



## *Zoning, paragenesis, and temperature of formation in the Lordsburg district*

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# ZONING, PARAGENESIS, AND TEMPERATURES OF FORMATION IN THE LORDSBURG DISTRICT

by  
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## INTRODUCTION

### LOCATION

The Lordsburg mining district lies immediately southwest of the town of Lordsburg in Hidalgo County, New Mexico. The district encompasses about 35 square miles, and is easily accessible by road from Lordsburg and other parts of the State. The Southern Pacific Railroad passes through the town, from which a rail spur about two miles in length, serves the northernmost group of mines.

The district is situated at the northern end of the Pyramid Mountains, which are typical of the Basin and Range province. Within the district, the highest hills are in the western part, where maximum elevations are a little in excess of 5,000 feet, creating a surface relief of some 500 feet. Prominent features are Eighty-Five Hill, Lee Peak, Look-out Hill, and Aberdeen Peak. The desert basins to the north, east, and west are at elevations near 4,200 feet and are reached by gently sloping pediments bordering the range. Climate and vegetation are typical of this part of the southwestern United States. Annual rainfall, most of which falls in the summer months, is about 10 inches, and the vegetation is correspondingly sparsely distributed.

### HISTORY AND PRODUCTION

The first claim location was made in 1870, and the outcrops had been moderately prospected by 1873. High grade silver ores were the initial attraction before the turn of the century, but since that time copper ores have been mainly sought after. The Emerald vein contained the most productive copper ores, and has been mined continuously over a strike of 4,350 feet and a vertical depth of nearly 2,000 feet. The average ore in this deposit contained 2.8 percent copper, as well as 1.23 ounces of silver and 0.11 ounces of gold per ton. The ores have also been valuable as a siliceous flux. The principal mine on the Emerald vein was the Eighty-Five, which has been inactive since 1932 until just recently. Production since 1933 has come largely from the Bonney and Miser's Chest mines. Other producing mines of note in the district have been the Waldo, Ruth, Anita, Henry Clay, and Atwood (Jones, 1965).

Production for the district for the years 1904 through 1959 amounts to 3,738,000 tons, valued at \$41,903,000 (Mineral Resources of the United States, 1904-31; Minerals Yearbooks, 1932-59). Considering the rate of production and the value of metals since 1959, the total value of the Lordsburg ores is considered to be near \$56,000,000, and makes it the principal district in Hidalgo County.

### RECENT DEVELOPMENTS

In 1967, Federal Resources Corporation purchased the Bonney-Miser's Chest mines, formerly owned by Banner Mining Company. Development and drilling programs were initiated to develop additional ore reserves. Federal Resources Corporation leased the Eighty-Five in 1968, which had formerly been operated by Diversified Mines, located near Lordsburg. More recently Federal Resources Corporation obtained a long-term lease on the Henry Clay mine, from Henry Clay Mines Inc., Toronto, Canada. This includes an extension of the Emerald vein, now producing good grades of copper, gold, and silver on the adjacent Eighty-Five mine (Eng. Mining Jour., Feb., 1970).

Recent development includes a 1300-level crosscut between the Bonney and Eighty-Five mines which was completed in early 1969. A drift at the 2,000-foot level at the Bonney mine is being driven northeastward along the Bonney vein, and from there it is proposed to extend a crosscut to the Emerald vein and drift northeastward as ore is encountered in the Eighty-Five and Henry Clay properties. There are also connections between the Henry Clay and the Eighty-Five on the 600-level and with the Atwood on the 400-level.

Geologic targets will be at lower depths which have been shown to be productive in parts of the Lordsburg district. Ore from these properties will be milled at the Bonney mine, which is expected to eventually accommodate between 400 to 500 t.d.p. Federal Resources is now satisfactorily employing a cut-and-fill technique at the Bonney which had formerly been exploited by a shrinking mining method. Values at the 2000-level in the Bonney mine are much the same as at more shallow depths (C. P. Dechert, personal commun.). Presently, there are no other producers in the district.

### PREVIOUS INVESTIGATIONS

The principal geological literature can be attributed to Lindgren, Craton and Gordon (1910), Lasky (1938), and Flege (1959). Early mining developments were summarized by Jones (1904, 1907), Wells (1909), Hill (1924), and Darton (1933). Detailed descriptions of petrologic and economic characteristics were given by Lasky (1935a, 1935b, 1936) and Lasky and Wootton (1933). Belt (1960) described some aspects of wall-rock alteration, whereas hypogene zoning and related phenomena were recognized by Clark (1962, 1964). Elston (1964) considered orogenesis and periods of mineralization in southwestern New Mexico, and the mining districts in Hidalgo County in particular (1965). Mining operations at the Eighty-Five mine were

described by Youtz (1931) and at the Atwood group by Huntington (1947) and Storms (1949). A review of the Bonney mine was given by an anonymous writer (1943).

