper | | Bliss sandstone | 50-150 | Gray to brown, massive to slabby, glauconitic, hematitic sandstone. Weathers to dark brown. |
| Precambrian | | | | | Diorite, gabbro(?), and amphibolite, with masses of red, coarse-grained granite; minor amounts of schist and gneiss. |

## Precambrian Rocks

Rocks of Precambrian age are exposed along the base of the southeast end of Fluorite Ridge (pl. 8). The total outcrop area is less than a quarter of a square mile, bounded on the north by overlying Paleozoic sediments and on the remaining sides by alluvium. Two rock types are exposed in approximately equal proportions; a coarse-textured red granite, and a more basic rock ranging from diorite to amphibolite. The relationship between the two rock types is not clear, but the granite appears to occur mostly as dikes and irregular masses, much disconnected by later faulting, contained within the diorite-amphibolite phase. If this interpretation is correct, the granite is the younger of the two.

Mapping by Darton (1916, 1917) indicated that Precambrian rock cropped out at several places on the north slope of Fluorite Ridge. These outcrops could not be verified, but appear to be merely zones within the Gila(?) conglomerate that contain an abundance of boulders of Precambrian rock. The same reasoning applies to the Pony Hills, 2 miles north of Fluorite Ridge, which Darton also had shown as a Precambrian outcrop. The latter area, however, is beyond the limits of Plate 8. The source of the Precambrian boulders, some of which measure several feet in diameter, is not known. Typically the boulders are composed of gneissic gray granite, which is in no way similar to the red granite contained in the exposure of Precambrian rock located in the southeastern part of the district. Precambrian rocks, however, must have been exposed north of Fluorite Ridge during late Tertiary times to account for the large boulders contained within the Gila(?) conglomerate.

## Paleozoic Sediments

Sediments ranging in age from Ordovician to Permian crop out in the southeastern part of the district. The most prominent exposure is a rectangular block located west of the Sadler mine. At this locality, the beds strike east and dip steeply to the north, exposing a fairly complete record of Paleozoic deposition. Starting at the Precambrian complex on the south and proceeding northward, increments of the Bliss sandstone, El Paso limestone, Montoya dolomite, Fusselman dolomite, Percha shale, Lake Valley formation, and undifferentiated Permian-Pennsylvanian sediments are exposed.

Complete stratigraphic sections are absent because of faulting, and. intense silicification, caused by the intrusion of the granodiorite porphyry, destroyed many of the lithologic features of the beds. For these reasons no attempt was made to measure stratigraphic sections. Table 13 summarizes the general lithology of the sequence, but the accompanying thickness measurements are only estimates based on measurements of Paleozoic sections in the nearby Cooks Range.

*Cambrian, Ordovician, Silurian, and Devonian sediments.* The outcrops of the Bliss sandstone, El Paso limestone, Montoya dolomite, Fusselman dolomite, and Percha shale are typical of exposures elsewhere in Luna County, and the reader is referred to pages 9-11 for details pertaining to the stratigraphy.

*Mississippian, Pennsylvanian, and Permian sediments.* The only Mississippian sediments exposed belong to the Lake Valley formation, being composed of medium-bedded, gray clastic limestones and massive crinoidal limestone. Outcrops are limited to a narrow east-striking band west of the Lucky mine, and a small fault block south of the Green Spar mine. The outcrop west of the Lucky mine appears to contain only about 100 feet of Mississippian beds. This abnormally thin section is probably due to faulting, for the Lake Valley formation is 370 feet thick in the Cooks Range only a few miles north of Fluorite Ridge.

Sediments of Pennsylvanian and Permian age were grouped together in order to simplify the geologic mapping. The Pennsylvanian beds consist of medium-bedded, gray calcilutites and a considerable amount of black fissile shale. The shale is exposed along a trail that leads to the Hilltop Spar mine. The Permian sequence is composed of interbedded gray limestone, limestone-chert conglomerates, and limestone-pebble conglomerates. A few shaly sandstone lenses also are present. The clastic beds have a distinct reddish color similar to the Abo formation exposed in the Cooks Range.

The Pennsylvanian beds are limited to the southeastern part of the district. The large outcrop areas noted as "undifferentiated Pennsylvanian and Permian sediments" in the northern and western parts of the district actually are Permian beds alone.

## Cretaceous Sediments

The Sarten sandstone is the only Cretaceous formation exposed in the Fluorite Ridge area. Tertiary andesite breccia and (or) Gila(?) conglomerate directly overlie the Sarten sandstone, indicating that the Colorado shale was stripped away, after deposition, by early Tertiary erosion. The lithology of the formation is given in Table 13.

## Tertiary Igneous and Sedimentary Rocks

Tertiary rocks exposed in the area consist of four types of sediments, plus granodiorite porphyry, andesite breccia, rhyolite tuff, andesite dikes, and basalt dikes. Age relationships between the several rock types are not thoroughly understood, but the most plausible sequence is shown by Table 13.

*Monolithic conglomerate.* Three small patches of conglomerate composed entirely of subrounded Precambrian rock fragments contained in a highly ferruginous matrix crop out west of the Sadler mine (pl. 8).

The largest outcrop, near the Hilltop Spar mine, passes beneath the granodiorite porphyry on the north side of the outcrop, indicating that the conglomerate is older than the granodiorite.

The conglomerate is composed of fragments of only one rock type —gneissic gray granite; hence, the name "monolithic conglomerate" aptly describes the formation. The size of the fragments ranges from sand size to boulders 2 feet in diameter. Under the microscope, the matrix is composed of angular fragments of feldspar and quartz imbedded in a highly ferruginous clay. It is interesting to note that the granite fragments are not similar to any rock found in the Precambrian complex that crops out at the southeast end of the ridge. The fragments, instead, are quite similar to the granite boulders found within the Gila(?) conglomerate north of Fluorite Ridge.

Darton (1917, p. 11) believed that the conglomerate was an intrusive breccia formed by friction at the margin of the granodiorite porphyry pluton. The rounding, however, of the granite fragments, as well as the presence of several lenses of siltstone in the most southern of the three conglomerate outcrops, provides definite evidence of sedimentary origin.

*Granodiorite porphyry.* The bulk of Fluorite Ridge is composed of greenish-gray granodiorite porphyry. The phenocrysts consist of oligoclase, orthoclase, hornblende, biotite, and minor quartz. The ground-mass is a microcrystalline complex of essentially the same minerals that form the phenocrysts, plus considerable chlorite.

The age of the granodiorite porphyry is not accurately known. It is certain that the rock was intruded after the deposition of the monolithic conglomerate and Sarten sandstone, but a definite age relationship between the andesite breccia and the granodiorite porphyry could not be determined. The andesite breccia, however, does not exhibit the intense effects of alteration as do the pregranodiorite rocks; hence, the writer tentatively has assigned the relative age of postgranodiorite to the andesite breccia.

A genetic relationship is indicated between the Fluorite Ridge granodiorite porphyry pluton and the granodiorite intrusive bodies exposed in the Cooks Range. The relationship is based on the similar compositions of the rock and the tendency for the bodies to spread laterally along the Permian-Cretaceous sedimentary contact.

*Andesite breccia.* A pediment surface of andesite flow breccia crops out southeast of the Sadler mine. The surface is bounded on the north and west by east- and north-striking faults respectively. A thin sheet of similar andesite breccia is exposed in isolated areas in the Pony Hills sandwiched between the Sarten sandstone and the Gila(?) conglomerate. As mentioned previously, the flow breccia is believed to be younger than the granodiorite porphyry.

The breccia is composed of angular fragments of andesite and latite imbedded in a dark, purplish-gray tuffaceous matrix. The breccia terminology is only partially correct, as definite rounding of the fragments, more typical of an agglomerate than a breccia, was observed in several places.

*Rhyolite tuff.* Light-gray, welded rhyolite tuff caps the andesite breccia sequence at several localities on the south slopes of Fluorite Ridge. The rhyolite tuff and the andesite breccia are believed to be members of the thick sequence of Middle Tertiary volcanic rocks exposed in the southern part of the Cooks Range. That the volcanic units are very thin in the vicinity of Fluorite Ridge may be due to the presence of a topographic high during Middle Tertiary time.

It should be noted that a considerable erosional break is evident between the andesite breccia and the rhyolite tuff. This statement is based on the presence of a variable thickness of sediments occurring between the two volcanic units in the northwest-trending ridges located east of Fluorite Ridge and beyond the mapped area. About 500 feet of interbedded red siltstone and shale and gray conglomeratic sandstone crops out on a high hill northwest of Puma Spring (secs. 4 and 5, T. 22 S., R. 8 W.). The sequence is capped by a welded rhyolite tuff identical in appearance to that exposed on the southern slopes of Fluorite Ridge, and the conglomeratic sandstone beds near the base of the hill contain numerous andesite pebbles, which probably were derived from a unit similar to the andesite breccia. The lithology of this sedimentary unit is somewhat similar to that of well-sorted parts of the Gila(?) conglomerate, but the fact that the sequence is capped by rhyolite welded tuffs and flows implies a Middle, not late-, Tertiary age.

*Gila(?) conglomerate.* Fluorite Ridge is surrounded on the north and east sides by a dissected surface of late-Tertiary sandstones and conglomerates believed to be correlative with the G.ila(?) conglomerate exposed elsewhere in Luna County. The sandstones and conglomerates crop out only as well-rounded ridges covered by lag gravel; therefore, the lithology of the sequence cannot be described in detail. The conglomerates are made up of well-rounded pebbles to boulders of Precambrian gneissic granite, various Paleozoic and Cretaceous sediments, and several types of Tertiary volcanic rocks. Lenses of olive-green arkosic sandstone, red mudstone, and marl are common, but the conglomerates themselves rarely show evidence of bedding .

A narrow strip of volcanic conglomerate extends northward from the Greenleaf mine to the Lucky mine. The volcanic conglomerate is, in reality, simply the basal part of the Gila(?) conglomerate, but it was desirable to map the former as a separate unit in order better to illustrate the complex structure present in the vicinity of the Greenleaf and Lucky mines. The criteria that set the volcanic conglomerate apart from the overlying Gila(?) conglomerate are: (1) greater percentage of volcanic and granodiorite porphyry rock fragments, (2) stronger cementation, which in part may be due to later silicification, (3) less rounding of conglomerate fragments, and (4) the tuffaceous nature of the matrix surrounding the conglomerate fragments in contrast to the arkosic sand matrix common to the upper parts of the Gila(?) conglomerate.

*Basaltic andesite and basalt dikes.* Two types of late-Tertiary or early-Quaternary dikes cut the earlier rock units, including the Gila(?) conglomerate. A northeast-trending basaltic andesite dike is exposed in the extreme southeast part of the area (pl. 8). The dike is difficult to trace because of the formation of lag gravel wherever the Gila(?) conglomerate crops out. This dike is foliated to a marked degree, indicating a very viscous melt at the time of injection, or shearing during the crystallization period.

A system of northwest-striking black basalt dikes cuts through the district. The basalt is fresh in comparison with the basaltic andesite, testifying to its relatively young age. The dikes are offset by numerous north-trending left lateral faults in the eastern part of the area; these small faults are not shown on Plate 8, in order to avoid needless detail. The fluorspar vein at the Grattan mine is located along a sinuous basalt dike that cuts the granodiorite porphyry.

### Quaternary Alluvium

The Quaternary alluvium that surrounds Fluorite Ridge is divisible into two types; first, a coarse gravel that forms a great alluvial fan surrounding the main ridge, and second, a sand-silt type of alluvium deposited in the flood plains of the principal arroyos that drain the area. Considerable difficulty was encountered during the field mapping in distinguishing between the alluvial fans and the lag-gravel-covered slopes of Gila(?) conglomerate. The best criterion for distinguishing between the two is the very heterogeneous composition of the Gila(?) conglomerate; the alluvial fans, on the other hand, generally consist only of the type of rock found at the gravel source.

### Structure

The overall structural picture of Fluorite Ridge is complex. Fortunately, the major structures were formed prior to the formation of the fluorspar veins. This fact was helpful not only to the mine operators but to the writer as well, because it eliminated the necessity for unraveling the complex pattern of preore faults present in the southeastern part of the district.

*Pregranodiorite porphyry structures.* The formation of the monolithic conglomerate prior to the intrusion of the granodiorite porphyry indicates considerable structural deformation during late-Cretaceous or early-Tertiary time. The mechanics of this early deformation can only be assumed, but it is likely that a large northwest-striking fault traversed the center of Fluorite Ridge. Evidence of the fault is given by the contrast in attitude of the steeply dipping block of Paleozoic rocks in the southeastern part of the district as compared with the much more gentle dips prevalent in the Sarten sandstone to the northwest.

*Structures formed by intrusion of granodiorite porphyry.* The assumed northwest-striking fault just mentioned provided the axis for the invasion of granodiorite porphyry. The granodiorite spread laterally along the Permian-Cretaceous sedimentary contact, thus forming an elongated domal structure. Evidence of this shape is clearly shown in the western part of the district by a breached plunging anticline (pl. 8).

The granodiorite was emplaced at relatively shallow depths because only the Sarten sandstone, Colorado shale, and possibly some early-Tertiary volcanic rocks formed the roof over the granodiorite. In the vicinity of the Hilltop Spar mine, the granodiorite intruded the monolithic conglomerate; thus, early-Tertiary volcanic rocks must have provided the sole cover over the granodiorite.

*Postgranodzorite porphyry structures.* Extensive faulting occurred after the emplacement of the granodiorite porphyry pluton, causing the general area of Fluorite Ridge to be uplifted. Subsequent erosion exposed the upper portion of the pluton, leaving only a few isolated remnants of the original roof. Faulting continued through the remainder of Tertiary time, as indicated by offsets in the basalt dikes.

The postgranodiorite porphyry dikes fall into three strike-direction groups, north, northwest, and northeast, which probably are controlled by faults of the same trends. The north-striking fault group is the most prominent. Several such faults pass along the east end of the range, causing granodiorite porphyry overlain by a thin mantle of Gila conglomerate to be downthrown on the east against Paleozoic sediments on the west. Another north-trending fault forms the east boundary of a Sarten sandstone outcrop in the north-central part of the district (pl. 8). This fault is readily traceable into the Pony Hills 2 miles farther north.

Northwest-striking faults are evident along the flanks of Fluorite Ridge. It is probable that many similarly oriented faults pass through the central part of the ridge, but offsets are difficult to detect there because granodiorite porphyry is the only rock type that crops out. Northeast-striking faults are limited to the south-central part of the district, and the offsets are minor in comparison to the other fault groups.

## CHARACTERISTICS OF THE FLUORSPAR VEINS

Except for the Hilltop Spar mine, the fluorspar deposits are limited to simple fissure veins. Very little wall-rock replacement is evident. The dominant trend of the veins is north, but a few east-striking crossveins are known, and the vein at the Grattan mine follows a northwest-striking basalt dike. The vein mineralogy is also simple. Fluorite is the only ore mineral, accompanied by abundant quartz, minor calcite, and rare barite. Pyrite has been reported in the deeper levels of the Sadler mine (Rothrock et al., 1946, p. 133), but sulfide minerals are absent elsewhere. The fluorite occurs in a variety of colors: transparent, white, pale green, pale red, and faint purple. Although large masses of pure fluorite are common, well-developed crystal faces are rare. The quartz occurs mostly in cryptocrystalline masses, but occasional vugs are found containing well-developed crystals.

The fluorspar veins were formed near the close of the Tertiary period or at the beginning of the Quaternary, because fluorite occurs in a northwest-trending late-Tertiary basalt dike at the Grattan mine. The paragenesis of the vein minerals is not fully understood, but evidence points to a relatively long period of silica deposition, fluorite being introduced during a brief intermediate stage. At certain places the fluorite-quartz veins have been brecciated and then recemented by additional quartz and fluorite. This fact indicates that the actual paragenetic sequence may be rather complex.

The veins are definitely controlled by faults. They occur, however, mostly in faults of small displacement; many of the faults of large displacement apparently were not favorable zones for ore deposition. This tendency is well demonstrated at the Sadler mine, where the large north-striking fault located immediately west of the mine is barren, whereas several parallel but minor fractures contain abundant ore. The veins are much more regular in strike direction and width in the volcanic conglomerate and Gila(?) conglomerate than in the granodiorite porphyry. The same tendency is shown vividly by the regularity of the basalt dikes in the conglomerates in contrast to the sinuous and splitting nature of the dike in the granodiorite porphyry at the Grattan mine (p1. 8). Apparently, the conglomerates formed sharp, clean breaks, whereas the granodiorite porphyry tended to shear and spall. In spite of this tendency, most of the fluorspar mined in the district has come from veins in the granodiorite porphyry.

Vein widths range from the vanishing point to as much as 20 feet, but the average width of the minable portions is about 3 feet. Vein splits and offsets are common and caused considerable dilution of the ore during mining. Fortunately, neither the quartz nor wall-rock interfered with the concentration of the ore by flotation methods. Also, the veined nature of the deposits made handsorting an easy and efficient method of upgrading ore diluted by mining.

The writer was unable to study the individual ore shoots in detail, because most of the stopes either were inaccessible or have been filled with waste. Lack of accurate mine maps also prevented drawing any conclusions as to the shape or size of the ore shoots at depth. On the surface, the fluorspar veins terminate either by pinching in width, anastomosing, or grading into simple quartz veins. Strike lengths of individual ore shoots seldom exceed 100 feet; ore shoots frequently occur, however, in tandem, yielding productive zones as much as 300 feet long. The stronger veins have been fairly persistent with depth; for example, the Greenleaf mine has been developed to 500 feet of depth without appreciable change in the character of the vein.

The Paleozoic and Cretaceous sediments have not proved to be favorable ore hosts. The vein at the Hilltop Spar mine is the only vein in such rocks that has offered much promise, but even that vein is very erratic. The reason the sediments are not favorable hosts could be a lack of throughgoing fractures or a high degree of reactivity between the mineralizing solutions and the carbonate-rich sediments, which in either case would prohibit extensive migration of ore-forming fluids. Another alternative, of course, is that prospecting has not been carried out diligently enough in the carbonate rocks.

## DESCRIPTIONS OF INDIVIDUAL MINES

No attempt was made to ascertain the location or status of the myriad of unpatented mining claims that cover the district. Rothrock et al. (1947) presented a simplified claim map of the area, but many additional claims are not shown on that map. A certain amount of confusion exists as to the true names of some of the mines, because successive operators have used different names for the same mine. The name usage employed below may not be acceptable to all persons familiar with the district.

Because of the inaccessibility of many of the mine workings, the descriptions of Rothrock et al. (1946) were freely drawn on to formulate some of the mine descriptions given below. Certain mines may be developed more extensively than the descriptions indicate because the report just cited was based on an inspection made in 1943; even though the writer has attempted to modernize each description, it is possible that some work was overlooked. Complete production data for the individual mines also are lacking. Rothrock et al. made estimates of individual mine production through 1942, but the writer was unable to find an accurate breakdown of the district's production since that date.

### Sadler Mine

*Location.* The Sadler mine is situated in the southeast part of the district, in the NW1/4 sec. 18, T. 22 S., R. 8 W. (pl. 8).

*History.* This mine is the oldest in the district, having been the site of the initial fluorspar discovery made by the American Fireman's Mining Co. in the summer of 1909. The following year, the mine was purchased by G. M. Sadler, who worked the mine intermittently until sometime in the 1920's. Ownership was transferred successively to Messrs. Hayner and Manasse, the La Purisima Fluorspar Co., and the General Chemical Co., the present owner. Rothrock et al. (1946) estimated that the mine had produced 32,000 tons of metallurgical-grade fluorspar up to 1942. The mine was active from 1942 to 1946 under the management of the General Chemical Co., but the amount of ore produced during that period is unknown. Little ore is believed to have been mined since 1946, and all mine machinery has been removed from the property.

