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Geochemical and biogeochemical studies in the Hansonburg Mining District, New Mexico

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GEOCHEMICAL AND BIOGEOCHEMICAL STUDIES IN THE HANSONBURG MINING DISTRICT, NEW MEXICO

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ABSTRACT

The Hansonburg mining district is in Socorro county in south central New Mexico. A Paleozoic section of thick Pennsylvanian limestone units, thin shale and arkose layers and thick Permian units of sandstone, siltstone and gypsiferous beds interlayered with thin limestone units unconformably overlie a Precambrian basement of granite. The sedimentary rocks are folded with north trends and plunges. Northerly, some easterly and northwesterly trending faults cut the folds. Galena, fluorite, and barite mineralization occurs along some of the northerly faults and as bedded replacements and fissure fillings in the Pennsylvanian Council Spring limestone.

Geological mapping and geochemical soil surveys of the northwestern part of the mining district indicate four major heavy metal anomalous areas and possible regional zoning of the metals. Copper values range from a low of 2.8 ppm to a high of 67.0 ppm. Lead values ranged from 5.3 ppm to 56 ppm, and zinc from below detection limit to 38.0 ppm.

Heavy metal determinations were made of soil and Creosote bush samples that were collected across a mineralized fault breccia zone of the Oscura fault. Results show that the lead values in soils in test profiles have distinct anomalous areas which range

from 11.5 to 98.0 ppm. Copper and zinc anomalies are also distinct, but with smaller ranges of 3.5 to 16.0 ppm and 3.0 to 21.5 ppm, respectively. Heavy metals in Creosote bush samples show similar anomalous zones, but copper has the greatest range (12.0 to 65.0 ppm). The range of lead is 5.0 to 28.0 ppm and for zinc, 10.5 to 21.5 ppm.

A rising trend of copper and zinc and constant lead content in sediments upstream along the Julian Arroyo suggests possible mineralization within the Alamogordo Bombing Range.

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I. INTRODUCTION

A. Purpose and Scope

The objectives of this study were to determine the geochemical distribution patterns of the base metals in the soils, arroyo sediments, and plants within the north fringe area of the Hansonburg mining district, New Mexico, and to investigate the relationship of the base metal patterns to known mineralization and possible channel ways of mineralizing fluids in the district. Another objective was to extend the geologic mapping of the district to the area studied and relate, if possible, the stratigraphy and structure to the geochemical patterns of base metals in the soils and plants.

Three hundred and five soil samples, fifty-five plant samples, eleven stream sediment samples from Julian arroyo, and fifteen altered rock samples were collected during the summer of 1972. Geologic mapping by the author extended the mapped area (Lewchalermvong, 1973; Kopicki, 1962; Kottlowski, 1953; Wilpolt and Wanek, 1951) to the north by approximately 3 square miles. The base map was a 1:24,000 enlargement of the 1948 Bingham 1:62,500 scale quadrangle map.

B. Previous Work

Jones (1904, p. 103) reported that the district, now known as the Hansonburg mining district, was named for a prospector, Pat Higgins, in 1872. Later Peters

(1882) described the copper occurrence in the "red beds" near Mocking Bird Gap and some production of "glance copper" which replaced feldspar grains and fossils in the red beds. Lindgren and others (1910) mentioned the lead prospect pits in the Pennsylvanian limestone. Johnson reported (1928) that there was no evidence of replacement of the wall rock, only fissure fillings.

The first detailed study of the district was complated by Lasky (1932). Brief mention of the district was given by Rockrock, Johnson, and Hahn (1946) and by Clippinger (1949). Kottlowski (1953) published a report which included a geologic map of the Mex-Tex and Royal Flush mines and descriptions of the local stratigraphy. Austin and Slawson (1960) completed a study of lead isotopes from the Blanchard Mine and showed a relationship between the environment of deposition and type of lead minerals present. Following this, a report by Kopicki (1962) described the controls of mineral deposition. He also described the paragenetic sequence of mineral deposition and included a geologic map covering the central part of the district. Roedder and others (1968) explained the physical and chemical parameters of ore deposition and paragenetic sequence based on fluid inclusion studies. Recently, Lewchalermvong (1973) completed an investigation of the district which included an evaluation of ore potential for the Mex-Tex and Royal Flush mines and surrounding areas, and a revised geologic map with cross-sections through the central part of the district.

C. Location and Access

The Hansonburg mining district is located in central New Mexico, 6 miles (9.65 km) south of the town of Bingham. The latter is 80 miles (128.72 km) south of Albuquerque along Interstate 25 and 30 miles (38.27 km) east of San Antonio on state road 380 (Figure 1). At Bingham, population three, a well-graded gravel road leads into the district. At this time, permission to enter the mining properties must be obtained from Taylor Mining Enterprises, Denver, Colorado.

The extended range of the Alamogordo Bombing Range (White Sands Proving Grounds) covers the entire district. Because of test activity, civilian residents are occasionally asked to temporarily vacate the area.

D. Geography

The Hansonburg mining district is part of the Mexican Highland Section of the Basin and Range Province (Fenneman, 1931). It is located between the Rio Grande Basin on the west and the Tularoso Basin to the east. The mining district is divided by two distinct physiographic features. The western half is included in the Jornado del Muerto plain (Journey of Death) and the eastern half is part of the Sierra Oscuras. The Jornado del Muerto is a north-south trending desert plain with an elevation of

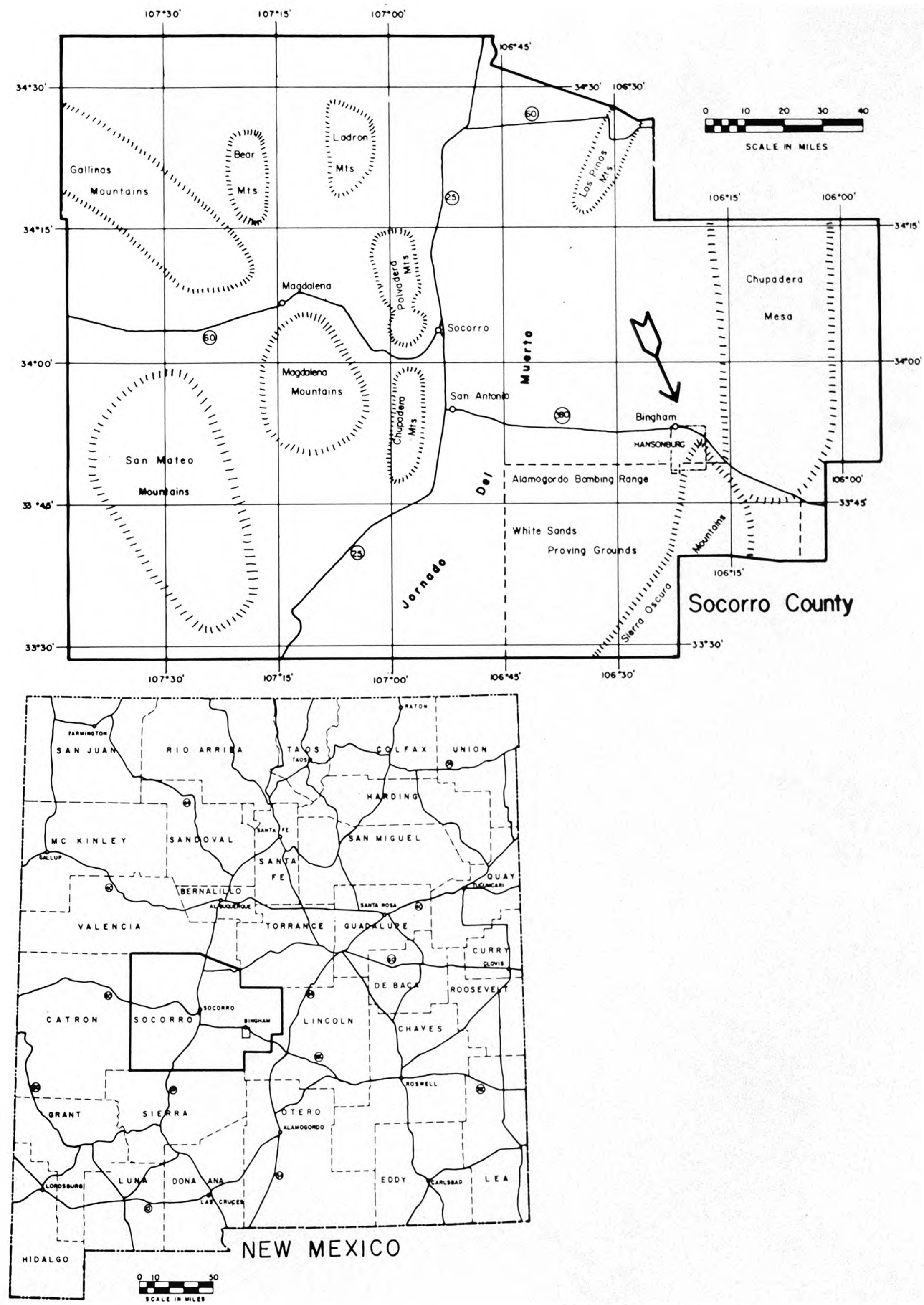

Figure 1. Index maps of New Mexico and Socorro County showing the location of the Hansonburg mining district

approximately 5,200 feet (1,585 m). This plain extends from Albuquerque to El Paso, Texas. The Sierra Oscura form a steep west facing north striking escarpment rising to a maximum elevation of 8,732 feet (2,662 m) at Oscura Peak. The escarpment is bounded by the Chupadera Mesa to the north and the San Andres Mountains to the south. The San Andres Mountains are a southerly extension of the Sierra Oscura.

Drainage in the district is westward through Julian Arroyo, which has water flow only a few times a year. These flows usually occur during July, August, and September. Rainfall in the area is only about 11 inches (28 cm) per year. The annual temperature averages approximately 56°F (13.3°C).

The economy of the area is based mainly on cattle ranching. Mining production has occurred in the past, but currently is dormant. A brief summary of the district is given in Table 1. Bingham which lies on the north edge of the district has a general store and post office.

Some grass occurs in the valley areas and is used for cattle grazing. Vegetation in the area is sparse. Cactus, Sagebrush, Creosote bushes, Greasewood trees, Juniper trees, and Pinon trees are the predominant plants.

Table I. History and production of the Hansonburg mining district (after Kopicki, 1962 with modifications).

DATE	OPERATOR	MINE	PRODUCTION
1872	Pat Higgins	Discovery of district	
1901	Alcazar Company	Hansonburg Hills	One car load of conc.
1916-1927	Western Mineral Products	Hansonburg Lead Mine	Several car loads in 1917
1943	F. L. Blanchard	Hansonburg Lead Mine	No production
1949	Portales Mining Co.	Hansonburg Lead Mine	Several car loads
1949	Scott Mineral Co.	Royal Flush	
1949	Mex-Tex Co.	Mex-Tex	150 ton/day
1949	Hurlow Mining & Milling Co.		Mill and prospecting
1949	Barrett	Prospects	
1961	Galbar, Inc.	Mex-Tex	Several car loads
1961	Sunshine Mining Co.	Blanchard Mine	Several car loads
1971	Basic Earth Science System, Inc.	Consolidated district	Prospecting and development
1973	Taylor Mining Enterprises	Control of entire district	Prospecting and development

II. GEOLOGI SETTING

The Hansonburg mining district is located in a region of Precambrian, Pennsylvanian, Permian, Tertiary and Quaternary rocks. South of the district along the Sierra Oscura escarpment, Pennsylvanian limestones rest on granite-greisen rock of Precambrian age (Kottlowski, 1953, p. 3). To the west, a succession of down-dropped blocks of Precambrian, Pennsylvanian, Permian, Tertiary, and Quaternary strata are present. Northwest of the district desert alluvium covers the surface. Here the bedrock is assumed to consist of down-faulted blocks of Paleozoic and Tertiary rocks. East and northeast of the district Tertiary intrusive rocks crop out on the Chupadera Mesa (Figure 2).