#### ACKNOWLEDGMENTS

The writer's own interest in the district was stimulated by W. E. Elston, who first suggested the distribution of mineralization in zones. Others from the University of New Mexico who helped with structural and mineralogical problems were V. C. Kelley, and A. Rosenzweig; Ming-Shan Sun, formerly associated with the New Mexico State Bureau of Mines also helped.

### GEOLOGY

#### REGIONAL SETTING

It has been recognized for some time (Butler, 1929) that some of the important mining districts of the western United States are concentrated around the margins of the Colorado and Columbia Plateaus. In parts of southern Arizona and southern New Mexico moderate erosion and shelf-type deposition took place in Paleozoic time. Continental sedimentation characterizes Triassic and Jurassic times, but there are areas of non-deposition and erosion in southern Arizona and southern New Mexico (Turner, 1962). In early Cretaceous time the structural framework changed, and a basin of deposition developed in southeastern Arizona and southwestern New Mexico. This resulted in accumulation of a thick overall section of Paleozoic and Mesozoic rocks in this area. The Laramide orogeny, and its accompanying igneous activity and mineralization, made its print in late Cretaceous to early Tertiary time. The two dominant physiographic features of the Southwest—the Colorado Plateau and the Basin and Range province—came into existence during the Cenozoic Era (Anderson, 1966). Burnham (1959) has shown that the base-metal mining districts around the Colorado Plateau are aligned in belts, narrow but up to several hundred miles long. Within these belts, metallogenic provinces occur, for example, the mid-Tertiary disseminated molybdenum province at the eastern margin of the Colorado Plateau (Clark, 1968, 1970). The Lordsburg district lies within a late Cretaceous-early Tertiary copper province which includes southwestern New Mexico, southeastern Arizona, and northern Mexico. A summary of the local geology is taken mainly from Lasky (1938) and Flege (1959) and is given below.

#### BASALT

The oldest rock exposed in the district is basalt. This unit is dark gray or purple, and usually aphanitic, although sparse phenocrysts of feldspar occur. It is the most common rock type, and was tentatively correlated by Lasky (1947) with volcanic flows interbedded with sedimentary rocks of Early Cretaceous age in the Little Hatchet Mountains. The basalt is at least 2,000 feet thick, as proven by the deep shafts of the district, and is the main host rock to subsequent igneous activity and accompanying mineralization. Essential minerals are augite and labradorite. Accessory minerals include hornblende, olivine, and magnetite. Much of the plagioclase is altered to sericite, clay, and carbonate.

#### INTRUSIVE BRECCIA

This volcanic unit intrudes the Cretaceous basalt and occurs in the form of small plugs, the most prominent of which is Atwood Hill, which is one mile long and 1,000 feet wide. Fragments from within the breccia consist of gray to greenish basalt in a basaltic matrix. In places, the breccia is light colored and contains fragments of basalt and feldspar. Fragments are usually small with a maximum diameter of three inches.

#### INTRUSIVE RHYOLITE

Both basalt and intrusive breccia are intruded by rhyolite, although field relationships show that granodiorite is later still. The rhyolite is light in color and is extremely fine-grained, occurring either separately or associated with the intrusive breccia. Previous workers have stated that they believe these intrusions are remnants of volcanic necks. Flege (1959) notes that the rhyolite has been sericitized and silicified, probably as a result of hydrothermal activity.

#### GRANODIORITE

In Late Cretaceous or early Tertiary time, a granodiorite stock intruded the basalt and rhyolite units. The present outcrop of the stock is in the shape of a horseshoe and forms the hilly western part of the district. The area exposed is 10 square miles, although as much as half of the body may still be hidden by basalt. Numerous small hills formed of the same rock are found in the central and eastern parts of the district and are interpreted as protuberances of the stock exposed by erosion (Fig. 1).