*Geologic setting.* The deposits consist of several north-striking veins in granodiorite porphyry. The granodiorite outcrop is obscured by a thin veneer of talus from the Paleozoic sediments located immediately to the west and higher up the hill slope. The sediments are separated from the granodiorite porphyry by a prominent north-striking fault, which in turn has been offset slightly by several east-striking faults. One of the latter faults has displaced volcanic conglomerate against the granodiorite porphyry immediately south of the mine. Farther south, still another fault causes andesite breccia to abut against the volcanic conglomerate. Minor offsets of the north-striking veins indicate that some of the movement on the east-striking faults is postore. In contrast, the large north-striking fault is believed to be preore.

*Mine workings.* The mine has been developed by two vertical shafts sunk on separate veins. Shaft No. 1 is located on the westernmost vein and is reported to be 180 feet deep, with levels cut at depths of 100, 160, and 180 feet. Shaft No. 2 is located 115 feet to the east of shaft No. 1 and is reported to be 110 feet deep, with a winze extending from the 110-foot level to a 170-foot level. A crosscut connects the bottom levels of the two shafts. An exploration adit was driven to the west from a point approximately 200 feet south of shaft No. 1.

*Ore bodies.* Perhaps as many as 10 distinct veins are present in the mine area, all striking north to northeast and dipping steeply to the east. Only two of the veins, however, have proved to be minable. The largest of the two is the vein that passes through shaft. No. 1, striking N. 35° E. and dipping 70° E. This vein will be called the No. 1 vein. The most extensive ore shoot mined on the No. 1 vein was located immediately south of the shaft. This shoot was approximately 90 feet long and extended from the surface to the 160-foot level. A smaller ore shoot mined north of the shaft extended fiom the surface down to the 100-foot level. The vein width averaged 5 feet in the stoped areas, but vein splits formed mineralized zones as much as 20 feet wide in some places. The vein narrows north of the shaft and then finally grades into a simple quartz-filled fissure. The talus-covered slope makes uncertain what ultimately happens to the vein south of the shaft. The east-striking fault that displaced volcanic conglomerate against the granodiorite porphyry may form the terminus of the vein.

The vein (No. 2 vein) that passes through shaft No. 2 is not so regular as the No. 1 vein. At the shaft, the strike of the No. 2 vein is approximately parallel to that of the No. 1 vein, but it then bends to a due north direction and apparently joins the No. 1 vein approximately 200 feet north of the shafts. The Y-shaped vein junction was trenched on the surface, but the amount of ore extracted was not great. The principal ore shoot on the No. 2 vein occurred immediately south of shaft No. 2, where a stope extends from near the surface to the 110-foot level.

The exploratory adit south of shaft No. 1 is 250 feet long and was driven in a N. 80° W. direction. The adit was portaled in volcanic conglomerate and passes through that formation until the large north-striking fault exposed on the surface is intersected 180 feet in from the portal. The adit continues 70 feet farther west, cutting El Paso limestone. The fault, as exposed in the adit, is 2-5 feet wide, strikes N. 12° E., and dips 60° E. The only fluorite mineralization exposed in the adit is limited to a few tiny veinlets that follow the fault zone. The writer can-

• not explain why the No. 1 vein was not cut by the adit. The east-striking fault that passes approximately midway between the adit portal and shaft No. 1 appears to possess some right-lateral movement, to judge from the offset of the north-striking fault on the surface (pl. 8); thus, the vein should have been intersected by the adit, for the vein and fault both dip east. Perhaps the original fault that localized the vein did not pass from the granodiorite porphyry into the volcanic conglomerate.

## Greenleaf Mine

*Location.* The mine is situated on a gentle slope of alluvium that leads away from the southeast end of Fluorite Ridge. The location is further defined as near the center of sec. 18, T. 22 S., R. 8 W., being approximately 2,000 feet in a S. 60° E. direction from the Sadler mine.

*History.* The Greenleaf mine was one of the last mines developed in the district, but in spite of the late start the mine was one of the district's highest ranking producers of fluorspar. The Greenleaf claims that cover the deposit were staked in 1938 by Joe Baca, but serious development was not undertaken until 1940, when D. F. McCabe gained control of the property. The mine was worked steadily by McCabe until 1944, producing an estimated 20,000 tons of direct-shipping, metallurgical-grade fluorspar and milling ore combined. The mine apparently was shut down from late 1944 until 1949. The second period of activity extended from 1949 through 1954, when the mine was worked first by H. E. McCray (1949-1952) and then by W. A. White and R. W. Mathis (1953-1954). White and Mathis operated the mine under lease from the Cleveland Flux Co., the current owner. It is reported that the mine was forced to close because of the depressed conditions in the fluorspar market, and not because of a lack of ore. An estimated 20,000 tons was produced during the period 1949 to 1954, thereby boosting the total mine production to 40,000 tons.

*Geologic setting.* The surface surrounding the Greenleaf mine is covered mostly by Quaternary gravel. The geologic setting must be synthesized by combining the underground exposures with the neigh-

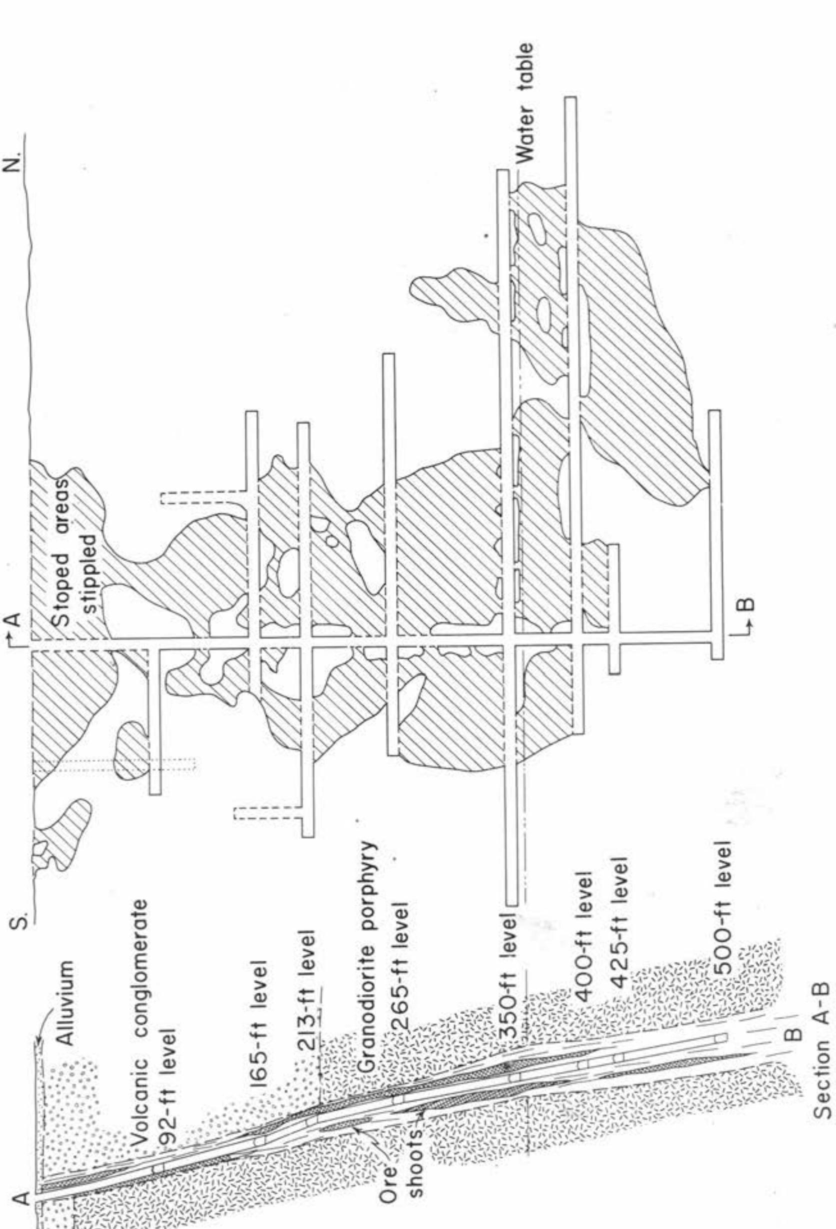



Figure 12. GREENLEAF MINE WORKINGS.
Compiled from mine owners' maps.

boring outcrop pattern. Volcanic conglomerate lies under a thin mantle of Quaternary gravel. The volcanic conglomerate, in turn, ranging from 20 to 200 feet thick, overlies the granodiorite porphyry. The presence of the granodiorite porphyry basement is substantiated by underground workings and outcrops at the Valley mine located three-fourths of a mile to the east.

A pediment surface on andesite breccia is exposed south of the Greenleaf shaft. It is postulated that a fault striking N. 70° W. displaced the andesite breccia against the volcanic conglomerate, the fault being a continuation of the one exposed south of the Sadler mine. The most prominent fault, however, is one that is exposed by the underground workings. This fault strikes N. 10°-30° E. and dips 60°-90° E. Rothrock et al. (1946) estimated a throw of 165 feet on the fault, the contact with the volcanic conglomerate being at a depth of 25 feet on the west side of the fault and 190 feet deep on the east. The fault is normal because the downthrown side is in the direction of the dip. The fault is exposed for only a short distance on the surface before it passes under the alluvium. Insufficient evidence is available upon which to base any sound conclusion as to whether the fault is related to either of the faults of similar trend that pass through the Lucky or San Juan mines. It is more likely that the Greenleaf fault is an entirely separate structure. In any event, the fault controlled the emplacement of the system of veins that constitute the Greenleaf ore zone.

*Mine workings.* The Greenleaf mine development consists of an inclined shaft 500 feet deep, with levels at 90, 165, 213, 265, 350, 400, 425, and 500 feet (fig. 12). The total level development amounts to approximately 3,000 feet of drifting and crosscutting. The most extensive level is the 350-foot level, which explored the vein 350 and 180 feet north and south of the shaft respectively. A maze of individual ore shoots allowed stoping to be conducted from the surface to the bottom level. Mining was by shrinkage stoping, and stopes were backfilled only as a convenient method of waste disposal. Ore was hoisted out of the sinuous inclined shaft in 1,200-pound-capacity buckets, which were loaded directly at the working place and then handtrammed to the shaft on dollies.

Water was encountered in the shaft at a depth of 367 feet. The inflow was considerable (as much as 650 gallons per minute) during the latter part of the life of the mine, when mining had opened up considerable ground between the water table and the 500-foot level. The water was troublesome because it weakened the stope walls and required the use of large pumps.

An inclined shaft was sunk in 1955 by White and Mathis about a quarter of a mile north of the Greenleaf mine on what was believed to be an extension of the same vein system. The shaft is inclined 70° S. and is 105 feet deep. The vein exposed is subeconomic. A shallow shaft and several trenches expose another vein about a quarter of a mile east of the Greenleaf mine, but the vein is weak, and the amount of ore removed must have been small.

*Ore bodies.* The. Greenleaf ore body is not one single vein; instead, it is a system of north-trending veins contained within the large fault zone described above. Vein junctions, splits, intersections, and small offsets are common. The vein system is much more complex in the deeper portions of the mine than nearer the surface, owing to the more extensive fracturing in the granodiorite porphyry during preore faulting than in the overlying volcanic conglomerate.

The veins are typical of the district, consisting essentially of quartz and fluorspar. Certain veins were brecciated and then recemented by additional quartz and fluorite, showing that minor movement occurred during the mineralization stages. Vein widths averaged about 4 feet in the stoped areas, and the ore averaged 50%-70% $CaF_2$. The size of the ore shoots that were mined was variable, ranging from mere pockets to lenses having a maximum dimension (in the plane of the vein) of 100 feet. In general, the ore shoots were slightly more persistent with depth than along the strike. The individual ore shoots terminated either against minor postore fault offsets or by pinching of the vein width. The ultimate vertical extent of the system is not known, however, for the 500-foot level (now flooded) is reported to have been in good ore when the mine shut down.

The tendency of the ore to occur in narrow lenses scattered throughout the fault zone was a hindrance to both development and exploration. Long-hole drilling into the stope walls proved to be a satisfactory method of prospecting for parallel veins, but narrow slices of wall rock between parallel veins caused considerable dilution of the ore during mining in certain areas of the mine.

## Grattan (Sadler No. 2) Mine

*Location.* The Grattan mine, also known as the Sadler No. 2, is located near the crest of Fluorite Ridge in the central part of the district. The mine is reached by a road that winds up to the ridge crest from the Lucky mine (pl. 8).

*History.* The Grattan mine was discovered by G. M. Sadler about 1909. A small tonnage of ore was produced by Sadler and others, but the deposit was not developed actively until P. L. Grattan purchased the property in 1934. The mine produced ore at a small but steady rate from 1934 through 1945. A large percentage of the ore was concentrated by flotation methods in a small mill erected by Grattan in Deming. Rothrock et al. (1946) estimated that the mine produced 12,000 tons by the end of 1944. The mine has been closed since 1945 except for a brief operating period in 1951, when Antonio Cristo obtained a lease from Grattan and produced a small amount of ore.

*Geologic setting.* The fluorspar vein at the Grattan mine is localized along the east margin of a basalt dike that intruded granodiorite porphyry. The average strike of the dike is N. 30° W., and dips range from 70° to 90° E. The age of the dike is believed to be late Tertiary or early Quaternary because the basalt is identical in appearance with similar dikes that cut Gila(?) conglomerate in other parts of the district. The dike is very sinuous, showing several splits and abrupt changes in strike, and its width ranging from 5 to 40 feet.

The country rock in the mine, excluding the basalt dike, is granodiorite porphyry, but Permian limestone and limestone-chert conglomerate form a thin cap resting on the granodiorite porphyry several hundred yards north of the mine. These sediments are an erosional remnant of the original roof that covered the granodiorite porphyry.

*Mine workings.* The mine has been developed by a vertical shaft sunk on the east margin of the basalt dike. According to Antonio Cristo (personal communication), the shaft is 434 feet deep, with levels spaced at intervals ranging from 50 to 100 feet. Mining was done by shrinkage methods. The granodiorite porphyry formed strong stope walls, but the blocky nature of the basalt probably caused considerable difficulty when stopes were mined in that rock.

On the surface, the vein has been explored by a series of trenches and shallow shafts for about 500 feet north and 800 feet south of the main shaft. The amount of ore removed from these shallow workings was small in comparison with that extracted through the main shaft.

*Ore bodies.* The writer was unable to descend into the main shaft because of uncertain conditions of ventilation and ladders. Rothrock et al. (1946, p. 139-140) described the deposit from an examination in 1943 as follows:

> The vein is in a crooked brecciated zone that dips 80° E. and generally follows the east side of the dike. The zone is rather finely brecciated within a few feet of the east wall of the vein, but elsewhere the rock is broken by more or less vertical fractures which on the west side extend as much as 40 feet from the finely brecciated zone. The larger veins of fluorspar occur in the finely brecciated rock, and the adjoining fractured rock contains fluorspar stringers. The deposit has a vertically banded appearance caused by wide strips and irregular masses of dark rock alternating with light fluorspar veins. The veins have been considerably shattered by post-mineral movement and contain many open fractures which increase the hazard of mining.
>
> On the surface the vein has been trenched and stoped almost continuously for 480 feet, but the lengths underground are not so great. The longest ore body underground is at the 200-foot level, where ore was mined for 120 feet north and 160 feet south of shaft No. 1. The ore shoots have an average aggregate thickness of 2 to 4 feet. Mining operations indicate that the depth of the ore body exposed at the surface is about 100 feet, whereas that of the body mined from the 200-foot level is at least 70 feet. The vein in the bottom of the shaft at a depth of 225 feet contained only narrow stringers of fluorspar, but when the shaft was deepened to 245 feet in 1945 another body of ore 21/2 feet thick was exposed.

> The vein is composed of coarsely crystalline white or light green fluorite, with intimately associated quartz that forms incrustations on vein walls and around rock fragments. The intervening spaces are filled with fluorite except for scattered vugs some of which are lined with drusy quartz. Deposition of quartz thus took place chiefly before the crystallization of the fluorite, but some quartz was formed later. The grade of the ore mined during 1942-1944 was estimated to average 50-55 percent $CaF_2$ and 20-25 percent $SiO_2$ (oral communication from Lynch Grattan, manager of the Grattan mines and mill).

The shaft was deepened to 434 feet after Rothrock's examination. Antonio Cristo (personal communication) stated that several additional ore shoots .were mined between the 200-foot and 400-foot levels during 1945 and 1951.

## Other Mines and Prospects

*San Juan mine.* The mine is located approximately 800 feet east of the Sadler mine (pl. 8). The San Juan unpatented mining claim on which the mine is located is owned by Cooper Shapely. The mine has not been worked since World War II, and the underground openings could not be entered; therefore, the description that follows is based solely on observations made at the surface. The total amount of ore removed was probably less than 5,000 tons.

The deposit consists of several north-trending fluorspar veins localized along small displacement faults subsidiary and parallel to a normal fault that displaced volcanic conglomerate against granodiorite porphyry (pl. 8). The strongest vein is located a short distance into the granodiorite porphyry footwall. The vein strikes N. 10° E. and dips 65° E. A vertical shaft, 320 feet deep according to the mine owner, was sunk on the south end of the vein, where the best ore crops out. The vein is traceable through a series of trenches and shallow shafts for approximately 1,000 feet north of the main shaft, but the northern part of the vein contains only thin stringers of fluorspar, which finally grade into a simple quartz vein. The vein cannot be followed south of the shaft, because the bedrock is concealed by Quaternary gravel.

Another north-trending fluorspar vein was prospected approximately 100 feet east of the first vein. The second vein is either in or immediately adjacent to the fault that separates the volcanic conglomerate from the granodiorite porphyry. The vein can be traced for only a short distance, and little ore was extracted. Several other minor veins also exist in the area.

*Lucky mine.* The Lucky mine is located at the east end of Fluorite Ridge, about one-half mile north of the Greenleaf mine. The mine was one of the first discovered in the district, but in spite of considerable underground development, only a few thousand tons of fluorspar have been mined.

The deposit consists of several narrow fluorspar veins located in and adjacent to a N. 10° E. normal fault that dips 60°-80° E. The fault forms the contact between Gila(?) conglomerate (hanging wall) and volcanic conglomerate (footwall). These are the only rock types that crop out in the mine area. The strongest vein exposed is controlled by the plane of the fault just mentioned, but several smaller parallel veins also occur in the footwall. The main vein was stoped from the surface to a depth of 50 feet over a strike length of 100 feet by the early-day miners. The Great Western Mining Co. sank an inclined shaft on the main vein during 1942-1943. The shaft was inclined 57° S. and was 310 feet in length (260 feet deep vertically). Other work consisted of 120 feet of drifting on the 200-foot level (vertical depth) and 210 feet of drifting on the 250-foot level. Although the drifts apparently were driven on the vein exposed on the surface, very little minable ore was found, and the mine was shut down.

The mine was reopened in 1952 by the Sierra Mining Co. The shaft was sunk an additional 90 feet (inclined at 80° S.), bringing the total shaft length to 400 feet, or 350 feet below the collar elevation. Drifts were cut at the 290-foot and 350-foot levels, and a small ore shoot was stoped north of the shaft between the 250-foot and 200-foot levels. The vein as exposed on the two bottom levels (290-foot and 350-foot) was not wide enough to be mined.

