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GEOLOGY AND ORE DEPOSITS OF THE NORTHERN PART OF THE HANSONBURG DISTRICT BINGHAM, NEW MEXICO

A Thesis
Presented to the Graduate Faculty of the
New Mexico Institute of Mining and Technology

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In Partial Fulfillment
of the Requirements for the Degree
Master of Science
in Geology

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by
Robert J. Kopicki

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ABSTRACT

The ore deposits of the Hansonburg District are hydrothermal veins of the cavity filling type belonging to the epithermal group. The ore minerals are galena, fluorite and barite, but an extensive suite of supergene copper, lead and zinc minerals are also present. Minor amounts of strontium and vanadium are ubiquitous in the ore deposits.

Ore deposition has been controlled by a combination of structural and lithologic factors. Ore was deposited in faults, breccia and sheeted zones, and along an illite shale horizon of the Pennsylvanian Burrego formation which disconformably overlies the massive Council Spring limestone. Replacement of the limestone has not been an important factor in ore deposition. Banded, vuggy and crustification textures are common to the scattered ore bodies. Relief along the disconformity is no greater in areas of mineralization than in non-mineralized areas.

The coarse crystallinity of the hypogene minerals indicates deposition from dilute solutions under low pressure, with the supergene minerals continuing to form under the present oxidizing conditions.

ACKNOWLEDGEMENTS

Special recognition must be given to Dr. Antonius J. Budding for his initial suggestion to use the area as a thesis subject, for his patience, cooperation and critical evaluation during the study.

A deep feeling of appreciation and gratitude is also extended to the other members of the Geology Department of the New Mexico Institute of Mining and Technology, and their associates in the New Mexico Bureau of Mines and Mineral Resources. These people have unselfishly given of their time, the use of their equipment and the benefit of their geologic knowledge to the completion of this study.

The author's parents have offered the incentive and the financial assistance which made the program of study possible--endearing gratitude is extended to them.

Some measure of thanks is due Mr. E. C. Anderson, of Socorro, Mr. Lee Downey, President of Galbar Inc., and owner of the property investigated, and his mine superintendant, Mr. Glen C. King.

Recognition is also due Mr. Charles Treseder for his assistance with photographic problems.

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GEOLOGY AND ORE DEPOSITS OF THE NORTHERN PART OF THE HANSONBURG DISTRICT, BINGHAM, NEW MEXICO

INTRODUCTION

This study was undertaken for the purpose of investigating the controls of ore deposition, and determining the paragenetic sequence of mineral deposition, in the Hansonburg District, a region approximately 35 miles southeast of Socorro, New Mexico.

The information compiled for this study should be of assistance in the further exploration and development of the mineral deposits in this region.

The work has involved intensive library research, local detailed mapping, and the collection and analysis of representative samples from the fissures, faults, prospect pits and mines of the area.

The mapping was carried out over a period dating from, October 30, 1960 to June 30, 1961. A Taylor altimeter, a Brunton compass, aerial photographs and enlargements of topographic maps were employed in the completion of the mapping part of the program of study.

Mineral identification of the samples collected was carried out with the aid of a Norelco X-Ray Diffractometer and Leitz Petrographic and Metallographic microscopes. Chemical and D.C. arc spectrographic analyses were used to determine the distribution of major elemental constituents and trace elements in the ore bodies.

Although this investigation has been limited to the northern part of the mineralized area on the west facing escarpment of the Oscura Mountains, some mining has been done for copper minerals on the eastern dip slope (Peters, 1882, Turner, 1903).

The literature on the ore deposits of the Southwestern U. S., and New Mexico in particular, contains many contributions to the understanding of the geology and mineralogy of the Hansonburg District. Kottlowski (1953) has published the most recent study on the ore deposits of this region. The present investigation is more intensive and is an extension of Kottlowski's work.

Location, Owners, and Accessibility

The mapped area includes parts of the eastern half of Sections 25 and 36, T. 5 S., R. 5 E. and portions of Sections 30 and 31, T. 5 S., R. 6 E. all of which lie in the Bingham Quadrangle, of Socorro County, New Mexico (Fig. 1).

Presently, Galbar Inc., of Carlsbad, is in possession of the claims formerly owned by the Mex-Tex Company. The claims are aligned parallel to the west facing escarpment of the Oscura Mountains and extend north and south from the Royal Flush Mine in Section 30 to the Barite Mine in Section 31 where they adjoin the northern boundary of the White Sands Missile Range (WSMR).

Mr. Ben Scott, of Socorro, previously mine superintendent of the liquidated Mex-Tex Mining Company, still has some interests in the northern end of the range.

The Sunshine Mining Company, under the local supervision of Mr. Earl Elstone, their representative and mine superintendent, is leasing and operating the Blanchard claims in Section 1, T. 6 S., R. 5 E. Although brief visits have been made to these workings, per-

Figure 1

Index Map

Index map to the location of Socorro County and the Bingham Quadrangle in which the mapping was completed.

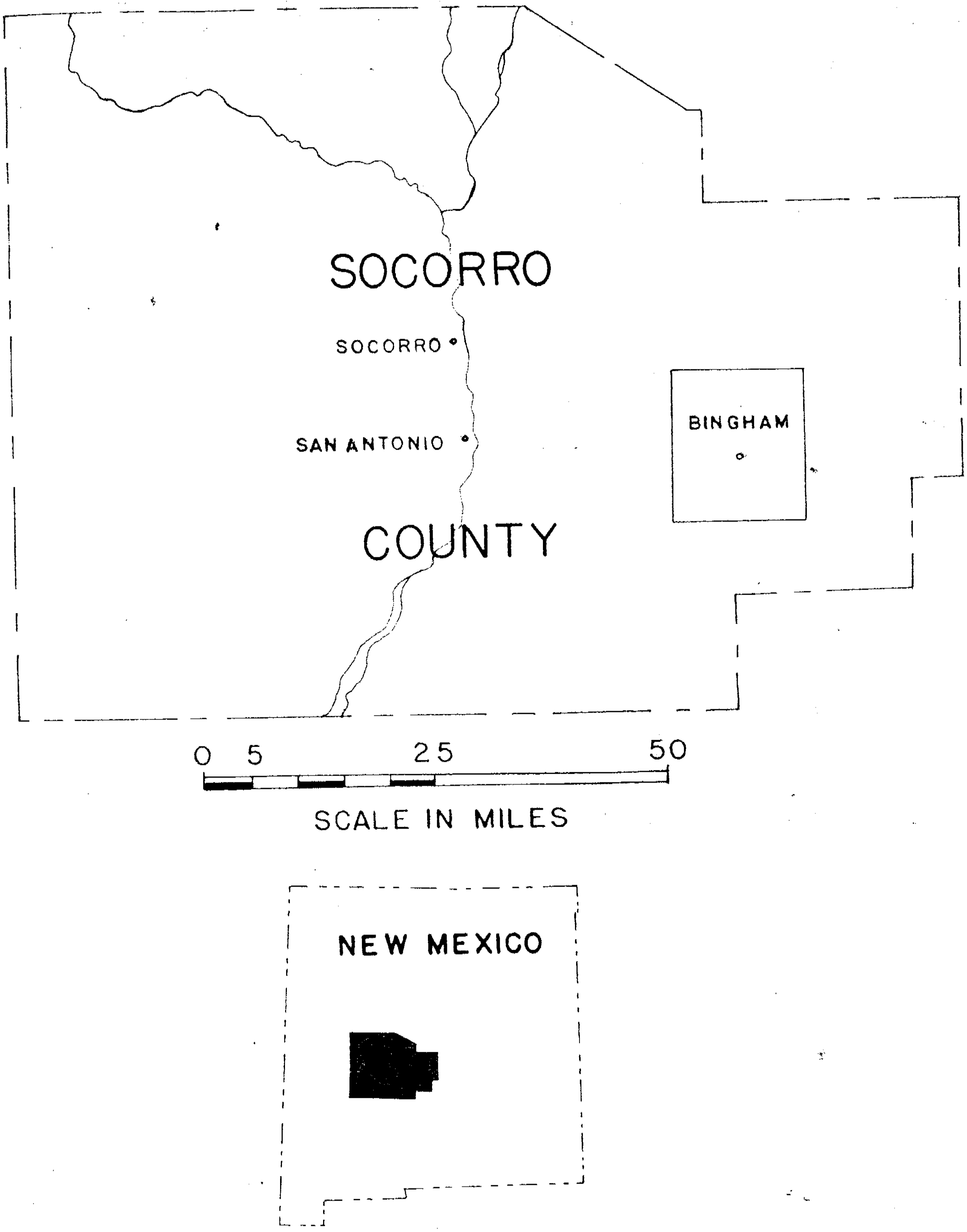
SOCORRO
COUNTY
SOCORRO
SAN ANTONIO
BINGHAM
0
5
25
50
SCALE IN MILES
NEW MEXICO

Figure 1

mission to incorporate them into the study could not be obtained.

The mining area can be reached most easily by traveling south from Socorro via U.S. Route 85 to San Antonio (10.6 miles), and from there east via U.S. Route 380 to Bingham (28.7 miles). The mine road (graded dirt) intersects Route 380, 0.4 miles east of the Bingham Post Office. The Royal Flush mine is situated 4 miles southeast of the intersection along this road. Permission for admission to this area should be obtained before any attempt is made to enter.

Physiography and Economic Geography

The Oscura Mountains, or the Sierra Oscura, are a part of the Mexican Highland Section of the Basin and Range Province, a segment of the Intermontane Plateaus Division. This section is characterized by "isolated ranges (largely dissected block mountains) separated by aggraded desert plains" (Fenneman, 1931). The Oscura Mountains and their adjoining basin, the Jornada del Muerto (Journey of Death), are physiographic features indicative of this section.

Whereas the mountains have steep wasting slopes, which coat the intermontane desert with their subaerial wastes, the basins are characterized by internal drainage incapable of moving the bolson veneer which covers the underlying rocks.

The internal drainage is a consequence of the low average annual precipitation, which amounts to about 11 inches per year, and most of which occurs during the summer. Sparse vegetation on the valley floors is also a result of this low rainfall. However, the higher elevations of the Oscura Mountains are covered by a juniper-pinion forest.

The mean annual temperature for this section is approximately 56° F.

Topographically, the range trends nearly north-south---another diagnostic feature of the Mexican Highland Section. The highest elevation in the region mapped is 6400 feet with higher elevations present to the south.

The steep mountain slope contrasts with the flat valley floor which has an average altitude of 5200 feet.

Julian Arroyo cuts across the northern end of the range and unites with the Jornada at an elevation of about 5700 feet. Only minor intermittent water courses transect the remainder of the range.

Water problems for mining and milling are also an inherent consequence of the meager rainfall. Not only must water be drilled for but it must also be transported from the regions most suitable for drilling--the eastern dip slope of the Sierra Oscura. Several catch basins have been constructed in the Royal Flush Mine area for the purpose of obtaining enough water to operate a bull jig for concentrating the ore before shipment to the mill at San Antonio, New Mexico. Only a pittance of water has been obtained by this method. The alluvial deposits of Julian Arroyo on which the catch basins are constructed rapidly absorb any water that is collected.

In contrast to the deficient water supply, timber for mining purposes is available within a few miles. However, the underground mining which has been done up to the present time has not utilized timber.

History

The water problems which necessarily hinder extensive development of the district at the present time, apparently plagued the early prospectors and miners who first entered the region. Consequently, the district has undergone a history of short, intermittent periods of mine development and exploration followed by relatively long periods of inactivity.

According to Jones (1904), the Hansonburg mining district was named for a prospector by the name of Hanson. However, as told locally, it was supposedly named after the headquarters of the Bursum ranch, the Hansonburg. The origin of the name is inconsequental but as in most mining districts which have been occupied by numerous mining concerns, names of places and workings are subject to change and interchange. As a result, some of the history of the region is difficult to follow. What is referred to by one concern as a specific mine may not necessarily be indicative of the same mine as referred to by another company. Consequently, some degree of interpretation is necessary to understand the history of the area.

Pat Higgins promoted the initial development of the district with his discovery of ore in 1872. Whether his discovery was of the type now known as "red-bed" deposits or of the hydrothermal type is not revealed in the literature.

Peters (1882) gives a timely and vivid description of his excursion to the Sierra Oscura copper-fields. They are presumably in the vicinity of what is now called Mocking Bird Gap and from his description are of the red-bed copper type, occurring in a formation interpreted, in terms of the presently defined stratigraphy, as the Bruton (Burton) formation or perhaps the lower part of the Permian units. He makes note of the fact that a group of miners were then working the prospect and shipping ore to the vicinity of what is probably now known as Carrizozo. The ore consisted of "glance copper" (chalcocite) replacing feldspar grains, plant fragments and fossils. These "ore veins" or beds were observed to be discontinuous and would disappear in a soft red marl.

The Alcazar Company developed a few properties in the district in 1901 and shipped one car of ore, presumably of copper concentrates.

Turner (1903) reports that the red-bed copper deposits of the district were worked by the Sierra Oscura Company and later by the Estey Mining and Milling Company. On the basis of his fossil data, the "copper-reefs", which he describes, would be assigned to the presently delineated Missourian Series. The ore reportedly is found in "reefs" containing copper glance and carbonate. ("One of the reefs is composed chiefly of shale, 2 to 3 ft in thickness, the whole of which is impregnated with glance and carbonate".) He also cites that there are some minor fault fissures containing chalcopyrite and that chalcocite nodules from the reefs contain bornite centers. Because the reefs are not directly associated with igneous rocks or alined structural features, he concludes that the copper ore is of syngenetic origin.

Lindgren, Graton and Gordon (1910) allude to the copper bearing potential of the district but only briefly mention that lead ore prospect pits are found in the Pennsylvanian limestone. The reference, however, is apparently made to the copper ore bodies of the Blanchard claims in the southern part of the district.

Further importance of the district's copper deposits is implied by Jones (1915). He mentions the "red-bed" ores but there is noticeable lack of consideration to the districts lead producing capabilities in his publication.

A later publication (Johnston, 1928) indicates that in 1916 the Western Mineral Products Company erected a 50 ton dry mill for the purpose of extracting galena and ignored the fluorite and barite which were regarded as gangue. This concern ostensibly operated in an area which has since become part of the bombing range (WSMR). Other observations made in this report indicated that there is no evidence for replacement of the limestone by the ore forming media and that the ore minerals were deposited as fissure or solution cavity fillings. Comments on the future prospects of the district were concluded in the statement: "the deposit appears to be surficial in character and it is unlikely that commercial bodies of either fluorspar or galena exist."

Lasky's (1932, 1933) publications overshadowed these previous few in terms of a more critical evaluation of the district. He refers to the previous concern mentioned by Johnston and reports that they shipped 15 cars of copper concentrates and a few of lead concentrates during World War I (1916-17), which was also a time of peak production of metals in New Mexico. The ore deposits were observed to occur as cavity fillings with mineralization along any single vein being discontinuous and with only pockets of ore developed. Lasky is the first to mention that there is a primary zoning of copper and lead minerals. He also refuted the syngenetic origin of the red-bed deposits. However, since the early areal descriptions on the locale's of these deposits are subject to interpretation, a comparison of the opinions of the authors cannot be made.

Rothrock, Johnson and Hahn (1946), in a resume'on the fluorspar resources of New Mexico, consider fluorite as a gangue mineral with regard to the lead and copper mineralization of the Hansonburg District.

As mentioned by Clippinger (1949), F. L. Blanchard, in 1943, had intentions of developing his interests in the southern part of the range, which until this time had been operated chiefly for galena. In 1949, the district began another period of activity with the major interested concerns being the Portales and Mex-Tex Mining Companies. Scott (page 2) had intentions of developing the property for both barite and fluorite. The major portion of the mining, at this time, was carried out by open cut methods and several cars of lead ore were shipped.

Kottlowski (1953) reported on the results of this renewed activity in the district. He cites, that the now inoperative Hurlow Mining and Milling Company had erected a mill and were exploring an ore body on their property. Also, the "Portales and Mex-Tex Companies were trucking approximately 150 tons of ore daily to their respective mills at San Antonio." Both companies produced galena concentrates while the latter, in addition, produced barite and fluorite. Supplementary interest in the area was shared by Mr. Barrett who was developing outcrops of ore in the Council Spring limestone.

Galbar Incorporated has resumed mining and some exploration on the old Mex-Tex claims. Their primary interest in the area is in producing satisfactory galena and barite concentrates, the latter of which would be suitable for use as a drilling mud additive. Several cars of lead concentrates have been shipped to the El Paso, Texas smelter, some of which have contained as much as 1% copper. Smelter payment has also been made on 7 to 8 oz/ton of silver and traces of gold in the lead concentrates. Mining has continued intermittently on an open cut basis on the Royal Flush and Julian-Malachite claims with a minor amount of underground development in the Mountain Canyon, alias the Ace High, alias the Downey Mine. Open cut mining has also been employed on the Caliche Claim.

The Sunshine Mining Company is presently leasing and operating the Blanchard claims in the southern part of the range. They intend producing galena, barite and fluorite concentrates as well as recovering by-product copper, silver and gold.

GEOLOGY

Sierra Oscura is a north-south trending fault block. The western escarpment forms a "fault line scarp" from the Oscura fault which borders the range on the west (Kottlowski, 1953). Movement along the Oscura fault has downdropped the Jornada del Muerto, to the west of the fault, along a high angle fault plane. The upthrown side, which forms the escarpment, is tilted gently to the east. However, the San Andres Mountains to the south of the Sierra Oscura, and of which the Oscura Mountains are an extension, are tilted to the west. The Jornada del Muerto is interpreted as a synclinal trough (Wilpolt and Wanek, 1951), and the Sierra Oscura is presumed to have adjoined it in a northward plunging anticlinal flexure before faulting occurred along the eastern limb of the syncline. In consequence to this northward plunging characteristic of the "paleo-flexure", the Oscura fault, which developed along the limb of the adjoined syncline-anticline, has a throw that increases to the south; northward, the fault dies out in the Oscura Anticline which is reflected in the anticlinal form of the Chupadera Mesa. The Tularosa Basin to the east of the Sierra Oscura is another synclinal basin into which the eastward tilted, fault block dips (Smith and Budding, 1959).