The granodiorite is pink or buff-colored in hand specimen. It consists of phenocrysts of plagioclase (oligoclase-andesine), which constitute about 40 percent of the rock, quartz grains (10 percent), orthoclase (5 percent), green hornblende (5 percent), and minor biotite. At the granodiorite-basalt contact, a hybrid rock results from the reaction of basalt with the intrusive granodiorite magma. The writer believes the Lordsburg granodiorite may have been emplaced early in the interval defined by the intrusion of the Santa Rita (63 m.y.), Hanover-Fierro (70 m.y.), and southeastern Arizona stocks (63 m.y. average), which are Late Cretaceous-Paleocene, and the nearby, but later, Little Hatchet Mountains (47 m.y.) granite, which is early-middle Eocene (Kottowski, Weber, and Willard, 1969). Consequently, the age of the mineralization, which is related to the granodiorite stock, is believed to be consistent with the mineralization epoch of the southwestern United States copper province.

#### GRANODIORITE PORPHYRY DIKES

These dikes cut both basalt and the granodiorite stock. They commonly have northeasterly or northwesterly trends, although a few strike east. They are regarded as genetically related to the granodiorite stock, although emplaced later.

#### TERTIARY RHYOLITE

Following a period of erosion, volcanic activity was resumed in middle Tertiary time. The southwestern and southern parts of the district are covered with pyroclastic material which overlies the basalt. Flege (1959) described



rhyolite tuff-breccias, rhyolite flows and tuffs, and glassy and welded rocks in the sequence. The sequence is 2,000 feet thick in parts of the Lordsburg quadrangle. Most of these rocks are exposed in the central part of the Pyramid Range, although the Leitendorf Hills immediately south of the Lordsburg district are made up of volcanic rocks that are believed to be the center of eruption.

#### QUARTZ LATITE DIKES AND PLUGS

Quartz latite bodies were regarded as earlier than the Tertiary pyroclastic rocks by Lasky, but Flege later found them cutting Tertiary pyroclastics in the central part of the Pyramid Range. The dikes occur in strings whose composite length may be several miles. Hand specimens have a gray matrix studded with phenocrysts of sodic plagioclase and orthoclase, smaller idiomorphic flakes of biotite, and rare quartz grains. There is some associated pyrite.

#### NORTH PYRAMID RHYOLITE

Rhyolite flows, probably of late Tertiary age, spread from the volcanic neck of North Pyramid Peak. They are found in the southeastern corner of the district and are recognizable by their buff color. The flows lie unconformably on the Tertiary pyroclastics and Cretaceous basalt.

#### FELSITE

The last phase of igneous activity is marked by the intrusion of rhyolitic dikes and plugs. This unit is dense, homogeneous, silicified in places, and hence, resistant to erosion. A well defined group of dikes crosses the district with an east-northeast alignment.

#### QUATERNARY DEPOSITS

Alluvium is much in evidence in the desert plains surrounding the Pyramid Mountains. Flege (1959) showed the alluvial contact at the flank of the range at elevations between 4,400 and 4,700 feet. Arroyos, developed by the radially disposed drainage pattern, become filled with gravel and fine elastic material long before they reach the margins of the range.

#### STRUCTURE

The Pyramid Range is probably bordered by major north-trending faults of middle to late Tertiary age, which are hidden by Quaternary deposits. Dips at Rim Rock Mountain, in the central part of the range, indicate a tilt to the northeast. Within the mining district itself, the granodiorite is well exposed in the west, and this may be an expression of eastward tilting.

The Cretaceous basalt does not contain any features that are indicative of its structural attitude; individual flows are difficult to recognize. The basalt has been perforated by a number of volcanic vents through which intrusive breccia and rhyolite have been emplaced. These bodies now have exposed diameters which vary from a few hundreds of yards to one-half mile.

The granodiorite stock did not penetrate to the surface, but has, of course, been exposed by erosion of the overlying flows. Lasky (1935b, 1938) considered the highest present

outcrop to be within 500 feet of the original top of the stock when it was emplaced. His conclusions are based on the presence of large areas of flat-lying contact metamorphosed rock representing the base of the overlying basalt.

Faults and fractures are grouped into three main sets, each with a specific trend and other characteristics. Veins are well developed in most faults and fractures and are summarized below:

**Northeast Veins.**—These include the Emerald, Bonney, Robert E. Lee, and Ruth veins. At the surface, the veins are poorly defined, although they commonly extend four and five hundred yards individually, or well over a mile en echelon. In the past these veins were highly productive and they still support the present copper producers.

**East-West Veins.**—Included in this group are the North and South Atwood veins, and those of the Owl and Susie mines. In the northern part of the district these veins have a prominent siliceous outcrop, although farther south the outcrop is not as well defined. Outcrop length is similar to the northeast group, but mineralization is sporadically distributed.