Above the 250-foot level, the vein has a volcanic conglomerate footwall and a Gila(?) conglomerate hanging wall, but on the 250-foot level, granodiorite porphyry is exposed a short distance into the footwall. The same rock is exposed again in a short crosscut into the vein footwall on the 350-foot level. The writer interpreted these exposures as indicating that the vein flattened and swung out eastward from the main fault with increasing depth, and that the granodiorite porphyry underlies the volcanic conglomerate at a local depth of less than 250 feet. The structural setting, therefore, is similar to that of the Greenleaf mine.

*Green Spar (Grattan State Land) mine.* The Green Spar mine, one-half mile northwest of the Grattan mine, is the westernmost fluorspar deposit in the district. The mine is located in sec. 2, T. 22 S., R. 9 W., which is owned by the State. During World War II, P. L. Grattan held a mineral lease from the State covering the deposit, and the mine was called at that time the Grattan State Land mine (Rothrock et al., 1946). Subsequently, Oscar Abrahams obtained the mineral lease, and the mine was renamed the Green Spar. The mine also fits the description of the Cox prospect described by Johnson (1928). Total fluorspar production from the mine is estimated to have been 3,000 tons, most of which was mined during World War II.

The mine is located in a geologic environment somewhat similar to that of the Grattan mine. The host rock is granodiorite porphyry, but erosional remnants of the original sedimentary roof, composed of the Abo formation and Sarten sandstone, cap the granodiorite porphyry immediately above (northwest) of the mine. These sediments are on the south limb of an elongated domal structure formed by the intrusion of the granodiorite porphyry (pl. 8). Fluorspar is limited to a group of closely spaced veinlets contained within a north-trending shear zone in the granodiorite porphyry. The shear zone is as much as 30 feet wide, but commercial ore is limited to only a fraction of this width. The veins range in strike from N. 30° W. to N. 15° E., and the dips range from 65° W. to 80° E. Individual vein widths seldom exceed 1 foot. The vein system can be traced for approximately 700 feet.

The deposit has been developed by a small open cut and by a vertical shaft 110 feet deep, with drifts excavated on the 60-foot and 110-foot levels. On the 60-foot level, drifts explore the vein system 120 feet north and 40 feet south of the shaft, whereas on the 110-foot .level, drifts extend 80 feet north and 20 feet south of the shaft. The veins exposed in the underground workings were narrow, and little ore was stoped. Most of the ore mined came from the open cut.

*Valley mine.* The Valley mine is located in the extreme eastern part of the district, about three-quarters of a mile southeast of the Sadler mine. The deposit was worked during the early 1950's by **H.** E. McCray, the current owner. The mine area actually is covered by Quaternary silt and gravel, but the mine workings have exposed granodiorite porphyry bedrock at a very shallow depth. Trenches nave exposed a vein that strikes N. 14° W., dips 85° E., and is traceable for 800 feet. Where observed, the vein consists only of quartz and fluorspar and has an average width of 1 foot. The granodiorite porphyry is thoroughly silicified and bleached adjacent to the vein. A vertical shaft, estimated to be 75 feet deep, was sunk on the northern end of the vein. The amount of ore produced must have been small, in view of the little amount of work done on the property.

Rothrock et al. (1946) have described several other mines and prospects in the Fluorite Ridge district, and the reader is referred to their report for additional information.

## RECOMMENDATIONS FOR FUTURE PROSPECTING IN THE • FLUORITE RIDGE MINING DISTRICT

The district is now dormant because of two basic reasons, the depressed conditions of the fluorspar market and the lack of appreciable reserves of developed ore. Most of the principal veins have been worked to extinction, and there has been little incentive for conducting an extensive exploration campaign to discover new ore in view of the low price received for fluorspar since 1954. (Acid-grade fluorspar dropped from $60-$65 per ton in 1953 to $47 per ton in 1955.) A rejuvenation of the district will depend on a radical improvement in the fluorspar price, coupled with the reopening of custom mills to upgrade the ore into a salable product.

In future prospecting, consideration should be given to the area lying between the Greenleaf and Valley mines. Granodiorite porphyry, the best ore host in the district, underlies this area at a relative shallow depth, being overlain by Gila(?) conglomerate and Quaternary gravel. Prospecting this area, however, will be difficult, the cover of Quaternary gravel necessitating drilling or the excavation of deep trenches to expose bedrock.

## FLORIDA MOUNTAINS MINING DISTRICT

### GENERAL

The Florida Mountains mining district is limited to the main mountain range. The manganese and fluorspar deposits located in the hill group known as the Little Florida Mountains, located north and detached from the main Florida Mountains, are classed as a separate district.

The Florida Mountains, one of the most prominent topographic features of Luna County, are a rugged north-trending range located southeast of Deming. The range is 10 miles long and as much as 5 miles wide. The highest peaks are Arco del Diablo, South Peak, and Gym Peak, each extending above 7,000 feet. The altitude of the surrounding bolson plain is approximately 4,200 feet; therefore, a maximum relief of 2,800 feet is present. Several roads lead to the base of the mountains, but access into the interior of the range is gained only on foot.

Lead, zinc, copper, silver, and gold have been mined from the district in the past, mostly in the period 1880-1920. Manganese deposits were exploited on the southeast slopes during the 1950's, when the manganese purchasing program of the U. S. Government was in effect. Mining activity is now at a standstill.

### GEOLOGY

Figure 14 is a geologic sketch map of the range, including the Little Florida Mountains on the north. The geology of the area is exceedingly complex, and only the general features will be described. For a fuller discussion of the geology the reader is referred to Darton (1917), Balk (1958), Bogart (1953), Kelley and Bogart (1952), and Kottlowski (1958).

#### Precambrian Rocks

The bulk of the Florida Mountains is composed of Precambrian rocks. The Precambrian consists of four types: (1) light-pink, medium- to coarse-textured granite; (2) gray, fine-grained porphyritic granite; (3) gneissic granite; and (4) dark-gray to greenish-black diorite and gabbro. The pink granite is the most common variety, and the rock weathers to brown rugged forms and blocks. The diorite and gabbro appear as wide sheets and masses intruded by the pink and gray granite. The Stenson mine is located within such a diorite mass. The gray granite is probably a facies of the more common pink granite, and the gneissic variety simply represents areas of intense metamorphism.

## Sedimentary Rocks

Sedimentary rocks in the Florida Mountains range from Ordovician to Tertiary. Table 14 summarizes the sequence.

TABLE 14. SUMMARY OF SEDIMENTARY ROCKS IN THE FLORIDA MOUNTAINS

| AGE | FORMATION OR GROUP | DESCRIPTION | THICKNESS (feet) |
|---|---|---|---|
| Tertiary | Gila(?) conglomerate | Silt, poorly cemented sandstones, sorted gravels, and volcanic conglomerates. | 1,000+ |
| Cretaceous(?) | Lobo formation | Interbedded red and buff calcareous siltstones, chert-pebble lenses, and limestone conglomerate. | 250-300 |
| Permian | Hueco limestone | Dark-gray, thick-bedded limestone. | 360+ |
| Mississippian | Lake Valley limestone | Gray, cherty limestone, with some interbedded shale. | 200+ |
| Devonian | Percha shale | Black, fissile shale. | 235+ |
| Silurian | Fusselman dolomite | Medium- to thick-bedded, gray to dark-gray dolomite. | |
| Ordovician | Montoya dolomite | Medium- to thick-bedded dolomite and limestone; sandy dolomite (Cable Canyon) at base. | |
| | El Paso limestone | Upper unit of thin- to thick-bedded, light-gray to blue-gray limestone; lower unit of dark-gray, thin-bedded, medium-grained crystalline dolomite. | 1020 |
| --------------------- Cambrian | Bliss sandstone | White orthoquartzite, pale-buff to brown sandstone, limy sandstone, and sandy limestone. | 50-185 |

The thicknesses of the Fusselman and Montoya dolomites have not been measured in the Florida Mountains because complete sections are not exposed, owing to complicated structure and pre-Cretaceous erosion.

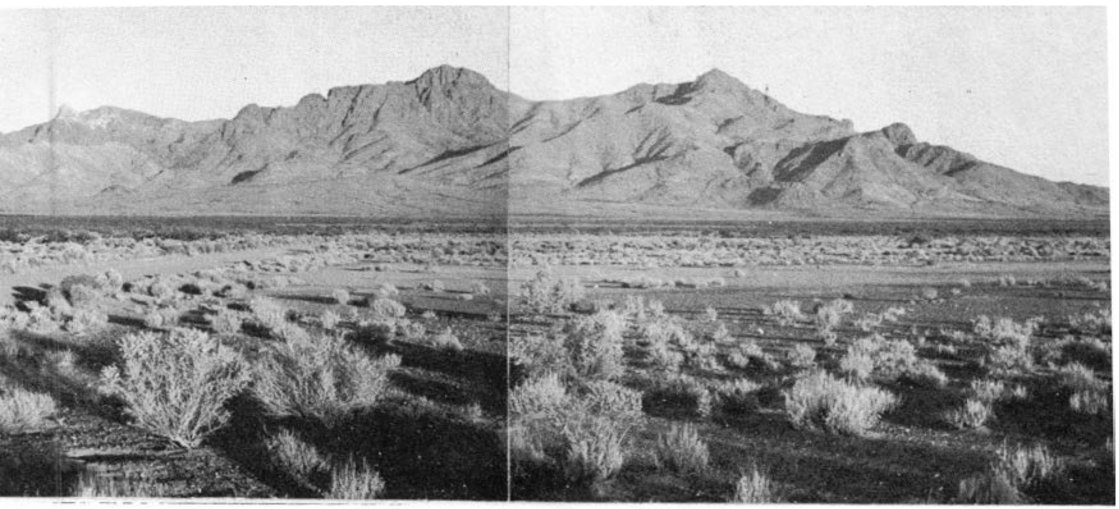


Figure 13. Florida Mountains.
Viewed from the west.

According to F. E. Kottlowski (personal communication), the thicknesses should approximate those in the Franklin Mountains, where Pray (1958) reports 429 feet of Montoya and 610 feet of Fusselman.

The geologic sketch map (fig. 14) shows only two divisions of the Paleozoic rocks. The upper group contains the Devonian to Permian sediments, and the lower group the Ordovician to Silurian. The Gila(?) conglomerate is not distinguished separately on the map; instead, it is grouped with the Tertiary agglomerate sequence (described below). Darton (1917) did not distinguish such a conglomerate formation, but the writer feels that the upper portion of his agglomerate 'sequence is best termed Gila(?) conglomerate because it is simply water- and wind-deposited alluvium devoid of any evidence of volcanic origin.

Pennsylvanian rocks are absent in the Florida Mountains. Kottlowski (1958) has advanced the theory that the entire region around the Floridas was a highland (island) during late-Pennsylvanian and early-Permian times.

## Igneous Rocks

Except for the Precambrian, large masses of intrusive rocks are absent in the Florida Mountains. Several northeast-trending rhyolite dikes and one basic dike of the same orientation cross the central portion of the range. These dikes are of Tertiary age.

The north end of the Florida Mountains is covered by a thick sequence of Tertiary agglomerate containing lenses of tuff, conglomerate, and siltstone, along with a few thin flows. The agglomerate is composed mostly of angular fragments of andesite and latite embedded in a gray or purplish tuff matrix. The sequence is rudely stratified, showing a northerly strike and easterly dip throughout most of the range. In the Little Florida Mountains, agglomerates of a similar character overlie a series of rhyolite flows. Although continuous outcrops between the two ranges are absent, it appears likely that the rhyolite is an intraformational unit of the agglomerate sequence, with the Florida agglomerate

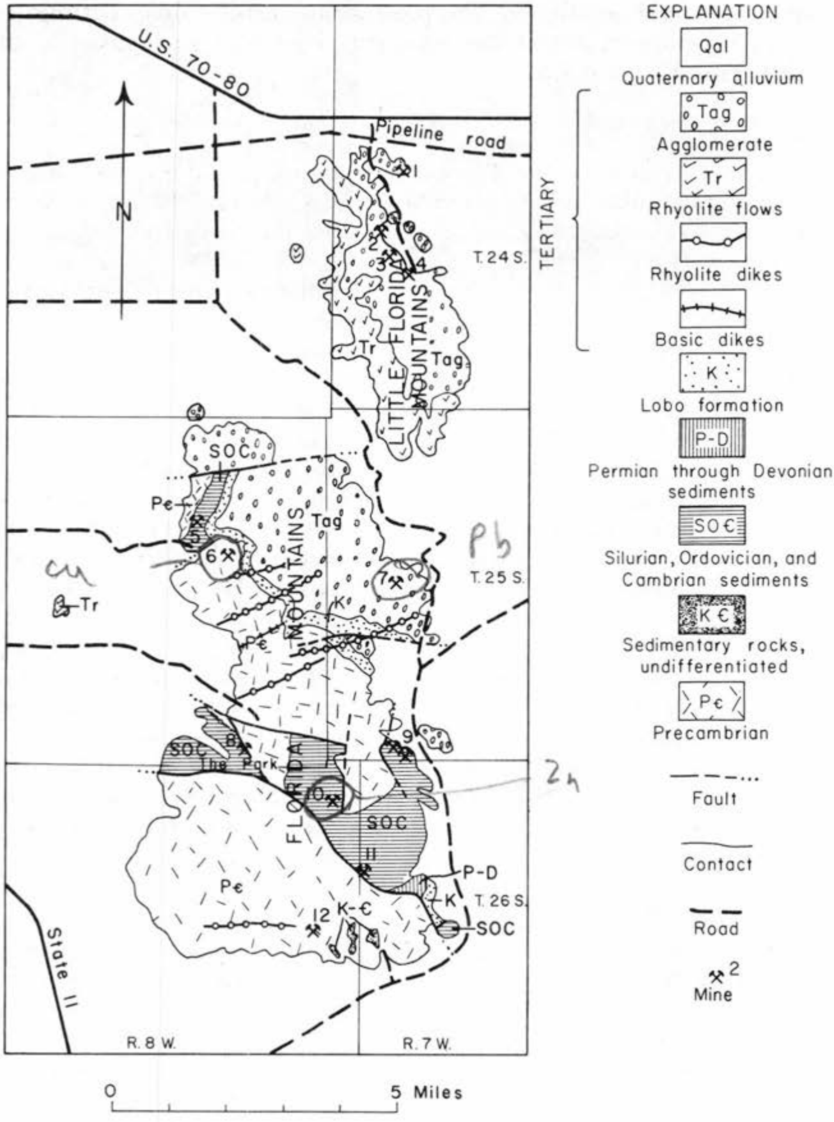



Figure 14. Geologic sketch map of the Florida and Little Florida Mountains.

Adapted from Darton (1917) and Lasky (1940). Index of mines (1) Spar mine; (2) Luna mine; (3) Killion mine; (4) Manganese Valley mine; (5) San Antonio mine; (6) Stenson mine; (7) Bradley mine; (8) Park mine; (9) Birchfield and White King manganese mines; (10) Lucky John mine; (11) Silver Cave mine; (12) Wet King manganese mine.

at the base and the Little Florida agglomerate at the top. Such a relationship would account for the presence of rhyolite dikes cutting the Florida agglomerate and the apparent absence of such dikes in the Little Florida Mountains.

### Structure

The structure of the Florida Mountains is complicated; indeed many of the problems have yet to be solved. Only a few of the significant features will be discussed here, with reliance on the early investigations by Darton (1917).

In general, both ranges (the main range and the Little Florida Mountains) are homoclinal structures with easterly dips. In the Florida Mountains, Precambrian rocks are exposed on the west side. Lower Paleozoic beds overlie the granite in the vicinity of Capitol Dome and in the Gym Peak area. A triangular block of Lower Paleozoic rocks has been downfaulted in The Park, northwest of South Peak. The beds dip to the east in all three of these areas, although the attitudes vary locally.

Upper Paleozoic rocks are limited to a small .exposure southeast of Gym Peak, where beds of Devonian, Mississippian, and Permian age are preserved on the dip slope of the much larger block of Lower Paleozoic rocks that form Gym Peak. Erosion and faulting have removed the Upper Paleozoic rocks in other parts of the range.

Considerable faulting, uplift, and erosion took place in the Florida Mountains during Pennsylvanian, and again during late-Permian or early-Cretaceous, time. Pennsylvanian rocks are entirely absent; the area is believed to have been an island during this period (Kottlowski, 1958). Evidence of pre-Lower Cretaceous faulting is well illustrated in the vicinity of Capitol Dome, where a northeast-striking fault of considerable magnitude passes underneath undeformed Lower Cretaceous sediments.

A large northwest-striking reverse fault extends from south of Gym Peak, across the range, and into The Park. This fault uplifted Precambrian granite on the south against Paleozoic and Lower Cretaceous rocks on the north. The displacement along the fault is estimated at 2,000 feet (Darton, 1917). Another large fault crosses the extreme north end of the range in an eastward direction, displacing the Tertiary agglomerate downward against Precambrian and Lower Paleozoic rocks. Many other faults further complicate the structure; their dominant trend is east.

An odd structural feature of the Florida Mountains is the occurrence of several blocks of Lower Cretaceous and (or) Paleozoic sediments entirely surrounded by Precambrian granite. These blocks are located on the southern slopes of the range, southeast of Gym Peak. Darton (1917, p. 10) explained these blocks as due to thrust faulting from the east.

DESCRIPTION OF THE MINES AND PROSPECTS

## Silver Cave Mine

*Location and access.* The deposit is located on the south slope of Gym Peak, in the SW1/4 sec. 7, T. 26 S., R. 7 W. The mine workings can be reached on foot from the road that skirts the east flank of the mountain range.

*History.* The deposit is said to have been worked in the period 188185 by the Carroll brothers. During this time a total of 1,800 tons of oxidized lead-silver ore was shipped, valued at $60,000 (Jones, 1904). The mine then lay idle until 1903, when the owners attempted to revive production. There is no known record of production, however, since 1885, and signs of recent activity at the mine site are absent. The deposit is covered by two patented claims, the Silver Cave Lode (M. S. 644) and the Pocohonta Lode (M. S. 632). The claims are listed on the county tax rolls as the property of L. R. Oldham, **H. M.** Raithel, and C. R. Scott.

*Geology of the deposit.* The mine is located on the north slope of an arroyo that drains to the east. Near the mine, the arroyo follows a large northwest-trending fault that has displaced Paleozoic sediments (on the northeast) against Precambrian granite (on the southwest). Farther east, the fault trace climbs the south slope of the canyon and then abruptly swings to the south.

The block of Paleozoic rocks northeast of the fault is a homocline dipping to the east and forms the bulk of Gym Peak. The beds range from Ordovician to Permian in age. Darton (1917) placed the Silver Cave mine in an area underlain by what he called Gym (Permian) limestone. Actually, the mine is within a massive, gray dolomite that the writer believes to be Fusselman dolomite. Complicated structure and intense silicification make accurate age definition difficult.

In the vicinity of the mine, the Fusselman(?) dolomite strikes N. 45° E. and dips 40° SE. A basic dike about 5 feet wide, trending N. 5° E. and dipping 70° W., has cut the dolomite. A steep incline was driven along the hanging wall of this dike. Little mineralization occurs at this location, but the incline apparently served as an extraction opening for ore stoped farther up and into the hillside.

A shallow shaft was sunk about 150 feet northeast of the portal of the incline, and some stoping was done on a N. 80° W. fracture zone containing replacement pods of oxidized lead-zinc ore. Little ore is left. The ore mineral was cerussite, accompanied by smithsonite(?), limonite, calcite, and quartz. The stope openings are not accessible without the aid of ladders, but they are believed to extend downward to the level of the incline. The mine dumps do not indicate a large amount of underground development.