A. Stratigraphy

The following descriptions include only those formations which crop out in and around the Hansonburg district. All Pennsylvanian formations above the upper Bolander group are visible along the Oscura escarpment in the district. Permian formations crop out toward the northeastern part of the district along the parallel north-south valley-ridge development. Because of erosion or nondeposition, Cambrian, Ordovician, Silurian, Devonian, and Mississippian rocks are not present and the upper Paleozoic rocks lie directly on the Precambrian.

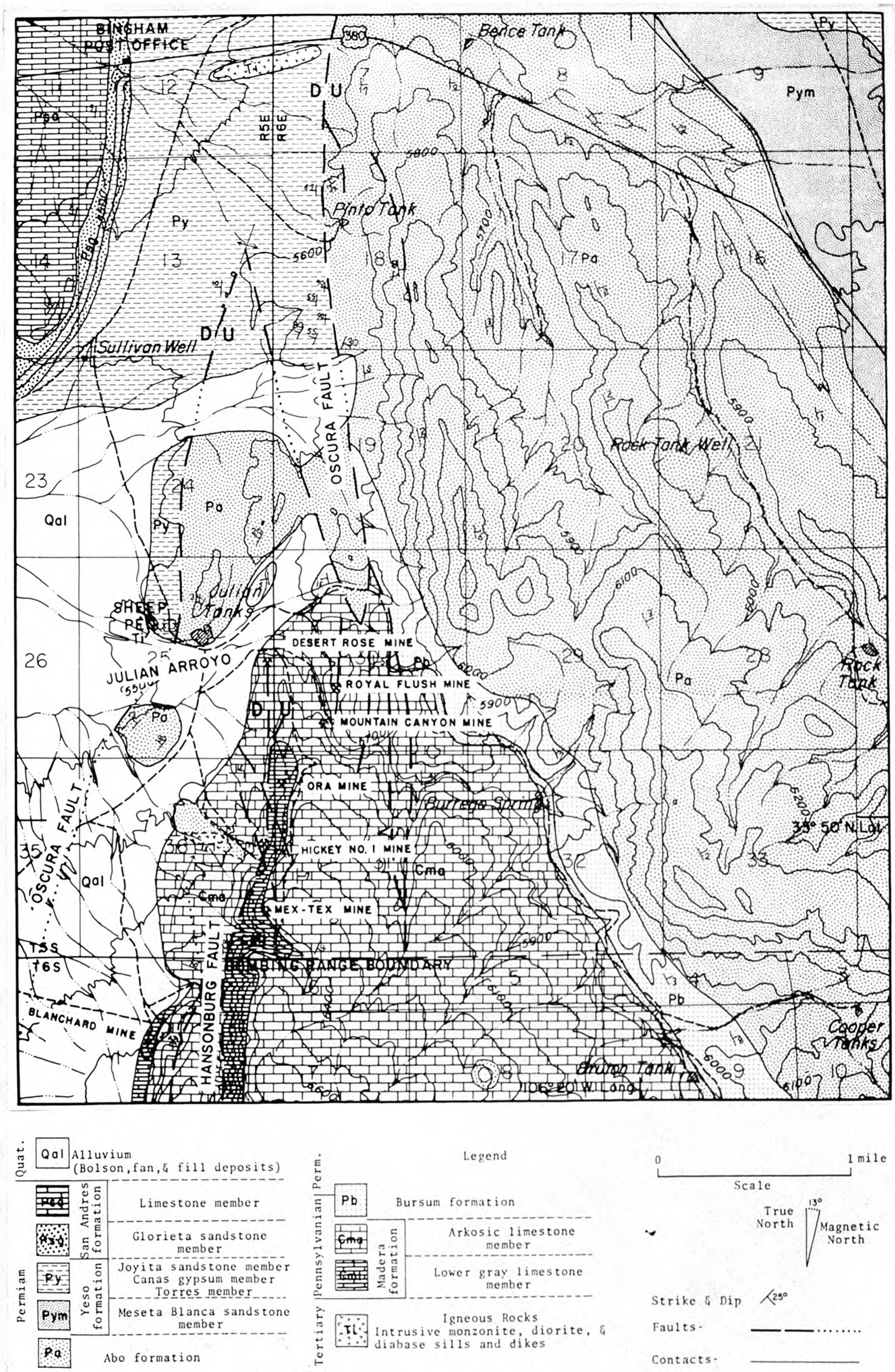

Figure 2. Generalized geologic map of the Hansonburg mining district, New Mexico (after Lewchalermvong, 1973; Kopicki, 1962; Kottlowski, 1953; and Wilpolt and Wanek, 1951).

Thompson (1942) classified Pennsylvanian strata by using fusilinids (Figure 3). He divided the Pennsylvanian rocks of New Mexico into fifteen formations. Because of the restricted map scale, however, the Wilpolt and Wanek (1951) classification is the basis for all Pennsylvanian and Permian strata shown on the maps of this report.

1. Precambrian System

Precambrian rocks are not exposed in the district, but they crop out along the base of the Oscura escarpment just south of the Blanchard mine at the southern map boundary. These exposures extend southward the entire length of the Sierra Oscura. The rocks are composed mainly of granite, gneiss, mica schist, and quartzite.

2. Pennsylvanian System

In this area of New Mexico, the Pennsylvanian rocks lie unconformably on the Precambrian. The former are composed of marine limestones and calcareous shales along with a small amount of sandstones and red beds. The thickness in the northern Sierra Oscura is about 900 feet (280 m). Nine major units have been described for this system in this area (Figure 3).

Bolander Group-- The Bolander group is composed of gray fossiliferous limestone and shale and a well developed bed of conglomeratic sandstone 70 feet (21 m) from the top of the group. Total thickness of the group is 123 feet (37 m).

Coan Formation-- The Coan formation is a gray to buff, cherty limestone 58 feet (18 m) thick. This formation is a prominent cliff former.

Adobe Formation-- The entire 50 feet (15 m) of the Adobe formation is composed of cherty to non-cherty limestone, gray shales, and fossiliferous arkosic sandstones. Because of the interbedded nature of the sandstone and shale with the limestone, this formation forms slopes.

Council Spring Formation-- The Council Spring is a massively-bedded, light gray to white, coarse to fine-grained, cliff-forming limestone about 19 feet (6 m) thick. The weathered cliff face of this limestone commonly breaks into vertical columns.

Burrego Formation-- The Burrego formation consists of 52 feet (16 m) of massive to massively-bedded, nodular, gray, to light gray limestone. Often, there is a red shale at the base of this formation.

Story Formation-- The lower 20 feet (6 m) of the Story formation is composed of a series of reddish-brown, shaley, arkosic and micaceous sandstones and a gray shale bed. The upper 38 feet (12 m) consists of light gray, massive to massively-bedded, fossiliferous limestone.

Del Cuerto Formation-- The Del Cuerto formation makes covered slopes. It is composed of 80 feet (24 m)

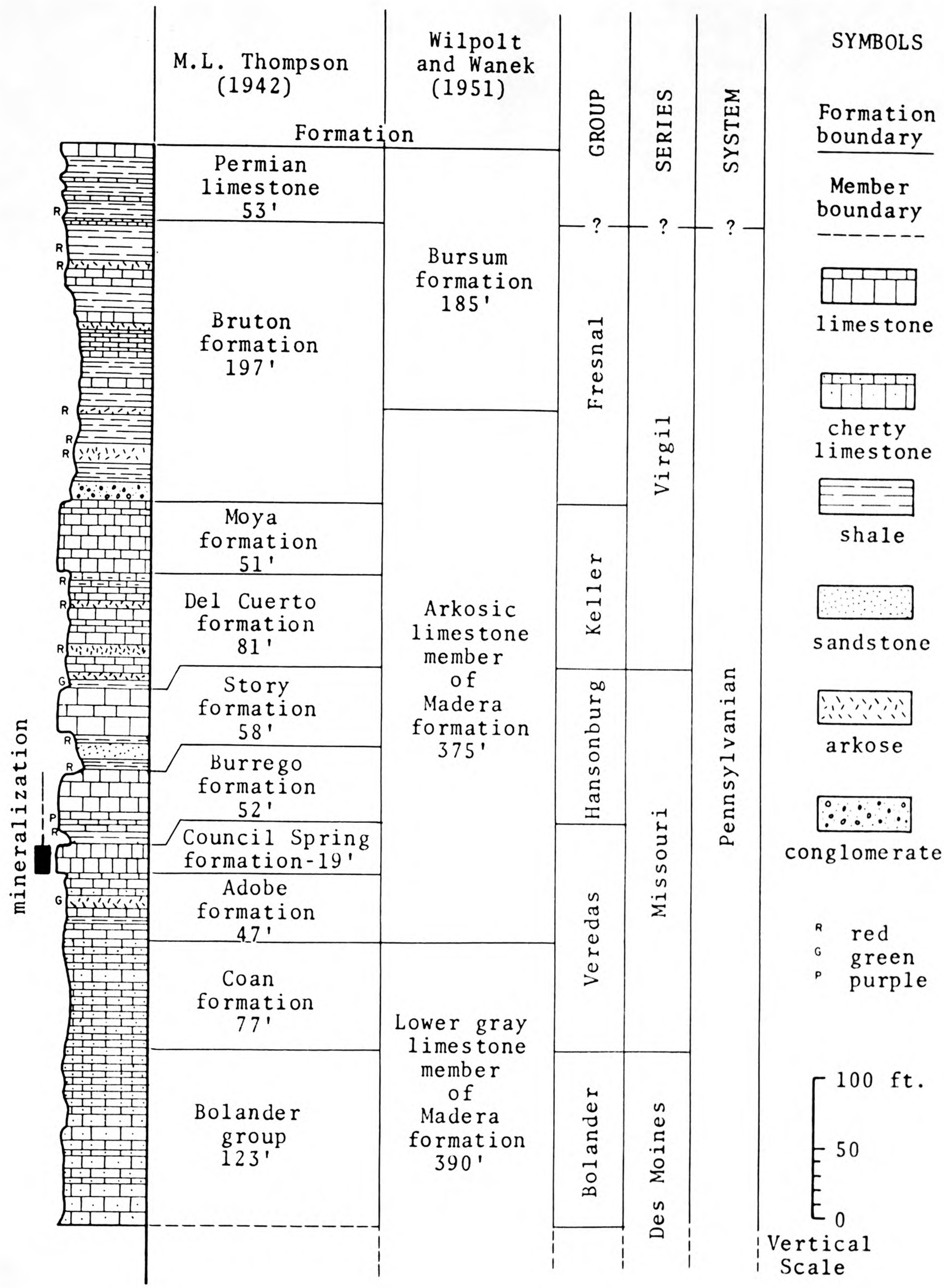

Figure 3. Stratigraphic section of the Pennsylvanian System in the Hansonburg mining district (after Kottlowski, 1953).

of irregularly bedded to nodular, gray limestone, red, green, and brown, highly arkosic sandstone, limestone conglomerate, and gray and red shale.