Pennsylvanian limestones are the major rock units of which the Oscura Mountains are formed. They unconformably overlie Precambrian granites which are not outcropping in the area mapped. However, they do appear farther to the south.

These Pennsylvanian strata form the western facing escarpment (Plate 3) and in the northern part of the range, where the fault block merges with the northward plunging anticline, red sandstones and shales of Permian age overlie the Pennsylvanian rocks.

Recent colluvial and alluvial debris from these formations conceal the Oscura fault along most of its extent and fill the Jornada del Muerto and associated arroyos with loose silt, sand and gravel deposits.

Stratigraphy

Precambrian Rocks

Kottlowski (1953), reports Precambrian rocks as belonging to the "granite-greisen" group of Johannsen's classification. However, no Precambrian rocks are outcropping in the area under investigation.

Pennsylvanian Formations

Thompson (1942) subdivided the Pennsylvanian sediments of New Mexico into several distinct formations on the basis of the microfossils (Fig. 2). Kottlowski (1953) measured a section of these Pennsylvanian strata in the Hansonburg District and subsequently modified Thompson's column to fit the local variations. He retained the original names for

Figure 2

Stratigraphic Column

Pennsylvanian nomenclature and stratigraphic column for the Hansonburg District. After Kottlowski, 1953, and Hambleton, 1959, with minor additions.

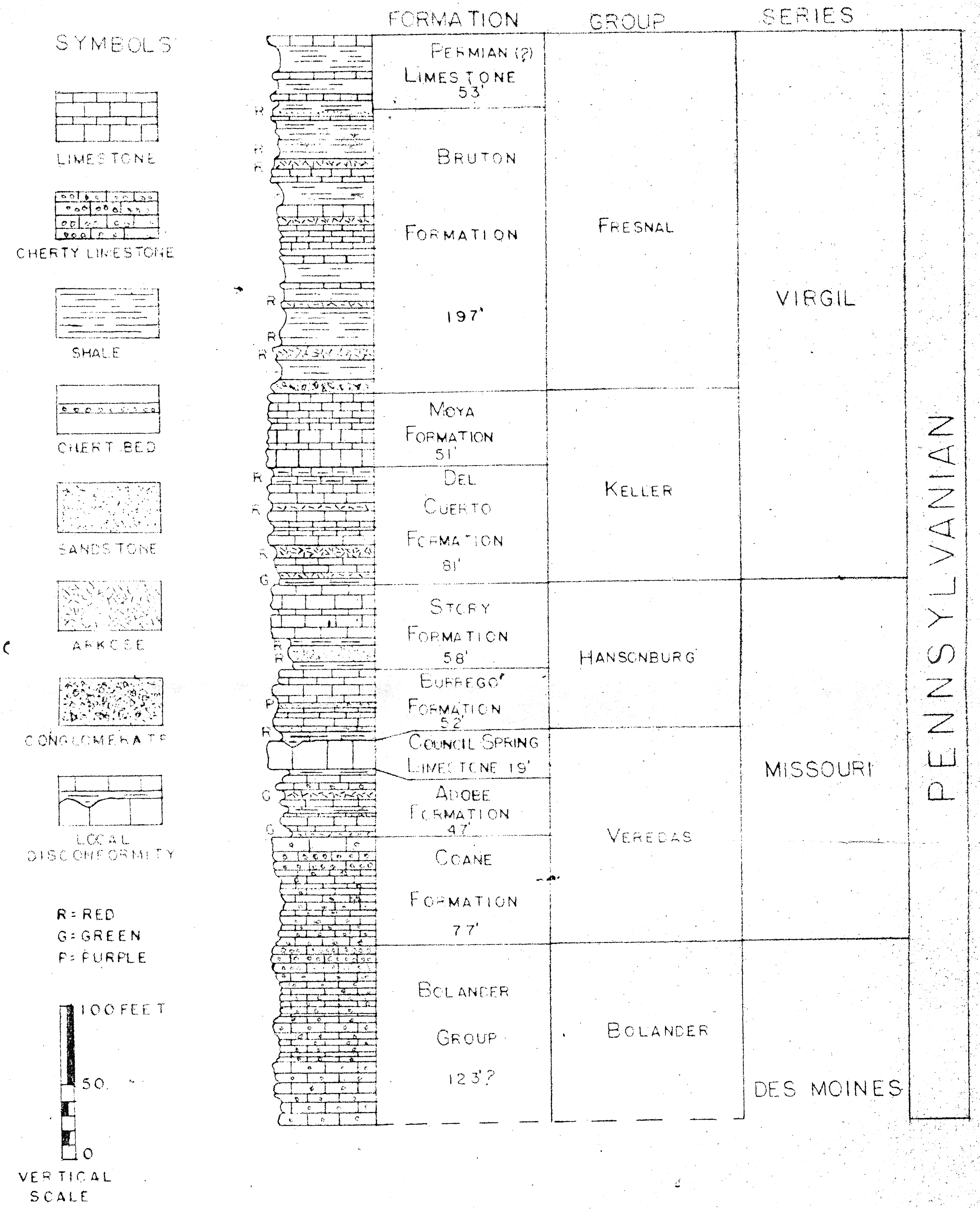
FORMATION
GROUP
SERIES
PENNSYLVANIAN
VIRGIL
MISSOURI
DES MOINES
FRESNAL
KELLER
HANSONBURG
VEREDAS
BOLANDER
PERMIAN (?) LIMESTONE 53'
BRUTON FORMATION 197'
MOYA FORMATION 51'
DEL CUERTO FORMATION 81'
STORY FORMATION 58'
BURREGO FORMATION 52'
COUNCIL SPRING LIMESTONE 19'
ADOBE FORMATION 47'
COANE FORMATION 77'
BOLANDER GROUP 123'?
R
G
P
SYMBOLS
LIMESTONE
CHERTY LIMESTONE
SHALE
CHERT BED
SANDSTONE
ARKOSE
CONGLOMERATE
LOCAL DISCONFORMITY
R = RED
G = GREEN
P = PURPLE
100 FEET
50
0
VERTICAL SCALE

FIGURE 2

the formations but described several additional discernible lithologic units in the column. Hambleton (1959), measured and described the different lithologic units of the Missourian Series in more detail in the same area.

Wilpolt and Wanek (1951) divided the Pennsylvanian strata into formational units of considerably greater breadth. They named the interval between the top of the underlying Sandia formation and the bottom of the Adobe formation of Thompson, the Lower, gray, limestone member of the Madera formation (390 ft). The Upper arkosic limestone member of the Madera formation (375 ft) includes all of Thompson's formational units from the bottom of the Adobe to the top of the Moya formation, plus 65 ft of his overlying Bruton (Burton) formation.

Although this latter classification is perhaps suitable for mapping on a regional scale, it does not show sufficient detail for mapping on a local basis. Therefore, an attempt has been made to use Thompson's classification which although satisfactory for stratigraphic purposes is not employed without inherent difficulties. Problems of correlation arise in trying to trace the various limestone members across faults and through concealed areas; only a few good marker horizons of strikingly different lithology exist, for example, the oldest unit of the Story formation, or the Council Spring limestone. Also, the relatively abundant megafossils have not been stratigraphically delineated for this sequence. Consequently, in areas just west of the Oscura fault, for ex-

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ample, the units as mapped, are subject to some uncertainty.

Mapping has been restricted essentially to the Pennsylvanian strata, mainly because ore deposits occur only in the Pennsylvanian sediments. As far as is known, no mineralized zones exist in the overlying Permian Abo formation.

For mapping purposes, the Pennsylvanian section (Fig. 2) has been divided into undifferentiable Bolander-Coane formations, Adobe, Council Spring Limestone, Burrego, Story, Del Cuerto, Moya and Bruton (Burton) formations.

Bolander Group

The Bolander group of the Upper DesMoines Series has been mapped by Kottlowski (1953) to the East of the Hickey No. 1 Mine and has been mentioned by Hambleton (1959), as being differentiable from the overlying Coane, on the basis of containing more chert. However, differentiation by this criterion is difficult to apply in the field area and no further attempt has been made to distinguish between these two units.

Coane Formation

The Coane formation occurs at the base of the Missourian Series, and has been mapped as an undifferentiated lithologic unit. According to Hambleton (1959), the formation consists of massive to medium bedded, gray to buff-weathering, cliff-forming limestones which become

Plate 3

Oscura Mountains

Composite picture of the westward facing escarpment of the Oscura Mountains, as viewed from the northwest. All formations are of Pennsylvanian age. The cliff forming limestone midway up the slope is the Council Spring limestone. The Snake Pit and Barite workings are visible at the top right hand side of the photo. The Royal Flush Mine (not visible) lies to the left on the photo.

progressively more argillaceous near the contact with the Adobe formation. Near the supposed base of the formation the units contain more limestone nodules and chert and hence the difficulty in distinguishing this formation from the Bolander group.

Fusulinids are fairly abundant in the formation, and Thompson (1942) cites that these are Triticites whereas, the underlying Des Moines contains Fusulina.

Thicknesses of 55 to 77 feet have been recorded for this portion of the Missourian Series.

Adobe Formation

The Adobe formation lacks resistant beds and forms slopes consequently accenting the cliff-forming characteristics of the underlying Coane formation and the overlying Council Spring limestone. The formation is described by Hambleton (1959) as being 62 feet thick. A basal unit of gray to greenish sandstone cemented by calcite grades laterally, from the area of the Hickey Mine northward into a friable sandstone, and further to the northeast, across Julian Arroyo it assumes characteristics similar to the arkosic sandstone at the bottom of the Story formation.

The upper part of the formation consists of interbedded, green to yellow shales, containing limestone nodules and cherty to non-cherty, non-fossiliferous to fossiliferous, gray, massive to medium bedded limestones. These limestones weather into low step-like cliffs within the Adobe formation.

Thompson (1942) suspects a disconformity between the Adobe and Coane formations.

Council Spring Limestone

The Council Spring limestone occurs at the top of the Veredas group in the Missourian Series. Its cliff forming characteristics make it a very distinctive and easily discerned formation when viewed along the escarpments or arroyos of the district. As can be seen from Plate 1 (pocket), the Council Spring girdles the entire mapped area in a narrow outcrop band.

use words no one understands

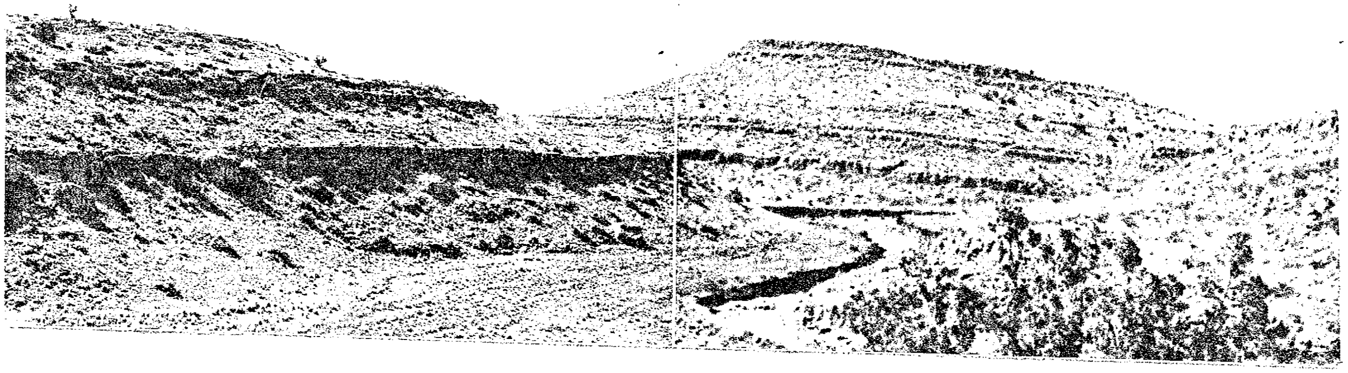
The circumvallation of the Council Spring is a consequence of the structural pattern developed between the Oscura and Hansonburg fault zones (Plate 2). The most important lithologic characteristic of the limestone is its fine-grained, massive-bedded development. Only a few fossils and a meager amount of chert are scattered through its 19 ft thickness. It weathers differentially from light-gray to buff-brown and has a tendency to break into vertical columns or blocky masses (Plate 4).

Despite its fine-grained character and other seemingly poor intrinsic characteristics as an ore depositing medium, a considerable portion of the mineralized zones of the district are found in the top of the Council Spring limestone and the bottom of the overlying Burrego formation.

Plate 4

Julian Arroyo

Composite photograph along Julian Arroyo, looking west, in the vicinity of the Hansonburg faults. The lowest cliff forming formation is the Council Spring limestone which tends to break into blocky masses (left foreground) or vertical columns (central background). Moya formation caps the hill in the background.



The "pot-holes" (Plate 5-A) developed in the top of the Council Spring limestone, along the disconformity, might be considered representative of a paleo-karst topography. However, by Thornbury's (1957, p. 317) prerequisites of karst regions, jointing, an essential requisite of karst areas, is not extensively developed or in direct association with the "pot-holed" surface in the Council Spring limestone. Only cross-sectional views of the disconformity were available for observation and the pot-holes may actually have a dimension of length which was not seen. If this premise is true, interpretations of this feature as a submarine furrow or a stream channel might be more applicable.

Burrego Formation

The Burrego formation in conjunction with the overlying Story formation comprises the entire stratigraphic portion of the column designated as the Hansonburg group (Thompson, 1942).

The existence of the disconformable surface, between the Council Spring limestone and the Burrego formation, is only locally developed and might be due to deformation prior to Burrego deposition (Plate 5-B).

In good outcrop areas, midway between the Oscura Fault and what has been designated the Hansonburg Faults, a nodular buff to brown weathering limestone is found capping the Council Spring and no evidence of the shaly layer exists.

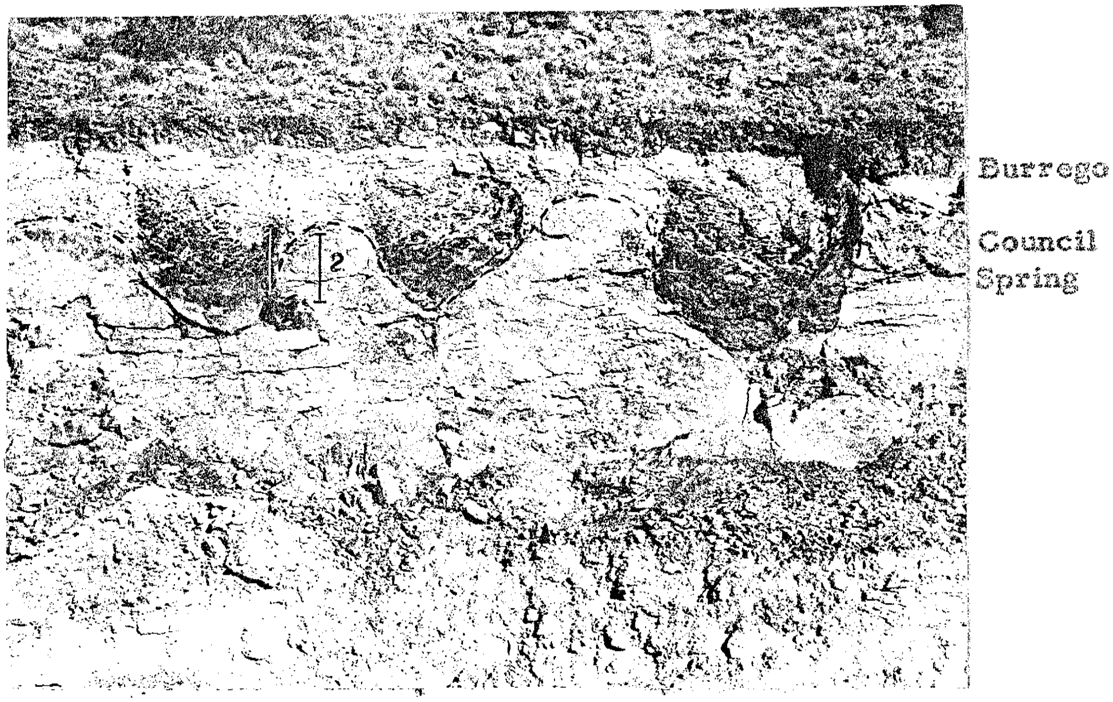
Plate 5
A
"Pot-holes"

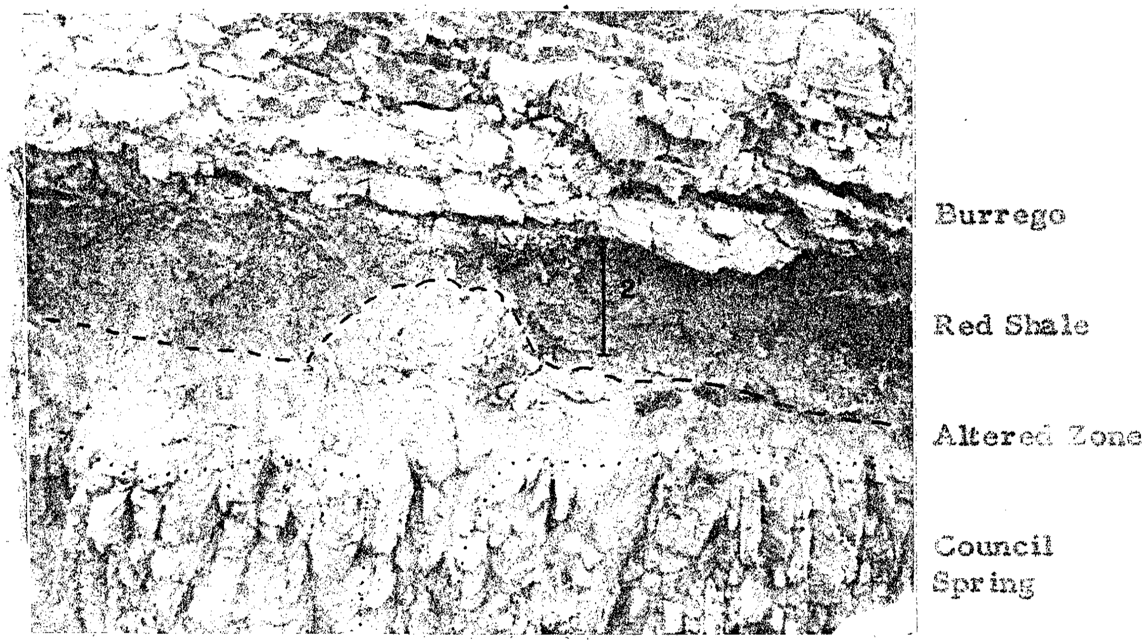
"Pot-holes" in the top of the Council Spring limestone filled by the first shaly member of the Burrego formation, as seen at the Caliche-Prospect on the west facing escarpment of the Oscura Mountains.