Prospect pits are scattered over the hillside in the vicinity of the Silver Cave mine, but no important ore occurrence was noted in any of these openings.

## Lucky John (Mahoney) Mine

*Location and access.* A lead-zinc-copper deposit is located on a high ridge about 1 mile north of Gym Peak; the location, as best could be determined, is sec. 1, T. 26 S., R. 8 W. The deposit can be reached only on foot.

*History.* The date of discovery is not known, but Darton (1917) indicated that the mine was worked as early as 1914. Several ore shipments are believed to have been made in 1915-17 and 1926. The mine was, and still may be, the property of the J. A. Mahoney Estate. There are no patented claims in the area, and the writer was not able to find any claim notices posted on the property. Signs of recent activity are absent.

*Description of the deposit.* The deposit is located in a block of Paleozoic sediments almost completely surrounded by Precambrian granite (fig. 15). The block dips gently to the east for the most part, but locally the attitude varies greatly.

The lead-zinc-copper mineralization is limited to a series of east-trending vertical veins in a gray dolomite believed to be Fusselman. In the vicinity of the mine, the beds strike almost due north and dip 10°50° E. Five distinct east-trending veins, as well as several other weakly mineralized zones, crop out on the crest of the ridge. Development consists of trenching on the veins, several vertical shafts, and one long adit driven into the ridge from the east side about 200 feet below the crest.

Several stopes have broken through to the surface; in these openings the vein widths range from 0.5 foot to 4 feet. The vein material is much oxidized at the surface, containing smithsonite, cerussite, malachite, and azurite as the ore minerals, in a gangue of limonite, quartz, barite, and calcite. A few specimens of galena were noted; apparently some sulfide ore was mined at depth. The strength of the vein outcrops tempts one to recommend this property for further development, but its remoteness would make the cost of such a program extremely high.

## San Antonio Mine

*Location and access.* A lead-zinc deposit is located about a quarter of a mile west of Capitol Dome near the base of the mountains. The area is reached by a truck trail leading south from the Spanish Stirrup road (fig. 14). The precise location is SE1/4 sec. 10, T. 25 S., **R.** 8 W.

*History.* The time of discovery and record of ore shipments are not known. The San Antonio group of unpatented claims, belonging to W. J. Upton, cover the deposit. Two patented claims, Sunset (M. S. 642) and Sunrise (M. S. 643), lie in the same general area; these claims are owned jointly by L. R. Oldham, H. M. Raithel, and C. R. Scott. Wade White did a minor amount of development work on the San Antonio claims in 1954, but little ore was shipped.

*Description of the deposit.* The local geologic setting is a block of east-dipping Ordovician sediments bounded on the north and south by east-trending faults, on the west by Precambrian granite underlying the sediments, and on the east by Tertiary sediments and agglomerates that overlie the Ordovician sequence. The sedimentary section exposed here has been described by Balk (1958) and is summarized as follows:

| | |
|---|---|
| LOBO FORMATION (Lower Cretaceous?) | Siltstone, chert pebble lenses, and a limestone conglomerate (250-300 feet). |
| MONTOYA GROUP (Ordovician) | Limestone and dolomite (35-125 feet). |
| EL PASO GROUP (Ordovician) | An upper part of gray limestone (865 feet) and a lower part of dark-gray dolomite (155 feet). |
| BLISS SANDSTONE (Ordovician and Cambrian) | Sandstone, orthoquartzite, and limy sandstone (50-185 feet). |

The lead-zinc deposits are restricted to the lower dolomite member of the El Paso group. The principal veins occur in and near a west-draining arroyo, where the sediments strike N. 10°-25° E. and dip 30°-40° E. On the north side of the arroyo, two shallow shafts have been sunk on two east-striking veins that dip steeply to the north. The veins are very narrow at the surface, the maximum width being about 2 feet. Several hundred feet south of the arroyo, two other narrow veins have been prospected, one striking N. 30° W., the other, N. 85° E. The exposed parts of the veins contain minor amounts of cerussite and smithsonite(?) in a gangue of limonite, calcite, and quartz.

Still farther south, a short adit was driven on a vertical vein striking due east just above the base of the El Paso group. The dip of the sediments increases to 60° E. here, but otherwise the mineralization is similar to that described above.

The amount of dump material present on the property indicates only a minor amount of underground work; likewise, the amount of ore shipped must have been small.

## Stenson Mine

*Location and access.* A small copper mine, called the Stenson, is located about 1 mile south of the San Antonio mine, near the center of sec. 14, T. 25 S., R. 8 W. The deposit can be reached by a dirt road trending to the east that leaves State Highway 11, 9 miles south of Deming. The distance from the highway to the mine is 6 miles.

*History.* The deposit is described by Lindgren et al. (1910) as having had about 1,000 feet of underground development by 1910. Since that time, another adit has been driven an additional 650 feet. An examination of the workings indicated that little stoping had been done; therefore, the amount of ore shipped must have been small. The deposit is covered by five patented claims, the Alabama, Georgia, South Carolina, Sunny Slope, and Western Slope, all part of Mineral Survey No. 1749. The county tax rolls list the claims as the property of Mrs. Lois Upton.

*Description.* The deposit is located within the large exposure of Precambrian rocks on the western slope of the range. The Precambrian consists of red and gray, coarse-grained granite, gabbro, and diorite(?). In the vicinity of the Stenson mine, a dark-gray, medium-grained rock, believed to be diorite, is predominant.

A small vein-fault zone trending N. 70° E., with dips ranging from 65° to 85° S., traverses the Sunny Slope and Georgia claims (fig. 15). Development consists of three adits and one shaft. The upper adit is caved at the portal, but is reported to be 150 feet long (Lindgren et al., 1910). A shaft from the surface extends through this level about 70 feet in from the portal. The middle adit is accessible for 390 feet, at which point it is badly caved. A raise, located 320 feet inside the portal, is reported to connect with a sublevel 60 feet above; the shaft from the surface also connects with the sublevel. The lower adit contains a total of 650 feet of workings, but of this distance only 500 feet was driven along the vein structure.

The exposures in the middle adit show a weak vein containing chalcopyrite, pyrite, magnetite, and quartz. The vein is partially oxidized, yielding malachite and limonite. The vein width varies widely, but the mean width is 3 feet. Much postore fault movement is evident along the vein.

In the lower adit, a definite vein is not visible. Instead, a zone 40 feet or more wide contains numerous randomly oriented veinlets and disseminations of pyrite and chalcopyrite. On the surface, in the vicinity of the portal, the diorite(?) is altered by bleaching and contains much limonite. The average grade of the zone explored by the lower adit is low, probably only a fraction of 1 percent copper.

### Bradley Mine

*Location and access.* A lead-zinc-silver prospect is located in sec. 18, T. 25 S., R. 7 W., about 1 mile southwest of the Nunn ranch. The property is reached by the road that passes through the gap between the Florida and Little Florida Mountains. A trail leaves this road 1 mile

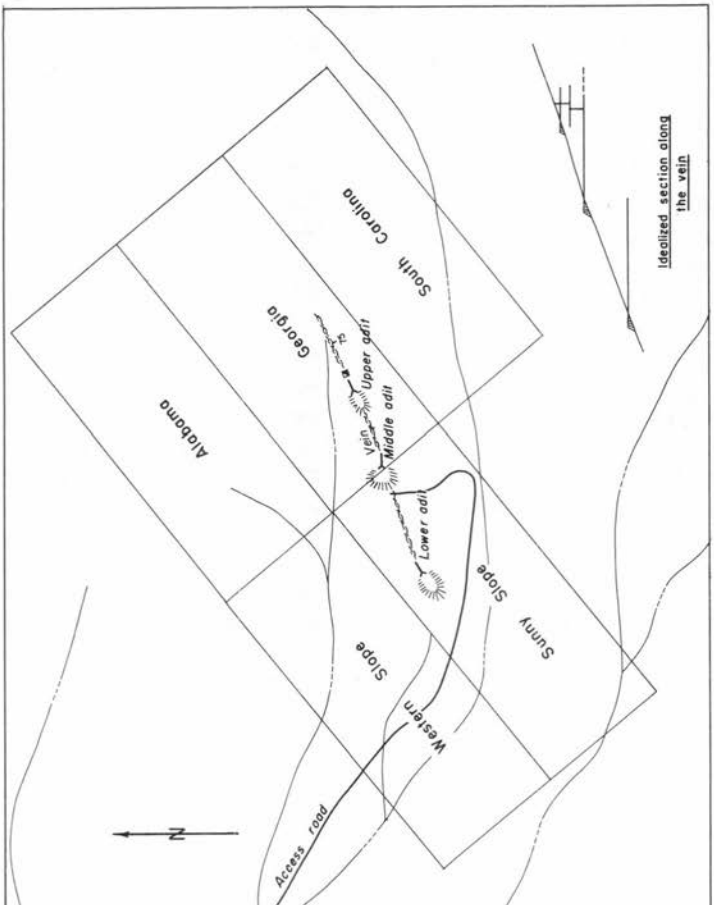



Figure 15. SKETCH MAP OF THE STENSON MINE.

south of the Nunn ranchhouse and leads three-quarters of a mile west to the mine.

*History.* This mine is believed to be one of the oldest in the district, having been worked in the early 1900's or earlier. The writer was not able to obtain a complete record of production, but one shipment was recorded in 1927 (Mineral Resources of the United States, 1927, part 1). The mine is believed to be owned by W. P. Birchfield, Jr.

*Description of the deposit.* The deposit is located in the Tertiary agglomerate sequence. In the vicinity of the mine, the agglomerate is composed of light brownish-gray tuffs and conglomerate beds that strike northwest and dip 10°-30° NE. An east-striking vein with vertical dip cuts the agglomerate. The vein has been developed by trenching and stoping for about 200 feet along the strike. The material on the dump indicates that the vein contains galena, sphalerite(?), and minor chalcopyrite, in a gangue of pyrite, limonite, calcite, and quartz. The vein width is variable, but the average is estimated to be 2 feet. Two large cuts were made in a tuff bed a few hundred feet west of the vein outcrop. These cuts do not show a distinct vein structure; copper stains, however, are present as streaks in the tuff.

### The Park (Hilltop) Mine

*Location and access.* An old zinc mine is located in what is known as The Park, a large amphitheater on the west side of the Florida Mountains. The precise location is the center of the S1/2 sec. 35,T. 25 S.,R. 8 W. The deposit can be reached by traveling 6.7 miles east to the end of a dirt road leaving State Highway 11 approximately 11 miles south of Deming. The road ends at an abandoned ranchhouse, from which the mine lies about one-half mile to the south.

*History.* The date of discovery and past ore shipments are not known. A discovery notice is posted nearby, which states that A. J. Malin staked the Hilltop claim over the deposit on December 20, 1958. The workings on the claim indicate that most of the development was done many years prior to Malin's staking.

*Description of the deposit.* The deposit is located near a northwest-trending fault that has displaced Precambrian granite on the northeast against Lower Paleozoic sediments on the southwest. The general attitude of the sediments is one of northeast strike and southeast dip. In the immediate area of the mine, however, the beds are contorted, presumably caused by movement on the aforementioned fault, which lies immediately to the northeast. The sediments at the mine are gray, crystalline, calcic dolomite beds, which weather to tan and grayish black. The beds are probably members of either the Montoya or Fusselman dolomite.

Several trenches, shafts, and pits expose indistinct veins that trend northwest and dip steeply to the southwest. The most promising vein strikes N. 55° W. and dips 65° S. The vein material is thoroughly oxidized, and the ore mineral is "dry bone" smithsonite accompanied by a minor amount of cerussite. Limonite is abundant. A grab sample from a small pile of handsorted ore near one of the pits assayed 26.4 percent zinc and a trace of lead. The sample is not to be considered as representative of the ore in place.

An adit was noted a quarter of a mile south of The Park mine, but it was not examined. It is in Precambrian rock.

*Manganese deposits.*[8] There are numerous manganese deposits in the Florida Mountains. Prominent among these are:

Birchfield mines, secs. 5 and 6, T. 26 S., R. 7 W., and secs. 31 and 32, T. 25 S., R. 7 W.

White King mine, SE1/4 sec. 31, T. 26 S., R. 7 W.

Wet King mine, NW 1/4 sec. 13, T. 26 S., R. 8 W.

These mines are reported to have shipped small tonnages during World War II, and again in the middle 1950's.

*Other deposits.* The Florida mining district has remained dormant, except for manganese mining, for a number of years. During the field investigation of the district, the writer did not have the advantages of an experienced guide to show him where the various mines and prospects are located. Hence, it is certain that a number of deposits were completely missed. After the termination of field work, the writer learned of the existence of several additional prospects, but time would not allow a reexamination of the area. These deposits are:

Birchfield zinc prospect, a zinc prospect located in the SW1/4 sec. 32, T. 25 S., R. 7 W. A carload of ore was reported to have been shipped from the deposit in 1949.

Shaw prospect, a copper prospect located in sec. 35, T. 25 S., R. 8 W. This prospect may be the adit noted south of The Park mine (see p. 127).

Waddel prospect, a galena, barite, and fluorspar deposit located in the S1/2 sec. 24, T. 25 S., R. 8 W. This deposit may have been remaned the Atir mine, in which case it was briefly explored by the Consolidated Minerals Corp. in 1959.

Edna Belle prospect, a lead prospect located in the W1/2 *sec.* 18, T. 25 S., R. 7 W. This deposit may be the same as the Bradley mine described above (see p. 125).

Window Mountain mine. Darton (1917) mentions a prospect of this name but fails to describe it.

Uranium occurrence. Purple fluorite containing a radioactive mineral is reported from the district, but the location of the occurrence is not known.

8. Manganese deposits are not described in detail in this report. See page 36.

# LITTLE FLORIDA MINING DISTRICT

## GENERAL

The Little Florida mining district consists of manganese and fluorspar deposits located on the east slopes of the Little Florida Mountains, an isolated hill group lying immediately north of the main Florida Mountains. Access is gained into the district by a gravel road leading south from U. S. Highway 70-80 approximately 9 miles east of Deming.

## GEOLOGY

The geology of the Little Florida Mountains has been described by Lasky (1940), and the reader is referred to that work for a detailed discussion. The Little Florida Mountains are essentially a north-trending ridge 5 miles long and as much as 2 miles wide, composed of east-dipping felsite flows and tuffs capped by a thick sequence of agglomerate (fig. 14). Lasky believed that this agglomerate sequence was mainly of sedimentary origin and thus called it a fanglomerate. The present writer, however, believes that the portions which cap the ridge (i. e., which directly overlie the felsites), are mostly true agglomerates composed of angular fragments of volcanic rocks embedded in a tuffaceous matrix. Conglomerate lenses are present, but they constitute only a fraction of the total thickness of the formation.

Farther east, away from the main ridge, conglomerate, sandstone, and water-laid tuff crop out as patches surrounded by Quaternary alluvium. These sedimentary beds are well exposed in several cuts along U. S. Highway 70-80 and at the Spar mine. The writer believes these beds to be Tertiary gravels (Gila? conglomerate). Therefore, there are three divisions of the Tertiary rocks in the Little Florida Mountains: felsite flows and tuffs at the base, an agglomerate sequence that lies unconformably on the felsite, and a layer of Gila(?) conglomerate resting on the agglomerate.

Numerous north-striking faults of small displacement cut the Tertiary rocks. These faults provided the zones for fluorspar and manganese deposition. Postore movement is evident, but it is not extensive.

## MANGANESE DEPOSITS

Lasky (1940) has described the manganese mines as they were developed in 1939, and the U. S. Bureau of Mines is reported to have reexamined the mines within the last few years. Therefore, only a brief description will be necessary here.

The first manganese ore was shipped from the district in 1918, and by 1939 over 16,000 tons of 45-percent manganese ore had been produced, mostly from the Manganese Valley mine. A few small shipments were made during World War II, but it was not until 1952 that the district was reactivated under the stimulus of the U. S. Government manganese buying program. The district produced manganese at a substantial rate

from 1952 until the mines were forced to close by the termination of the Government's buying program in September 1959.

The principal mines and their locations are:
Manganese Valley, SE I/ sec. 19, T. 24 S., R. 7
W. Killion, NW1/4 sec. 19, T. 24 S., R. 7 W.
Luna, SE1/4 sec. 18, T. 24 S., R. 7 W.

The deposits consist of north-striking veins, controlled by preore faults, in the Tertiary agglomerate. Lasky (1940, p. 61-63) describes the veins as follows:

> Typically, each vein has an almost perfect footwall, slickensided and grooved and composed of silicified fault breccia (jasperoid) presumably formed by the first opening of the vein fissures. Where the vein is composed of several members or strands, each may have a similar footwall At many places the jasperoid forms a low cropping, 2 feet or less high, so that it is possible to trace veins that on the whole have inconspicuous outcrops. Where this kind of cropping is absent or where the fanglomerate [agglomerate] is as resistant to weathering as the jasperoid, the veins are best traceable by means of a low jasperoid scarp, locally manganese-stained or slickensided; elsewhere it is locally possible to trace them by means of meager float or by low inconspicuous hollows.
>
> The ore consists of manganite, psilomelane, pyrolusite, and wad that (1) fill cracks in a shattered hanging wall, (2) replace an abundant postjasperoid but pre-mineral gouge and breccia, and (3) replace the finer-grained part of the fanglomerate wallrock, as well as some of the coarse fragments. The cracks in the shattered hanging wall are commonly filled with crystalline manganite, which in the aggregate, may constitute as much as a third of the

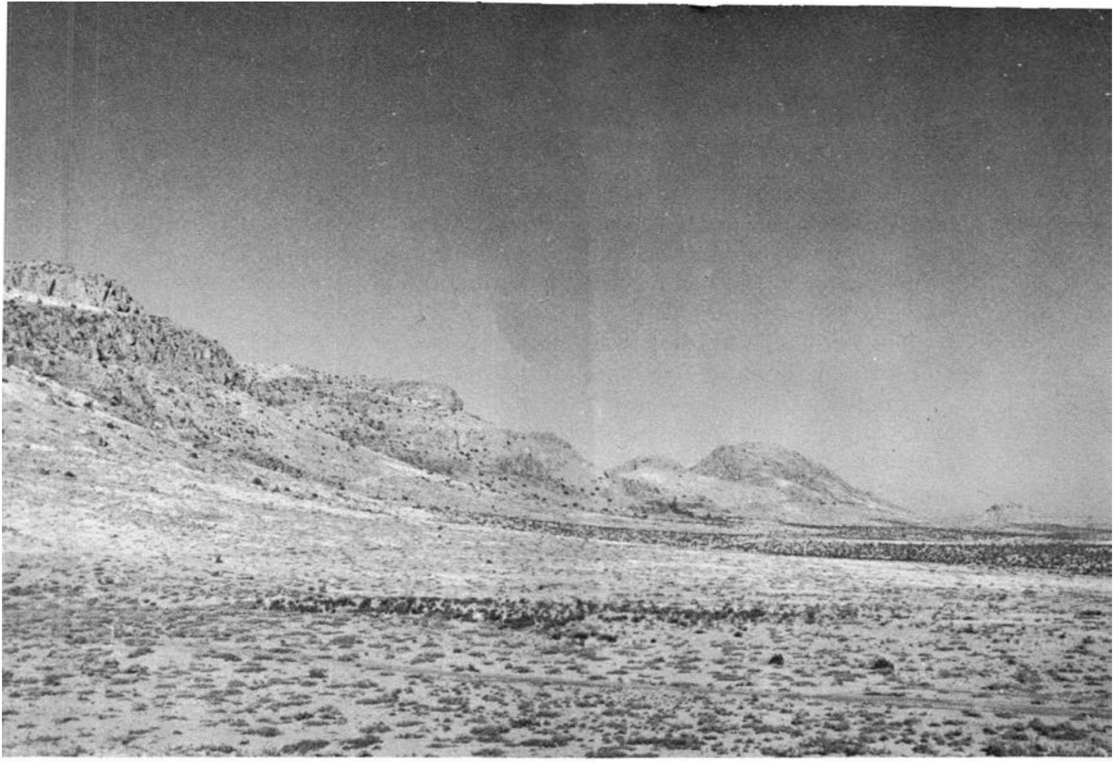


Figure 16. LITTLE FLORIDA MOUNTAINS.
Viewed from the southeast.

ore minerals. Much of the ore for which the term "pudding ore" is used consists of fragments of rock, each commonly with a crust of hard psilomelane and each partly replaced by manganese oxide, in a matrix of soft clayey material composed largely of wad and pyrolusite.