Moya Formation-- The 50 feet (15 m) of the Moya formation is composed of massive to massively-bedded limestone with some thin layers of irregularly bedded to nodular limestone. This unit caps most of the dip slopes in the district. The Moya is a cliff-former.

Bruton Formation-- The Bruton formation is composed of 197 feet (60 m) (Kottlowski, 1953) of soft, red shale interbedded with nodular limestone. This formation forms the slope below the massive basal Permian limestone.

Bursum Formation-- The Bursum formation is a transitional formation between the Pennsylvanian and Permian rock. All rock below the massive white limestone occurring at the top of this formation is considered Pennsylvanian (Kottlowski, 1953). All rock above and including the massive limestone is considered Permian. This formation contains 185 feet (56 m) of variegated shale, thin beds of arkosic sandstone, arkosic conglomerate, and gray limestone.

3. Permian System

The Permian rocks of this region have been divided into four formations (Figure 4). They date from early to middle Permian. An unconformity is located at the top of the Permian system in this area.

Abo Formation-- The 300 to 790 feet (91-241 m) of Abo formation consist of dark red shale, dark red sandstone, arkosic sandstone, and conglomerate. Mudcracks, ripple marks, cross-bedding, and fossilized plants are typical of this formation.

Yeso Formation-- The Yeso formation is composed of four members: Meseta Blanca, Torres, Canas, and Joyita. At the bottom of the Yeso is 190 to 355 feet (58-108 m) of Meseta Blanca sandstone. This contains reddish-brown and variegated sandstone and some sandy shale. This member forms valleys on the dip slope of the Abo formation. The overlying Torres member is composed of 310 to 1,000 feet (94-305 m) of variegated sandstone and siltstone, gray limestone, and gypsum.

The Canas gypsum member is next up in the section. It contains a maximum of 190 feet (58 m) of thick beds of gypsum interbedded with siltstone and limestone. At the top of the Yeso formation is the Joyita sandstone. This member is composed of 30 to 150 feet (9-46 m) of variegated sandstone and siltstone, and gypsum.

San Andres Formation-- The San Andres formation has three members: Glorieta, Limestone, and Upper. At the base is 33 to 200 feet (10-61 m) of white to light-yellow and light-gray, medium to coarse-grained, cross-bedded Glorieta sandstone. The middle member is known as the Limestone member. It has 270 to 396 feet (82-121 m) of dark gray, thin to medium-bedded limestone interbedded

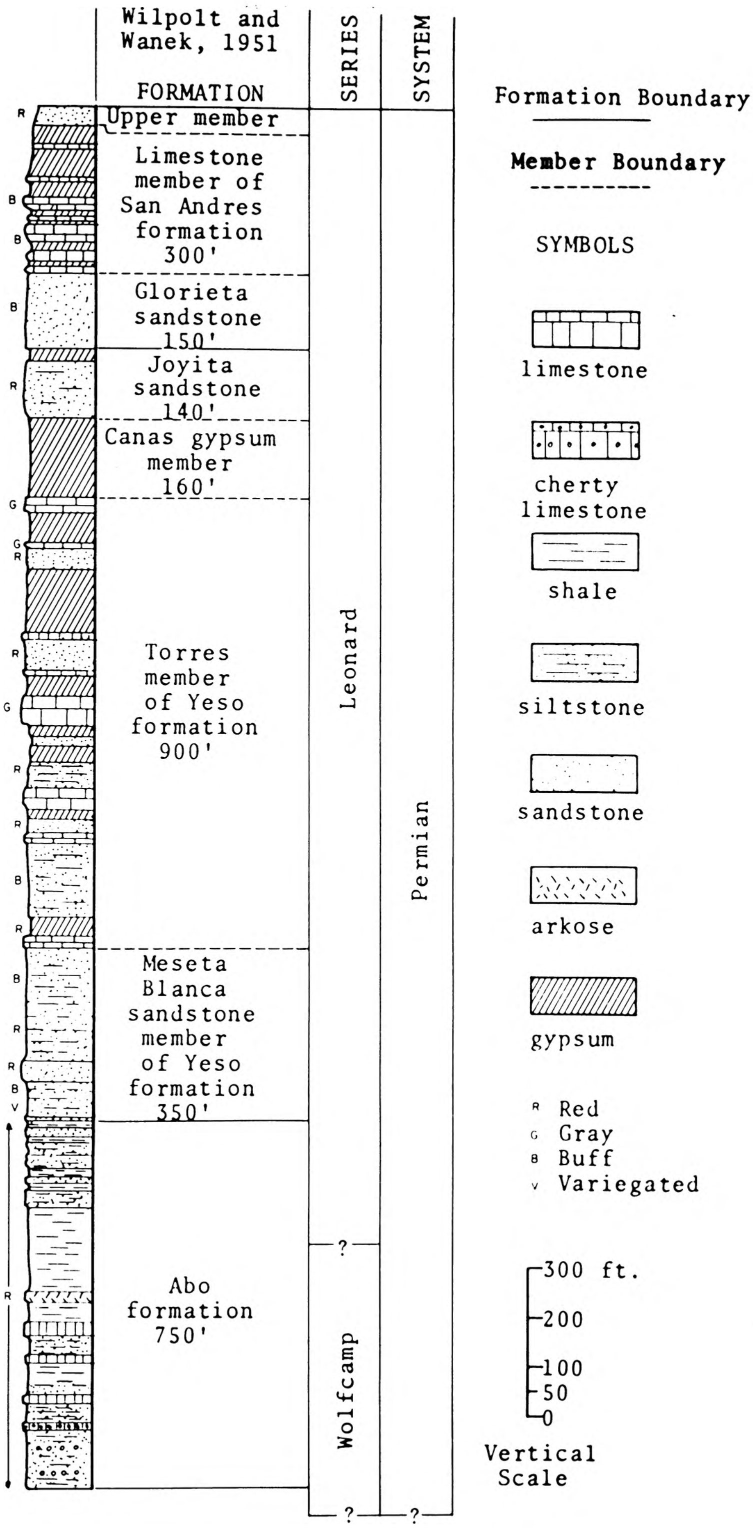

Figure 4. Stratigraphic section of the Permian System in the Hansonburg mining district (after Wilpolt and Wanek, 1951).

with gypsum layers and gray sandstone. The top member of Yeso formation is called the Upper member. It contains 5 to 3 feet (1.5-11 m) of variegated siltstone and sandstone with some interbedded gray limestone. This member is entirely eroded away in the area.

4. Tertiary Intrusive Rock

The Pennsylvanian and Permian strata are intruded by dikes and sills of monzonite, diorite, and diabase. A dike 500 feet (152 m) wide and 3,000 feet (915 m) long, of hornblende-sodaclase diorite, crops out 500 feet (152 m) south of state road 380 and just east of the gravel road le ding into the mining district (Kottlowski, 1953, p. 6). A smaller dike of hornblende-monzonite (Lewchalermvong, 1973) is 1,500 feet (458 m) northwest of the Julian Tank where it intruded the Yeso formation. A small sill-like intrusive body of diabase has been identified between the Mex-Tex mine and the main gravel road leading to the Blanchard property. Age dating of the dike at the nearby Jones Camp area by the New Mexico State Bureau of Mines and Mineral Resources gives an age of 27.2 million years. This corresponds to the mid-Tertiary and could be a good indication of the age of other dikes and sills in the area.

5. Quaternary Alluvium

Most of the valleys in the district are filled with silts, sands, and gravels. In the northern part of the district, the silt, sand, and gravel are mostly derived from the red beds. In the southern part of the district, the alluvium is mostly from weathered Pennsylvanian limestone.

B. Structure

The Hansonburg district has a relatively simple structural setting. The district covers part of the southern portion of the Oscura anticline, a large asymmetrical northward-plunging fold. Westward the anticline parallels the major Torres syncline. On the east the anticline grades into the homoclinal Chupadera Mesa (Wilpolt and Wanek, 1951). Several much smaller northward plunging anticlines and synclines are superimposed on the Oscura anticline within the district.

The north-south trending fault block of the Sierra Oscura, which bisects the district, was formed by movement along the Oscura fault. The fault has a north-south strike along the west facing escarpment of the mountains. The Jornado del Muerto plain, west of the Sierra Oscura has been down dropped along the high angle Oscura fault. The Sierra Oscura to the east form a westerly facing escarpment with cuestas dipping gently to the east. The Oscura fault is best described as a pivotal fault with apparently a zero stratigraphic throw north of the Hansonburg district. The displacement increases to about 4,000 ft. (1,220 m) 12 miles (19 km) south of the district where all surface indication of the fault vanishes under a cover of desert alluvium.

The Hansonburg fault block consists of Pennsylvanian and Permian rocks which lie between the Oscura escarpment and the Oscura fault. West of the Mex-Tex mine the block is down-dropped about 550 feet (168 m) (Kottlowski, 1953, p. 7) and lower Permian rocks occur against lower Pennsylvanian formations (Wilpolt and Wanek, 1951). See Figure 5.

Parallel with these major faults is a complex system of minor faults directly associated with the known mineralization. According to Kopicki (1962, p. 28), two major and one minor periods of faulting are recognizable: (1) High angle faulting which began at the end of Late Cretaceous and continued until the beginning of Early Tertiary, (2) Faulting during Middle to Late Tertiary time causing features such as the Rio Grande depression, Jornado del Muerto, and the Sierra Oscura, and (3) Some minor faulting during Pennsylvanian time. Kopicki (1962, p. 29) categorizes the faults in the Hansonburg district into three groups: (1) Possible pre-Burrego faults which are essentially barren of hydro-thermal mineralization, (2) Faults formed prior to and contemporaneous with mineralization and which are extensively mineralized, and (3) A few faults which may have been formed during a post-mineralization period. Strike-slip movement along the faults is minimal and is apparently related to torsional stresses of previous faulting (Kopicki, 1962).

C. Mineral Deposits

Known mineral deposits in the district are along the face and back slopes of the Sierra Oscura escarpment. Here they locally relate to the areas of Council Spring limestone outcrops.

Crystals of galena, blue and purple fluorite and barite blades of several inches in a matrix typify these deposits. Quartz occurs as anhedral masses in silicified limestone mixed with other minerals and as a druse covering other minerals (see Figures 7 and 8). Kottlowski (1953) reports that, at the Royal Flush mine, the three ore minerals were: barite, 30-55%; fluorite, 12-23%; and galena, 5%. Kopicki (1962) describes 36 additional minerals from the district. Table 2 is a compilation of the minerals presently known in the district.

Some minor mineralization is visible along fault zones in other formations such as the Coan, Bolander, Yeso, and Abo. The deposits are roughly pod-shaped and their axes parallel the direction of strike of associated faults. The largest dimensions are approximately 100 feet (30 m) in width, 800 feet (244 m) in length, and 20 feet (6 m) in exposed height.

Table II. Minerals present in the Hansonburg mining district (rearranged after Kopicki, 1962).