B

Pre-Burrego Fault

Fracture zone in the Council Spring limestone below the red shaly zone of the Burrego formation. The fault does not extend into the overlying limestone member of the Burrego. The light colored "pimple" in contrast with the red shale is a brown hydrothermally altered zone which spreads laterally out along the contact. (Picture taken north of the Ora Mine in a cross-cut trench looking South).


2
Burrego
Council Spring


2
Burrego
Red Shale
Altered Zone
Council Spring

Beyond the interest already devoted to this single unit of the Burrego, is the additional significance it has as an ore depositing medium. Nearly all the mineralization which has any lateral extent is found along a plane approximately concordant with the position occupied by this shaly unit, i.e., between the top of the Council Spring limestone and the overlying limestone members of the Burrego formation. Subsequently, this shaly unit is used as a marker horizon for ore exploration and development in the area mapped.

The remaining portion of the Burrego formation is considerably less conspicuous and consists of light gray to gray weathering limestones. It also contains more nodular limestone members and is considerably more fossiliferous than the older formations. The units vary in character from irregular to even bedded to massive in both the vertical and lateral directions. An important lateral change noted occurs along the horizon occupied by the purple and green crinoidal sandy limestones in the lower half of the formation (Kottlowski, 1953). In the northern part of the range, they give way to purple and green micaceous "sandstones" which are extremely shaly and very friable and consequently occupy receding positions on the slopes of the Oscura Mountains. The similarities of this purple member of the Burrego to the first member of the overlying Story formation would present some problems in lithologic distinction were it not for differences in thickness between the two members. The former is approximately 4-5 ft thick while the latter measures about 21 ft in thickness.

However, the two formations are not without other similarities. Both contain black mottled units near their contacts with the overlying formations. The black mottling effect is attributed to contained algae (Hambleton, 1959). In the Burrego limestone units, the background is usually a lighter gray than in the Story formation.

A distinction between the Burrego and Story formations could perhaps best be made by a thorough description of the abundant megafauna, principally brachiopods, which occur in both formations.

Story Formation

The Story formation contains perhaps one of the most useful and distinctive marker horizons of all the lithologies in the section studied. Within its 58 foot thickness is a basal member, approximately 20 ft thick, consisting of a dark red to maroon, micaceous to arkosic sandstone. The arkosic or micaceous character varies laterally. This unit is overlain by a 2 to 3 ft thick gray to greenish shaly member.

The upper 25 ft of the formation consist of two dense, fine grained, massive limestone units separated by a nodular limestone horizon. The lower of the two units is generally light gray while the upper unit varies from dark gray to blue gray in color. Both units contain abundant brachiopods which score the surface of the limestone with their white, curvilinear outlines. In addition, the surface of the upper unit is blazed with a sporadic agglomeration of black mottlings. Yet, as distinctive as this upper unit may seem to be, it is quite easily confused with either the topmost unit of the Burrego or the second massive limestone unit of the Moya formation. This latter unit is approximately of the same thickness as the uppermost member of the Story.

Del Cuerto Formation

At the bottom of the Keller group of the Virgil Series is the Del Cuerto formation which to all appearances conformably overlies the Story. The basal unit consists of red and green limy shales not unlike the shales found along the disconformable contact between the Council Spring limestone and Burrego formation. Thompson (1942) on the basis of faunal evidence, regards the contact between these two formations as representative of a disconformity. However, no evidence of a paleokarst or furrowed surface in the massive limestone bed at the top of the Story formation was found. There is also no evidence of mineralization along this horizon, such as occurs between the Burrego formation and the massive Council Spring limestone.

The shaly unit comprises only about 3-4 ft of the total thickness of the Del Cuerto formation which is approximately 80 ft thick. The remaining portion of the Del Cuerto formation consists of interbedded, nodular gray limestones with red, green and brown weathering, medium grained, arkosic sandstones. The limestones vary in lithologic character from dense, fine-grained, massive beds to those which are more coarsely crystalline and contain limestone nodules in irregularly bedded, slabby units. A few of these nodular beds were observed to have a reddish hue on a weathered surface. The arkosic members, in many instances, bear lithologic characteristics similar to those already cited for the arkoses in the Story and Burrego formations.

The limestone formations contain little or no chert but the upper limestone members of the formation, in some locales, exhibit black mottled surfaces.

Fossils are profusely distributed throughout the limestone section and are generally more abundant in the upper units. Horn corals, crinoid stems, and brachiopods are the major constituents of the assemblage. Some sparsely distributed Bellerophon gastropods were noted in what may either be the Del Cuerto or Moya formations. A further distinction is impossible for the genera have only been delimited to the Virgil Series in this area.

The formation weathers to a slope with the limestone units forming step-like terraces among the more easily eroded arkosic sandstone and shaly members. Generally, the upper and lower contacts of this formation are not clearly defined because of the talus debris characteristic of this formation and the overlying Moya formation.

Distinction between the Del Cuerto and Moya formations, for mapping purposes, is based upon the measured thickness.

Moya Formation

The Moya formation is the uppermost of the massive bedded limestones in the section examined. It is also the youngest formation of the Keller group. The entire formation (51 ft thick) consists of limestone as reported by Thompson (1942). The contact with the overlying Bruton formation was not seen within the area and the presumption might well be made that the more evenly bedded limestone units at the top of the formation, as described by Thompson (1942) have been removed by erosion.

The lower units are dense, massive bedded, buff weathering limestones which become coarser grained and more fossiliferous vertically. However, the lower limestone bed conformably overlying the Del Cuerto is somewhat bioclastic and grades vertically into the first massive unit of the Moya. Very little chert is disseminated through the formation but black mottled surfaces are an inherent characteristic.

Spatially, the massive beds are found capping the hills except for portions of the dip slopes where mass wastage and other erosion processes have broken up the Moya formation into vertical columns and blocky masses exposing the underlying beds.

Bruton Formation

The Bruton (Burton) formation constitutes the youngest of the Pennsylvanian sediments mapped. Outcrops of the Bruton formation have been indicated as questionable on the west side of the Oscura fault south of the Hickey Mine. With additional paleontological and stratigraphic control the beds between the Hansonburg faults might possibly prove to be Bruton, as mapped by Wilpolt and Wanek (1951).

The incomplete section of Bruton mapped, consists of interbedded red shales, purple arkoses, conglomerates and thin, irregularly bedded, nodular limestones. The conglomerates may show graded bedding with cemented quartz and feldspar grains.

Clastic arkoses with typical red weathering characteristics are the prominent features of this formation.

Mid-Tertiary (?) Intrusives

Numerous authors (Doyle, 1951, Harley, 1934, Johnston, 1928, Kottlowski, 1953, Rothrock, 1946, Tovote, 1919) have indicated the close association of mineralization in the Pennsylvanian sediments of the Southwest, and in some cases in the Hansonburg District in particular, with igneous activity in the Tertiary.

Although no intrusive rocks were noted in the immediate vicinity, generalizations, as to the action of deep seated, regional, igneous activity, may be made. Rothrock (1946) regards the mineral deposits of the Rio Grande Valley as being derived from the crystallization of ascending aqueous solutions, acidic in composition, which were ultimately conceived in a crystallizing, deep seated, cooling magma, in Tertiary time.

Tovote (1919) cites that part of the Tertiary period in the Southwestern U.S. was characterized by fracturing with a general northwest-southeast trend and andesitic igneous activity which was followed by a period of rhyolitic vulcanism favoring the development of north-south and east-west fractures. On the basis of fracturing, the mineralization of the Hansonburg District might best be dated to the andesitic period. However, from mineral associations for this period, as indicated by the author, allocation of the Hansonburg District should be made to the rhyolitic period.

Kottlowski (1953) indicates that "sills and dikes of monzonite and diorite intrude into the Pennsylvanian strata of the Sierra Oscura". He has also noted the occurrence of a "hornblende sodaclase diorite" sill north of the area mapped. Small crystals of barite are reportedly associated with the diorite and consequently the conclusion that the mineralizing solutions may have had their genesis from a crystallizing magma of intermediate composition seems valid. However, the actual direct association of igneous rocks and mineralization in this area cannot be proven.

Quaternary Alluvium

The mass wastage and internal drainage characteristics of the region greatly encourage the development of a loose pediment gravel and alluvial veneer consisting almost entirely of limestone. Only the more friable and coarsely crystalline units of the Pennsylvanian and Permian strata contribute to the silt and sand size particles distributed in Julian Arroyo and within the bolson covered surface of the Jornada del Muerto. Most of the silt and sand particles are derived from the Permian Abo formation, and accordingly the color of the bolson alluvium bears a red cast.

Colluvial talus deposits within the mapped area are composed almost entirely of rock debris procured from the associated Pennsylvanian limestone section. This agglomeration of different sized material is often found cemented by caliche or gypsite or both. The constituent mass conceals portions of the main Oscura and other minor faults in addition to geologic contacts along the west facing escarpment.

Structure

Incorporated within the relatively simple structural image portrayed by the regional geology (page 10), is a complex system of faults which parallel or sub-parallel the Oscura fault (s).

Wilpolt and Wanek (1951) have indicated that the region has definitely suffered the effects of two major periods of tectonic activity and quite possibly the consequences of a third minor period. The first period of orogeny occurred in the interval starting at the end of Upper Cretaceous deposition and before the beginning of Lower Tertiary deposition and was accompanied by folding and high-angle faulting. Effects of the second period of mountain building are assumed to have been more widespread. During the Middle and Upper Tertiary, such structural features as the Rio Grande Depression, the Jornada del Muerto and the Oscura Mountains were developed. This period is also regarded as one of extensive volcanic activity. Only meager evidence is available in the mapped area to attest to an earlier minor Pennsylvanian orogeny.

Faults in the area under investigation have been placed into three groups; (1) possible pre-Burrego-faults, which are essentially barren of hydrothermal minerals, (2) faults formed prior to and coincident with mineralization which are extensively mineralized, (3) a few faults which may have been formed during a post-mineralization period.

Only one good vertical exposure of a fault (Plate 6-A & 5-B) was observed which may attest to movement in the Pennsylvanian. This fault extends into the overlying Burrego formation only as far as the middle part of the red shaly member. No evidence of the fault is found in the limestone members of the Burrego and there is also no apparent displacement of the Council Spring limestone along the nearly vertical plane of the fault. Surface exposures of what have been considered minor faults or fractures and which consequently haven't been mapped, exist only on the surface of the Council Spring limestone and cannot be traced vertically into the overlying Burrego. However, in these areas the shale member of the Burrego formation may be considered to absorb any of the movement which has occurred along these fractures.

A buff-brown altered zone in contrast with the red shale is associated with the fault. This altered zone rises above the fault in an eruptive "pimple" (Plate 6-A) and spreads laterally along the previously described disconformable contact between the shaly member of the Burrego formation and the Council Spring limestone. Analyses carried out on the altered zone and the red shaly member, Table I, might indicate a possible hydrothermal origin for the altered zone with the buff-brown color of the altered zone attributed to limonite staining, with the limonite derived from the oxidation of pyrite.

TABLE I

Analyses of Burrego Red Shale and Limonitic Material of the Altered Zone

	Red Shale	Altered Zone
Clay Analysis*	Illite or sericite	Illite or sericite
Elemental Analysis		
Conc		
High	Si, Ca, Al, Mg	Si, Ca, Al, Mg, Fe
Low	Fe, Ti	Ti, Cu
Trace	Mn, K, Cr(?), Ni(?)	Mn, V

* Clay analyses by X-ray powder diffraction techniques
Elemental analyses by D.C. emission arc techniques

The fault is assumed to have acted as a conduit for the distribution of later hydrothermal fluids.

The second group of faults, those formed approximately concurrent with mineralization, are dated to the later Tertiary period of deformation cited by Wilpolt and Wanek (1951). This period of orogeny is apparently the one which has caused the major structural and physiographic trends in evidence in the area at the present time. However, the effect of possible Pennsylvanian faulting cannot be discounted as a factor in determining the position and distribution of the present structures. In fact, the existence of a Pennsylvanian set of faults may be hard to recognize due to later movements which could have occurred.

The faults of the second group are positioned along the base of the west-facing escarpment. The many North-South trending faults seen in Sec. 36 and 30 may be considered a broad fault zone, 1/4 mile wide, associated with what has been designated the main Oscura fault(s). Movement along the zone has been such that the greatest displacement is in the southern part of the range and rapidly decreases to the north where the displacement is absorbed by the overlying incompetent Permian Abo beds. The interim surface between the Oscura fault zone and the Hansonburg faults has been named the Hansonburg fault block (Plate 2). Unlike the Oscura fault(s), the Hansonburg faults decrease in throw to the South. This en-echelon movement has produced a northeasterly dipping fault block, whose surface is a broad, dissected, sloping plain which exhibits only minor variations in dip.

In the southern part of the range, where the bottom of the Coane formation is presumed to be thrown against the middle part of the Bruton formation, along a high angle reverse fault plane, the stratigraphic throw along the Oscura fault is about 450 feet. In the northern part of the range, between the Oscura fault(s) and those named the Axis faults (Plate 2) the displacement is only 52 feet as measured by the positioning of the lower part of the Burrego opposite the upper part of the Story formation. Relative displacement along the en-enchelon and parallel group of faults associated with the Oscura fault, varies from a few feet to perhaps a few inches. Field evidence would seem to indicate that these faults meet the present surface at high angles becoming nearly vertical in depth.

The trace of nearly all the faults in the district is outlined by either a narrow (two inches to three feet) silicified or mineralized zone in direct association with a wider brecciated zone, (5 ft to 50 ft). Drag along the faults by the less competent members of the formations (Plate 6-B) may account for the development of the wide fracture zones in the over- and underlying more competent limestone members. The variable slope of the faults may be a function of the breccia zones which are visualized as having a wide outcrop near the surface and subsequently become narrow corridors of brecciated material with depth.

Some of the faults, may exhibit a "knife-edge" spacing with no silicification or mineralization along part of their outcrop. In all cases

Plate 6

A

Pre-Burrego Fault

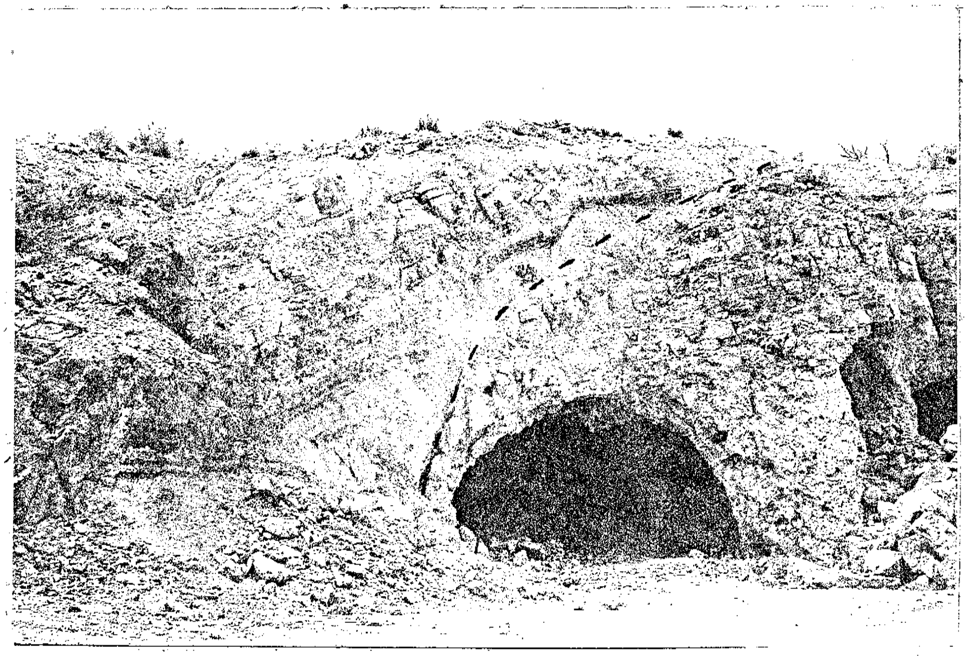
A full view of a pre-Burrego fault. The eruptive "pimple" (outlined) marks the trace of the fault into the disconformable, shaly member of the Burrego formation. The surface of the Council Spring limestone exhibits only minor undulations in this area.

B

Fault Plane Drag

View southeast along the Little Oscura fault which shows the drag along the fault plane. The lower part of the Story formation (left) lies against the lower part of the Burrego formation (right).


2



though, a brecciated zone is found.

Minor strike-slip movement associated with vertical displacement along the fault plane is found on the faults near the northeast corner of Sec. 36. These faults have an azimuth east of north and are considered to have evolved in response to adjustments required under a torsional stress field imposed by prior faulting along the Oscura fault coincident with the tilting of the fault block.