**Northwest Veins.**—This trend is developed only by the Fluorite vein and the smaller veins parallel to it in the southern part of the district. The Fluorite vein has a prominent siliceous outcrop, although sulfides are entirely subordinate to gangue minerals in this set.

**East-Northeast Veins.**—This set cuts the northeast group and is represented by the Fort Savage and El Dorado veins. Sulfides are sporadic.

**North-South Veins.**—This is a poorly represented group in the north-central part of the district, in which sulfides are subordinate to gangue minerals.

In general, fissure-veins frequently change from one trend to another, although they may be terminated at intersections with another set. Dips are usually steep, and movement occurred along the fracture several times, as evidenced by the common presence of brecciated vein material and slickensides.

#### ORE DEPOSITS

Fissures, related to the emplacement of the granodiorite stock, contain the mineralization of economic importance. The Lordsburg district has been divided into the Virginia (Shakespeare, Valedon, Ralston) subdistrict occupying the northern part, whereas the Pyramid (Leitendorf) subdistrict occupies the southern part.

Vein materials show brecciation by repeated movements along the fissures that they occupy. Fragments of wall-rock and early formed mineral aggregates are partly replaced by later stages of mineralization and are cemented by gangue. Lasky (1938, p. 30) described in some detail the sequence of reopening of the fractures and the subsequent mineralization that filled the openings. Banding of ores at Lordsburg is not common. For the most part, ore minerals fill small fractures and cavities in the previously formed materials.

#### MINERALOGY AND PARAGENESIS

In the Virginia area each stage is characterized by a distinctive suite of sulfides and (or) gangue. Stage 1 is characterized by hydrothermal alteration of the wall rocks, including for-

mation of tourmaline and specularite, recognizable in the Emerald, Bonney, Atwood, and Anita veins. Stage 2 deposition followed reopening of the veins, with development of considerable coarse-grained and massive chalcopyrite, together with lesser amounts of pyrite, sphalerite, and galena. Coarse-grained quartz is also well developed. Between stages 2 and 3, parts of the veins were leached by hydrothermal solutions, which removed part of the earlier gangue minerals and fragments of wall rock. Reopening, accompanied by further brecciation preceded deposition of quartz, pyrite, and chalcopyrite of stage 3. Sulfides are sparingly distributed in quartz which characteristically forms part of the crystal lining of numerous cavities. The fourth stage was also preceded by reopening of the veins. Abundant pink calcite, exhibiting scalenohedral crystals, and minor amounts of chalcopyrite and galena were deposited. Veins were reopened again prior to deposition of white calcite and minor chalcopyrite in stage 5. The sixth and final stage of mineralization is invoked by formation of minor amounts of quartz, calcite, and fluorite (Fig. 2).

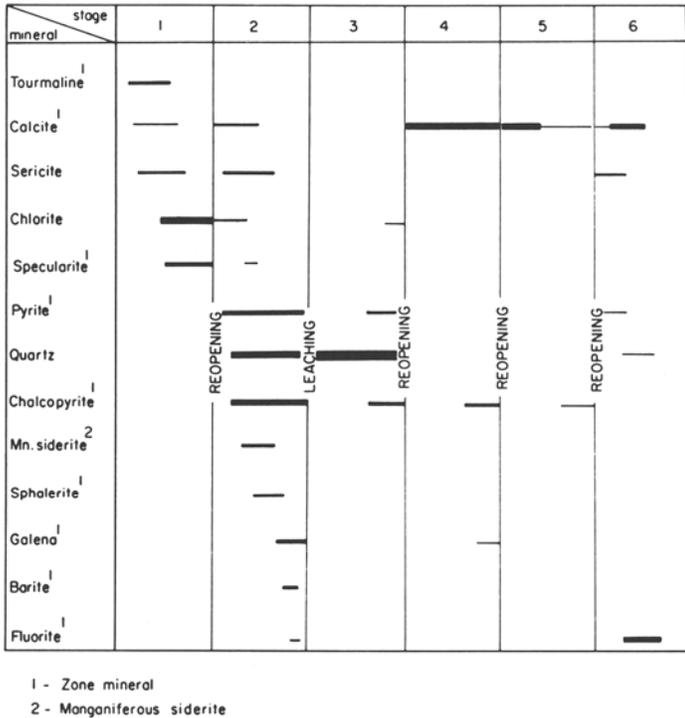


FIGURE 2.  
Mineral succession in the Virginia subdistrict  
(after Lasky, 1938).