	Hypogene		
Carbonates		Sulfides	
calcite	$CaCO_3$	alabandite	MnS
dolomite	$CaMg(CO_3)_2$	argentite	Ag_2S
rhodochrosite	$MnCO_3$	chalcopyrite	$CuFeS_2$
siderite	$FeCO_3$	galena	PbS
Haloids		marcasite	FeS_2
fluorite	CaF_2	pyrite	FeS_2
Oxides		sphalerite	ZnS
psilomelane	MnO_2	stromeyerite	$(Ag,Cu)_2S$
quartz	SiO_2		
Sulfates			
barite	$BaSO_4$		
celestite	$SrSO_4$		
gypsum	$CaSO_4 \cdot 2H_2O$		
	Supergene		
Carbonates		Vanadinates	
aurichalcite	$2(Zn,Cu)CO_3 \cdot 3(Zn,Cu)(OH)_2$	cuprodescloizite	$2(Cu,Zn,Pb)_3V_2O_8 \cdot (Cu,Zn,Pb)(OH)_2$
azurite	$2CuCO_3 \cdot Cu(OH)_2$	Sulfates	
calcite	$CaCO_3$	anglesite	$PbSO_4$
cerussite	$PbCO_3$	brochantite	$CuSO_4 \cdot 3Cu(OH)_2$
malachite	$CuCO_3 \cdot Cu(OH)_2$	chalcanthite	$CuSO_4 \cdot 5H_2O$
rosasite	$(Cu,Zn)CO_3 \cdot (Cu,Zn)(OH)_2$	gypsum	$CaSO_4 \cdot 2H_2O$
Haloids		jarosite	$K_2Fe_6(OH)_{12}(SO_4)_4$
atacamite	$CuCl_2 \cdot 3Cu(OH)_2$	linarite	$(Pb,Cu)SO_4 \cdot (Pb,Cu)(OH)_2$
Molybdates		spangolite	$Cu_6AlClSO_{10} \cdot 9H_2O$
wulfenite	$PbMoO_4$	Sulfides	
Oxides		bornite	Cu_5FeS_2
goethite	$Fe_2O_3 \cdot H_2O$	chalcocite	Cu_2S
limonite	$2Fe_2O_3 \cdot 3H_2O$	covellite	CuS
murdochite	Cu_6PbO_8		
plattnerite	PbO_2		

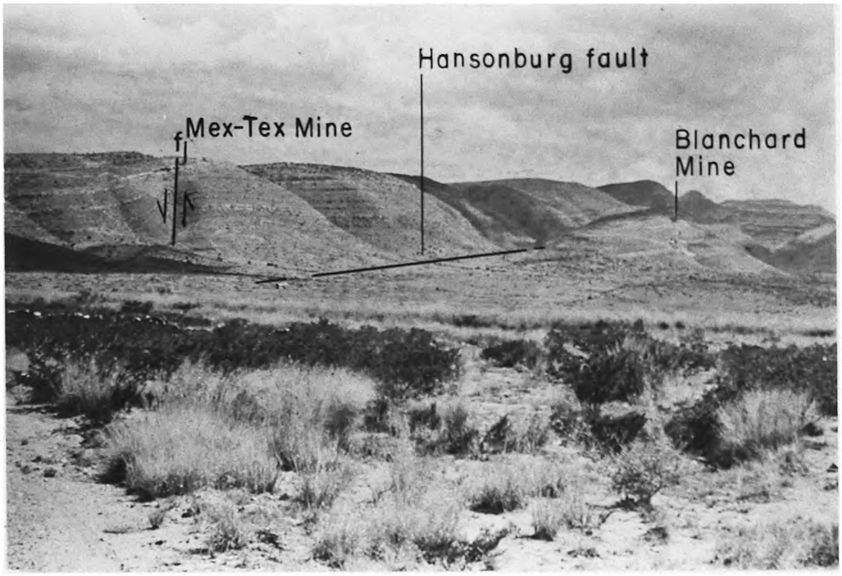

Figure 5. General view of the Hansonburg mining district toward the southeast. The Hansonburg fault is at the base of the escarpment of Pennsylvanian formations. A nearly vertical fault (f) with associated drag folds and pinching of beds can be seen at the Mex-Tex mine.

NOTE: NO DRAG FOLDS! (1981) IT IS A REVERSE FAULT. (MAY BE THRUST?

Figure 6. Portal of the Royal Flush mine with fault zone (f) on left.

The major mineralization occurs mainly as open space filling along fracture zones cutting the gently dipping limestone beds. Large open vugs filled with barite blades, fluorite, and galena crystals are abundant. Crusts of drusy quartz are commonly present in these open vugs. Replaced limestone occurs roughly parallel to and along fissures and bedding planes in the limestone. Coontail type structures are commonly observed in the deposits.

Kopicki (1962) cites three structural controls for ore deposition: faults and associated fractures, breccia zones, and sheeted zones.

North-south trending faults and related fractures carry fissure veins with abundant o en space within the vein filling. Mineralization along these veins is usually sporadic. It ranges from ore grade fluorite, galena, and barite to barren. Early local deposition of silica may have sealed the channelways to later ore fluids.

Lewchalermvong (1973) describes the zones of mineralization as near the point of least displacement along the fault, Vertical displacements are no more than 60 feet (18 m) in the vicinity of the various deposits. The upthrown fault block has been more favorable for replacement ore deposition.

The other structural controls of importance are breccia and sheeted zones. The pattern consists of fractures parallel to the bedding planes. These provided

Figure 7. Large boulder of partly silicified limestone replaced by quartz and fluorite. Vugs lined with quartz. Minor galena grains and malachite staining.

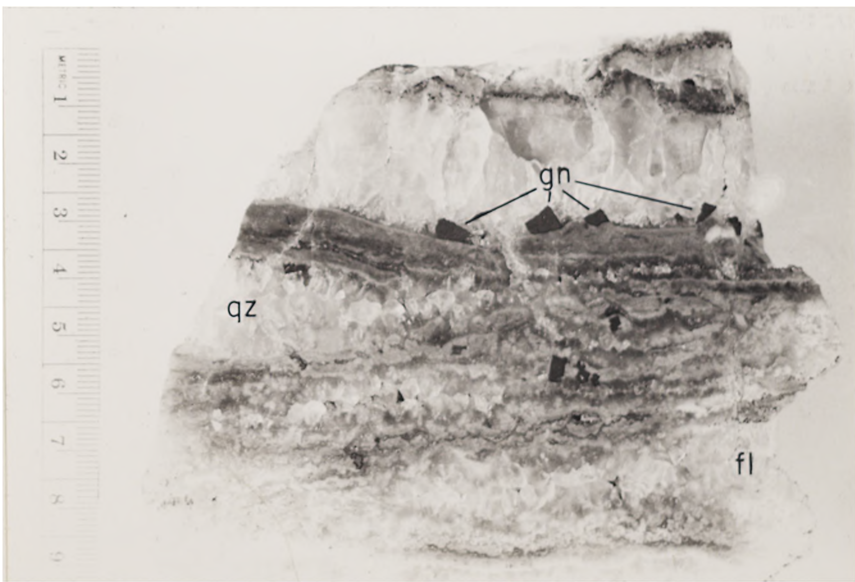

Figure 8. Typical "Coon Tail" ore from Mex-Tex mine. Contains galena cubes, banded silicified limestone, and crustiform quartz and fluorite. Galena (gn), Quartz (qz), Fluorite (fl).

open space for the movement of ore fluids and mineral deposition. Like in the faults and fissures, the mineralization is discontinous within the structural zones. Silica apparently sealed or filled much of the open spaces before the precipitation of metallic minerals by the ore bearing fluids. The breccia zones are essentially vertical. They form mushroom-like bodies widening toward the surface and narrowing at depth.

The top of the Council Spring limestone has some characteristics of a paleo-karst topography. These consist of channels and hole-like depressions (Kopicki, 1962). A shaley member of the overlying Burrego formation fills the holes and channels in the limestone. Shale is present only above the mineral deposits. It appears to have blocked the rise of the ore fluids and caused their localization. The impervious shale at low temperatures and pressures may also have diverted the fluids laterally resulting in the replacement of the limestone and filling of the cavities in the formation (Figure 9). Banded onyx along a fault zone at the Blanchard mine (Figure 10) and the presence of large chambers in the Council Spring limestone at the deposit suggest that a hot-spring environment existed in the area. Proctor (1964) describes a similar hot-spring environment on the north fringe of the Tintic district, Utah.

Figure 9. Alteration zone of limonite, sericite-illite, quartz, calcite, and gypsum above Council Spring limestone near Mex-Tex mine.

Figure 10. Banded tan onyx from fault zone near Blanchard mine. Location at adit of Figure 11.

Shales above the Council Spring are sericitically altered (Kopicki, 1962, p. 30). Part of the arkosic sandstone member of the Del Cuerto formation which overlies the mineral deposits also shows similar alteration, but to a lesser extent. This alteration in the arkosic sandstone suggests that the shale member of the Burrego formation did not completely block the rising mineral-bearing fluids or connate and meteoric waters which could have affected the mineralogy of the arkosic sandstone.

D. Possible Nature of the Ore Fluids

Rothrock, Johnson, and Hahn (1946) suggest that mineral deposits of the Rio Grande valley formed from fluids derived from deep-seated cooling magmas during Tertiary time. Ames (1958) concluded from fluid inclusions studies of fluorite, barite, and galena, at the Portales mine (Blanchard mine), that: (1) A trend of decreasing sodium to potassium ratio correlates with falling temperature of inclusion filling as indicated in the Portales samples. This progressive potassium enrichment would be expected in the normal course of crystallization of a granitic rock; (2) Chlorine content is highest in the galena, indicating possible transport of lead as a chloride; (3) The general chemical composition of the fluid inclusions suggests continuous activity of the mineral depositing solutions over a period of time represented by deposition of the Portales mineral suite; (4) The similarity of chemical composition of the fluorite from the Portales mine and from another location 90 miles (145 km) to the southwest should be due to similar source and depositional environment for both locations; (5) Low calcium values obtained from Portales galena and Portales barite reflect the effective sealing of the limestone wallrock by the initial siliceous solution; (6) Deposition of fluorite in the Portales mineral suite does not necessarily indicate a sudden or sharp rise in the calcium content of the depositing solution; and (7) Filling temperature of Portales barite is estimated at 130-140° C and for fluorite at 90-100°C.

Slawson and Austin (1962) report from their lead isotope studies that the mineral deposits of the Hansonburg district could have formed by solutions rising along fault planes from a deep source. Kopicki (1962) concludes that long distance transport of ascending hydrothermal fluid mixing with meteoric water at low pressure and temperature resulted in the mineral deposits of the district.

Roedder, Heyl, and Creel (1968), from a fluid inclusions study of fluorite in the district, suggest five stages of fluorite development. The first three stages of fluorite formed at a constant temperature of 186-205° C with an increase in salinity from 10 percent to 15 percent. Later stages of fluorite formed as the temperature gradually decreased to about 140° C, with the salinity of the ore fluid increaseing to 15 percent. Roedder speculates that the fluids were slow moving, moderate to strong saline brines with high chloride content and at a temperature of around 200° C. He suggests that flushing of the old fluid with new would explain the increase in saline content of the brine and the enrichment of crystals with radiogenic lead (J-type). He also suggests that the corrosion displayed on the fluorite crystals is a result of the very unstable nature of the ore fluid caused possibly by faulting during deposition. Lewchalermvong (1973) concludes that the connate water of the sediments interacting with meteoric water, pH control, temperature, and pressure determined the character of the ore fluids of the Hansonburg district.

E. Paragenesis

Disagreement exists among the workers in respect to the paragenetic sequence of the major minerals of the Hansonburg district. Ames (1958) suggest a time sequence of galena-barite-fluorite. Kopicki (1962) indicates that the intermixing of supergene minerals with the hypogene minerals suite, which in itself has had a complex history, only compounds the difficulty of interpretation within the area. He shows a paragenetic sequence of galena-fluorite-barite. Roedder, et al. (1968) list a sequence of barite-galena and 5 periods of fluorite.