### FLUORSPAR DEPOSITS

At the northeast end of the district, several veins carry substantial amounts of fluorspar and barite in addition to manganese. The most promising veins of this group occur on six patented mining claims, known as the Spar group (M. S. 1930), which lie along the section line between secs. 7 and 8, T. 27 S., R. 8 W., about three-quarters of a mile south of U. S. Highway 70-80.

The Spar group of claims were patented in 1925 by J. T. Duryea, and four or five carloads of _metallurgical-grade fluorspar was reported to have been shipped prior to 1937 (Talmage and Wootton, 1937, p. 77). The claims then were purchased by the General Chemical Co., the present owner. This company operated the property intermittently until 1951, but the tonnage produced during that period is not known.

The deposit consists of several veins, three of which have been prospected thoroughly. The veins occur in what the writer believes to be Gila(?) conglomerate, but Tertiary agglomerate is probably present at a shallow depth. The veins have been developed by one vertical shaft, two inclined shafts along the veins, and numerous trenches and pits.

The underground workings, however, could not be examined, because of the absence of ladders in the vertical shaft and poor timbers in the inclines. According to Cooper Shapely (personal communication), the vertical shaft is 150 feet deep, and the inclines are approximately 100 feet deep (vertical distance).

The two inclined shafts were sunk approximately 100 feet apart on a vein that strikes due north and dips 75° E. This vein has been stoped thoroughly to the surface near the inclines. The vertical shaft was sunk about 150 feet east of the northernmost incline. Another north-striking vein, but dipping only 50° E., has been mined midway between, and north of, the two shafts. The third vein strikes N. 40°-50° W. and dips steeply to the northeast. It lies 100 feet northeast of the vertical shaft but is terminated against the vein that dips 50° E.

The mineralogy of the veins is identical; fluorite is the 'ore mineral, accompanied by manganese oxides, barite, calcite, and quartz. An examination of ore specimens on the dumps revealed that the probable paragenesis of the ore was an initial stage of fluorspar, barite, calcite, and quartz, followed by recurrent movement along the veins, and then deposition of the manganese oxides in a final stage.

The veins range from the vanishing point to as much as 6 feet thick; the average was estimated to be 2 feet. The $CaF_2$ content of the ore was estimated visually to range from 20 to 60 percent.

## CARRIZALILLO-CEDAR MINING DISTRICT

### GENERAL

Topographic maps of southern Luna County show two distinct mountain groups in the vicinity of Hermanas, the Carrizalillo Hills to the south and the Cedar Mountain Range extending to the northwest to the county line (fig. 1). The Carrizalillo Hills are an extension of the Cedar Range, and in both areas there are only a few mineral deposits. For these reasons, the writer combined the two into a single mining district. Jones (1904, p. 184) termed this same area the "Stonewall district."

The early history of mining and prospecting in this district is not known, but Darton (1916) briefly mentioned a gold-copper prospect near Hermanas. The area probably was prospected as early as the late 1800's; the failure, however, to uncover large deposits has retarded the development of the district. Some production certainly has been made from the several mines and prospects described below, but records of the actual shipments are not available.

### GEOLOGY

Tertiary volcanic rocks form the bulk of the Cedar Range and the Carrizalillo Hills. Typical of the region, there are three broad divisions of the volcanic rocks: Upper, basalt and basaltic andesite flows with interbedded thin flows of gray latite; Middle, rhyolitic tuffs, welded tuffs (ignimbrite), and minor flows; Lower, andesite flows, breccias, and tuffs.

Basalt flows crop out north of Hermanas in the vicinity of the Smyer ranch headquarters. These particular basalts may be Quaternary in age, in part at least, for the appearance of the tops of the flows is quite fresh. The basalt, however, is partially covered by gravel deposits, suggestive of a late-Tertiary age. More detailed study is required to determine if a fourth unit of volcanic rocks (i. e., Quaternary basalt) exists here, or if the basalt is simply an upper member of the Tertiary basalt sequence.

Sedimentary rocks are limited to the Klondike Hills, located in the extreme northwestern part of the Cedar Range, and a smaller exposure about 2 miles east of Cedar Mountain Peak. In the Klondike Hills the sediments range from Ordovician Bliss sandstone to undifferentiated limestones of Pennsylvanian age. The exposure east of Cedar Mountain Peak measures approximately one-half mile by 11/2 miles in area and contains only Escabrosa limestone, undifferentiated Pennsylvanian limestones, and clastic beds of Lower Cretaceous age.

The structure of the Cedar Mountain Range is essentially a homodine striking northwest and dipping northeast. The Lower andesite sequence forms the main northwest-trending ridge of the range. The Middle rhyolite sequence overlies the andesite; inasmuch, however, as the tuff beds were easily eroded, the unit crops out in a broad valley immediately northeast of the andesite belt. Tertiary basalt, which overlies the Middle rhyolite sequence, forms a low ridge that parallels the main ridge but is separated from it by the broad erosional valley of Middle rhyolite (fig. 17).

Gila(?) conglomerate overlies the Tertiary basalt sequence on the northeast side of the range. The gravels are coalesced alluvial fans that have been dissected by later erosion. The same type of gravel is exposed on the southwest slopes of the range west of Hermanas.

The structural picture of the Cedar Mountain Range is complicated by northwest-striking normal faults. One of these faults follows the southwest front of the range, where the Gila(?) conglomerate is faulted against the Lower volcanic sequence. Another fault follows the north-

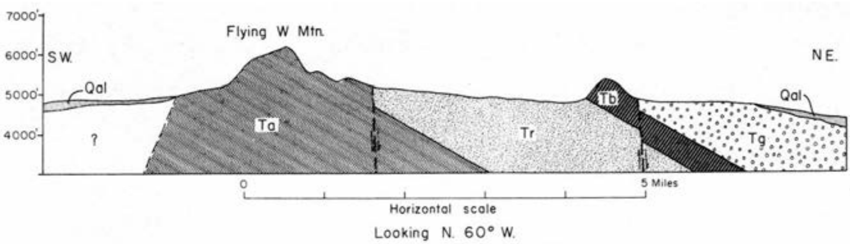



Figure 17. Cross-section of the Cedar Mountain Range near Flying W Mountain.

east slope of the main ridge:This fault zone passes through Hermanas, where it is marked by numerous thick quartz veins.

The Carrizalillo Hills are composed mostly of the Lower andesite sequence, but the Middle rhyolite sequence is present as erosional remnants on the higher ridges. In the vicinity of the Calumet mine, wide rhyolite dikes appear to have intruded the andesite.

## DESCRIPTION OF MINES AND PROSPECTS

### Calumet Mine

A copper deposit is located in the southern part of the Carrizalillo Hills approximately three-quarters of a mile north of the Mexican border. The location is defined further as being almost on the section line between secs. 11 and 12, T. 29 S., R. 11 W. The deposit can be reached from Hermanas by traveling 2 miles east on State Highway 9, thence 21/2 miles south on a truck trail to a windmill, and finally another 2 miles southwest to the mine.

The mine (fig. 18) is located on the south contact of a wide northwest-trending dike of pale-pink rhyolite that was intruded into purplish-gray andesite. A shallow vertical shaft was sunk on a fracture zone, parallel to the dike, containing stringers of malachite, limonite, calcite, and minor quartz. An adit was driven to intersect the shaft from the southwest.

A small, roughly circular alteration zone is present immediately southeast of the shaft. A prospect pit in this zone exposed only limonite stains on narrow fractures. Two shallow pits were sunk on the northeast side of the dike. The northern pit exposes a vein of limonite and manganese oxide that strikes N. 20° W. and dips 60° W.

According to Jim Patterson (personal communication), the mine belongs to F. C. Yeager, of El Paso, Texas. Yeager is said to have done considerable development at the property in 1956.

### Prospects Near the Johnson Ranchhouse

Two copper prospects are located approximately 1 mile east of the Johnson ranchhouse, which in turn is situated 2 miles southwest of Hermanas. The names, owners, and early history of the prospects are not known. One of the deposits is probably the same as that noted by Darton (1916, p. 106).

One prospect is located near the center of the S1/2 sec. 28, T. 28 S., R. 11 W. Here a wide quartz vein strikes N. 30° W. and dips 70° E. The host rock is probably latite. The hanging wall of the quartz vein is much brecciated and contains chrysocolla, malachite, and azurite as fracture fillings in the breccia over widths as great as 20 feet. The average grade of the deposit is low, probably less than 1 percent copper. Manganese oxides and limonite are common gangue minerals. A vein of calcite parallels the footwall, but it does not contain copper minerals.

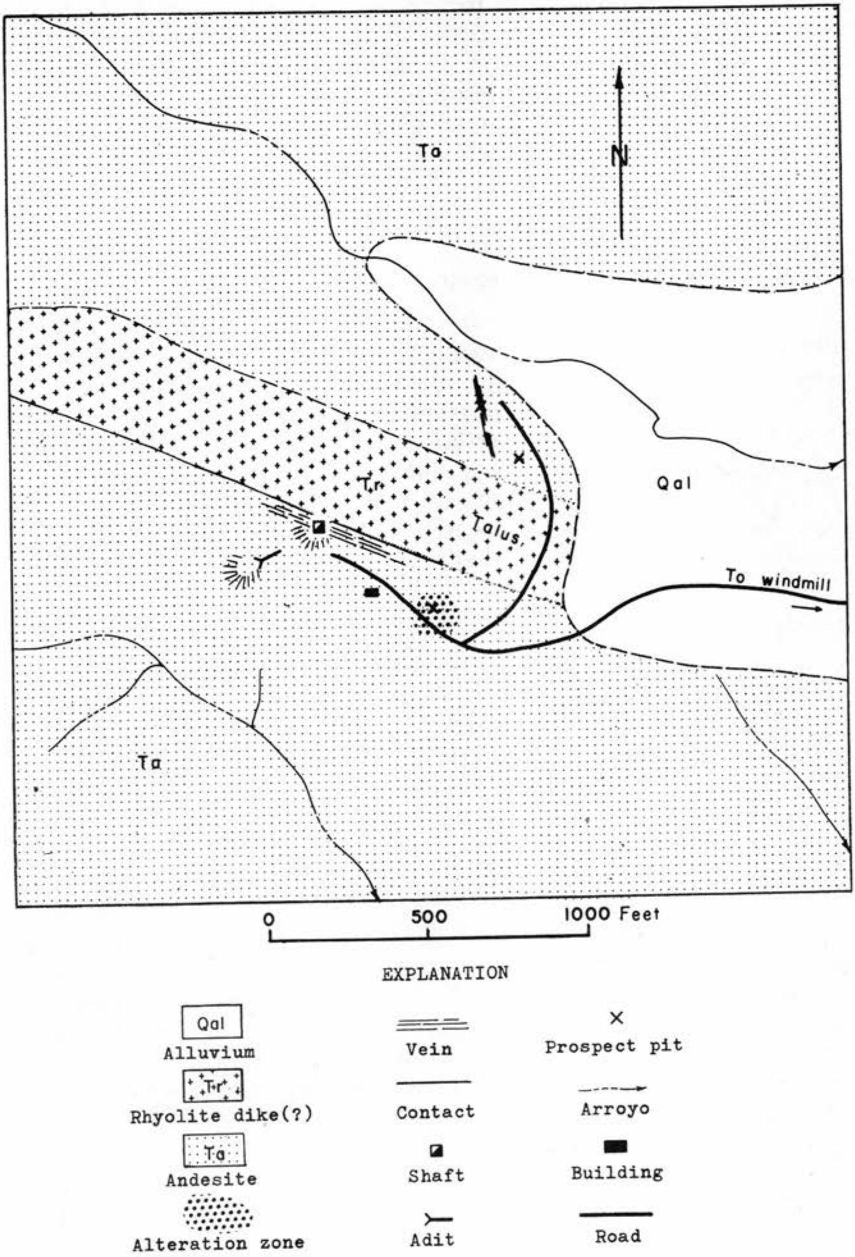



Figure 18. SKETCH MAP OF THE CALUMET MINE.

The second prospect is located in the NE1/2 sec. 33, T. 28 S., R. 11 W., about one-half mile southeast of the deposit described above. Malachite and azurite occur in a breccia zone, approximately 10 feet wide, in purplish gray andesite. The breccia zone strikes N. 60° W. and dips 70° N. The breccia is cemented by manganese oxides, calcite, and quartz, whereas the copper minerals occur more as a simple staining. The amount of manganese present is considerable, but the copper content is only about 1 percent.

### Gold Prospects Near Hermanas

Several unnamed gold prospects are located immediately east of Hermanas and north of the Southern Pacific Railroad. The workings consist of several shallow shafts and numerous prospect pits, which were sunk on northwest-trending quartz veins. These quartz veins are believed to be related to the northwest-striking fault zone mentioned previously. The quartz veins do not carry visible amounts of sulfides, and assays ' of two grab samples taken from two shaft dumps yielded only traces of gold. Nevertheless, reliable reports indicate that the veins do contain some gold, and a few shipments were made of such ore in the early days.

### Burdick Claim

To the writer's knowledge, the only patented mining claim in the Carrizalillo-Cedar mining district is the Burdick (M. S. 2035), located near the old Flying W ranchhouse in sec. 27, T. 27 S., R. 12 W. The property is now part of the Smyer ranch. Access to the area is gained by traveling approximately 4 miles northwest from Hermanas to the Smyer ranch headquarters, and thence 5 miles farther northwest over a truck road.

The claim is located in an area underlain by rhyolite tuffs and breccia. The Lower andesite sequence that forms the main ridge of the Cedar Mountains is exposed about one-half mile to the southwest. The claim has been prospected by two shafts, both inaccessible, but each less than 100 feet deep. The shafts were sunk on a bleached and pyritized zone of rhyolite welded tuff and breccia. The material on the shaft dumps is much oxidized, but distinct cubic limonite casts are present in the rock, indicating the former presence of pyrite. Although the shafts are said to have encountered gold ore, the quantity and grade must have been disappointing, for recent signs of activity are absent.

### Lucky Mine

A lead prospect is located in sec. 2, T. 27 S., R. 13 W. The deposit lies about 3 miles south of the Beauchard ranchhouse in the northern part of the Cedar Mountain range. Access to the ranchhouse is gained from Gage by traveling 41/2 miles south to the El Paso Natural Gas Co.

compressor station, and thence 11 miles in a southwesterly direction. Roads are almost nonexistent from the ranchhouse to the mine, and one is forced to walk the last 3 miles.

The deposit is located in a block of sedimentary rocks surrounded by the Middle and Upper units of the volcanic sequence. The block of sediments measures approximately 11/2 miles in an east direction and is one-half mile wide. The outcrops are mostly limestone-cobble conglomerate beds interbedded with gray, medium-bedded limestones of Lower Cretaceous age. A small amount of medium- to thick-bedded, light-gray limestone, devoid of conglomerates, is exposed west of the Lucky mine. This limestone is probably of Mississippian and Pennsylvanian age.

The sedimentary block is surrounded on all sides except the north by rhyolitic welded tuffs (Middle volcanic unit). On the north the block is faulted against black basalts (Upper volcanic unit) that overlie the tuffs.

Figure 19 is a sketch map of the Lucky mine area. Lead mineralization is limited to a steeply dipping N. 50°-65° E. vein system in gently dipping Lower Cretaceous limestone. Immediately east of the deposit, Tertiary basalt has been downfaulted against the limestone. This fault

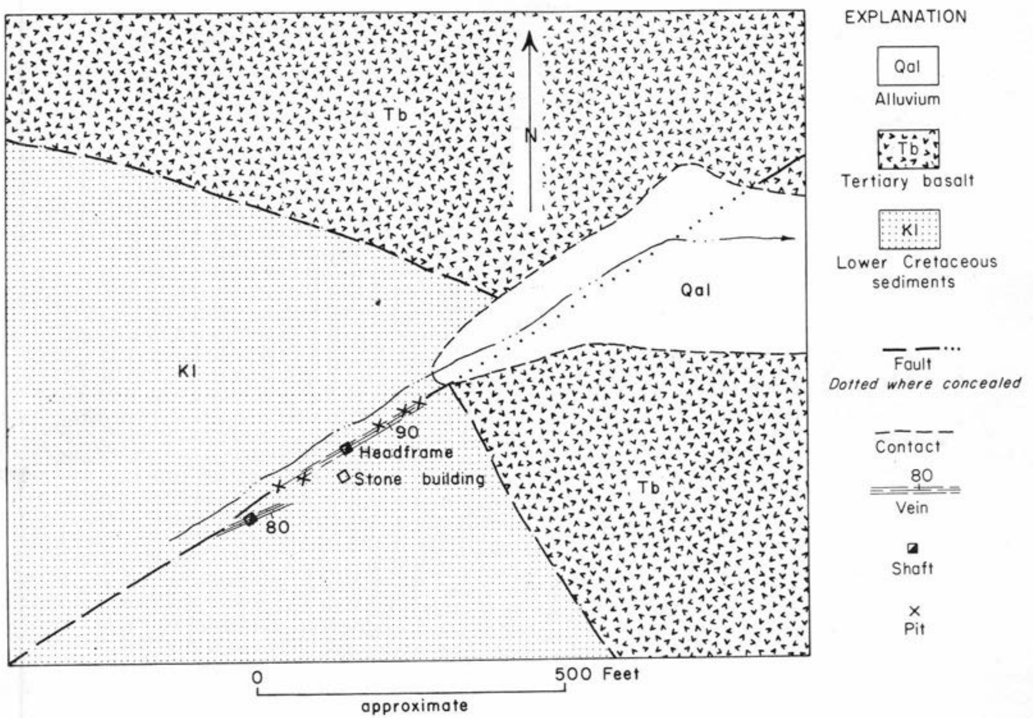



Figure 19. SKETCH MAP OF THE LUCKY MINE.

has been displaced by another fault paralleling the vein system. The age of the latter movement is probably postore.

The deposit has been developed by two shallow (less than 50 feet) shafts and several pits. The two shafts were sunk on narrow galena-bearing quartz-calcite veins, whereas the pits reveal only sparse mineralization. The veins contain a minor amount of copper, as evidenced by slight malachite staining of the outcrops.

The history and past production of this mine are not known. A claim notice was found in a discovery monument, stating that the Lucky mine No. 1 claim was staked over the vein by Marcus Pacheco and Pinky Sample on May 2, 1956. Attempts to communicate with these owners were unsuccessful. The much-weathered timber headframe indicates that at least some of the work was done many years prior to the staking by Pacheco and Sample.

### Klondike Hills Prospect

A small prospect is located in the Klondike Hills about one-half mile northeast of the Beauchard ranchhouse. The prospect is near the section line between secs. 22 and 23, T. 26 S., R. 13 W. Its name is not known. The prospect is on the southern slopes of the Klondike Hills, which are composed of Paleozoic sediments. A gray, thick-bedded dolomite, believed to be Fusselman dolomite, crops out in the immediate vicinity of the prospect. Two shallow shafts and several trenches were sunk on ferruginous vein outcrops. Economic mineralization was not detected in the workings except for minor malachite stain.