Preemptive evidence for a third group of faults, those without any mineralization, is best found in fissure veins which have been brecciated by a later movement along antecedent fault planes after the primary phase of mineral deposition had ceased, (Plate 7-A). Other evidence which might be offered includes faults along which no hydrothermal minerals exist. But, since mineralization along faults is extremely variable, the non-existence of any hydrothermal minerals may only signify an unsuitable area of deposition (the Hansonburg faults may tentatively be placed in this class (Plate 7-B).

Minor faults which were not mapped are associated in parallel to subparallel arrangement with the other groups of faults. The azimuths of fracture zones or jointing planes associated with all the faults were recorded. In the event the surface of the joint was coated by either siderite or calcite the trend of the joint was recorded as a parting.

Plate 7

A

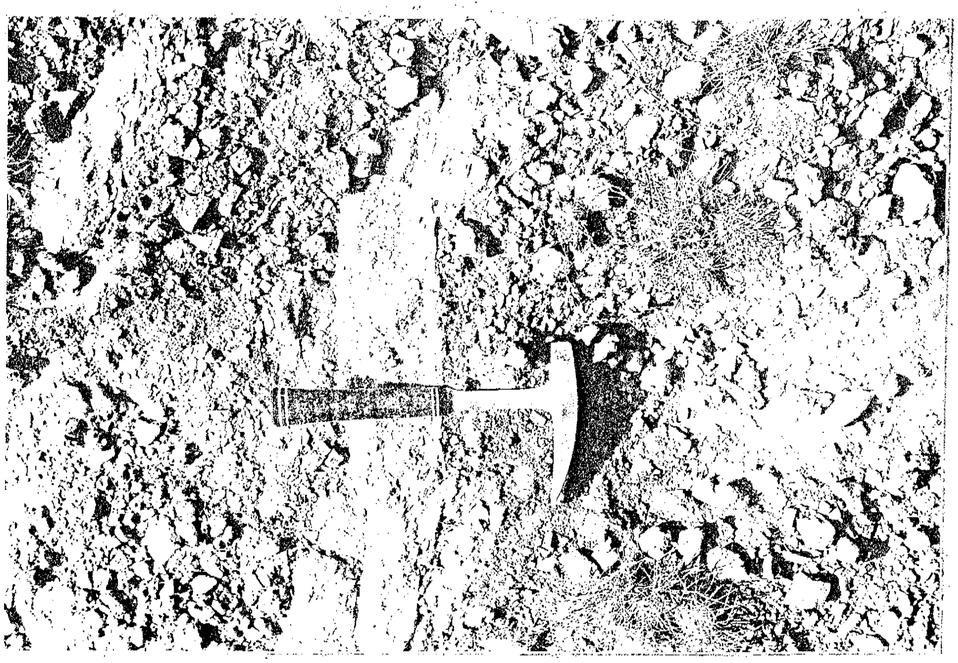
Barite Breccia

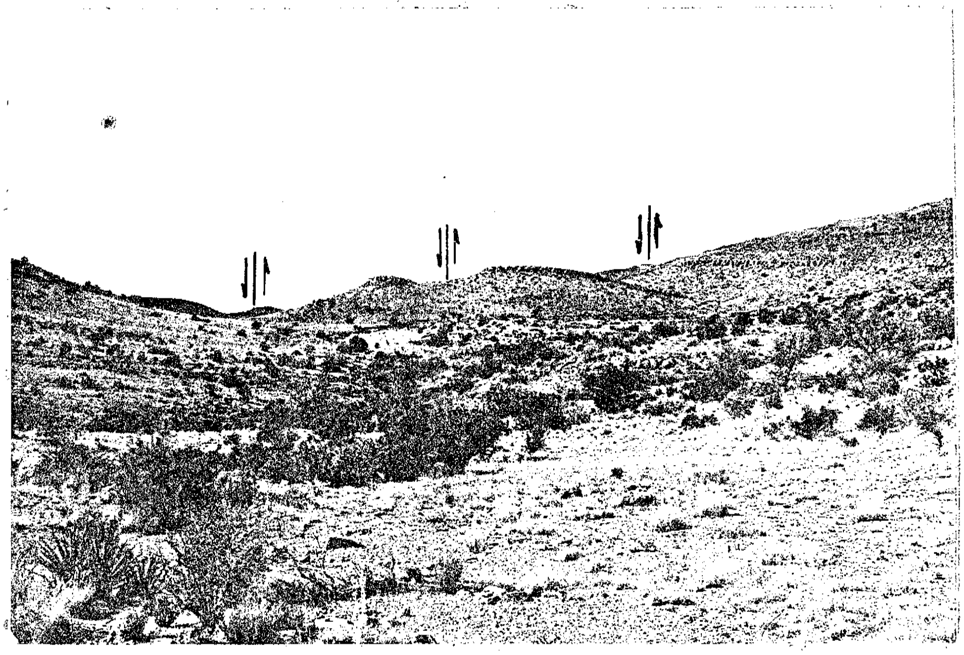
A fissure vein of barite and fluorite along the Oscura fault, south of the Mountain Canyon Mine, in which the barite has been brecciated.

B

Hansonburg Faults

A view north along the Hansonburg faults which clearly indicates the movement along the fault planes. The cliff forming limestone is thought to be in the Moya formation with successive blocks down-dropped to the West. Displacement is about 50 ft and decreases rapidly towards the foreground.





Partings are more in evidence than their progenitors, joints. The siderite fillings may vary in width from a fraction of an inch to almost three inches across. Two orientations are predominant, a northwest and a northeast striking set. Generally the northwest set is more sharply defined, is less variable in trend and is often the wider of the two sets. Also the northwest set in most cases parallels the faults with a maximum contrast in strike varying from north to N 25 W. The average or most statistically prevalent trend is N 5 W and this azimuth is visualized as representative of the major structural attitude for the area. Most of the faults have an average lineament approximating this value.

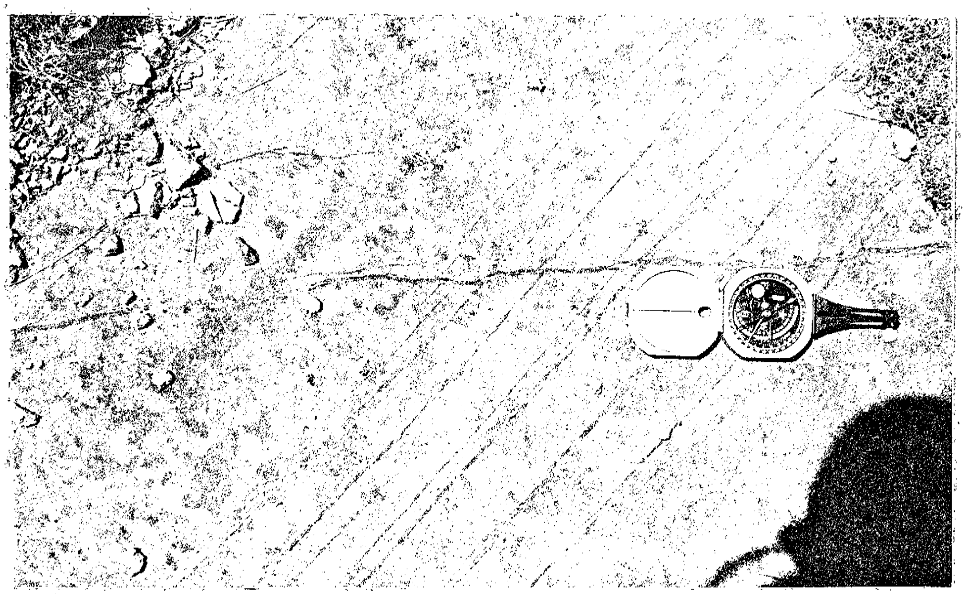
The northeast set exhibits greater variation in strike, from north to N 40 E. However, nearly all partings measured, with a trend exceeding N 25 E, appear to be formed later than the northwest set (Plate 8) and quite often a siliceous stringer cleaves the siderite filling along its axis. By analogy, the northeast striking faults are assumed to be later in development than the more northwesterly striking faults.

There is also a statistical variation in the number of partings, of both sets, within any locale. Generally, the sets are more numerous in the locales bordering the Oscura fault(s) and rapidly decrease in number east toward the Hansonburg faults. Petrographic investigations

Plate 8
A

Partings

Partings on the surface of the Del Cuerto formation northeast of the Mountain Canyon Mine which illustrates the character of the northwest and northeast sets (compass lies along the northeast set) and exemplifies that the northeast set is later than the northwest set. A white silica stringer passes along the center of the northeast parting which is filled with siderite.



indicate that relative displacements up to several millimeters have occurred along these partings.

In a review of the regional geology for the district, many striking similarities were found to exist between the geology and mineralogy of the Oscura Mountains and that of the Northern Caballo and San Andres Mountains. Some of the analogies have been directly indicated while others can only be inferred (Doyle 1951, Johnston 1928, Kottlowski 1955, Rothrock and Johnson 1946). Consequently, the premise may well be validated to extend some of the structural and mineralogical interpretations made on a regional basis for these areas to the Hansonburg District. This line of reasoning has proved successful in the preceding structural analysis and in some cases may be extended to a study of the ore deposits in the Oscura Mountains.

ORE DEPOSITS

Elemental Distribution

In order to establish elemental variations in the area nearly all the faults were sampled, especially those lacking in visible mineralization. About 30 samples were subsequently ground for emission spectrographic studies (Appendix I) which have indicated the distribution of introduced elements on a qualitative basis. (Relative estimates on the elemental content of the samples analyzed are reported as high or medium, low and trace). The elemental analyses have in many cases proved useful as an aid in determining the mineralogy or expected mineralogy of a locale, besides establishing the elemental variations among faults.

The results of this portion of the study have indicated that there is less variation in the elemental content from fault to fault than there is along any single fault.

TABLE II

Elemental Analyses for the Area

Background elements: Ca, Al, Si, Mg, Mn, Fe, K, Na, Cr(?), Ni(?)
Introduced elements: Sr, Ba, Fe, Pb, Cu, Zn, V, Ti, Ag, Mo

The background elements listed in Table II were found in all the faults with the exception of chromium and nickel which were found only in the shaly member of the Burrego formation immediately above the Council Spring limestone. The background elements are ubiquitously distributed throughout the rocks of the stratigraphic column and are considered to have been mobilized by the mineralizing fluids which permeated the region and are thus regarded as contaminants in the faults. Consideration must be given to the fact, however, that a large portion of these background elements, especially silica, may also have been introduced.

The most profusely distributed introduced elements are: Sr, Pb, Fe, V, Ti, and Cu. Barium is noticeably absent along some of the faults. Wherever barium is found however, strontium is also in abundance but the converse is not true. Silver and molybdenum were found as trace elements only along the Axis and Royal Flush faults. The absence of these two elements along other faults is attributed to the difficulty in obtaining representative samples. In most cases, the collection of samples was restricted to exposed faults and both elements form soluble complexes which are readily dissipated in surface exposures (Rankama and Sahama, 1950). If more samples were available from underground workings, a greater preponderance of these two elements might be expected.

Ames (1957) lists some of the anionic elemental constituents of the area. Chlorine is apparently the most ubiquitously distributed of these and is reportedly found in the vacuoles of galena, barite and fluorite.

The elemental content of samples taken from Julian Arroyo, Table III, reflects a very slight change from the elemental analyses completed on the faults, fissures and sediments of the area. The more noticeable changes are in the lack of any recorded silver or molybdenum and the more definitely ascertained distribution of chromium.

TABLE III

Elemental Analyses on Samples from Julian Arroyo*

Conc:	Heavy Mineral Fraction	Light Mineral Fraction**
High	Ca, Fe, Al, Mn, Sr, Ti, Ba, Si, Mg	Ca, Al, Na, Si, Mg
Low	Pb, V	Fe, Mn, Sr
Trace	Cr, Na, K	K, Ti, V

* Samples sized to minus 65 and plus 150 mesh Tyler
** Density separation at S.G. = 2.94

The most important conclusion which can be drawn from the study of elemental distribution is in relation to the relatively even distribution of introduced elements among the faults. The area must have been extremely "open" or consisted of very "permeable ground" which allowed for extensive migration of mineralizing fluids along the conduits provided in the form of fault or breccia zones. The other important facet of the examination is the variation of elemental content in relation to the paragenetic sequence of hypogene deposition.

Mineralogy

The introduced and background elements of the Hansonburg District are combined in a number of chemical compounds of different oxidation states to produce a wide ranging suite of minerals. In the area mapped, only galena, barite and fluorite can be considered ore minerals and are perhaps the most common in occurrence. An unequal distribution of other minerals is characteristic for the district as a whole.

The following list of minerals includes both those reported in the literature as well as those identified in this study.

Alabandite, MnS

Alabandite has not previously been reported for the district and only one crystal of it was found in a silicified limestone. Identification was made on the basis of etch tests and confirmation was by microchemical tests. The crystal measured 1 mm by 0.5 mm and possessed a good basal cleavage.

Atacamite, $CuCl_2 \cdot 3Cu(OH)_2$

Atacamite has not been positively identified in the mineral suite from the northern part of the district. However, Sun (1947) has reported its occurrence in association with other supergene minerals. The mineral is probably more abundant at the Blanchard properties in the southern part of the range.

Aurichalcite, $2(ZnCu)CO_3 \cdot 3(ZnCu)(OH)_2$

Aurichalcite, one of the last supergene minerals to form in the area, occurs as bright, green, acicular matted, to felty incrusting crystals which are readily distinguished in hand specimen. Crystals as long as one centimeter have been measured. The mineral is most commonly found in druses, lining cavities in the silicified limestone. Aurichalcite has a rather limited distribution and is most commonly found in the locale of the Snake Pit and Barite mine workings and dumps.

Azurite, $2CuCO_3 \cdot Cu(OH)_2$

Azurite is another mineral with a rather limited distribution. Good specimens for paragenetic relations are not available in the area mapped, and subsequently the mineral has not been incorporated in the paragenetic diagram. Its genesis, however, may be assumed to be nearly coincident with that of malachite. Both Sun (1947) and Kottlowski (1953) have reported its occurrence in the district.

Barite, $BaSO_4$

Barite is perhaps the most abundant ore mineral in the district. It is ubiquitously distributed along faults, fractures and solution cavities in zones measuring, at a maximum, two feet wide. A variety of forms have been noted: earthy and granular varieties fill fractures and the interstices between crystals in some barite breccia zones; laminated, crested varieties are most common in the mine areas where the ore minerals are distributed laterally, parallel to the bedding planes; radiating, stout-bladed crystals with well formed crystal faces are most profoundly developed in solution cavities. The sizes of the crystalline varieties vary in length from a fraction of an inch to blades nearly 12 inches long.

Possible color discriminations can be made. Both pure white and buff-brown to tan varieties have been observed. The spectrochemical differences between the two color varieties can be seen in Table IV.

TABLE IV

Elemental Differences in Barite Species

Conc:	"White Barite"	Buff-brown Barite
High	Sr>Ba	Ba>Sr, Ca
Low	Ca	Al, Ti, V, Cu, Mg
Trace	Al, Fe, Ti, V, Cu, Si, Mg	Fe, Si

Strontium nearly always occurs as a contaminant along with calcium in barite. All three elements can enter into diadochic substitutions with each other but calcium is a necessary constituent to balance the differences in ionic sizes between strontium and barium (Rankama and Sahama, 1950). Perhaps the "white barite" listed above, because of its high-strontium content, should more aptly be named barytocelestite (Ford, 1955).

Bornite(?), Cu_5FeS_4

Bornite is another mineral not previously described from these mines. It can only be seen in polished section under high magnification and occurs as a thin skin (less than 1 mm wide) replacing chalcopyrite in direct association with goethite. The presumption is offered that this mineral may be the enargite referred to by Lasky (1932). Distinction between the two minerals in polished section has been made on the basis of optic properties--enargite is anisotropic while bornite is isotropic. The slight color variation which normally exists between the two minerals is undiscernible under high magnification, but the isotropism of bornite is better revealed.

Brochantite, $CuSO_4 \cdot 3Cu(OH)_2$

Brochantite is similar to atacamite in occurrence and has been reported for the district (Sun 1957).

Calcite, $CaCO_3$

Calcite is one of the omnipresent gangue minerals, and exists in a number of forms and a variety of colors. Minute (less than 0.05 mm) to coarse (greater than 2 cm) crystals may be found as coatings on earlier formed minerals, as vein fillings resembling a comb texture, and as disseminated agglomerations in a silica matrix. Fibrous to earthy varieties in addition to some subhedral to anhedral calcite play a role as a cementing medium. Light brown, yellow, green, white and crystal clear species were noted. Spectrochemically determined contaminants include; Mg, Cu, Mn, and Sr. The magnesium bearing variety does not have the optic properties of dolomite.

Celestite, $SrSO_4$

Celestite is perhaps a somewhat rare mineral in spite of the high elemental strontium content for the district. However, part of its apparent scarcity may be attributed to the difficulty in distinguishing between this mineral and barite in thin section, without employing some other means of confirmation. Flame tests are generally not satisfactory. As stated under the description for barite, both minerals are perhaps better grouped together under the combined name, barytocelestite. However, some portions of the faults in the district spectrochemically show only strontium and no barium content.

Megascopically, the mineral appears white and a deceptive bluish hue may sometimes be observed.

The presence of strontium in high concentration adversely effects the specific gravity in pure barite concentrates used as drilling additives. Barite has a specific gravity of 4.3-4.6 while celestite's is considerably lower, 3.95-3.97 (Ford, 1955).