Mineralogical, chemical, textural, and structural, data suggests that the mineral deposits of the Hansonburg district should be classified as epithermal. Details of the deposits which support an epithermal classification are: (1) The base metal mineral suite is similar to that of other epithermal deposits (2) Large crystals filling open fracture represent a near surface depositional environment, (3) Fluid inclusion studies by Roedder and Ames reveal a temperature of deposition of 200° C or less, (4) Banded onyx along faults near known mineralization is typical of low temperature deposition, (5) Shale overlying the Council Spring limestone apparently blocked the upward movement of mineral-bearing hydrothermal fluid and indicates a low hydrostatic fluid pressure.

The possibility of zoning has been reported in the Hansonburg district by Lasky (1932, p. 72) and Kopicki (1962, p. 78). Copper zoning was reported by Lasky who stated: "Depth should disclose a greater percentage of copper minerals."

Kopicki (1962, p. 78) refers to vanadium zoning: "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 [galena] localization or statistical preponderance to the shale member of the Burrego formation".

III. GEOCHEMICAL AND BIOGEOCHEMICAL INVESTIGATIONS

Geochemical and biogeochemical investigations were carried out in the northwestern part of the Hansonburg mining district. Soil sample sites were selected on a grid system. Some soil and plant samples were collected along traverse lines across the Oscura fault and sediment samples were collected along the Julian Arroyo. Soil, plant, and sediment samples were collected for heavy metal analyses. Results of laboratory analyses of each sampling procedure were related to known and predicted geology and a statistical analysis made. Results were plotted on maps and profiles of the area.

A. Soil Type and Thickness

The soil of the northwest part of the Hansonburg mining district is typical of arid areas. Red iron oxide, quartz sand grains, and clay along with varying amounts of gypsum grade downward into weathered bedrock with relict rock structure suggestive of C horizon soil (Hawkes and Webb, 1967, Hunt, 1972). Soils overlying the thick gypsum beds of the Yeso formations are typically a fine grained white gypsum with lesser amounts of quartz sand grains.

The thickness of the soil in the area ranges from 0 to over 30 feet (9.2 m) where the Julian Arroyo intersects the Jornada del Muerto plain. Soil thickness in the area of the soil and plant surveys ranges from 0 to about

5 feet (1.5 m). Slope characteristics suggest some northwest mass-wasting movement in the northern section of this part of the district and westerly mass-wasting in the southern section of this area.

B. Plant Type

The Creosote bush (Larrea tridentata) grows in the soils of the district (Figure 12). It is found in abundance in the desert southwest of the United States at elevations from 3,000 feet (915 m) to 7,000 feet (2140 m).

The Creosote bush is a multi-branched evergreen shrub with small, shiny leaves and deep root system. It has yellow flowers and a hairy, bluish fruit and grows to a maximum height of about 8 feet (2.4 m) in the Hansonburg mining district. If burned, or after a rainstorm, it has a strong odor of creosote. The plant is very well adapted to extremely severe climate and poor soil conditions, and has no economic value except possibly some minor soil stabilization. Wherever it grows, other plant species diminish in number. (Dwyer and Gay, 1964, Valentine and Gerard, 1968)

C. Sample Site Selection

1. Heavy Metal Soil Survey

Scattered and minor mineralization of barite, fluorite, and galena occurs on the fringe areas of the mining district. The northwest fringe area of the district was chosen for general soil sampling because of the presence of a mineralized section of the Oscura fault which extends from the central part of the district into and under the thin soil cover of the selected area (Figure 2). Any heavy metal (copper, lead, and zinc) anomaly in the soils might possibly indicate mineralization along the Oscura or other faults, or mineralization at depth in the Pennsylvanian formations.

To evaluate this northwest section of the mining district, an approximately tenth mile (.18 km) grid sampling pattern was used (Figure 15). For identification of samples, the number before the hyphen of the grid locations represents the north-south coordinate and the number after the hyphen represents the east-west coordinate (see Appendix). Sample sites were located with Brunton compass and pacing.

2. Detailed Heavy Metal Plant and Soil Survey

Detailed biogeochemical and geochemical surveys were conducted across a mineralized portion of the Oscura fault along traverse W-E located at grid coordinates 11.3-22 (Figures 12 and 15). A biogeochemical survey was conducted over the same fault along traverse A, located at grid coordinates 11.8-22, about 300 feet (91 m) north of the W-E traverse line. Minor mineralization in fault breccia was visible in a prospect trench near sample site 0 on traverse A (Figures 13 and 14).

Figure 11. North part of Blanchard mine area. Adit on fault zone (f) Council Spring limestone (columnar limestone) against lower part of Story formation and an alteration zone above the Council Spring limestone along road cut.

Figure 12. Panorama of part of soil and plant sampled area. Grid coordinates 11.3-22. Creosote bushes in fordground and the Abo formation on the horizon.

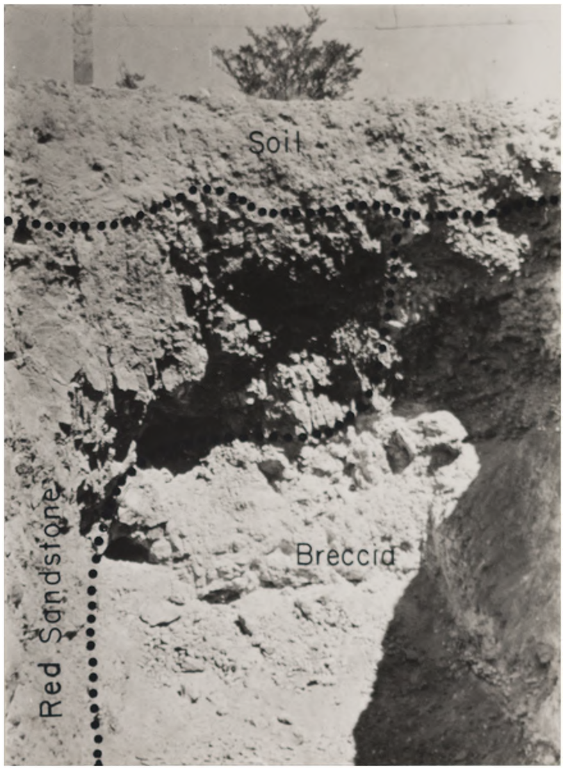

Figure 13. Trench in Oscura fault zone. Grid coordinates 11.9-22. Top three feet - C-horizon soil. Left wall unmineralized, slightly shattered red sandstone. Floor and right wall mineralized sandstone breccia similar to Figure 14.

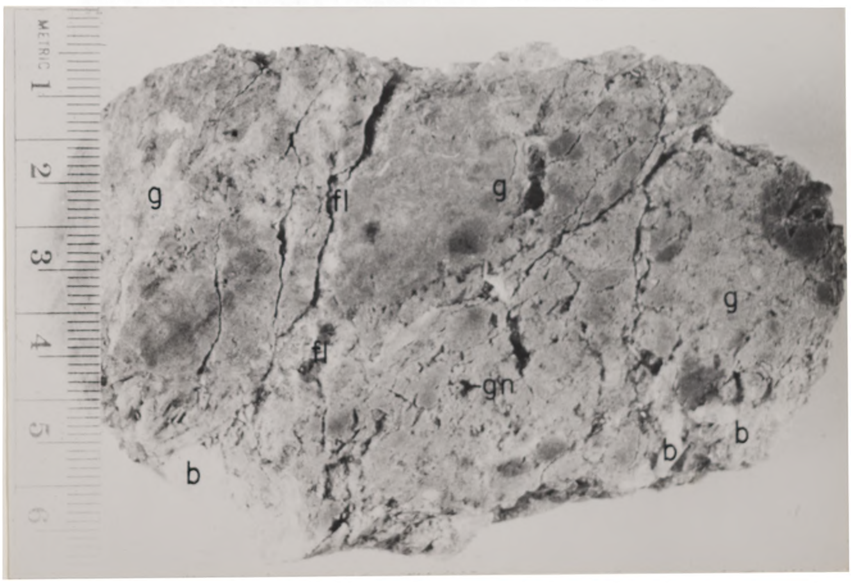

Figure 14. Oscura fault breccia with small fluorite veinlets (fl), white barite (b), a speck of galena (gn), and mainly Yeso formation sandstone gangue (g). Grid coordinates 11.8-22.

On traverse W-E, both Creosote bush and soil samples were collected every 10 feet (3.0 m) and along traverse A, only Creosote bush samples were collected every 25 feet (7.6 m).

The objective of the detailed survey was to compare the trace metal distribution in the soil and plants across the fault and possibly reveal relationships between the soil and plant trace metal content and/or a relationship with subsurface mineralization. The deep roots of the Creosote bush, by bringing elements to the surface, will allow a sampling at depth of any heavy metals present.

D. Soil Sampling Procedure

Soil samples were collected by scraping away the top few inches of dry, loose soil so to prevent contamination of the underlying soil. A hand trowel was then used to dig a 10 inch (25.4 cm) deep hole in the cleared area. About an 8 ounce (227 gm) soil sample was collected from the bottom of the hole and put into a plastic bag along with its sample identification number. The bag was sealed and another identification number placed on the plastic bag.

E. Plant Sampling Procedure

Approximately 3 ounce (85 gm) samples of leaves and small twigs were collected from several parts of the Creosote bush at individual sample sites (Brooks, 1972, p. 115). Only healthy plants were sampled. Samples and sample identification numbers were put into individual plastic bags and sealed. Additional identification numbers were placed on the bags.

F. Laboratory Sample Preparations and Analyses

Procedures used for soil and plant preparation and analyses follows those of Harms (1969) and Perkin-Elmer (1968), respectively.

1. Soil Sample Preparation

Soil samples were dried in an oven at 100° C for 10 hours. Each sample was homogenized, then sieved and the individual minus 80 mesh fraction set aside for a hot nitric acid leach. One gram of each minus 80 mesh sample was placed in a 50 ml Pyrex beaker and 5 ml of concentrated nitric acid added to each beaker. The beakers were placed in a hot sand tray and gently boiled for 30 minutes and periodically stirred with individual Pyrex stirring rods. The beakers were allowed to cool and 5 ml of double distilled water added to each beaker. These were again put back into the hot sand tray until boiling commenced. The samples were cooled and filtered. Filtrates were saved and their volume raised to 50 ml with the addition of double distilled water. Samples were then ready for analysis.

2. Plant Sample Preparation

Plant samples were dried at 100° C for 24 hours.

The samples were then finely ground and one gram portions of the ground plant tissue placed in 100 ml Pyrex beakers. Five (5) ml of concentrated nitric acid and 2 ml of perchloric acid were added to each beaker and these then covered with a watch glass. The beakers were placed in a hot sand bath tray and allowed to boil gently until all plant tissue was digested. Ten (10) ml of double distilled water were added to each of the beakers and the solutions filtered. Filtrates were saved and their volumes raised to 50 ml with double distilled water. Samples were then ready for analysis.

G. Analyses and Calculations of Metal Concentrations

Filtrates of both soil and plants, along with standard solutions and blanks of nitric acid diluted to 20% with double distilled water were analyzed for copper, lead, and zinc with a Perkin-Elmer, Model 303, atomic absorption spectrophotometer. By plotting the standard solution's peak heights versus known metal concentrations of the standard solutions in parts per million (ppm), standard curves were obtained for copper, lead, and zinc. Peak heights of the filtrates were compared to those of the standard solutions on the standard curves to yield the metal concentrations of the filtrates. A volume correction factor (50) was multiplied to each concentration to obtain the correct sample metal concentration.