## FREMONT MINING DISTRICT

### GENERAL

The Fremont district, as defined here, includes that portion of the Sierra Rica hills which extends into the extreme southwest corner of Luna County. The International mine (lead-zinc-copper-silver-gold) is the only mine to have produced ore in the district; several other productive mines, however, are located in the same hill group in Hidalgo County and Mexico. A deposit of perlite is reported in the volcanic hills north of the Sierra Rica, but the writer was not able to find the deposit.

### GEOLOGY

Figure 20 is a geologic sketch map of the district. The Sierra Rica hills are composed of Lower Cretaceous sediments, which have been mapped as part of the Howells Ridge formation by Strongin (1956). Lasky (1947) originally described this formation in the Little Hatchet Mountains. The formation consists of red beds of mudstone, shale, limes'tone, sandstone, and conglomerate. In the Sierra Rica hills, the formation is divisible into three lithic units: a lower unit of red beds, a

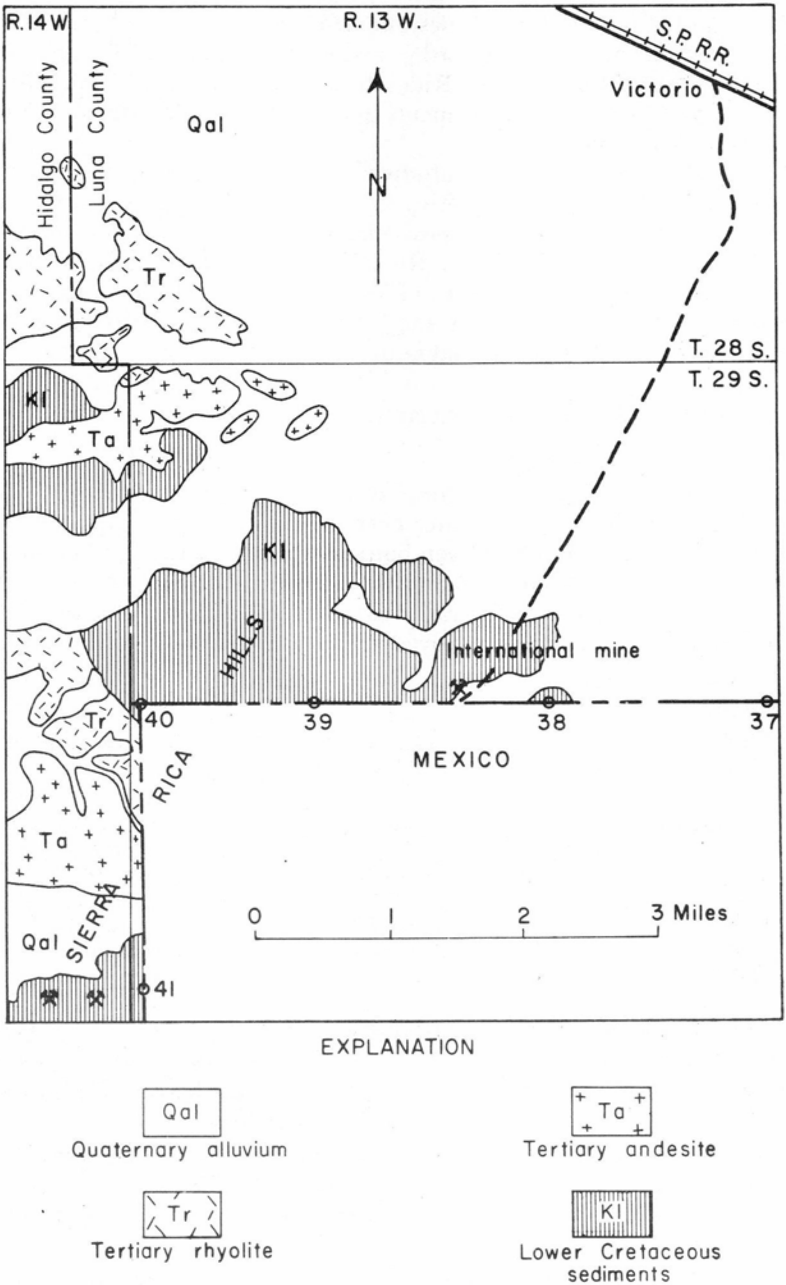



Figure 20. Geologic sketch map of the Sierra Rica hills.
Adapted from Strongin (1956).

middle unit of gray to black limestone, and an upper unit of sandstone. The formation measured by Lasky in the Little Hatchet Mountains is 1,325 feet thick. The Howells Ridge formation is probably equivalent to the Lower Cretaceous sediments found in the Victorio and Tres Hermanas Mountains.

An andesite sequence, overlain by rhyolite, is exposed in the Apache Hills northwest of the Sierra Rica hills. These two volcanic units are related to similar sequences exposed in the Cedar Mountains.

The structure of the Sierra Rica is complex. Folding and thrust faulting is evident west of the International mine, and numerous high-angle faults further complicate the picture. The International vein is along a northeast-striking normal fault.

## DESCRIPTION OF THE INTERNATIONAL MINE

### Location and Access

The International mine is located in the NEV$_I$ sec. 16, T. 29 S., R. 13 W. The name is appropriate, because the mine lies right on the Mexican border, midway between boundary posts 38 and 39. The property can be reached from Hermanas by traveling 12 miles west on State Highway 9 to the abandoned railroad siding of Victorio, and thence 5 miles southwest over an unimproved road leading directly to the mine.

### History

The International mine has a long history. J. M. Hill examined the property in 1909 (Lindgren et al., 1910, p. 346) and stated:

> The first claim was located in 1880 by Volney Rector, the present owner. It is reported that the mine has produced about 50 tons of lead-silver ore, valued at $___per ton, all of which was shipped previous to 1889. The best shipment, a small one of 10 tons, ran 40 per cent of lead and $62 to the ton in silver,when the latter metal had a value of 95 cents. At present there are about 80 tons of galena ore of medium grade on the dump and as much more in one of the scopes.

Annual reports on New Mexico mining operations by the U. S. Geological Survey and the U. S. Bureau of Mines note the following production for the period 1910-1959: 1917, 1 car (railroad); 1918, 1 car; 1923, 3 cars; 1924, 3 cars; 1925, 6 cars; 1947, 129 tons.

If it is assumed that the railroad car shipments were 50 tons each, the total recorded production of the mine is only 879 tons. It is reasonable to assume, however, that additional shipments were made that were not recorded.

The ownership of the mine has changed hands many times since Volney Rector's original claiming. The mine is now the property of Joseph Deckert, of Deming, who owns the original claims. These claiins are still valid even though the remainder of the section in which they lie is now owned by the State of New Mexico. The mine has been referred to by names other than the International, such as the Keno, Rattlesnake, Rector, and probably still others.

## Geology of the Deposit

The International vein is localized along a high-angle fault that strikes N. 45° E. The structure is traceable for approximately 4,000 feet on the United States side of the border and for a similar distance on the Mexican side. Ore mineralization has been found, however, only along 2,000 feet of this strike length, and approximately half of this length lies in Mexico.

Figure 21 is a sketch map of the mine area, showing the northeast-striking vein-fault. The southeast side of the fault is interbedded red sandstone, shale, and limestone conglomerate typical of the lower unit of the Howells Ridge formation. The northwest side of the fault is composed of interbedded limestone, shale, and sandstone. The presence of limestone, and the fact that the beds are more grayish than red, as on the southeast side of the fault, indicate that they are probably part of the middle unit of the Howells Ridge formation. If this is true, the northeast side of the fault is downthrown in relation to the southeast side. Several thin basalt sills have been injected into the sediments on both sides of the fault.

Away from the vein-fault, the beds on both sides of the fault strike N. 50°-90° E. and dip 10°-40° N. Near the fault, the beds are contorted in a manner that faintly suggests some tear movement (left-lateral) along the fault in addition to the vertical movement already described.

The deposit has been developed on the United States side of the border by three vertical shafts and by numerous pits and trenches. Development has not been as thorough on the Mexican side. The shafts have been numbered for the convenience of this description (fig. 21). Their reported depths are: No. 1, 100 feet; No. 2, 150 feet; No. 3, 250 feet.

Shafts Nos. 1 and 2 are not accessible because of rotten timbers. The No. 3 shaft was filled back to the 150-foot level with sand and debris during a flash flood according to Joseph Deckert (personal communication). Most of the stoping is believed to have been done from drifts driven from the No. 3 shaft. The vein has been stoped through to the surface immediately south of this shaft.

The vein ranges from 1 to 10 feet thick on the surface. The primary-ore mineral assemblage includes galena, sphalerite, and chalcopyrite, accompanied by a quartz, calcite, and pyrite gangue. The value of the ore is enhanced by the presence of some gold and silver. Oxidation has yielded the usual "oxide" minerals on the outcrops. Ore mineralization extends from the border to a short distance northeast of the No. 3 shaft; favorable signs are absent farther northeast. The vein commonly follows

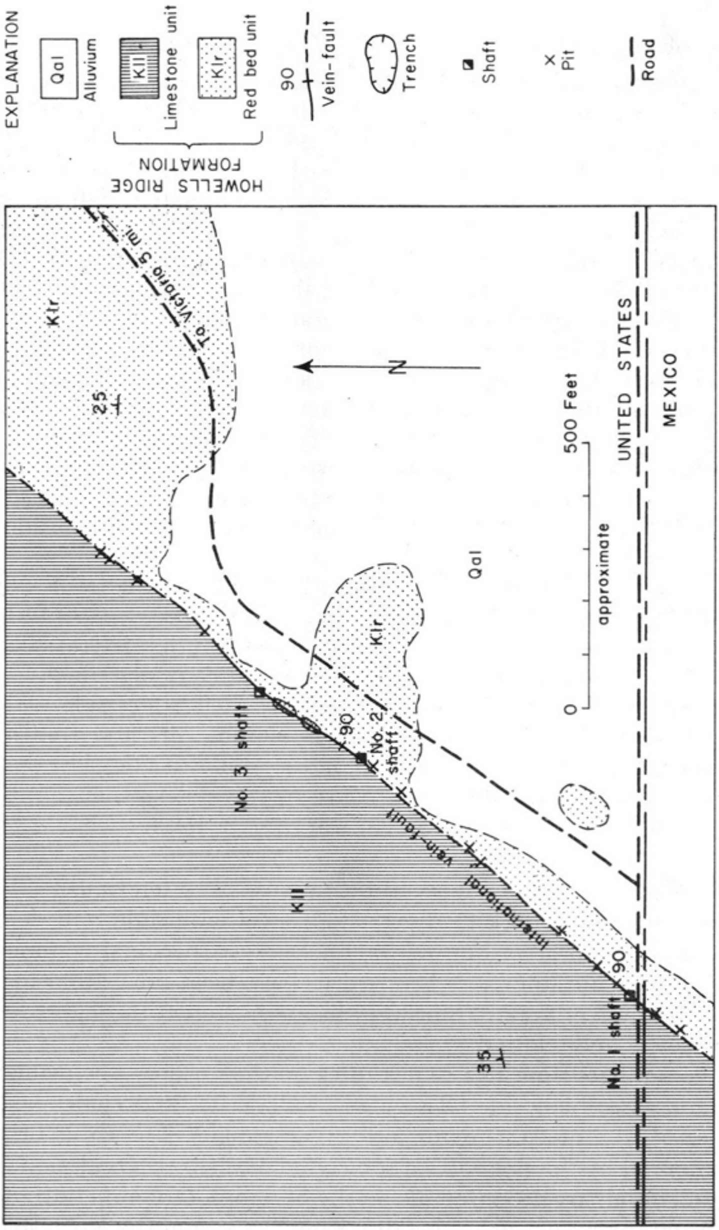



Figure 21. Sketch map of the International mine.

the southeast side of a band of reddish grit several feet thick. It is believed that this grit was formed by the crushing of original sandstone beds during faulting; later the crushed zone was recemented with silica and calcite, probably during the ore-mineralization stage.

The International mine is blessed with a vein outcrop 1,000 feet long, which averages approximately 4 feet wide. Several small but good-grade ore shoots were mined in the past. It is reasonable to assume that additional ore would be found if the vein structure were thoroughly prospected by core drilling. The writer cannot in any way guarantee, however, that the profit realized from the ore shipments would exceed the exploration, development, mining, and transportation costs required to get the ore out of the ground and to a smelter.

## SPECIMEN MINERAL LOCALITIES

A description of the mineral deposits of Luna County would not be complete without at least a brief mention of some of the localities that provide excellent specimens for mineral collectors. Agate, Mexican onyx, spurrite, fluorescent calcite, and many other minerals have been collected from deposits in Luna County for many years by persons interested in mineralogy. Indeed, a few persons earn their living by selling these specimens.

At the outset, the writer wishes to state that the majority of the deposits described below are owned by private individuals who have either staked claims, leased, or purchased outright the lands covering them. Therefore, one should always obtain the owner's permission prior to collecting on his property.

### AGATE

Luna County is somewhat famous for its agate deposits. There are too many deposits to describe each individually; however, three of the more important localities will be discussed briefly.

#### Burdick Hills

Figure 22 is a geologic sketch map of probably the best agate occurrence in the county. The deposit lies in secs. 10, 11, 14, and 15, T. 26 S., R. 11 W. It can be reached .by traveling approximately 16 miles southwest of Deming on the Hermanas road, State Highway 331, and thence 5 miles due east on a dirt road. The deposit has beeri staked by Eddie Lindberg, F. C. Leach, Earl Westmorland, and others.

The rock outcrops at the deposits are all of volcanic origin. The volcanics are divisible into two units: an upper or "caprock" unit of gray latite(?), and a lower unit of light-gray, altered tuff. The agate is restricted to the tuff beds. The latite "caprock" is barren, forming a layer ranging from 50 feet to the vanishing point. The structure of the deposit suggests a dome, in which case the curved outcrop of latite south of the main outcrop may represent a second layer of latite that originally overlay the deposit but was removed by erosion. Gila(?) conglomerate is exposed west of the agate deposit. The agate occurs both as veinlets and small pods in the tuff. The veinlets are randomly oriented, generally of very short length, and extremely variable in width. The better agate is well banded and possesses any combination of the following colors: colorless, white, gray, blue gray, brown, and reddish brown. Moss agate is also present.

F. C. Leach (personal communication) states that occasional thin, flat-lying lenses of agate are found near the surface. These lenses may represent either an original agate zone that formed at the top of the tuff beds immediately below the latite "caprock," or ,they may have been formed from vein agate that accumulated residually at the surface during erosion.

Although the origin of the agate is not definitely known, the writer favors the hypothesis that free silica was formed during the weathering

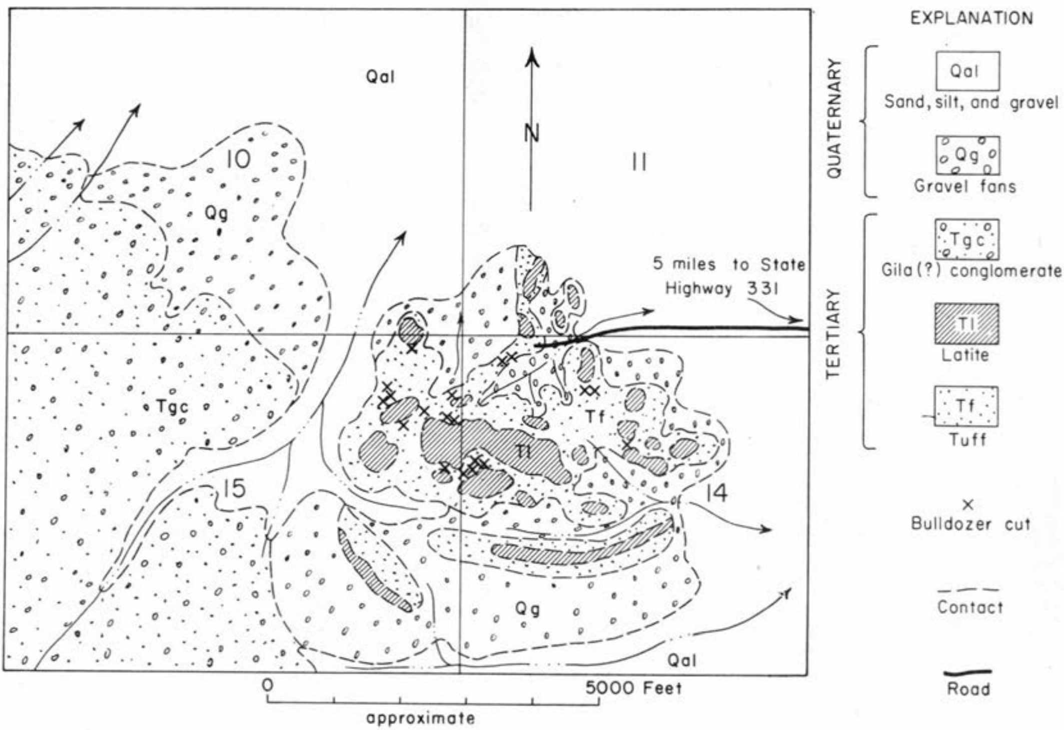



Figure 22. SKETCH MAP OF THE BURDICK HILLS AGATE DEPOSIT.
T. 26 S., R. 11 W.

or other type of alteration of the tuff beds. The silica then accumulated to form veins and pods in open spaces formed in the tuff.

The deposit has been worked extensively, the "mining" method being very simple. The tuff beds are first ripped with a bulldozer. This uproots and exposes the agate veinlets and pods. Then each agate exposure is explored carefully by hand, with the help of nothing but a geologist's pick. Finally, the handpicked pieces are washed in a pail of water to remove the claylike tuff and to facilitate examination of the specimens for determining the degree and form of banding, color, shape, and other factors that affect their value.

### Hermanas Thunder-Egg Agate Deposit

Thunder-egg agate occurs in altered latite flows and tuff about 1 mile northwest of Hermanas. The deposits lie on the Hilborn and Gore ranch in secs. 16 and 17, T. 28 S., R. 11 W. Sec. 16 is a State-owned section on which Eddie Lindberg (personal communication) has leased the mineral rights. The thunder eggs are almost round nodules ranging from 1 inch to almost 1 foot in diameter. The "eggs" generally have three principal zones: an outer ring of mottled-brown chalcedony or gray quartz, an intermediate zone of agate, and an inner zone filled with colorless or bluish-gray massive quartz. The center may also be a vug containing radiating quartz crystals.

### Fluorite Ridge Area

Angular to rounded fragments of carnelian are found on the bolson plains near Fluorite Ridge, particularly on the north side. The fragments range from sand-grain size to pieces as large as one's fist. The color varies from nearly colorless to rusty red. Carnelian veins are not found in Fluorite Ridge itself, and it is believed that the fragments were derived from some remote source.

Opaline agate is reported 3 miles north of Florida, which in turn is located 14 miles northeast of Deming on State Highway 26. The writer has not visited this area.

## MEXICAN ONYX (TRAVERTINE)

An excellent deposit of Mexican onyx is located in sec. 24, T. 28 S., R. 9 W., on the south slopes of the Tres Hermanas Mountains. The deposit, which is claimed by Eddie Lindberg, can be reached by traveling 4 miles west-northwest from Columbus on a road that passes the town cemetery.