Cerussite, $PbCO_3$ and Anglesite, $PbSO_4$

Cerussite and anglesite are so intimately associated with each other in their occurrence that they have been grouped together for discussion purposes. The two minerals appear in compact concentric layers (Plate 9-A) and occasionally in alternating layers, around galena. Distinction between the two can readily be made by means of a differential staining test. When a specimen containing the two minerals is allowed to come in contact with a saturated solution of potassium dichromate for five minutes and is then removed and dried, the anglesite is preferentially stained yellow and the cerussite orange. Other distinctions between the two minerals can be made microchemically (Ford, 1955). By incorporating these two techniques, anglesite was invariably found to be the white or uncolored mineral, whereas the cerussite is gray to black in color. Anglesite may be found replacing the cores of galena cubes, but cerussite is never found in this manner. However, either mineral may be found in direct contact with, and replacing galena along its periphery. Usually galena which is found in a nearly pure (little silicified) limestone, shows little to no alteration to anglesite or cerrusite.

Chalcanthite, $CuSO_4 \cdot 5H_2O$

Chalcanthite was identified optically and chemically. It constitutes another mineral not heretofore described for the district. Most commonly the mineral is found in the cores of boxwork structures previously occupied by galena cubes. Felted tufts of fibrous, pale blue to green crystals appear to be the most common habit. Crystals more than three mm's long are unusual. Microchemical tests indicate that zinc is a common elemental associate and perhaps the mineral would best be classed as a zinc-copper chalcanthite (Ford, 1955). The Snake Pit and Barite Mine areas are the only places where the mineral was found.

Chalcocite, Cu_2S,and Covellite , CuS

Chalcocite and covellite constitute another closely intermixed group. They are best viewed in polished section under high magnification where differences in polarization make them readily distinguishable (Short, 1940). The minerals are found only in association with galena and chalcopyrite which are replaced by the chalcocite-covellite amalgamation. The bladed habit of covellite is common while chalcocite may assume either a bladed or a massive structure. Variations in color from light blue to blue for covellite and from a gray blue to light blue for chalcocite are prevalent and according to Edwards (1960) seem to depend on the origin (either unmixing or solid solution).

Chalcopyrite, $CuFeS_2$

Chalcopyrite exhibits good zonal replacement textures, wherein the mineral is successively bordered by bornite, chalcocite and covellite, in a matrix of goethite. Minute (less than 0.5 mm) massive granules of the mineral can be seen in hand specimen but the mineral is best viewed in polished section (Plate 9-B). Samples for analyses have been collected from breccia zones in the Royal Flush Mine and in the Del Cuerto outliers located to the west of the Oscura fault in the eastern part of Sec. 25.

Cuprodescloizite, $(Cu, Zn, Pb)_3 V_2O_8 \cdot Cu, Zn, Pb(OH)_2$

Cuprodescloizite, like calcite, is a ubiquitous gangue mineral. Vanadium, the element which characterizes the mineral, is found in nearly every spectrochemical analysis run. The first clue to cuprodescloizite's identification was afforded by spectrochemical analyses (reported in Table V) and from the associations of the minerals

Plate 9

A

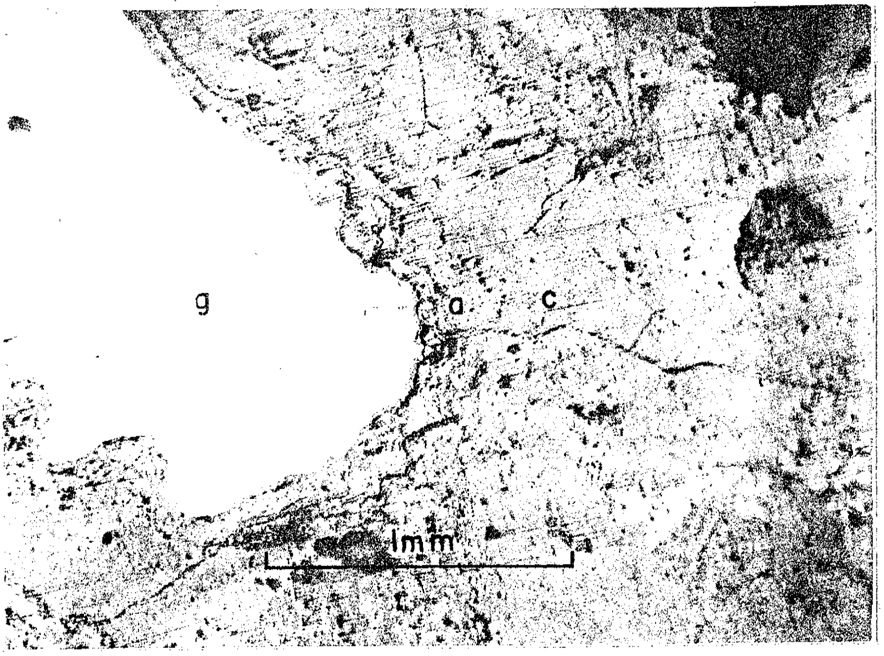
Anglesite-Cerrusite Metasome

Photomicrograph of a polished section illustrating galena (g) being replaced by anglesite (a) bordered by cerrusite (c).

B

Covellite-Chalcocite Metasome

Photomicrograph of a polished section illustrating chalcopyrite (cpy) being replaced by covellite (cov) and chalcocite (cc) in a matrix of goethite (go).


g
a
c
1mm


cov
cc
cpy
cc
1mm

cited by Hess (1911) from the Northern Caballos Mountains.

TABLE V

Elemental Constituents in Cuprodescloizite

Conc:	
High	Pb, Cu, V
Medium	Ca, Al, Mn, Fe, Cr
Low	Sr, Mo, Ti, Co, Rh(?)
Trace	Zn, Hf(?)

Confirmation of this mineral species was made by X-ray analysis. The rather varied group of associated or reported elements is not difficult to comprehend considering the number of elements that vanadium can be complexed with or replace in diadochic substitution (Rankama and Sahama, 1950). Vanadium may have played a very significant role in determining the lateral distribution of ore fluids along the shale zone in the Burrego formation (Rankama and Sahama, 1950) and certainly its effect as a strong oxidizing agent cannot be discounted in relation to the development of some of the supergene minerals.

Cuprodescloizite has been found in a number of forms, the most common of which are: (1) drusy masses of small, acicular crystals coating fine-grined, siliceous material in a gossan or (2) as a massive, incrustation of earlier formed minerals. The olive-green color of cuprodescloizite is very characteristic. The mineral's common associate, descloizite, may be present but was not positively identified.

Since the vanadium content of the enclosing rock appears to decrease outward from the associated faults, geochemical surveys for vanadium, based on a close grid system, might be used to delineate the faults or fault zones in the area.

Dolomite, $CaMg(CO_3)_2$

Dolomite is regarded by Sun (1957) as a hypogene mineral. The mineral was distinguished from calcite in thin section principally on the basis of crystal form, whether euhedral or anhedral (Kerr, 1942). Since this is not an absolute criterion for differentiation between the two minerals, any mention of calcite will also imply an inference to dolomite or a magnesium rich calcite. The distribution and occurrence of the two minerals in the early mineralization period is quite similar.

Enargite, $3Cu_2S \cdot As_2S_5$

Enargite, as mentioned briefly under bornite, was questionably reported by Lasky (1932). On the basis of polarization properties, a similar appearing mineral has been called bornite (Short, 1940). The lack of arsenic in spectrochemical analyses from the mapped area also refutes the occurrence of enargite.

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Fluorite, CaF_2

Fluorite may be regarded as either a gangue or ore mineral depending upon the metallurgical recovery circuit used and the opinions of the different authors (Lasky, 1932, Johnston, 1928, Clippinger, 1949, Rothrock, Johnson and Hahn, 1946).

Locally, the mineral is found lining veins bounding a core of barite (Plate 10-A), as banded incrustations on silicified limestone, and as coatings in vugs or solution cavities. Megascopically, galena is coated by fluorite which occurs as amethystine, or pale green to blue and white cubes which in turn are coated by barite crystals. Microscopically, fluorite is found as subhedral to anhedral crystals or as a fine grained filling between barite breccia fragments.

Penetration twins are fairly common as are modified cubes (octahedral faces) and octahedrons. Crystals vary in size from a fraction of an inch to those measuring two to three inches on a side.

Zonation of different colored varieties is commonplace. The usual contrast is a core of blue or amethystine fluorite which is surrounded by a green or white shell. Occasionally, the amethystine type may be seen coating the usually last formed white variety.

This paragenetic color differentiation is very deceptive, especially in vein surfaces which are exposed to the sun. When colored fluorite is heated, it quickly changes to the clear variety. Consequently, spectrochemical analyses, Table VI, were carried out to establish any differences in composition between the several colored types of fluorite.

TABLE VI

Semi-quantitative Spectrochemical Analyses of Fluorite

	Blue	Light Green	Clear
*Conc:			
High	Ca	Ca	Ca
Low	Si, Mg	Si, Mg	Si, Mg
Trace	Al, Cu, Ti, V, Mn	Al, Cu, Ti, V	Al, Cu, Ti, V

*Relative content between the colored varieties

Ca	in	blue>green>white
Mg		white>green>blue
Si		blue>white>green
Al		blue>white>green
Cu		white>green>blue
Ti		white>green>blue
V		white>green>blue

As can be seen from Table VI vanadium's content is somewhat anamalous. It is assumed to be an earlier deposited element and its concentration should therefore decrease with continuous deposition. The delimiting of manganese to the blue variety of fluorite places somewhat of a restriction on the deposition of alabandite in the paragenetic scheme.

The higher vanadium content in the late fluorite may be regarded as evidence for a resurgence or a migration of hydrothermal fluids.

Rothrock, Johnson and Hahn (1946), in addition to the above contaminants in fluorite, have also reported "barite, quartz and calcite." Ames (1947) has reported that the "salt concentration of fluids in the barite and fluorite inclusions is about 25%."

The often observed corrosion or etching of fluorite cubes may be attributed to a late hydrothermal stage of deposition or to the tendency for calcium fluoride to dissolve in the presence of carbon dioxide (Rankama and Sahama, 1950).

Galena, PbS

Galena, along with barite and fluorite has been described as one of the three principal minerals in the district. Both the habit and size of the crystals are comparable to those of fluorite, except for the existence of octahedrons which are rare. Polished section analyses reveal galena cubes replaced by either anglesite or cerrusite and also showing covellite and chalcocite replacement (see paragenesis, pg. 83). Replacement of silicified limestone by galena (Plate 10-B) is rare but is more common in fault and breccia zones rather than in zones of lateral migration. Galena enclosed in either a dense calcite or silica matrix does not usually show evidence of alteration. Spectrochemical determinations on "pure" galena crystals or fragments of crystals reveal a wide range of contaminating elements, Table VII.

Plate 10

A

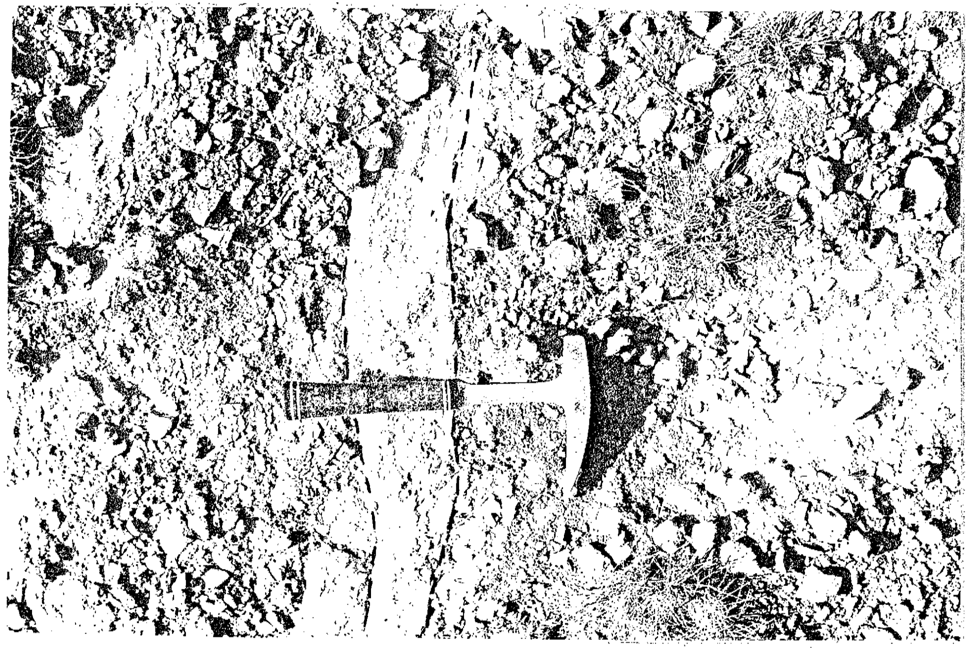
Crustification

Fissure vein along the Oscura fault in a silicified limestone. A crustification texture of barite and fluorite is evident.

B

Galena Replacement Texture

Photomicrograph of a portion of a galena cube replacing the fine grained silicified matrix in which it occurs. (Crossed nicols).



fluorite barite fluorite

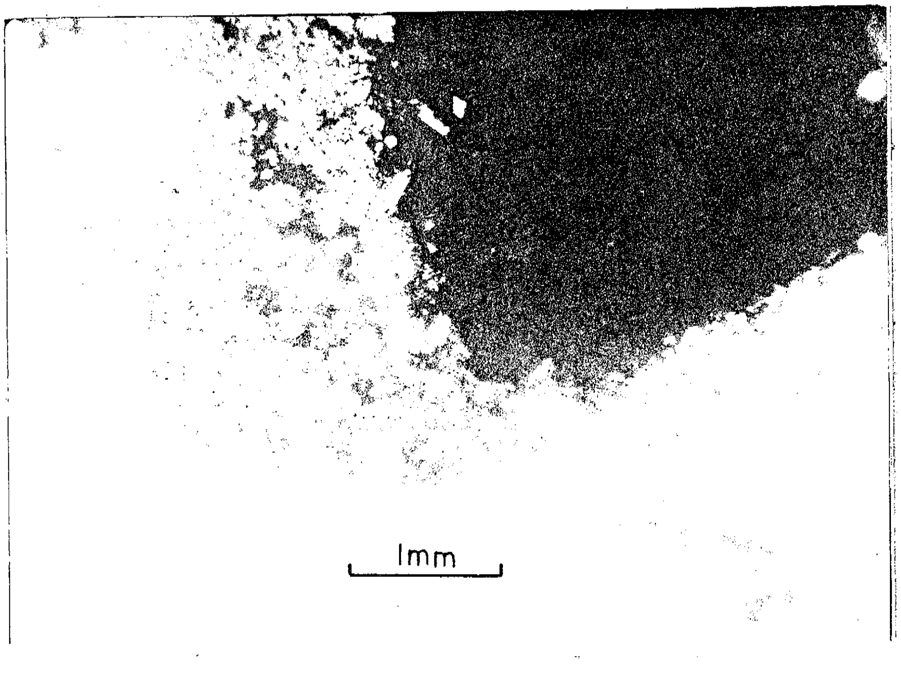


TABLE VII

Elemental Content of Galena

Conc:	
High	Pb, Ca, Ba, Fe, Sr
Low	Al, V, Si
Trace	Mn, Ag, Cu

The seemingly anomalous accumulation of Ca, Ba, Fe and Sr in galena is not altogether unexpected in terms of the possible diadochic substitutions of lead by these elements, as envisaged by Rankama and Sahama (1950).

The occurrence of silver can be attributed to the probable existence of stromeyerite along cleavage planes in the galena. Lasky (1932) has also reported the existence of microscopic particles of chalcopyrite in galena. This association, however, was not seen.

Galena cubes are found in the fault and breccia zones but are much more disseminated than in the shaly zone. The presence of vanadium in galena, may account for the greater tendency for galena to form within the zone previously occupied by the shaly member of the Burrego formation, (see also Cuprodescloizite, pg. 49).

Ames (1947) reports that the "chlorine content is five times higher in galena inclusion fluids than in fluorite or barite." He, therefore, suggests the transport of lead, in the original hydrothermal fluid, in the form of a chlorine complex.

Goethite, $Fe_2O_3 \cdot H_2O$, and Limonite, $2Fe_2O_3 \cdot 3H_2O$

Goethite and limonite have been grouped together because of the similarities they bear to each other in their physical and chemical properties.

Limonite is perhaps easier to describe in that it occurs principally as an ocher-brown to yellow brown gossan along faults and breccia zones. The mineral has almost the entire range of areal elemental constituents associated with it. Limonite is assumed to have developed from the oxidation of pyrite with the adsorption of the extraneous elements.

Goethite, or more properly perhaps, a mixture of hydrated iron compounds (Ford, 1955) is found exhibiting zonal replacement textures after chalcopyrite (Plate 11-A and Edwards, 1960). The mineral occurs in compact massive to granular zones surrounding chalcopyrite and is found only in association with it. Etch tests on a polished surface produce anomalous results, at times indicating the presence of tennantite, tetrahedrite, sphalerite or magnetite.

Microchemical tests may function just as inaccurately to indicate the presence of Zn, Cu or Fe. Spectrochemical analyses on gross samples, Table VIII, indicate the maximum range of elemental composition.

TABLE VIII

Elemental Composition of Goethite

Conc:	
High	Fe, Ca, Cu
Low	Si, Mg
Trace	Ti, V

Gypsum, $CaSO_4 \cdot 2H_2O$

Gypsum, another ubiquitous gangue mineral, has a relatively wide ranging depositional history. In hand specimen it can be observed incrusting earlier formed minerals or as a filling in vugs, solution cavities or in the interstices of adjoined crystals of fluorite, galena, etc. Crystalline laths, (2.5 mm x 0.4 mm) and earthy to granular varieties are best seen in thin section. Colors may vary considerably from white to all shades of green. Some of the microchemically determined contaminants include zinc, copper and iron.