IV. RESULTS OF TRACE METAL ANALYSES

Anomalous metal values for the soil survey were considered greater than twice standard deviation (Hawkes and Webb, 1967, p. 30) for the copper, lead, and zinc concentrations in the northwest part of the Hansonburg district. Mean and standard deviation values were calculated after erratic high metal values were omitted. As a check on threshold values, histograms of metal values were constructed for copper, lead, and zinc.

A. Heavy Metal Soil Survey

In the heavy metal soil survey, copper values ranged from a low of 2.8 ppm to a high of 67.0 ppm. Lead values ranged from 5.3 ppm to 56 ppm, and zinc values, from below detection limit to 48.0 ppm.

Results of the analyses indicate that the two main soil types in this part of the district, i.e., dark red, and white gypsiferous, have different mean and standard deviation values for copper, lead, and zinc. Copper concentrations in the dark red soil have a mean value of 7.3 ppm, a standard deviation of 2.4 ppm, and a threshold value of 12.1 ppm. Lead concentrations in the same soil have a mean value of 14.3 ppm, a standard deviation of 3.8 ppm, and a threshold value of 21.9 ppm. Zinc concentrations in this soil have a mean value of 14.9 ppm, a standard deviation of 4.9 ppm, and a threshold value of 24.7 ppm.

In the white gypsiferous soil, copper concentrations have a mean value of 4.5 ppm, a standard deviation of 1.0 ppm, and a threshold value of 6.5 ppm. Lead concentrations in this soil have a mean value of 16.5 ppm, a standard deviation of 3.4 ppm, and a threshold value of 23.3 ppm. Zinc concentrations in the soil have a mean value of 3.8 ppm, a standard deviation of 2.0 ppm, and a threshold value of 7.8 ppm. See Table 3.

1. Anomalous Areas and Geologic Relationships

Figure 15 shows twice standard deviation patterns for copper, lead, and zinc concentrations in the soils of the northwest part of the Hansonburg district. While anomalous heavy metal values occur in several different sub-areas in this part of the district, only four areas are supported by a combination of four or more anomalous values of copper, lead, and zinc. These areas are labeled *A*, *B*, *C*, and *D*.

Area *A* has one copper, two lead, and four zinc samples showing anomalous values. This area apparently is underlain by a northwest-southeast trending fault. A sharp change in the strike of the bedding from a north-south to a northwest-southeast direction and an abrupt cut off of bedding after the change in strike direction suggests the existence of a fault at this location.

Contaminations of heavy metal from the town of Bingham on Highway 380, 500 ft. (152 m) to the north on a gravel road leading into the mining district on the east are possibilities.

Area B has four copper and two zinc samples with anomalous values. This area is located on the southern edge of a Tertiary diorite dike. Any evidence of faulting in this area is obscured by desert cover, but the intrusive's size suggests faulting and/or folding of beds could occur nearby.

Area C shows four copper, three lead, and six zinc samples with anomalous concentrations. The southern edge of the area has tight folding of the Yeso formation along with a sharp cut off of bedding toward the south suggesting a possible northeast-southwest striking fault.

The presence of a water tank and a dirt road in this area should be considered as possible sources of metal contamination.

Area D has eight copper, one lead, and two zinc samples with anomalous values. This area overlies a part of the Oscura fault and three minor northwest trending faults. Mineralization, mainly barite with minor amounts of fluorite and galena, occurs in fault breccias in several prospect pits and trenches in the area.

Some metal contamination from prospecting activity is a possibility in this area, but the large areal extent of the anomalous area and the limited prospecting activity suggests contamination effects on metal concentrations

Table III. Statistical results of the heavy metal soil survey.

	Dark Red Soil			White Gypsiferous Soil		
	copper	lead	zinc	copper	lead	zinc
Mean	7.3	14.3	14.9	4.5	16.5	3.8
Standard Deviation	2.4	3.8	4.9	1.0	3.4	2.0
Threshold	12.1	21.9	24.7	6.5	23.3	7.8

Figure 15. Geologic map of the northwest part of the Hansonburg mining district, New Mexico, with grid overlay showing locations of anomalous concentrations of copper, lead, and zinc in the soil.

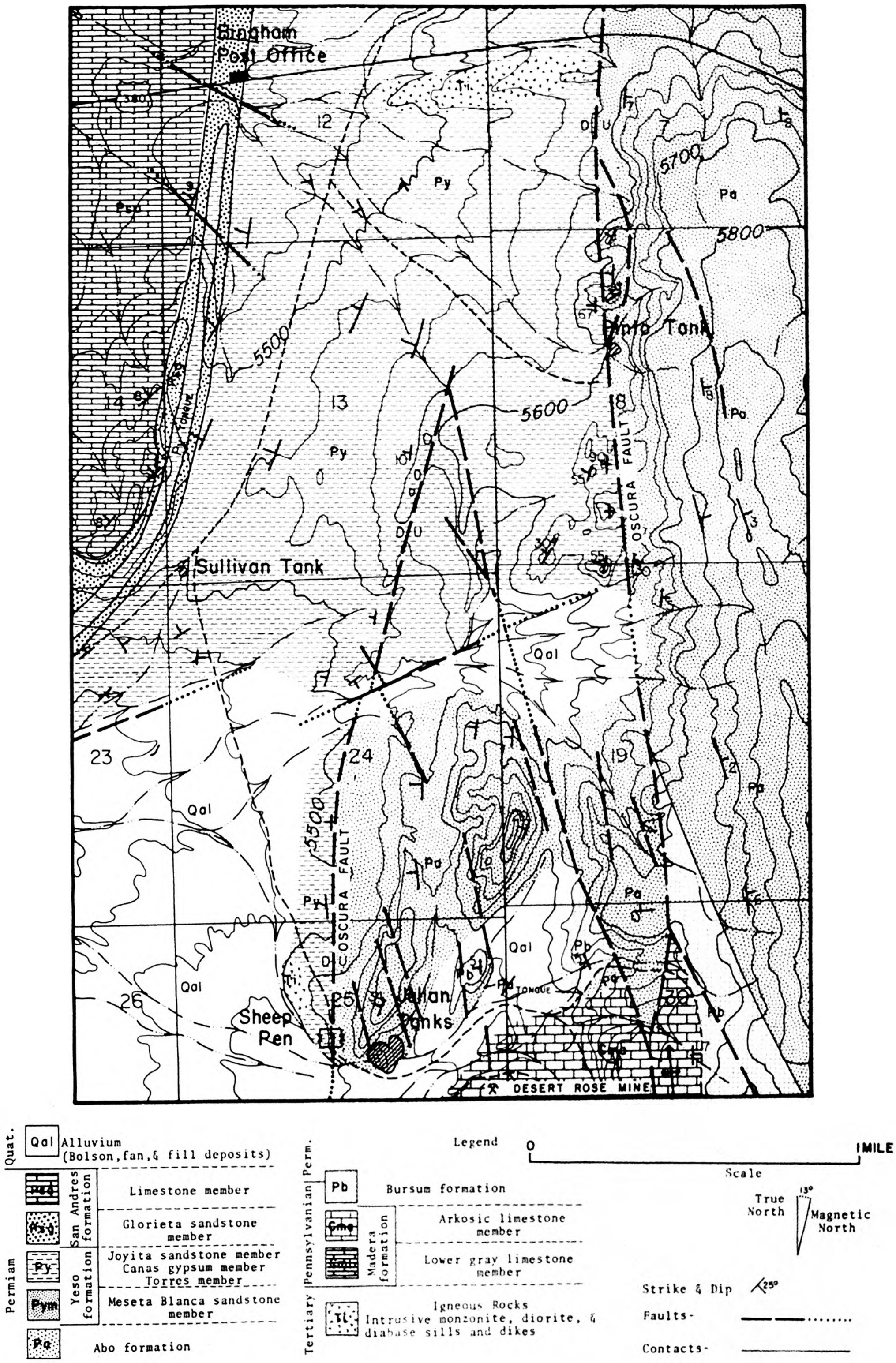

Figure 15. Geologic map of the northwest part of the Hansonburg mining district, New Mexico, with grid overlay showing locations of anomalous concentrations of copper, lead, and zinc in the soil.

are probably small.

2. Trend Surface Analyses

Some preliminary trend surface analyses maps were prepared of the heavy metals in the northwest part of the district by the "expected value method" of Krumbein, (1956, p. 2173). This is a simplified method of trend surface analysis used for a grid pattern of relatively few rows and columns.

The set up for the calculations of trend copper values is shown on Table 4. Copper values taken from the grid locations (Appendix) were placed in rows and columns. Row and column means were calculated then placed along the right and top edge of the "Expected Values" table, respectively. In the same table corresponding row and column means were added and the Grand Mean subtracted from the total which gave the "Expected Value" at the related table locations. For example, the entry 13.1 on the "Expected Value" table was calculated by adding 9.50 to 10.09 and subtracting 6.54. The result rounded off to 13.1. The expected copper values were contoured to form the regional trend surface map of Figure 16. Similar procedures were used to prepare the trend surface maps of Figures 17 for lead and 18 for zinc.

Although this method does not take into account any underlying trends which lie at angles to the grid direction and automatically includes all direct

Table IV. Table of "Expected Values".

Coordinates	Observed Copper Values 20	21	22	23	24	25	26	27	Row Sums	Row Means
34	22.8	10.5	4.5	3.8	6.0	9.3	12.3	11.5	80.7	10.09
33	7.0	3.5	5.3	5.3	5.3	5.3	7.0	3.5	42.2	5.28
32	9.8	5.0	4.0	7.0	4.5	4.5	7.0	7.0	48.8	6.10
31	9.8	5.0	5.8	5.8	5.0	9.0	5.0	5.0	50.4	6.30
30	10.5	3.8	4.0	7.3	8.0	7.3	5.8	5.8	52.5	6.56
29	4.8	3.8	8.5	4.8	2.8	5.5	4.8	6.5	41.5	5.19
28	6.5	7.5	4.8	6.5	4.8	4.8	10.5	6.5	51.9	6.49
27	4.8	5.2	3.3	8.3	9.0	5.8	4.8	9.0	50.2	6.28
Column Sums	76.0	44.3	40.2	48.8	45.4	51.5	57.2	54.8	418.2	
Column Means	9.50	5.54	5.03	6.10	5.68	6.44	7.15	6.85		*6.54

* Grand Mean

"Expected Values"									
Column Means	9.50	5.54	5.03	6.10	5.68	6.44	7.15	6.85	Row Means
	13.1	9.1	8.6	9.7	9.2	10.0	10.7	10.4	10.09
	8.2	4.3	3.8	4.8	4.4	5.2	5.9	5.6	5.28
	9.1	5.1	4.6	5.7	5.2	6.0	6.7	6.4	6.10
	9.3	5.3	4.7	5.9	5.4	6.2	6.9	6.6	6.30
	9.5	5.6	5.1	6.1	5.7	6.5	7.2	6.9	6.56
	8.2	4.2	3.7	4.8	4.3	5.1	5.8	5.5	5.19
	9.5	5.5	5.0	6.1	5.6	6.4	7.1	6.8	6.49
	9.2	5.3	4.8	5.8	5.4	6.2	6.9	6.6	6.28