The deposit is contained in the later latite sequence that forms the small hill group in which the deposit occurs.[9] The Mexican onyx occurs

9. See pages 41-45 for a more detailed description of the geology of the Tres Hermanas Mountains.

in thick but short north-trending veins in the latite; mammillary forms are common, indicating open-space filling. The veins are wide enough to allow the mining of blocks measuring up to 5 feet in diameter. Two stages of calcite deposition are evident, an "onyx" first stage, followed by fracturing and the deposition of massive calcite in the second stage. The total effect is a "breccia" of Mexican onyx fragments cemented by massive white to colorless calcite. In spite of the fracturing, large pieces of well-banded, cream to honey-yellow "onyx" are abundant.

Mexican onyx occurs sparingly in the lead-silver veins of the Victorio mining district south of Gage. Although the "onyx" is of excellent quality, it occurs only in thin veins.

Darton (1916, p. 109) mentions another occurrence "3 miles northwest of Mirage"; actually, this deposit lies on the southeast slope of Goat Ridge, in sec. 4, T. 22 S., R. 9 W.

## SPURRITE

A. H. Koschmann identified this rather rare contact silicate mineral in the Tres Hermanas mining district in 1928 (Lasky and Wootton, 1933, p. 83). Spurrite is a pale-gray to distinctly purple mineral formed near the contacts of intrusive rocks with limestone; the chemical formula is $Ca_5CO_3(SiO_4)_2$. The mineral is valued as a rare collector's item and as

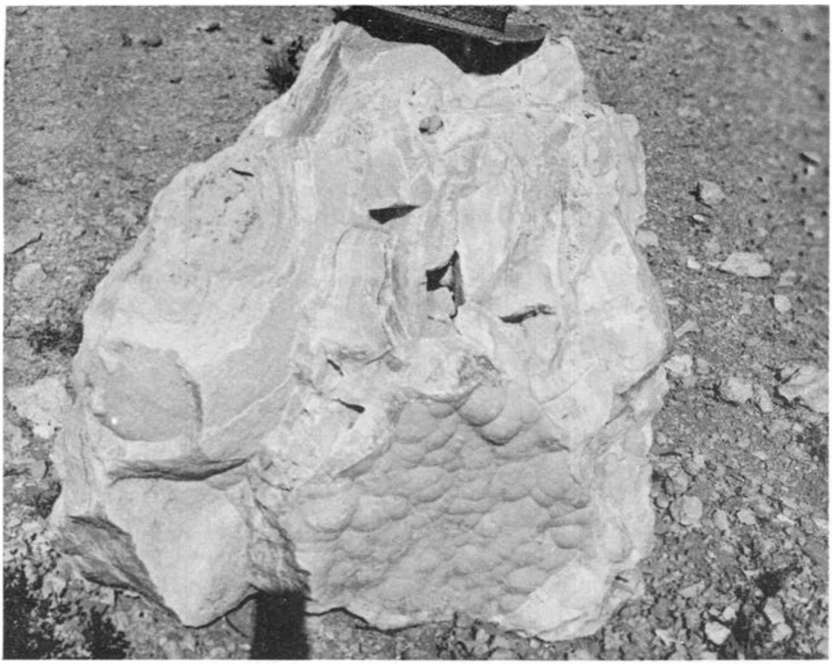


Figure 23. Mexican onyx boulder from the Lindberg deposit.

an ornamental stone. On weathering, the mineral quickly forms a white coating of calcium carbonate.

The spurrite occurs in a limestone xenolith in quartz monzonite on the east slope of South Sister Peak. The precise location is the N1/2NWIA sec. 6, T. 28 S., R. 8 W. The base of the mountain can be reached by traveling 2 miles east on a dirt road that leaves State Highway 11 approximately 6 miles north of Columbus. A steep foot trail leads up to the deposit from the base of the mountain.

The spurrite at this deposit is massive and mostly purple; megascopic crystals are absent. The mineral occurs as a band, probably an original limestone bed that was transformed to spurrite by silication. The band is as much as 5 feet thick, but the strike length is only about 20 feet. The remainder of the xenolith, which covers only a few acres, is strongly metamorphosed limestone containing appreciable amounts of andradite garnet, wollastonite, diopside, and probably additional silicate minerals. Pyrite grains are also present. Other bands of spurrite may exist in this same xenolith, but the deposit is so covered by talus that detailed examination is difficult.

## GEHLENITE AND CLINOHUMITE

Gehlenite and clinohumite occur in small, highly metamorphosed xenoliths along the margins of a small intrusive body 2 miles east of Camel Mountain. The deposits are located in secs. 4 and 9, T. 29 S., R. 5 W., and can be reached by traveling 16 miles east of Columbus along the road that parallels the Southern Pacific Railroad.

Figure 24 is a geologic sketch map of the area. The geology is difficult to analyze because blow sand completely covers the area except for a few hills that rise above the plain and have been swept clear. The intrusive body is a greenish-gray to dark-gray, fine-grained rock believed to be diorite. Even though the outcrops are limited to the isolated knobs, the diorite appears to be circular in plan, covering about 1 square mile; it may be a plug.

Small black crystals of clinohumite, as much as 3 mm in diameter, occur in a highly altered xenolith of limestone(?) on the north side of the diorite mass. This mineral was identified by M.-S. Sun in samples collected by the writer. Massive greenish-gray to brown gehlenite occurs in a small xenolith on the southwest side of the diorite mass. The mineral had been reported in this area by Northrop (1959, p. 257), and Sun confirmed this on examining specimens collected by the writer. The gehlenite is very similar in appearance to the spurrite in the Tres Hermanas Mountains, the only difference being its color. Both clinohumite an gehlenite are valued only as being fairly rare silicate minerals.

## DUMORTIERITE

A thin vein of dumortierite, a rare aluminum borosilicate, is known south of the Mahoney mining area in the Tres Hermanas Mountains. The vein is located high on the southwest side of a steep hill of quartz

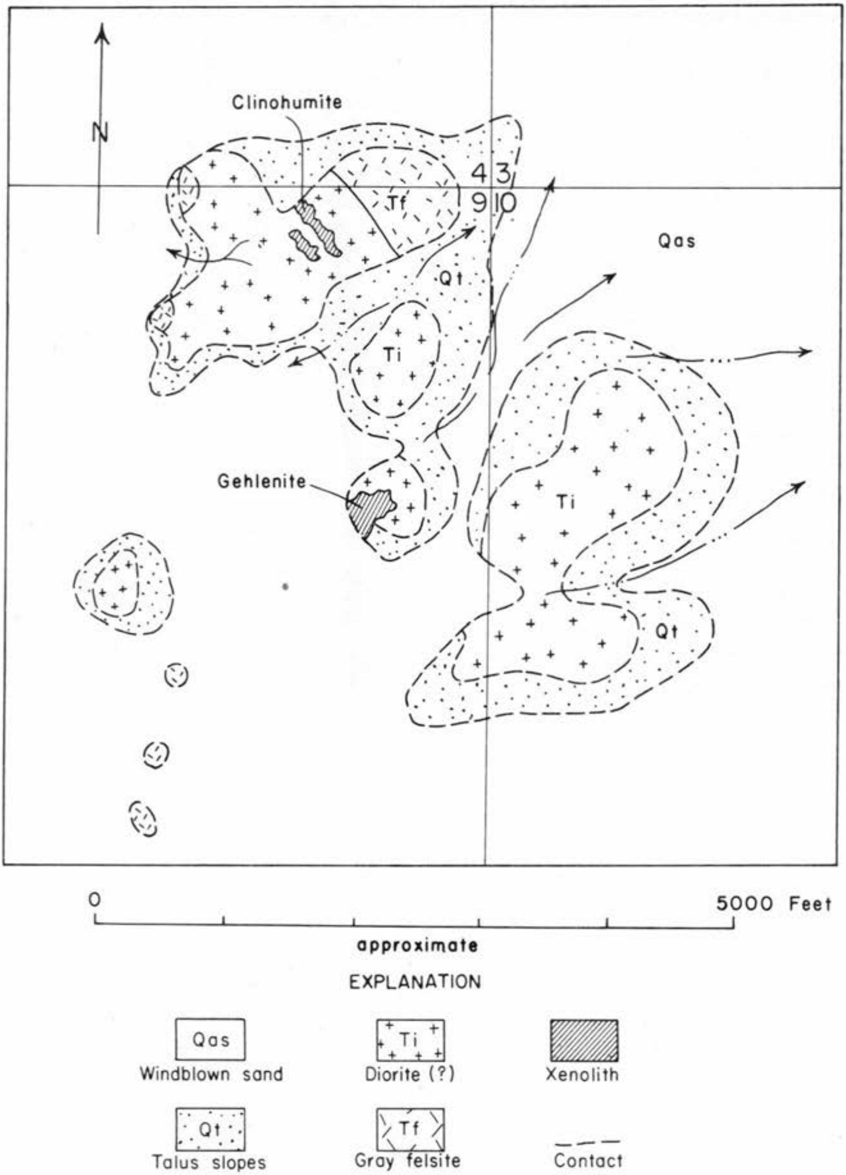



Figure 24. SKETCH MAP OF THE CLINOHUMITE AND GEHLENITE DEPOSITS NEAR CAMEL MOUNTAIN.

T. 29 S., R. 5 W.

monzonite located in the SW1/4 sec. 27, T. 27 S., R. 9 W. (pl. 1). The vein contains muscovite mica and quartz in addition to the dumortierite.

### FLUORESCENT CALCITE

Fluorescent calcite occurs in a cavelike water course on the south slope of South Sister Peak in the Tres Hermanas Mountains. The occurrence is only a few hundred yards southeast and below the spurrite deposit (see p. 146). The "cave" was formed by solution along the contact between quartz monzonite and a limestone xenolith; it can be entered through a 200-foot inclined adit that was driven due west into the hillside.

The calcite crystals found lining the "cave" walls and in small solution fractures are said to fluoresce pink, red, and brilliant lavender (Northrop, 1959, p. 157). Uranoan calcite that fluoresces green is also present. L. P. Zumwalt is believed to be the present owner of this property.

### LEAD MINERALS

Galena, cerussite, and anglesite are common minerals in the lead deposits described elsewhere in this report. It should be noted, however, that the Cooks Peak and Victorio mining districts have yielded museum-type specimens of cerussite and anglesite. Also, the Cooks Peak district is the "type locality" for the mineral plumbojarosite, this mineral having been first described from specimens collected there (Hillebrand and Penfield, 1902).

### ZINC MINERALS

In addition to the common varieties of smithsonite and sphalerite found in many deposits in Luna County, the less common silicate minerals willemite and calamine are abundant in the Mahoney mining area in the Tres Hermanas district (see p. 51).

### TUNGSTEN AND BERYLLIUM MINERALS

The writer has been privileged to see several fine specimens of wolframite that were collected from the Irish Rose vein in the Victorio mining district. Scheelite, beryl, and helvite also occur in the same area.

### MANGANESE MINERALS

Excellent specimens of psilomelane and pyrolusite are obtainable from the various manganese deposits in Luna County. In addition, manganite is present in the Little Florida district.

### FLUORITE

Specimens of fluorite of museum grade have been found in the Fluorite Ridge district (see p. 95-117).

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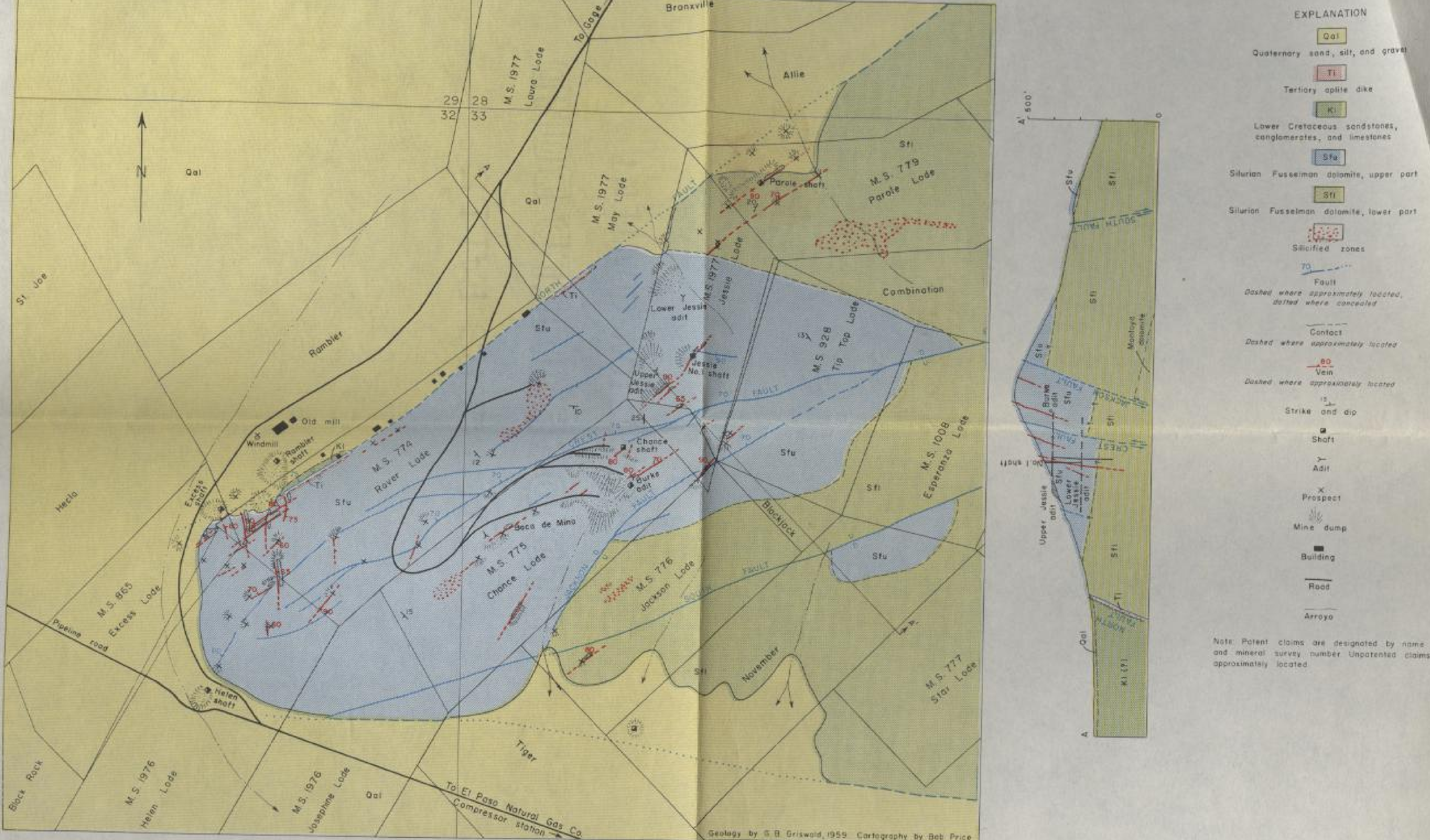
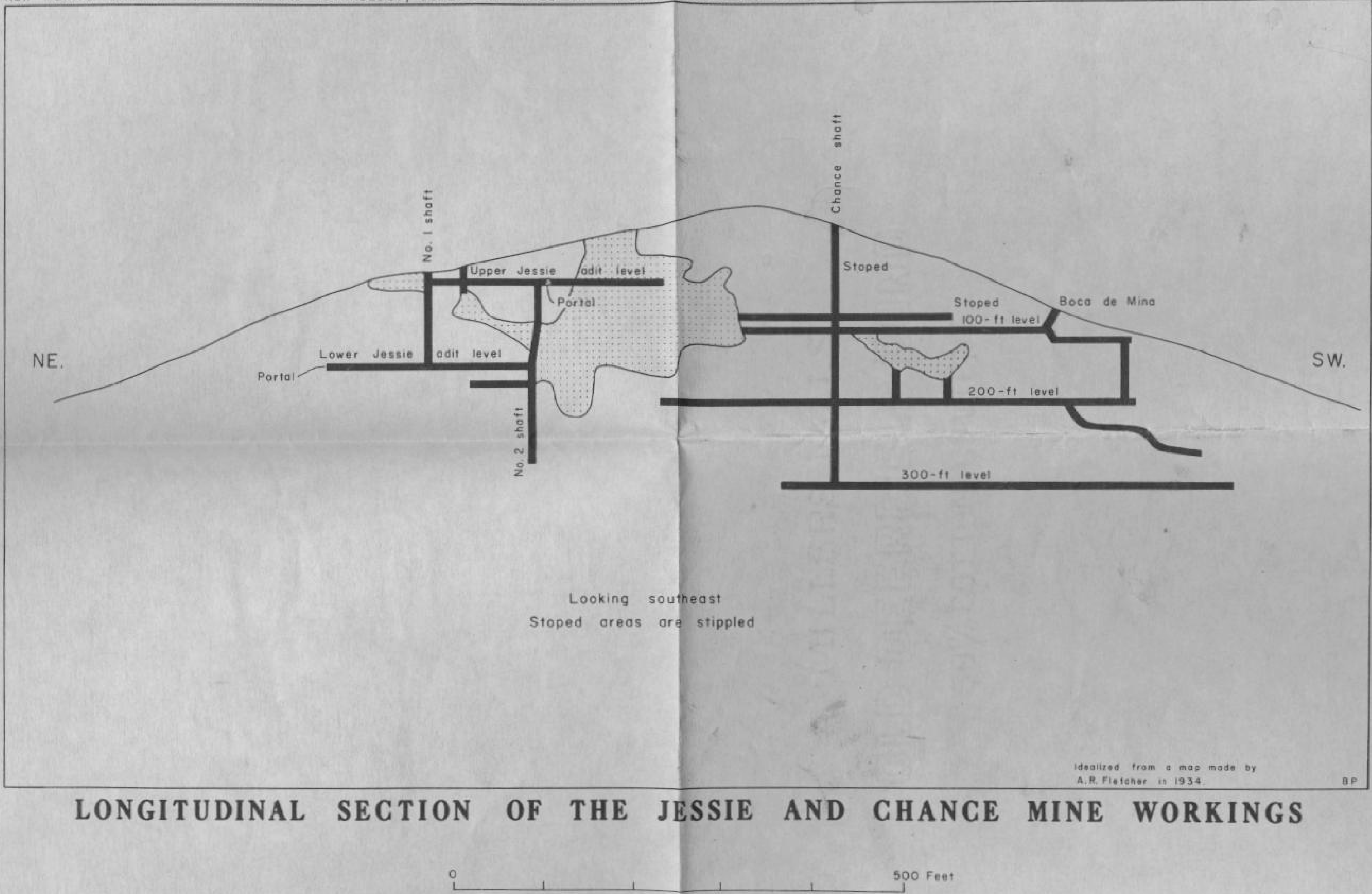
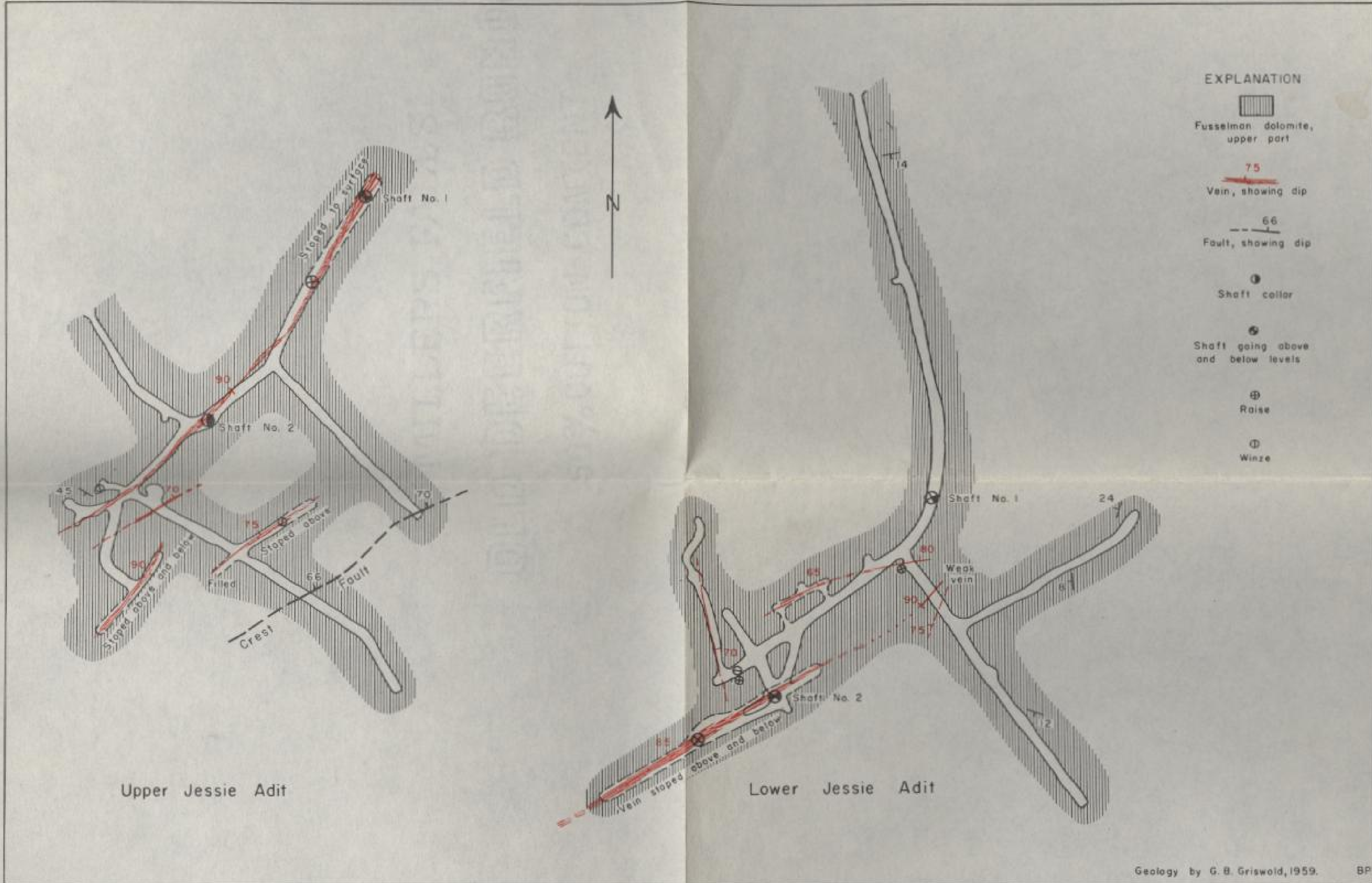