There are differences in mineralogy between the Virginia and Pyramid subdistricts. Ankerite, rhodochrosite, chalcocite, digenite, bornite, and stephanite are peculiar to the southern area. Manganoean calcite is believed to be present in both subdistricts. The succession of gangue minerals, particularly the carbonates, is also at some variance (Fig. 3).

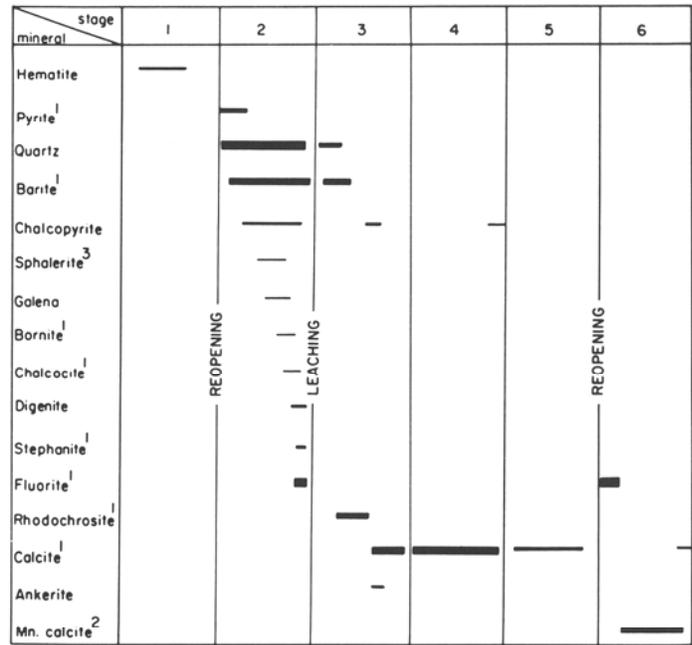


FIGURE 3.  
Mineral succession in the Pyramid subdistrict  
(after Clark, 1962).

The writer was unable to find any tourmaline, sericite, chlorite, or calcite in the first stage, partly, it must be admitted, because of the lack of fresh underground exposures. A specimen from the Susie mine contains the only hematite identified in the Pyramid subdistrict. As in the Virginia area, the second stage is the main period of sulfide mineralization. In addition to chalcopyrite, chalcocite, digenite, and bornite were assigned to this stage, together with small amounts of stephanite, galena, sphalerite, and fluorite. In fact, fluorite developed in both subdistricts (Clark, 1962) at both the second and sixth stages is cited as a genetic link between the two areas. A good marker of the third stage is the masses of drusy quartz crystals lining cavities produced by hydrothermal leaching following the second stage. A little chalcopyrite with barite, rhodochrosite, and calcite were also deposited. The fourth stage is represented mainly by calcite. Stage 5 is solely represented by calcite, again showing scalenohedra. The sixth and final stage, following reopening, is represented by fluorite and manganoean calcite. The writer believes that fluorite is genetically related to the granodiorite stock. In support of this, it is hard to believe that fluorite should take up a zonal distribution to such a marked degree if this relationship were not so. Furthermore, the fluorite vein is zoned as are the other veins in the district, being associated with sulfides in some places. In contrast, Elston (1962, 1964) records fluorspar deposits formed by hot springs in late Tertiary or early Quaternary time in parts of southwestern New Mexico.

## SUPERGENE ALTERATION

Although Lasky has recorded enrichment of ores to lower levels in some localities, in general, supergene alteration extends to a depth of 600 feet. At the surface, veins are coated with secondary minerals of copper, iron, and manganese. Secondary chalcocite has been identified in hand specimens and polished sections. The high content of silver in the Pyramid area has been regarded as due to supergene enrichment, following deposition at shallow depths.

Boxworks characteristic of primary sulfides, which have since been leached, were used in determining the original distribution of ore minerals at the surface where no underground openings were available for use. In general, the highly siliceous nature of the ore in the central part of the district permits transportation of leached materials, whereas the higher carbonate content in the peripheral parts of the district more readily induces precipitation of acid supergene waters. In addition, a distinctive fluorite boxwork helped define the zonal distribution of the mineral assemblages.

## HYPOGENE ZONING

In the Lordsburg district hypogene zoning occurs in both subdistricts. In the northern area zones are arranged around the granodiorite stock on its northern, eastern, and southern sides. But in the southern area the relationship of zones to a source of mineralization is not as clear.