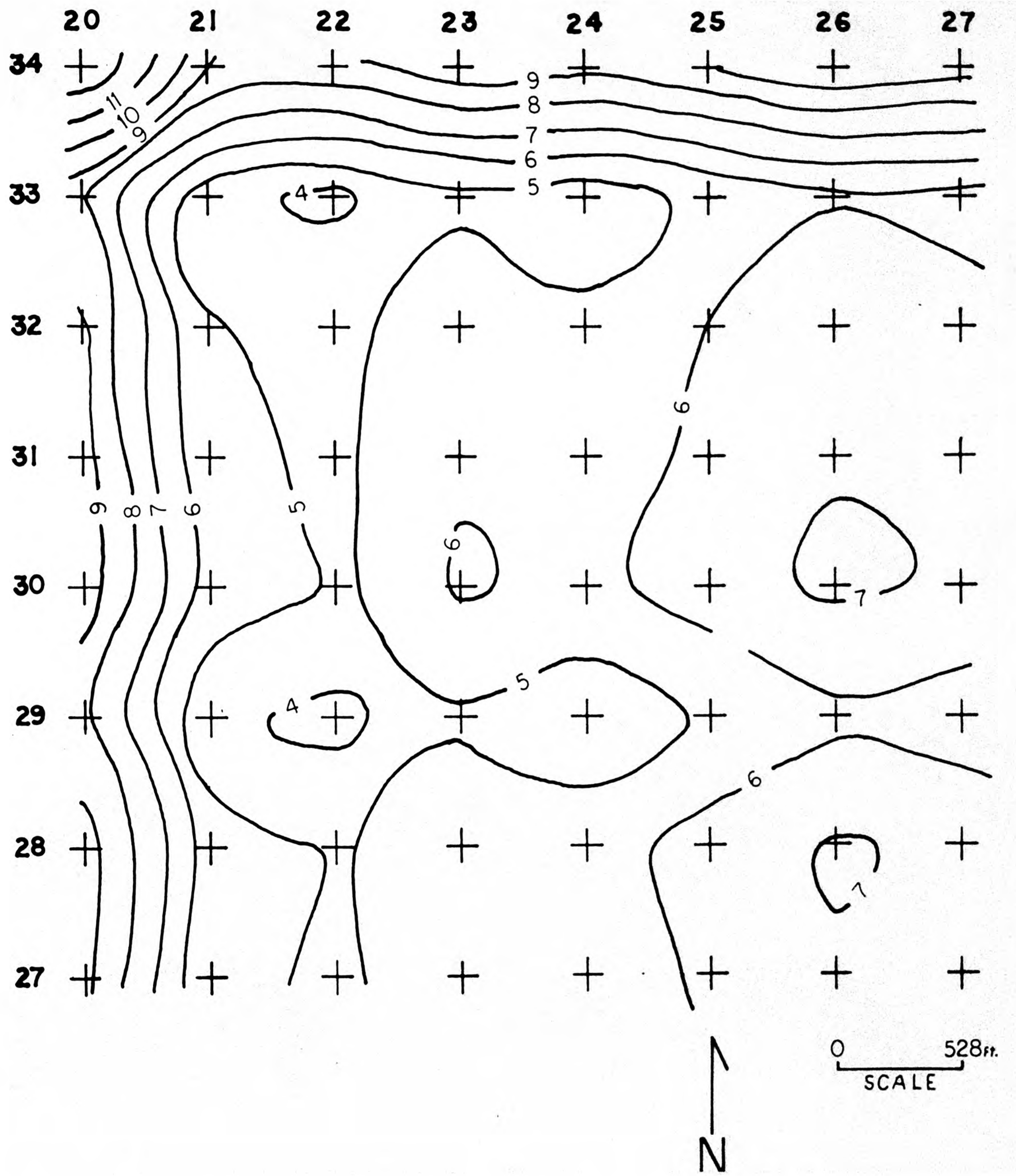

Figure 16. Regional trend surface map of copper concentrations in the northwest part of the Hansonburg mining district, New Mexico.

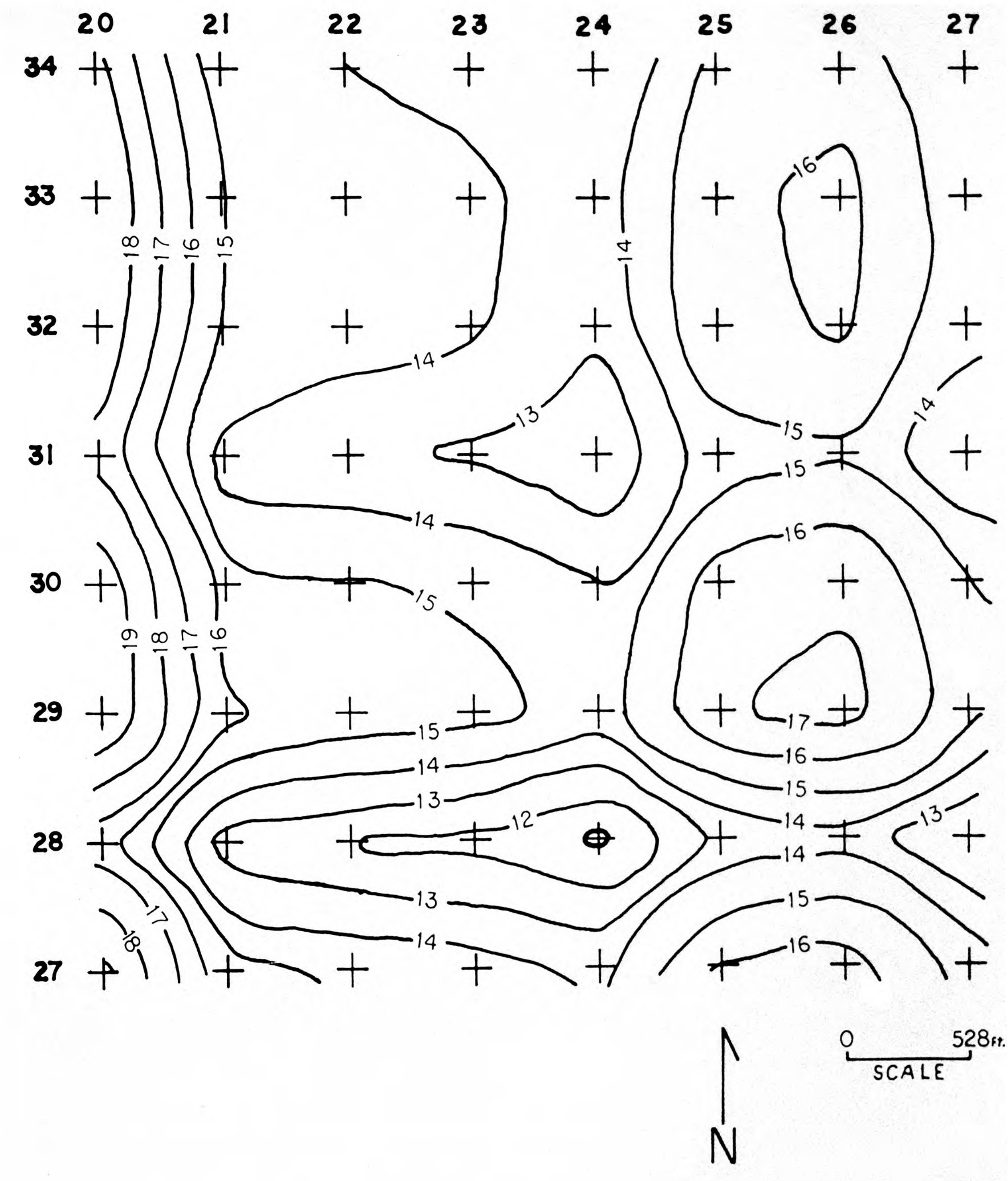

Figure 17. Regional trend surface map of lead concentrations in the northwest part of the Hansonburg mining district, New Mexico.

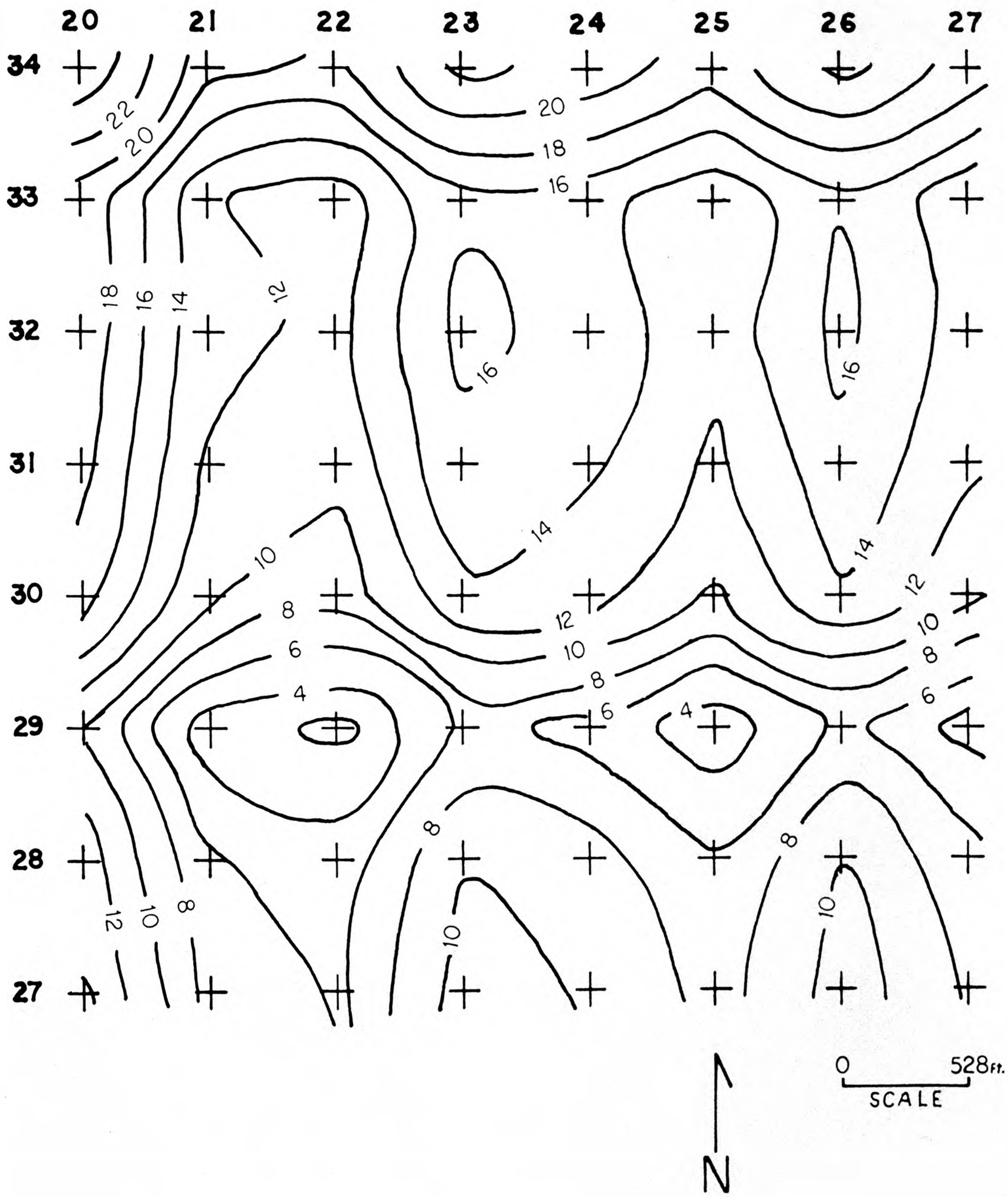

Figure 18. Regional trend surface map for zinc concentrations in the northwest part of the Hansonburg mining district.

polynomials in the regional surface. Krumbein (1956, p. 2177) states, "... it does provide a quick method for rough analysis of limited areas within larger facies maps." Krumbein (1956, p. 2184) also says: "As a rule the regional and local facies surfaces are interpreted in terms of their qualitative features rather than in terms of the exact numerical values obtained. Hence, for many reconnaissance analyses simplified methods are suitable and may in some instances be strengthened if the grid is laid along the trends on the underlying facies maps."