Jarosite, $K_2Fe_6(OH)_{12}(SO_4)_4$

Jarosite, although not an uncommon mineral in the mapped area, is a rather difficult one to confirm. In some cases, the prevailing habit as a yellow-brown incrustation on late quartz crystals and the mineral's subadamantine luster tend to distinguish it from other associated supergene minerals. The mineral's relationship to the other supergene minerals, however, is not well known and only very broad limits can be placed upon it in the paragenetic analysis of the area.

Linarite, $(Pb,Cu)SO_4 \cdot (Pb,Cu)OH_2$

Linarite is one of the early formed supergene lead minerals and is found incrusting quartz and limonite. The deep, azure blue color of the mineral in addition to its subadamantine to vitreous luster combined with a crystalline development as crusts of elongated or tabular blades (maximum 3 mm long) is characteristic of linarite in hand specimen. The mineral appears to coat rosasite and at other times seems to be coated by it.

Malachite, $CuCO_3 \cdot Cu(OH)_2$

Malachite, another of the late forming copper supergene minerals, is found coating siderite, quartz, limonite or goethite and plattnerite. The mineral is sparsely distributed throughout the mapped area and exists in a number of crystal habits. Bright to pale green aciciular crystals are common but the mineral may also occur as a granular incrusting material or in radiating, fibrous, aggregates. Microchemical tests reveal some zinc may be associated with copper in the structure.

Marcasite, FeS_2

Marcasite, like alabandite, is a rather rare mineral and has not previously been reported for the district. The mineral, in small amounts, can easily be confused with pyrite in polished section. The only distinction between the two minerals is the anistropism of marcasite versus the isotropic character of pyrite. On samples seen from the area (but not collected by this author), marcasite occurs as bronze-yellow, tabular to pyramidal, twinned crystals coating barite. The mineral association in polished section with alabandite and its association in hand specimen with barite, seems to imply a rather wide depositional range for the mineral. However, the existence of marcasite in polished section is subject to question.

Murdochite, Cu_6PbO_8

Murdochite, a copper lead oxide, was first identified as a new mineral species by Fahey (1955). Shortly thereafter the mineral was recognized in the Hansonburg District and has been reported by Sun (1957). Jet-black cubes (2 mm on a side) or octahedrons with a metallic to adamantine luster characterize the mineral. More often, however, the mineral's faces may be tarnished, especially on exposure to weathering. Crystals of murdochite may be seen delicately balanced on slender aurichalcite crystals or as is more often the case, incrusting plattnerite.

Plattnerite, PbO_2

Plattnerite is similar in color and luster to murdochite but occurs in either of two forms, slender acicular crystals (maximum 3 mm long) or as a massive incrustation on linarite where plattnerite seems to assume the tabular crystal habit of that mineral. When the surface of the massive variety becomes tarnished on exposure, a dull black to brownish-black surface results and the mineral may easily be mistaken for massive psilomelane. Microchemical tests for lead and manganese have been used whenever doubt in the identification arose.

Psilomelane, MnO_2

Psilomelane occurs commonly as a dull, iron-black to black, earthy to massive coating (occasionally with a dendritic pattern) on many of the minerals previously described. It apparently has a wide paragenetic depositional range in the supergene phase of mineralization.

Pyrite, FeS_2, and Sphalerite, ZnS

Pyrite and sphalerite are two minerals presumed to have formed in the early stages of hypogene mineralization, but since deposition have weathered to form their common supergene associates. Sphalerite from the Blanchard workings, coated by gypsum, has been seen.

Quartz, SiO_2

Quartz is the most ubiquitous gangue mineral. It is intercalated with calcite along the contacts of faults where fine-grained quartz (average 0.25 mm long and 0.05 mm wide) is replacing the limestone. This quartz may be considered as the massive variety when viewed in hand specimen, along with the narrow veins of quartz which transect it - about 0.5 mm wide (Plate 11-B). Later, more coarsely crystalline quartz grains, euhedral to anhedral in character (Plate 12-A) coat vugs and line solution cavities in drusy masses. This late quartz has an average minimum length of 0.4 mm long and 0.1 5 mm wide. All variations from clear to differently hued green, yellow etc., crystals are common with this late phase quartz.

Rhodochrosite, $MnCO_3$

Rhodochrosite has not been absolutely shown to exist but the available evidence strongly hints of its close association with siderite. Fawn-colored, subhedral to anhedral crystals of what is believed to be the mineral, have spectrochemically shown high concentrations of manganese over iron content. Low concentrations of calcium and traces of strontium and silicon were also recorded.

Plate 11

A

Zonal Replacement Texture

Zonal texture of goethite or limonite after chalcopyrite as seen in polished section. The variation of reflectivity of the bands is attributed to possible differences in orientation of goethite or limonite, differences in granularity of the two minerals or differences in hydration state between goethite and limonite.

B

Second Period Quartz

Photomicrograph of a silicified limestone cut by a vein of second generation quartz emplaced along a fossil for a short part of its extent. (Crossed nicols).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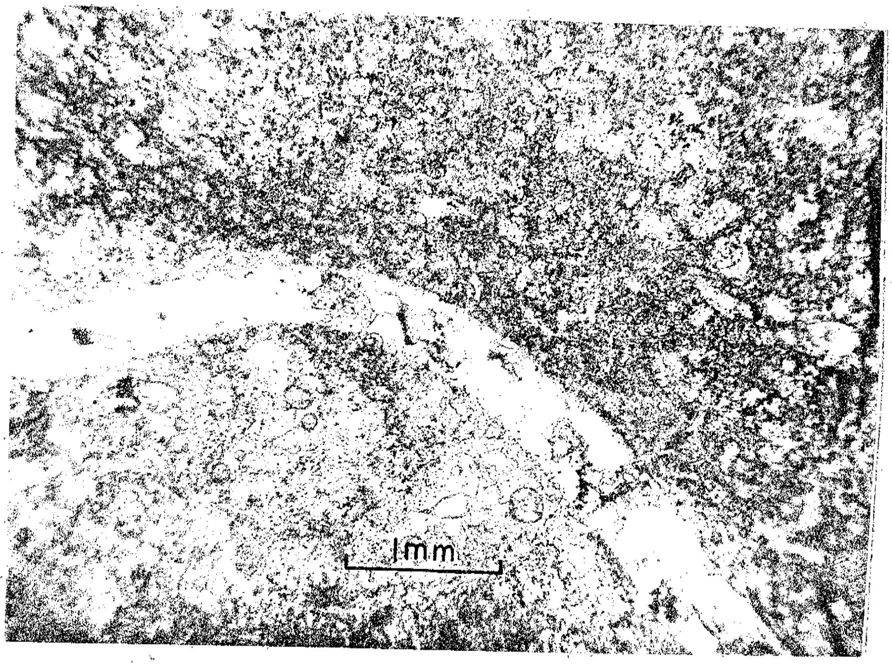
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Plate 12

A

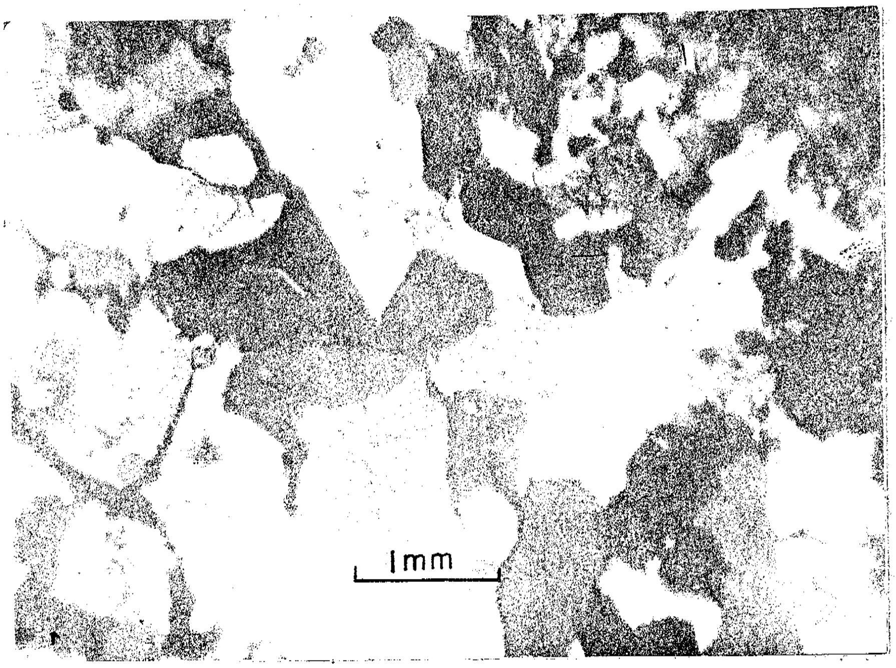
Late Quartz

Photomicrograph of third generation or late quartz lining a vug. (Crossed nicols).

B

Barren Fault Zone

A barren zone along the Royal Flush fault. The mineralized area to the south of this point is much more extensive. The picture was taken along a north-south azimuth, looking north.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Rosasite, $(Cu,Zn)CO_3$·$(Cu,Zn)(OH)_2$

Rosasite is another mineral not previously described for the area. Although its color is the same as aurichalcite's and the microchemical tests are similar, the two are readily distinguished. Rosasite occurs only in mamillary spherules and is coated by plattnerite when viewed microscopically.

Siderite, $FeCO_3$

Siderite occurs principally as a joint and vein filling mineral characterized by euhedral to anhedral, vitreous, brown crystals. Some magnesium, calcium, strontium and manganese are common contaminants as determined by emission spectrography. Since the evidence for rhodochrosite is tentative, both the minerals might be grouped together under a single heading, manganosiderite. As stated previously (pg. 36) relatively fine grained siliceous stringers often fill the northeast partings, along which siderite occurs, and coarse grained, so-called "late quartz" may be found coating siderite.

Spangolite, $Cu_6AlClSO_{10} \cdot 9H_2O$

Spangolite is either another anonymic mineral in the mapped area or it has been confused with malachite. Sun (1957) reports it as a rare mineral. Specimens containing what has been called spangolite were seen from the Blanchard workings which are outside the mapped area but the mineral has not been incorporated in the paragenesis reported herein.

Stromeyerite, $(Ag,Cu)_2S$, and Argentite, Ag_2S

Stromeyerite and argentite are two minerals which are difficult to distinguish in polished section, except on the basis of polarization colors (Short, 1940). When dealing with a small amount of sample, the distinction is difficult to make. Lasky (1932) reported argentite crystals in galena. On the strength of polarization colors a mineral viewed along the cleavage traces in galena and exhibiting an exsolution texture (Bastin, 1957) may be called stromeyerite. Its occurrence would agree with the trace of copper reported in galena. Guild (1917) has reported stromeyerite in galena as an eutectic intergrowth. Whether the texture of the sample examined can be considered an intergrowth is questionable. More often argentite is the mineral regarded as exhibiting exsolution phenomenon with galena.

Tennantite, $5Cu_2S \cdot 2(Cu,Fe)S \cdot 2As_2S_3$

Tennantite is no longer regarded as a valid reportable mineral for the area. From Lasky's (1932) description of the mineral in polished section with associated minerals and in view of the fact that goethite may give anomalous etch tests, the mineral thus far reported as tennantite is thought to be a form of goethite or limonite. Additional evidence which may be offered is the lack of arsenic and/or antimony in the spectrochemical analyses for the area.

Wulfenite, $PbMoO_4$

Wulfenite is reported by Sun (1957) for the Hansonburg District. However, this mineral was not found in the mapped area. Its scarcity may be due to the minor amount of molybdenum found by spectrochemical methods in the samples examined.

This compilation of ore and gangue minerals by no means exhausts the possibilities for the existence of other or new species of minerals in the area. Massicot, for example, is susceptible to formation under a late hypogene or an early supergene depositional environment. (The mineral may quite easily be confused with jarosite.)

A literature survey of reported minerals in the Northern Caballos and San Andres Mountains might be used as an aid to the establishment of additional mineral species in the Hansonburg District. The reported mineral suites for both these areas, in terms of barite, fluorite and galena deposition, are quite similar to those of the Hansonburg District.

Ore Controls

Ore deposition in the northern part of the Hansonburg District has been controlled by geologic structure and lithology of sedimentary beds.

The most important structural features to consider are, (1) individual faults and fractures, and (2) breccia and sheeted zones. Individual faults and fractures, nearly all of which lie parallel or subparallel to the average north-south trend of the district, show some mineralization along their outcrop. In areas where the fractures or faults remained open, true fissure veins were developed. They are characterized by typical open space filling with crustification (Plate 10-A). Deposition along any vein, however, is usually discontinuous and narrow (average 1-2 feet); lenticular ore veins may change rapidly into silicified zones with only disseminated ore minerals (Plate 12-B) or into totally barren zones with neither silica nor ore minerals present.

Replacement by ore minerals, of siliceous fault material or adjacent limestone, is negligible. Lasky (1932) has suggested that silica which was deposited by the initial hydrothermal phase prevented extensive replacement of the limestone by the ore minerals. However, there is evidence for both galena and barite replacing silica and limestone (Plates 10-B and 13-A), but only to a minor extent.

Silicification along the faults implies replacement of the adjoining rocks. Some of the limestones, particularly the more massive, non-cherty ones, show a progressive change outward from the faults, from a fine-grained silica zone, with extensive limestone replacement, to zones, not more than three feet on either side of the fault, where coarsely to finely crystalline calcite prevails.

Frequently, the areas of bifurcation or intersection of faults are barren.

Fault breccias apparently provided cavities or cave-like openings in which ore deposition could take place (Plate 13-B). But, ore mineralization along breccia zones is just as discontinuous as along faults--silica, in some cases, had filled in the spaces where ore deposition might have taken place.

Usually, the siliceous material in breccia zones bounding the fractured rock shows good slickensides. The slickensides seem to have developed concurrently with silica introduction and movement along the fracture surfaces.

All breccia zones, as stated previously are viewed as mushroom-like provinces--wide on the present surface and decreasing in width with increasing depth along the fault plane. Since mineralization is limited to the breccia zones and does not extend laterally outward into the limestone for any great distance, hydrothermal deposition is considered to be a near surface phenomenon.

Sheeting which developed parallelto the bedding planes, adjacent to some faults (Plate 14), locally provided enough open space for deposition to take place. The best example of this was seen along the Oscura fault, south of the Hickey Mine where a high strontium barite (barytocelestite) was deposited in nearly horizontal bands within the non-differentiated Coane-Bolander formation. The mineralized zone extends horizontally westward from the fault for about 25 feet; however, north and south extensions of the zone are limited. Two explanations might be offered to the limited extension of the barite zone; (1) the different response of the rock to the forces which produced sheeting and (2) the possibility that hydrothermal fluids ascended and were limited to narrow ore shoots along the fault plane. Actually both factors might have played a significant role.

Sheeting and ore deposition does take place within some of the other formations of the area, but is usually limited to within two to three feet of the fault plane or breccia zone.

As a result of the variable nature of the ore along faults and breccia zones, numerous prospect pits and several small mines (the Hickey and Desert Rose Mines, for example) are scattered across the mapped area. The prospect pits are generally not deeper than 30 feet and their development has depended on the width of the ore zone or limonitic gossan seen outcropping along the fault plane. If the assumption is valid, that the top layers of rock debris on the dumps surrounding

Plate 13

A

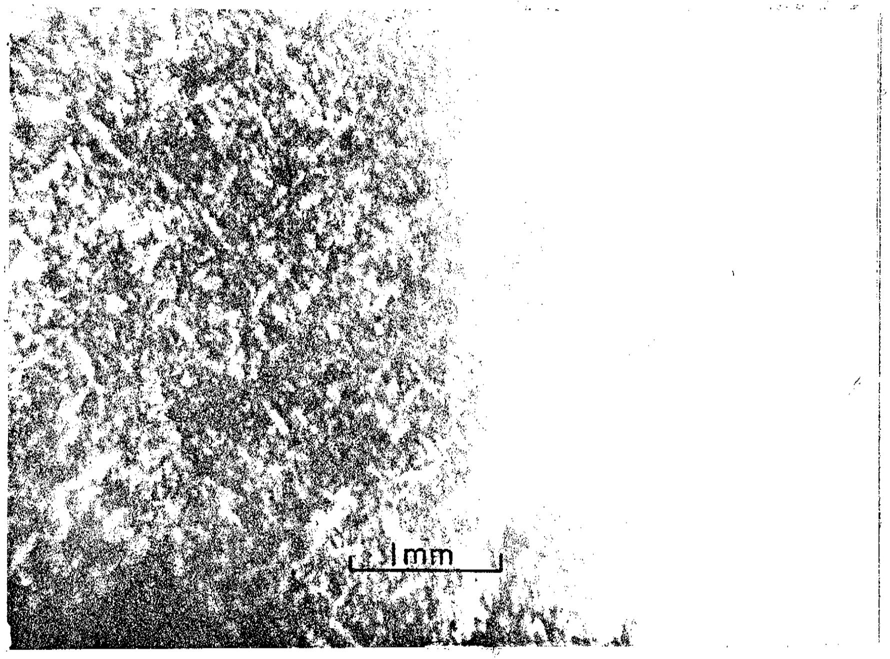
Barite Replacement Texture

Photomicrograph of a blade of barite replacing part of the silicified limestone matrix in which it occurs. (Crossed nicols).

B

Breccia Ore Zone

Breccia fragments of limestone (ls) surrounded by galena (g) and barite (b) crystals in the southwest wall of the Royal Flush Mine.