In the Virginia subdistrict, the association tourmaline specularite-pyrite-chalcopyrite is predominant in a subsurface core zone at a depth of 700 feet. This subsurface assemblage occurs in the area of the Eighty-Five, Henry Clay, Anita, and Atwood mines (Fig. 1). The occurrence of tourmaline at this depth reflects the vertical as well as the horizontal zoning in this camp.

A central zone is spatially distributed around the core zone. It is represented by the zone mineral assemblage of chalcopyrite-pyrite-specularite. Galena and sphalerite occur only in the upper levels of the mines in this area, particularly the Banner and the Atwood, and this is indicative of an assemblage representing the intermediate zone. The intermediate zone differs from those preceding inasmuch as chalcopyrite is no longer the predominant sulfide.

The peripheral zone has been drawn on the first appearance of fluorite in working outward from the core to the margin of the district. The peripheral zone assemblage of gangue minerals is fluorite-calcite-barite.

The boundary of the central and intermediate zones has been placed at the Anita. The core zone is found at depth in No. 2 shaft, and Lasky found fluorite on the dump. Consequently, it appears that all four zones are represented in this mine. The Anita thus provides the best example of vertical telescoping in the district, the change from core to peripheral zone taking place in less than 1,000 feet vertically, whereas laterally a similar mineralogical transition takes place in a distance of over one mile. The interpretation of this phenomena is that mineralization took place at shallow depths.

In the Pyramid area a core zone has not been recognized, partly because the deepest levels in the mines are only about 500 feet below the surface. Absence of tourmaline and a smaller amount of copper suggest that maximum temperatures of formation in this area were lower than those of

the core zone. Central, intermediate, and peripheral zones have been drawn for this subdistrict, but they cannot entirely be equated with the zones farther north except for the peripheral zone.

A small central zone has been drawn around the Nellie Bly and Robert E. Lee mines and is represented by the assemblage chalcopyrite-bornite. The intermediate zone embraces the principal silver producers in the Lordsburg district, the Venus and Last Chance mines. Smelter returns for the Venus show 12 ounces per ton of silver, and 20 ounces per ton for the Last Chance. But in no place are galena and sphalerite as well developed as in the Virginia area. The zone association is considered to be "silver"-rhodochrosite-barite. The peripheral zone has again been delineated by the first appearance of fluorite and is represented by the assemblage fluorite-calcite-barite.

Although the mineralization and paragenesis are similar in both areas, differences exist. Spatially the Pyramid area is no farther removed from the exposed parts of the stock than the peripheral zone in the Virginia area. If the mineralization at Pyramid is regarded as part of the district as a whole, it could well represent an association common in the outer zones of other districts (Emmons, 1936). Unfortunately, the asymmetrical disposition of the zones and the apparent temperatures of formation in both subdistricts scarcely support this contention.

## TEMPERATURES OF FORMATION

The relatively widespread occurrence of a common sulfide led Clark (1962) to use the sphalerite geothermometer in the Lordsburg district. The method of x-ray fluorescence analysis of sphalerite was done at the New Mexico State Bureau of Mines in 1961-62. The results of this work suggest a maximum temperature of formation of 550° to 580°C in the Pyramid area. Uncertainties arising from the character of the mineral assemblages, assumption of equilibrium conditions, and the later work of Barton and Toulmin (1966) show that another geothermometer should be used as a check.

Qualitatively, trace amounts of cadmium were found in the sphalerites, which Goldschmidt (1954) considers as characteristic of high temperatures of formation. The maximum amount of cadmium in sphalerites obtained from the Eighty-Five mine is 0.6 percent (Burnham, 1959). Traces of tin are probably present in ore from the central zone, collected from the 1300-level of the Banner mine. Furthermore, the core zone assemblage containing copper and tourmaline has been cited as a high temperature indicator in other deposits (Lindgren, 1933).

The core and central zones in the Virginia area are believed to be nearest the source of the mineralizing fluids. Minerals with high temperatures of formation tended to be deposited nearer the source, whereas the lower-temperature assemblages were not deposited until the fluids had cooled by traveling upward and outward for considerable distances. There is a broad relationship between zoning and paragenesis, as minerals of the earlier stages are mainly confined to the inner zones.

## CLASSIFICATION

The combination of initial high temperatures of formation and shallow depth of emplacement suggests that the copper-tourmaline deposits of the Lordsburg district can be assigned to the xenothermal class.

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Playas Valley with Animas Mountains in left background. View northwest. Note lack of notable relief in deep bolson gravels of Quaternary age.  
(Photograph by Wengerd)