# GEOLOGIC MAP OF MINE HILL, VICTORIO MINING DISTRICT

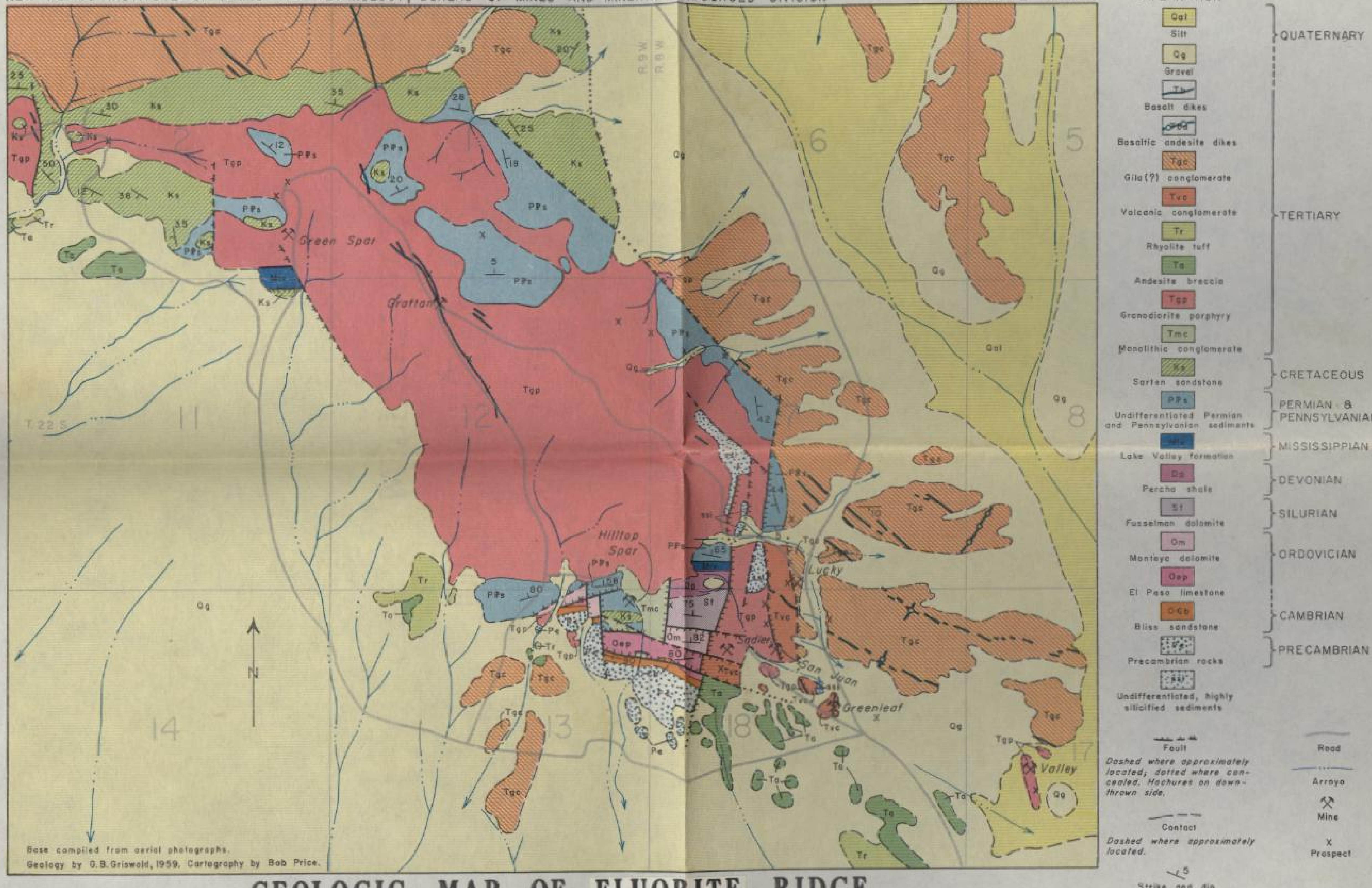
0 500 1000 Feet




# LONGITUDINAL SECTION OF THE JESSIE AND CHANCE MINE WORKINGS

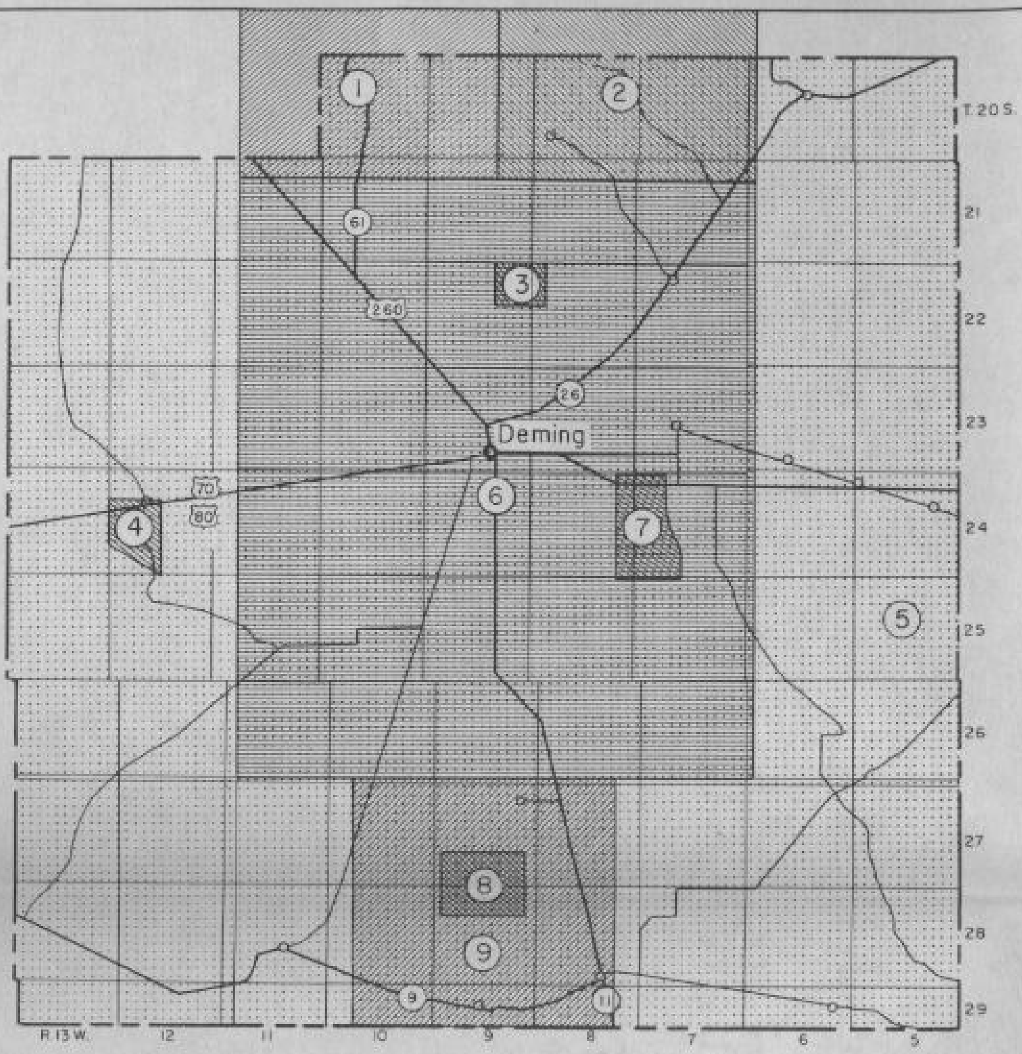



# PLAN MAPS OF THE JESSIE ADIT LEVELS




# GEOLOGIC MAP OF FLUORITE RIDGE

0 1 2 Miles

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2. Jicha, H. L., Geology and mineral deposits of Lake Valley quadrangle, Grant, Luna, and Sierra Counties, New Mexico, N. Mex. Inst. of Min. and Technology, State Bur. Mines and Mineral Res. Bull. 37, pl. 1, 1:48,000
3. Geologic map of Fluorite Ridge mining district, pl. 8, in pocket, 1:21,000
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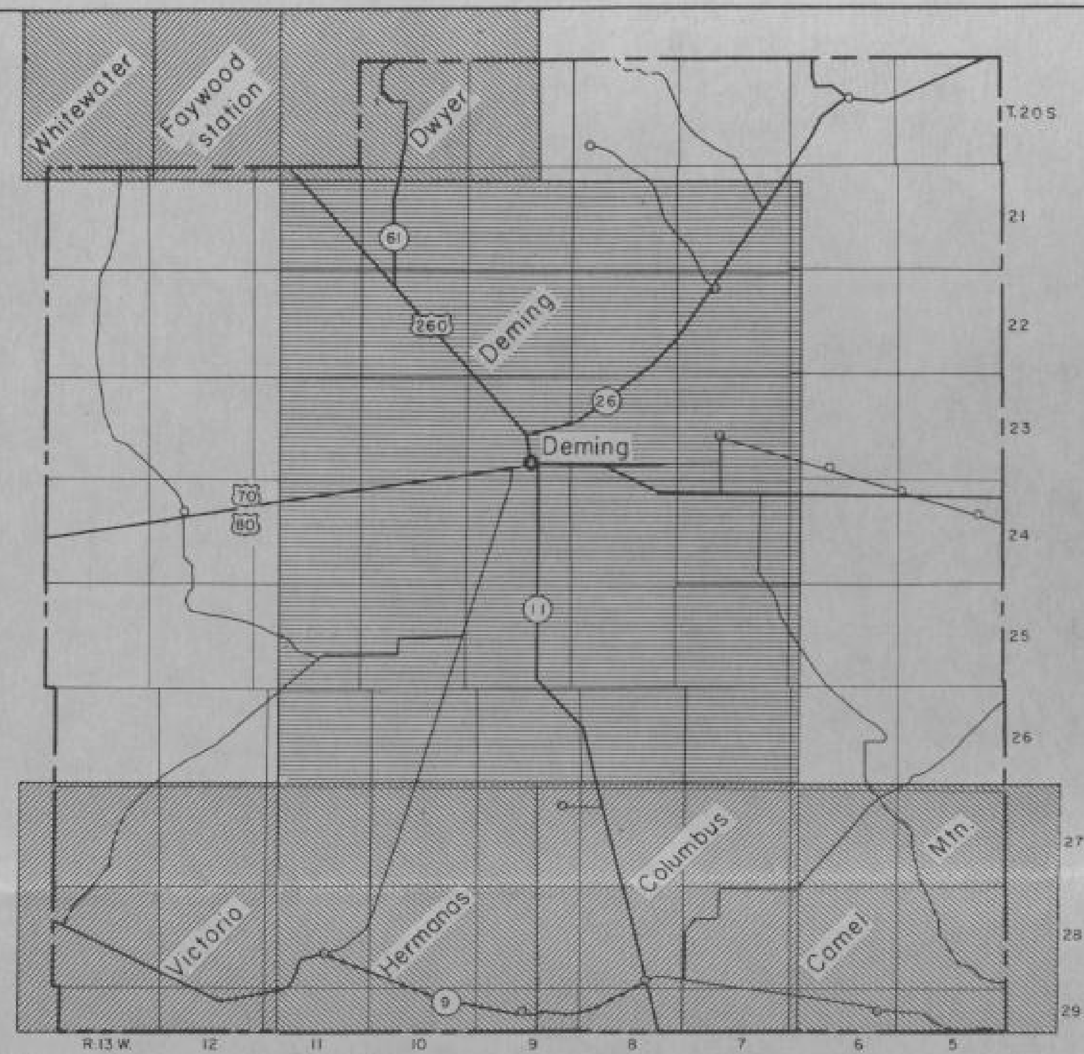
5. Darton, N. H., Geology and underground water of Luna County, U. S. Geol. Survey Bull. 618, pl. 1, 1:187,680
6. Darton, N. H., Deming quadrangle, U. S. Geol. Survey Geologic Folio 207, map, 1:125,000
7. Lasky, S. G., Manganese deposits in the Little Florida Mountains, Luna County, U. S. Geol. Survey Bull. 922-C, pl. 9, 1:24,000
8. Geologic map of the northwest portion of the Tres Hermanas Mountains, pl. 1, in pocket, 1:37,500
9. Balk, Robert, Geologic map of the Tres Hermanas Mountains, currently being prepared for publication by the N. Mex. Inst. of Min. and Technology, State Bur. Mines and Mineral Res., 1:62,500

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| Quadrangle | Edition | Size | Scale |
|---|---|---|---|
| Camel Mountain | 1917 | 15 minute | 1:62,500 |
| Columbus | 1917 | 15 minute | 1:62,500 |
| Deming | 1892 | 30 minute | 1:125,000 |
| Dwyer | 1956 | 15 minute | 1:62,500 |
| Faywood Station | 1947 | $7\frac{1}{2}$ minute | 1:24,000 |
| Hermanas | 1917 | 15 minute | 1:62,500 |
| Victorio | 1917 | 15 minute | 1:62,500 |
| Whitewater | 1949 | $7\frac{1}{2}$ minute | 1:24,000 |

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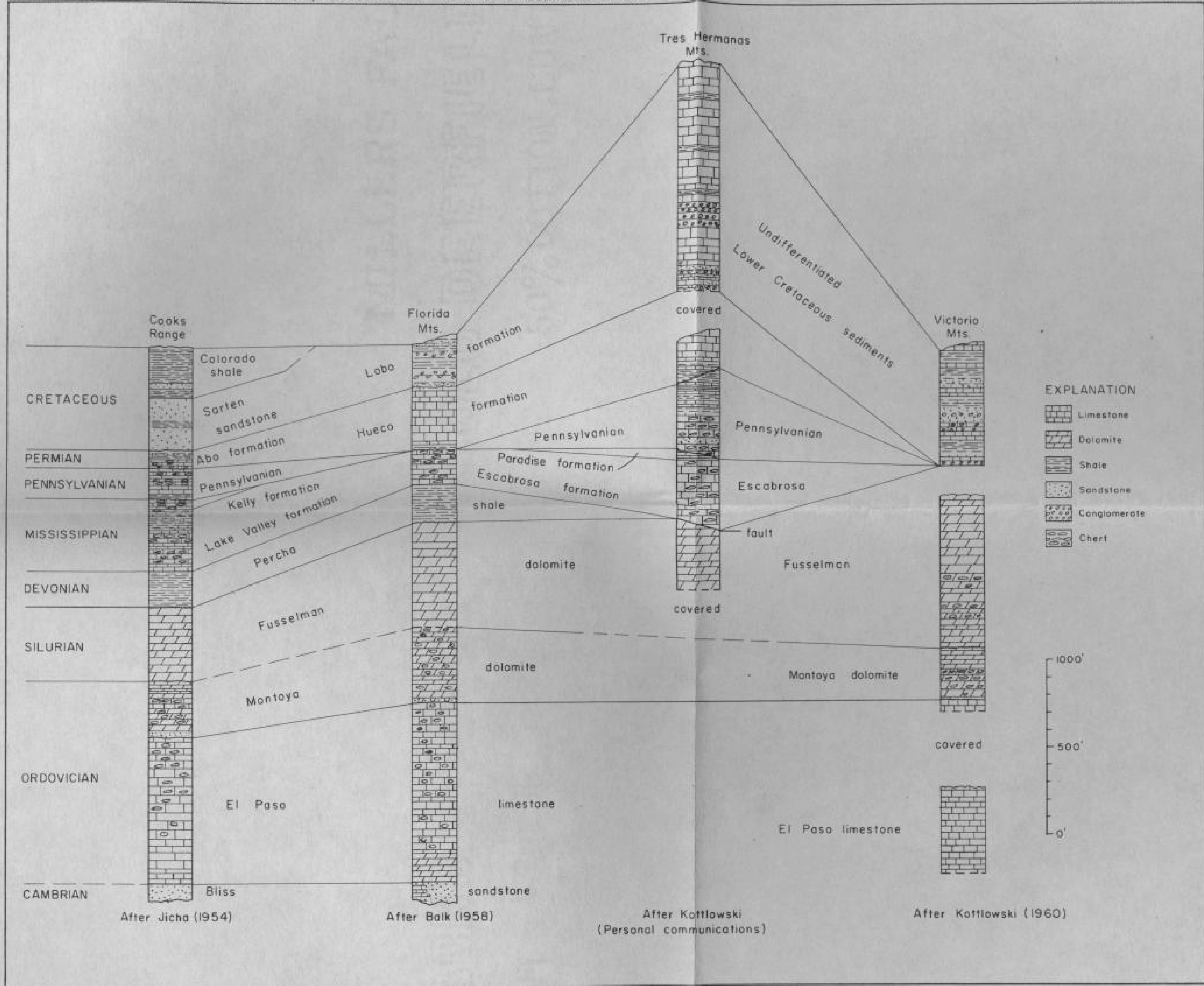


**COLUMNAR SECTIONS IN LUNA COUNTY**