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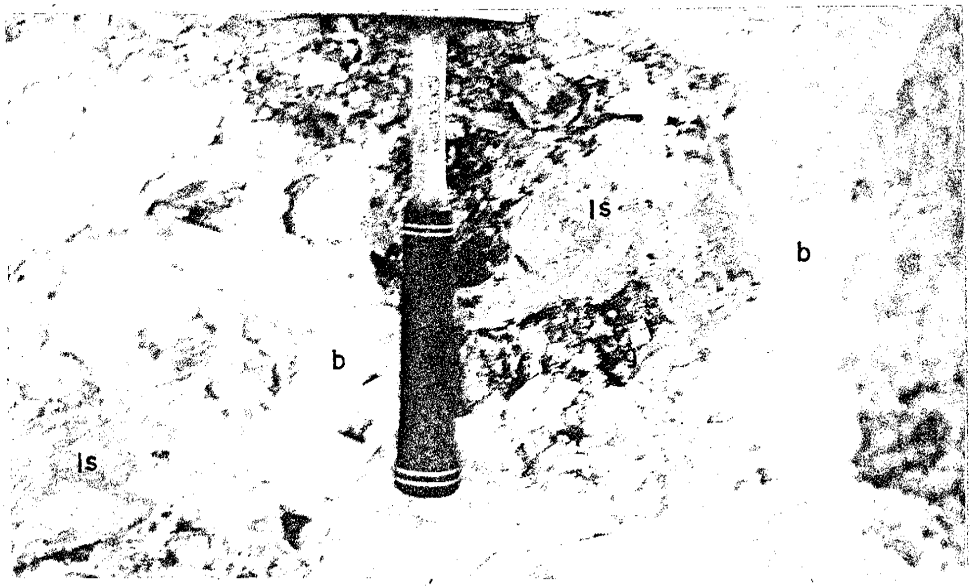


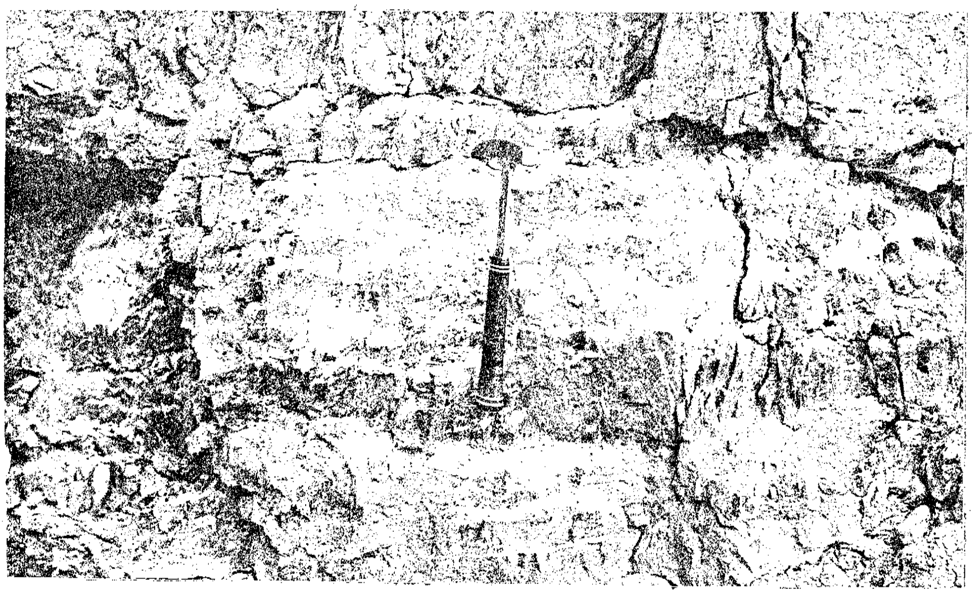
ls
b
b
ls

Plate 14

Sheeting Ore Zone

Sheeting of undifferentiated Coane-Bolander formations along the Oscura fault, south of the Hickey Mine on the west facing escarpment. A high strontium barite (white) is interlayered with the limestone.

Plate 14



the prospect pits were the last removed, then the ore zone must decrease with depth. The top layers of dirt on the dumps are nearly barren in visible ore minerals.

The mines in the area, like the prospect pits, have a limited development, a single level with only one tunnel, the adit, is driven along the fault plane.

Stratigraphic control places greater restrictions on the location of ore zones and the relative abundance of ore minerals. Only the shaly member of the Burrego formation, which fills in the channels or furrows cut into the top of the Council Spring limestone, seems to have had enough lithologic dissimilarities from the other available formations to act as a zone of deposition.

Only a very cursory examination of this shaly zone has been made and as previously stated (pg. 30) has been identified as a low potassium, high calcium and magnesium illite containing shale. The origin of such an anomalous shale is questionable. Hambleton (1959) has reported that the shale members in the Missourian formations above and below the ore shale contain montmorillonite or kaolinite. He also reports from Grim (1953) that the expected alteration product of montmorillonite is a high potassium, illite clay. Sidwell and Warn (1951) suggest a possible metasomatic origin for the illite of the region. Ostram and Potter (1961), in a recent publication, report that illite weathers to a montmorillonite with loss of potassium ion by interlayer exchange with the hydronium ion of chlorite through oxidation. This change is described for an unconformity at the Mississippian-Pennsylvanian contact in the Illinois Basin. The chlorite for the transformation is presumed to be derived from a local source. However, none of these theories seems applicable to the Hansonburg District.

In any event, the oldest shaly member of the Burrego is different compositionally from the shales in the formations above and below it.

All ore zones located in the shale horizon of the Burrego formation are associated with faults, which acted as conduits for the introduction of mineralizing fluids. This combination is a necessity to the formation of ore along a stratigraphic horizon. However, even this combination does not produce a very wide or extensive ore zone. The shale at a maximum is only 5 feet thick and the estimated maximum lateral extent of mineralization outward from the fault (at the Royal Flush) is considered to be about 60 ft. (This estimate is made without the benefit of drilling data). The thickness of the ore zone viewed in cross section diminishes away from the fault. Consequently, the implication is made that a small portion of the underlying Council Spring limestone and the overlying Burrego formation are mineralized near their boundaries with the associated fault,and that the ore zone is somewhat tabular in shape.

A banded ore fabric is typical of the ore zone (Plate 15-A). The contact of this zone with the top of the Council Spring limestone is undulating in apparent response to the channels which were originally cut into its surface. The channels have been the best areas for solution cavity development (Plate 15-B) with the depth of the ore in the solution cavity about the same magnitude as the average depth of some of the "potholes" in the limestone.

The relatively extensive enrichment process which has taken place along this horizon has restricted the major development of mining and stripping operations in the area to the contact of the Council Spring limestone with the Burrego Formation. However, despite the stratigraphic favorability of the horizon, the ore in the horizon remains as discontinuous as the ore in the faults. But wherever there is a good exposure of ore in a fissure vein or fault, ore has been found in the nearby stratigraphic shaly member of the Burrego formation.

To supplement the observations made here, Johnston (1928) reports fluorite in a clay matrix for the Lava Gap Prospect in the northern end of the San Andres Mountains which is also in Pennsylvanian rocks. Tovote (1919) has noted the enrichment of ore zones in contact with shale in his report on the ore deposits of the southwestern U.S.

One other possibility exists for restriction of ore fluids to this horizon. Since ore deposition is considered to be a near surface phenomenon, the effect of dilution on ascending hydrothermal fluids by surface waters in this horizon cannot be discounted. In other words, the ground water table may have been considerably higher than it is at the present

Plate 15

A

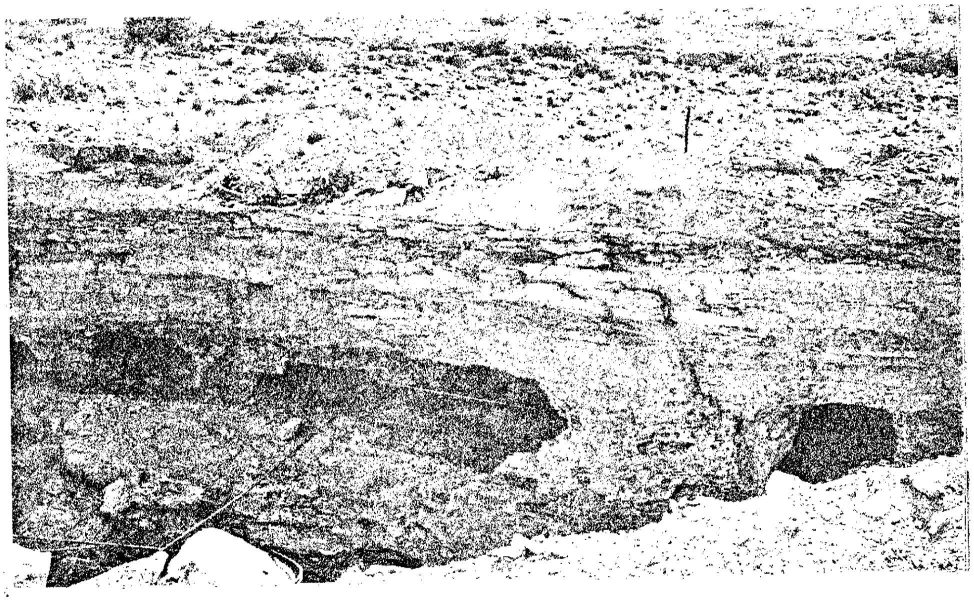
Banded Ore Zone

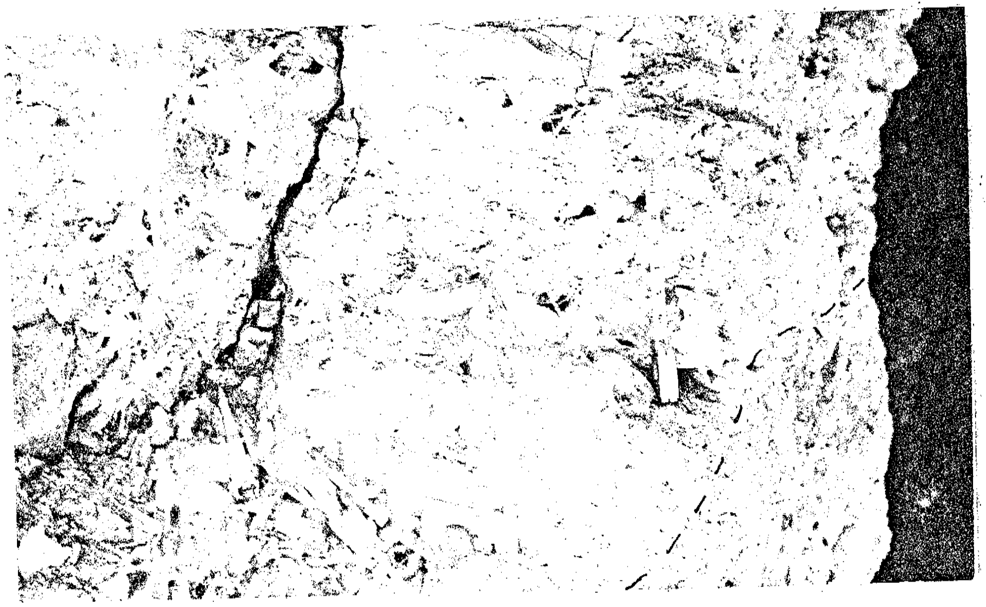
View along the portal of the Royal Flush mine. The tabular nature of the ore body is well exhibited as is the banded fabric of the ore. Vugs among the bands are visible in the lower right hand corner of the picture.

B

Solution Cavity Filling

A solution cavity filled with radiating sheaves of barite crystals. The depressed surface on the top of the Council Spring limestone corresponds to the "potholes" noted in Plate 5-A. The view is from the north wall of the Ora Mine.





time. One possible means of determining a phenomenon of this nature, would be through a carefully controlled zonation study of possible mineralized zones below the present zone of oxidation.

Zonation

Stratigraphic zonation, that is enrichment of a particular stratigraphic horizon, is obvious. The deposition of ore minerals in or along a shaly horizon may be influenced, at least in the Hansonburg District, by the yet unknown affinity that vanadium has for shale (Rankama and Sahama, 1950). Vanadium's occurrence with galena, may therefore have directed that mineral's localization or statistical preponderance to the shale member of the Burrego formation.

Spatial zonation is difficult or impossible to evaluate in the area. Good vertical exposures along faults, to any significant depth, are lacking and consequently no parameters can be established for this type of study at the present time. Lasky (1932), however, suggests a not uncompatible zonation of copper and lead minerals for the district.

Paragenesis

All the visible and present estimatable ore lies in the zones of oxidation and supergene enrichment. The supergene suite of minerals are much more widespread and varied than their progenitors within the hypogene class. The intermixing of supergene minerals with the hypogene suite, which in itself has had a complex history, only compounds the difficulty of interpretation within the area.

Several apparent cycles or anomalous sequences of deposition are present and their resolution depends strictly on the interpretation of the worker. The relative or generalized sequence of deposition of the prediscussed group of minerals for the Northern part of the Hansonburg District is given in Figure 3. The sequence has been determined on the basis of polished and thin section studies, field observations and elemental analyses.

The most generally observed sequence is indicated by the solid lines. The maximum range of deposition of the mineral in relation to its associates is indicated by the dashed lines. Queries denote a possible wider range of deposition than that observed in the samples examined.

The assignment of sphalerite and pyrite to the earliest stages of deposition is purely hypothetical but their presence is necessary to account for their associated and derived supergene products. Assignment has been made on the basis of the higher possible temperatures of crystallization these minerals may exhibit in relation to quartz deposition.

Quartz deposition or silicification has occurred in the early stages of crystallization in two separate periods or perhaps, in one long intermittent phase. Evidence for this is readily observed in the size differences between the quartz crystals. The first deposited and finer grained quartz constitutes the phase which silicified the limestone. The second phase cuts across the first in tiny fractures which did little more than act as a filling for the fracture. Other evidence for 2 phases can be seen only under the microscope. Crystalline quartz overgrowths on initially formed (first phase) quartz crystals with an interphase of calcite or boundary of black spherulitic unidentifiable material are common.

Third or last phase quartz deposition is represented in even coarser grained euhedral to anhedral crystals lining vugs or cave-like openings. This phase is presumed to represent the last and waning stages of hypogene deposition.

Chalcopyrite and galena are positioned in the time of deposition scale on the basis of chalcopyrite granules occurring in galena (Lasky, 1932) and by the restriction of chalcopyrite to the silicified breccia zones. However, the phase relationship of chalcopyrite deposition to the quartz phases is not definitely known.

Deposition of alabandite can be restricted to a rather short period first of all on the basis of mineral occurrence in the silicified limestone and secondly on the basis of the elemental occurrence of manganese in galena and what has been called the first stages of fluorite deposition (see pg. 54). Palache, Berman, and Frondel (1946) report that the mineral is usually deposited by the action of hydrogen sulfide on manganese bearing waters. This reaction necessitates placing the mineral with the sulfide phase of hypogene deposition, that is, concurrently with galena.

The general sequence of deposition for the major ore minerals is galena, first, fluorite later, and barite, last. Some overlap between the three is common. They occasionally exhibit an apparent anomalous association with other minerals in the sequence. For example, galena may be seen coating late quartz. In nearly all cases however, this association is only apparent and the galena cube is in reality attached to a host, sometimes by only one corner, with the quartz crystals growing in the space under and around the cube. However, the association of barite on fluorite and fluorite on the preceding barite with repeated barite deposition, cannot be explained in such a manner. The only alternative is to postulate a resurgence in hydrothermal fluids or an interruption in the phases of fluorite and barite deposition. The former theory is favored in that it accounts for the anomalous behavior of vanadium in the late fluorite, and the etching of fluorite cubes. However, corrosion of fluorite may also be attributed to the mineral's solubility in a carbon dioxide atmosphere (Rankama and Sahama, 1950). Some of the most deeply etched cubes are coated by calcite.

If a resurgence theory is valid, it is only regarded as a revitalization of the depositing power of the hydrothermal fluids with deposition of barite and fluorite in the same order. Hence, no change in the paragenetic relations for barite and fluorite is required.

Stromeyerite (or argentite) occupies a position of indefinite extent in the time relationships established. However, the mineral is known to occur after galena deposition and before covellite started to form. Another reason for placing it rather early on the paragenetic time scale is the relatively high unmixing temperature (300°C) that stromeyerite, at least, exhibits with chalcocite (Edwards, 1960). Argentite-chalcocite and argentite-galena unmixing occurs at even higher temperatures.

Bornite's time relationships to the other minerals is known to an even lesser extent. No conclusion on bornite's position as a hypogene or supergene mineral can readily be reached from the study of the samples collected. If bornite is considered to be hypogene in origin, the mineral is known to form within the intermediate temperature range (less than 500°C) (Edward, 1960) for hydrothermal minerals. Bornite deposition ended prior to covellite-chalcocite and goethite formation.

Marcasite is known to follow barite in formation since it coats the mineral, but whether marcasite is hypogene or supergene, is again not known. Marcasite's usual temperature of formation as a hydrothermal mineral is below 300°C (Edwards, 1960) and consequently the mineral hasbeen consigned to a field of mineral deposition which might be representative of that temperature.

Siderite and rhodochrosite formed before late quartz was deposited. However, their initial period of deposition may have begun quite early. Their commencement of deposition is difficult to evaluate because the minerals only occur as a filling in partings which are

Figure 3

Paragenesis

Minerals of the Hansonburg District and their relative orders of deposition.

Relative Paragenesis for the Minerals in the Northern Part of the Hansonburg District Bingham, New Mexico

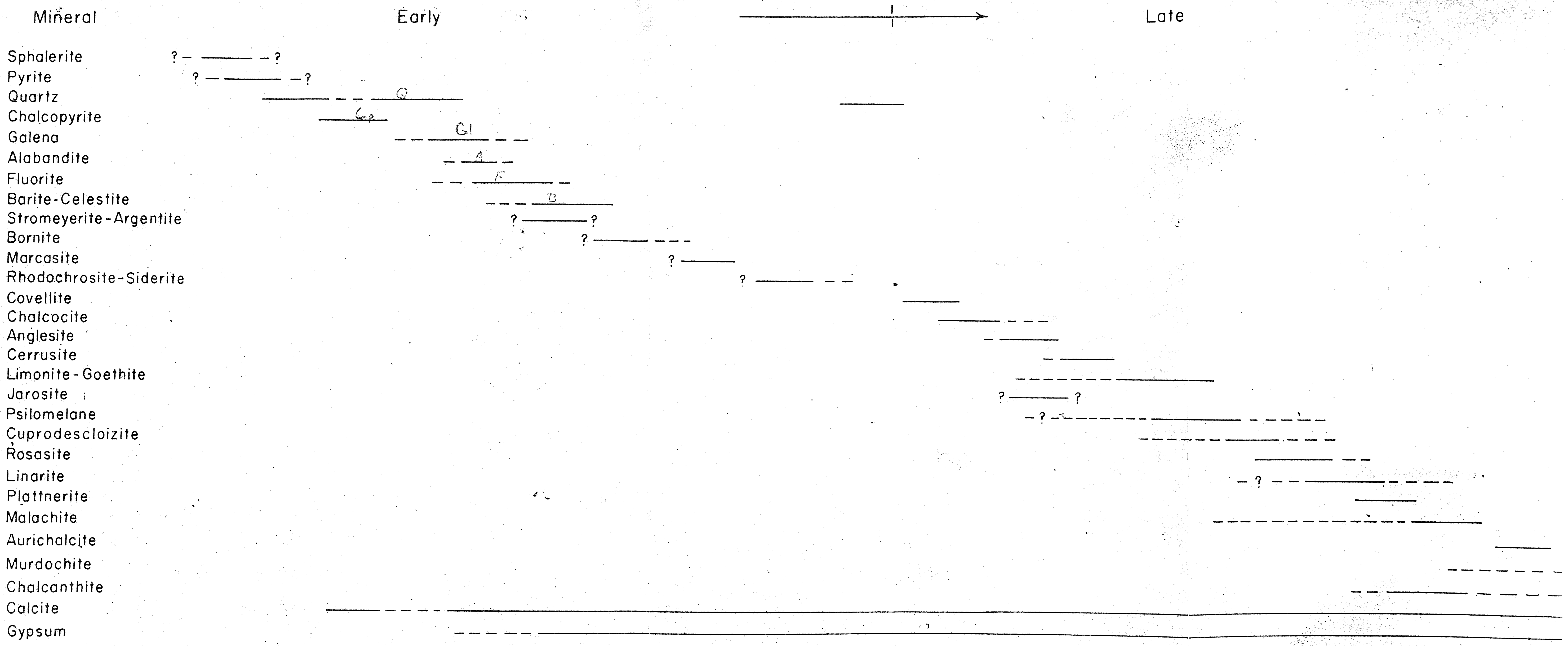


Figure 3

scattered throughout the area, and not in direct association with other minerals.

The replacement relationships between covellite-chalcocite, anglesite and cerrusite have been studied in polished and thin section. The observed sequence of replacement seems to be cerrusite, anglesite, chalcocite, covellite and quartz, in that order. The actual relationships can best be arrived at by assuming covellite to be the original metasome of the host, galena. "As the covellite replaced the galena, the substituted lead atoms diffused outward and encountered the sulphate ions of the oxidizing solution and were precipitated as lead sulphate" (Edwards, 1960, pg. 121), according to the equation:

$$CuSO_4 + PbS = CuS + PbSO_4$$

The lead sulphate on contact with a carbonate rich environment then changed to the more insoluble lead carbonate.

In other locales however, the galena host was directly converted into the sulphate on oxidation (Rankama and Sahama, 1950), according to the equation:

$$PbS + O_2 = PbSO_4$$

The volume change which accompanied these reactions was enough to cause the displacement of late quartz which was deposited on galena. This is the explanation offered for the usually sparse coverage of galena cubes by late quartz, even though the cube may be surrounded on all sides by euhedral quartz crystals.

Similar changes must have accompanied the replacement of chalcopyrite by covellite and chalcocite with the subsequent alteration to zoned limonite or goethite (Edwards, 1960). The volume changes involved here were enough to compact the limonite into a goethite-like mineral against the enclosing rock. With continued alteration, lack of space caused some fracturing of the enclosing silicate zone.

Since this alteration does not take place in the zone of secondary enrichment, the width of the bands of covellite and chalcocite remain nearly constant.

With the possible exception of marcasite, no other minerals could be classed as typical of the zone of secondary sulphide enrichment. Also, if the zone of secondary sulphide enrichment were present, the chalcocite-covellite bands would be expected to become wider, at least around chalcopyrite grains.

The bladed habit of the covellite in the chalcocite is considered to represent primary as opposed to secondary development of this mineral. Consequently, the paragenetic time relationships of covellite and chalcocite to the other minerals is consiered to be representative of the last stages of hypogene formation or the very early stages of supergene alteration and deposition.

Following covellite and chalcocite formation, the environment of deposition may have changed rapidly which would account for the alternating layers of anglesite and cerrusite.

Since limonite is found in direct contact with quartz crystals, its maximum range of deposition is extended to include the period of anglesite-cerrusite formation.

The paragenetic time lines of the supergene minerals have been ended short of the present period of formation, but at least some of the minerals are considered to be still forming. Restriction of the lines to their indicated length, short of the present time, has been dictated by the later formed supergene minerals which are coating the earlier. Consequently, the solid line, as was the case with the hypogene minerals, indicates a possible, more favorable period of deposition.

Jarosite is then the only mineral remaining which might require an explanation. Jarosite is found coating late quartz, but is not coated by any other minerals. Therefore, the mineral's position on the paragenetic time scale is tentative. The position of subsequent minerals in the paragenetic scheme is self-explanatory.

The physio-chemical relations fit the paragenesis established. For instance, lead ion in the +2 state (linarite) is oxidized to lead ion in the +4 state in plattnerite and murdochite.

The order of deposition of galena and fluorite favorably agrees with the decrease in the Na/K ratio measured by Ames (1957) for the two minerals from the Hansonburg District. He noted that the "Na/K ratio decreases from 2.3 in galena to 0.1 in fluorite ... which indicates a continuity of mineral depositing solutions over the time and temperature range represented by the Hansonburg suite."

Other authors (Kottlowski 1953, Lasky 1932) had arrived at a similar paragenetic scheme, as the one established, for the ore minerals. However, dissenters to this order of deposition also exist. Ames (1957) on the basis of heated stage analyses of vacuoles in barite and fluorite crystals indicates that barite had a temperature of deposition ranging from 130°C to 140°C while fluorite exhibited a range from 90°C to 100°C. The order of deposition would then be galena, barite, fluorite, in that order. Rothrock, Johnson and Hahn (1946) have reported the sequence of deposition as quartz, fluorite, barite, calcite, and galena followed by later quartz. Clippinger (1949) implies a similar depositional sequence.

Deposition

The source of the ore solutions is problematical. Only by projection or analogy to areas of known igneous activity with associated hydrothermal deposition can any premise be offered for the possible type of fluid which deposited the ore. The evidence, based on the occurrence of the regionally developed "hornblende-sodaclase diorite sill" (Kottlowski,

1953) and the comparisons which can be made with such areas as the Northern Caballos, points to fluids derived from Tertiary intrusives which had an intermediate composition. Since there is no direct association of intrusives and ore zones, the implication is made that long distances of transport of ore fluids were involved before they were able to reach areas of a suitable depositional environment. A relatively long distance of transport also implies rather cool depositing solutions.

The local distribution of the ore in faults, breccia zones and tabular ore zones of limited extent implies that the fluids were under low pressures, for forcible entry of fluids was not the major control on ore deposition. In the Hansonburg District, pre-existing structures are by far more important in determining the ore zones.

The solutions first deposited silica which may have been preceded by limited sphalerite and pyrite deposition. Silica bearing solutions partially replaced the limestone country rock, and were rapidly chilled in the process. The result was a fine grained silica matrix in the faults and around the breccia fragments.

Subsequent deposition involved the introduction of more silica coincident with galena deposition.

Ames (1957) believes that lead was transported as a chlorine complex. This hypothesis agrees with the concentration of fluorine in a separate phase which is usually later than the chlorine phase in the differentiation of late magmatic fluids (Rankama and Sahama, 1950). However, chlorine as a separate phase, frequently occurs with the complex sulfate and carbonate anions in minerals (Rankama and Sahama, 1950) and therefore should be classed as a later phase in the Hansonburg District. The latter theory is favored for it permits the deposition of alabandite in a reducing (hydrogen sulphide) environment and for the introduction of vanadium ions, which are associated with galena, in a low oxidation state. Part of the mobility of the vanadium ion depends on its ability to be oxidized (Rankama and Sahama, 1950) and thus participate in later supergene activity.

The initial silicification period also prepared the solution cavities, vugs, and cave-like openings in which galena, fluorite and barite deposition could take place. The host rock was extremely permeable, due to the previous fracturing in the area and solutions migrated from place to place precipitating anew, ore minerals on top of previously formed ore minerals. The large size of the crystals suggests dilute solutions acting over long periods of time (Garrels and Dreyer, 1952). Whether the dilution effect was from the action of descending ground waters which occurred at the shaly horizon in the Burrego formation, cannot be evaluated. Subsequent deposition involved a decrease in temperature of the mineralizing solutions and a change in the environment of deposition nearly coincident with the formation of euhedral quartz crystals on the previously formed minerals. An oxidation environment with supergene enrichment has prevailed since this last phase of quartz deposition, with the progenitor of this phase being the originally deposited ore minerals.

The tabular shape of the horizontally distributed ore bodies and the variable nature of ore in the faults, in addition to the banded, vuggy and crustification textures for the area, restricts classification of the deposit to the mesothermal-epithermal group of hydrothermally formed ore deposits. The hypogene mineral suite for the Hansonburg District also covers the range of temperatures often cited as characteristic for meso-epithermal deposits. From the conclusions reached by Garrels and Dreyer (1952), the textures and ore minerals of the Hansonburg District would bear similarities to those developed experimentally at low temperatures and pressures. The existence of the "pimple" (pg. 30) attests to the introduction of ore fluids at low pressures. Other evidence for a low pressure system is the limited extent of the ore deposits in the sheeting and breccia zones.

Exploration

The somewhat surficial character of the ore and its discontinuous nature does not make estimates of ore reserves very amenable to calculation, especially without drilling data. However, many locales are present which might indicate favorable locations of ore zones at depth.

Perhaps the best means of delineating the possible ore zones would be to follow the trace of a fault to the point where it becomes a wide fissure vein. In the event the vein is situated in the younger units of the Burrego formation or the older horizons of the Story formation, shallow prospect pits or shafts might be dug to the top of the Council Spring limestone in search of laterally distributed ore zones, which are the ones most profitable to mine. In still younger formations, drilling to the top of the Council Spring limestone close to promising fissure veins, should delineate ore bodies. Stripping and open pit mining, if extended along the present outcrops of the Council Spring limestone with the Burrego formation should also prove profitable, especially in areas in close proximity to faults, veins and breccia zones.

Since vanadium is intimately associated with galena in the deposition of that mineral and because of vanadium's mobility, geochemical methods, using vanadium as an indicator element, might be employed to delineate favorable zones of ore deposits.

Lasky (1933) reports, copper, lead and zinc ores at the Precambrian-Paleozoic contact near Mocking Bird Gap in the Northern end of the San Andres Mountains. The size of these deposits might indicate the possibility of drilling for similar type ore zones in the Hansonburg District.

The area with the greatest ore potential, however, would be in the Jornada del Muerto which is essentially unexplored. Areas deserving more immediate attention in this region would be in the outliers of the Del Cuerto formation to the west of the Oscura fault. Copper mineralization similar to that found in the Royal Flush Mine warrants a more concentrated and intensive investigation than has previously been made by the single prospect pit located on the outlier.

SUMMARY

The geology and ore deposits of the northern part of the Hansonburg District have been studied with the purpose of establishing the controls of ore deposition and the paragenesis of mineral deposition. In the process of mapping the area, a local disconformity was found to exist at the Pennsylvanian, Council Spring limestone-Burrego formation contact. A low potassium, high calcium and magnesium illite shale which occupies the horizon above the Council Spring limestone is the one most enriched in ore minerals. However, ore minerals also occur in or along sheeted, breccia and fault zones, but ore mineralization of this latter type is discontinuous and very disseminated. Since ore zones of the former type are only located in and near faults, combinations of structure and lithology are viewed as the most important ore controls. Two more subtle and less well defined controls may also be alluded to; (1) the effect of ground water dilution on hydrothermal fluids at the shaly horizon in the Burrego formation and (2) the unexplained affinity that vanadium has for shale zones.

Studies of the elemental areal distribution have proved useful as an aid in determining the mineralogy or expected mineralogy of an area and can also be used in delimiting the paragenesis of some of the minerals. The uniform distribution of introduced elements among the faults of the area indicates the existence of very permeable ground at the commencement of mineralization.

Permeability, however, is a factor of at least two periods of faulting; (1) those faults which developed in the Pennsylvanian and (2) those which developed in the later Tertiary period of orogeny. An even later period of faulting occurred along some of the antecedent fault planes but was not associated with any mineralization.

The hypogene phase of mineralization was accompanied by either two periods of silicification or by at least one long intermittent phase. The initial period of silicification partially replaced the limestone but also limited the replacement action of the later deposited hypogene minerals.

Galena, fluorite and barite are the most abundant ore minerals but a minor amount of chalcopyrite is also present. Alabandite and bornite are previously unrecognized additions to the early formed suite of minerals whereas tennantite and enargite, which were previously reported, have been discredited. New additions have also been made to the supergene suite of minerals in the form of rosasite and chalcanthite.

The paragenetic study of the ore minerals indicates that there is some hint of a resurgence in the depositing power of the hydrothermal fluid as concerns barite and fluorite deposition. The different colored varieties of fluorite have an order of deposition in themselves which results in the formation of zoned fluorite crystals.

Although there is considerable overlap in the formation of the supergene minerals, a minimum range or period of formation can be assigned on the basis of the later formed minerals coating the earlier.

Deposition was largely by open space filling at near surface conditions. Crustification, vuggy and banded ore textures attest to this. The coarse crystallinity of the ore points to deposition from dilute solutions under relatively low pressures. The hypogene suite of minerals, however, includes a possible temperature of formation range usually cited for meso- to epithermal ore deposits.

Despite the discontinuous and surficial nature of the ore in tabular and lenticular ore zones, the Hansonburg District is still viewed as possessing great potential as a mining district with the advent of a more extended and intensive exploration program.

RECOMMENDATIONS FOR FURTHER STUDY

Although the scope and purpose of the investigation have been satisfied, numerous deterrents arose during the period of study which delayed the gathering of data and presentation of results. Consequently, in the interests of obtaining more knowledge about the area already mapped and discussed, and prior to the future investigation of the Blanchard claims in the southern part of the Hansonburg District, the following recommendations are submitted for resolution:

1. More detailed stratigraphic studies, especially as regards the disconformity at the Council Spring limestone-Burrego formation contact. (Possibly the disconformable surface may transect part of the Burrego formation.)

2. To determine the geomorphological characteristics of this surface--whether a karst, submarine or subaerial topography.

3. To delineate paleontologically the megafauna for the district prior to additional or more detailed mapping.

4. To establish lithologically the differences or similarities in the shale formations in the district in greater detail than by the cursory examination made.

5. To examine the igneous rocks, regionally distributed, as an aid to establishing the type fluids from which the ore bodies may have been derived.

6. To make more detailed structural studies along the Oscura and Hansonburg faults north and south of the area mapped. (The en-echelon movement along these faults seems to indicate that the northern part of the Hansonburg District is a hinge area for scissor type faults).

7. To determine the elemental paragenetic sequence of the district in relation to the mineral paragenesis.

8. To quantitatively establish the variation of Al to Si content or similar ratio in absolutely determining the paragenesis of the different colored fluorite varieties.

9. To ascertain the effect which vanadium may have as an ore control in shaly beds.

10. To clearly establish the usefulness of vanadium as a geochemical indicator element in delineating ore bodies.

11. To prove or disprove the existence of zoned deposits with the advent of greater vertical exposure along faults and fissures in the district.

APPENDIX I

Gross samples of faults, breccia zones, fissure veins, and sedimentary rocks collected for D.C. arc emission spectrographic analyses were first reduced to quarter inch fragments in a chipmunk crusher and were then pulverized to minus 65 mesh. Iron fragments introduced in the crushing and grinding process were removed with a one amp hand magnet. The sample was split then coned and quartered to obtain a representative five gram sample which was subsequently ground to approximately minus 200 mesh in an agate mortar. A representative 20 to 40 mg sample of the ground material was used as the charge for analysis.

Single crystals of galena, barite and fluorite were first examined under the microscope to determine the purity of the sample to be used. Only crystals without alteration or adjoined minerals were taken for analysis. The crystals were then crushed and pulverized in an agate or mullite mortar to about minus 200 mesh. Since relative semi-quantitative analyses were to be carried out, carefully weighed 20 mg samples were used as the charge in the electrode.

A 3/16 inch sample electrode with an 1/8 inch counter electrode were used in all burns. All hard rock samples (fault material) and gossans were given a 10 second preheat prior to burning the arc. Crystal analyses were not preheated.

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All analyses were carried out on a meter and one half ARL spectrograph which has a lined diffraction grating of 15,000 lines to the inch. The arc was maintained until all the sample had volatilized. A sector wheel setting of 6% with a 30 micron slit width was used in all burns. The arc was struck with a short current of 13 amps but was operated at a current of 9 amps. No dilutents were used with any of the samples. Spectrographic plates were read by comparison with a standard chart.

High and medium elemental content, as reported in the Tables, implies concentrations greater than 1%. Low values have an approximate elemental concentration range from 1% to 0.1% whereas a trace of an element signifies concentration values below 0.1%.

Samples for X-ray diffraction analyses were ground in a similar manner. The analyses were carried out using copper radiation with a nickel filter.

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This thesis is accepted on behalf of the faculty of the Institute by the following committee:

A. J. Budding

Clay T. Smith

M. F. Stubbs

Frank E. Kottlowski

Date: 8-29-61

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