Some metal zoning is suggested. High copper (Figure 16) and zinc values (Figure 18) trend toward the north and west borders of the sampled areas. High lead values (Figure 17) occur along the west border and along an area extending from grid coordinate 27-26 north to the northern border of the map. This area of higher lead values lies over the northern extension of the Oscura fault. The pattern may indicate a possible relationship between the higher lead concentration trends of the area and the Oscura fault.

B. Detailed Heavy Metal Plant And Soil Survey

Three sets of samples were collected across the Oscura fault zone. One set of plant samples was collected along Traverse A (coordinates 11.8-22) and two sets of samples, one plant and one soil, were collected along traverse W-E at coordinates 11.3-22 (Figure 15).

Means and standard deviations were calculated for the heavy metal concentrations of the plant and soil samples. The profiles of metal content of the heavy metals across the Oscura fault area are distinctive and meaningful even though every zone of high metal values is not necessarily supported by metal values higher than twice the standard deviation. The metal profiles show in detail possible relationships of heavy metal concentrations in the plants and soil to mineralized zones.

Five plant background samples averaged 24.0 ppm copper, 8.0 ppm lead, and 17.0 ppm zinc. Copper values ranged from a low of 12.0 ppm to a high of 65.0 ppm. Lead ranged from 5.0 ppm to 28.0 ppm, and zinc from 10.5 ppm to 21.5 ppm.

Nineteen soil samples showed copper concentrations ranging from a low of 3.5 ppm to a high of 16.0 ppm, lead values ranging from 11.5 ppm to 98.0 ppm, and zinc from 3.0 ppm to 21.5 ppm. The average concentration for copper was 7.6 ppm, for lead 28.7 ppm, and for zinc 6.5 ppm.

1. Traverse A

Traverse A, at coordinates 11.8-22 (Figure 19) shows the profiles of heavy metals in plant samples across a mineralized portion of the Oscura fault zone. Three areas of high heavy metal concentrations are

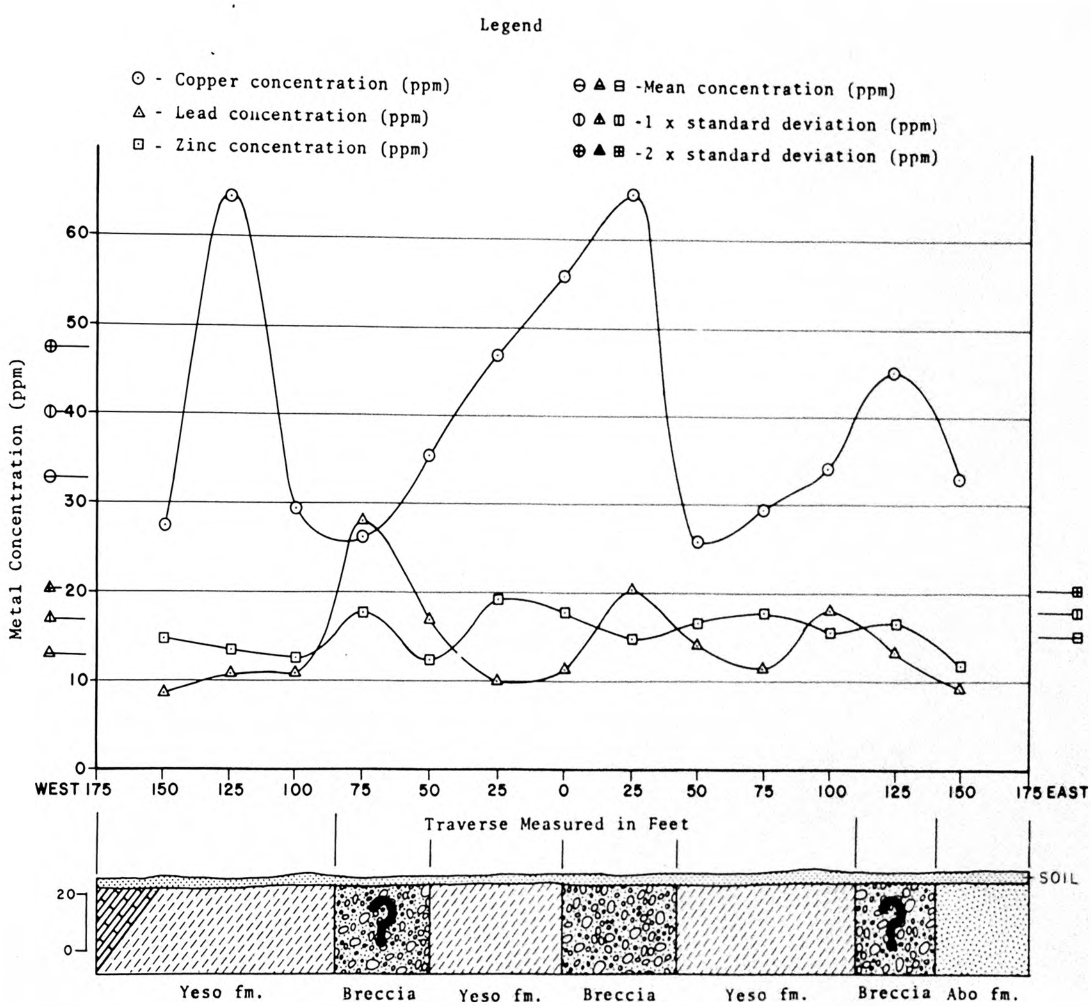

Figure 19. Copper, lead, and zinc concentrations of Creosote bush samples across the Oscura fault zone (Traverse A) near coordinates 11.8-22 showing related geology and possible mineralized breccia zones.

visible. From 50 west to 85 west, lead and zinc show high values and copper low. One lead value at 75 west is slightly greater than the copper value of the same sample. This is the only case in the area where copper has a lower concentration than lead in the plant samples. From 0 to 45 east copper and lead concentrations are high and zinc values low. Copper values show a trend of increasing concentrations from 75 west to 25 east. After an abrupt drop in copper content east of 25 east, the copper values gradually increase to a high at 125 east while lead reaches a high at 100 east.

2. Traverse W-E (Plant)

Traverse W-E at coordinates 11.3-22 (Figure 20) is a plot of the heavy metal values in plant samples collected 300 feet (91 m) south of traverse A. This profile shows an erratic but generally increasing copper concentrations from 160 west to the high copper value at 170 east and then decreasing values to 200 east. A trend of increasing copper content from 50 west to 80 west along with increasing zinc values from 10 west to 80 west is apparent. Lead values show a significant increase from 40 east to 80 east and then decrease in values to 120 east, followed by another high between 140 east and 180 east.

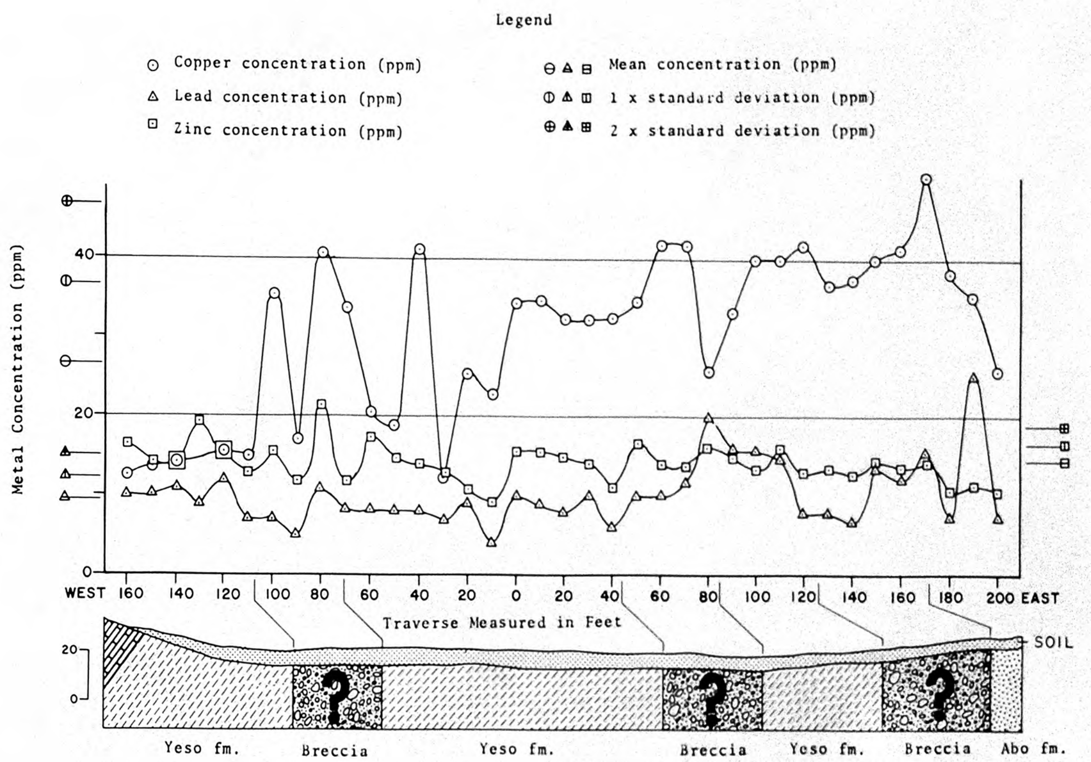

Figure 20. Copper, lead, and zinc concentrations of Creosote bush samples across the Oscura fault zone (Traverse W-E) near coordinates 11.3-22 showing related geology and possible mineralized breccia zones.

3. Traverse W-E (Soil)

Traverse W-E at coordinates 11.3-22 (Figure 21) shows heavy metal concentrations in soil samples across an Oscura fault breccia zone. Three distinct zones of high heavy metal content occur along the traverse. High values occur from 110 west to 70 west for copper and to about 90 west for both lead and zinc. Each metal value increases from west to east in this zone, then generally decreases easterly. High lead values occur from 30 east to 60 east then an abrupt decrease with another high zone from about 120 east to 170 east. Copper and zinc show a gradual increase in concentration from the west to a high at 100 west, then a gradual decrease to 0, toward the east, from where their values gently rise to a high near 50 east. Both copper and zinc decrease toward 90 east from 50 east, then zinc gradually decreases eastward while copper rises to a slight peak near 160 east in a subdued way following the lead vlaues. Copper then decreases eastward toward the end of the traverse.

Copper and zinc values are much more subdued in range and content than for lead in the soil samples. This contrasts to the much wider range and higher values of copper than for lead or zinc in Creosote bush samples.

C. Heavy Metal Arroyo Sediment Survey

Eleven sediment samples were collected at intervals

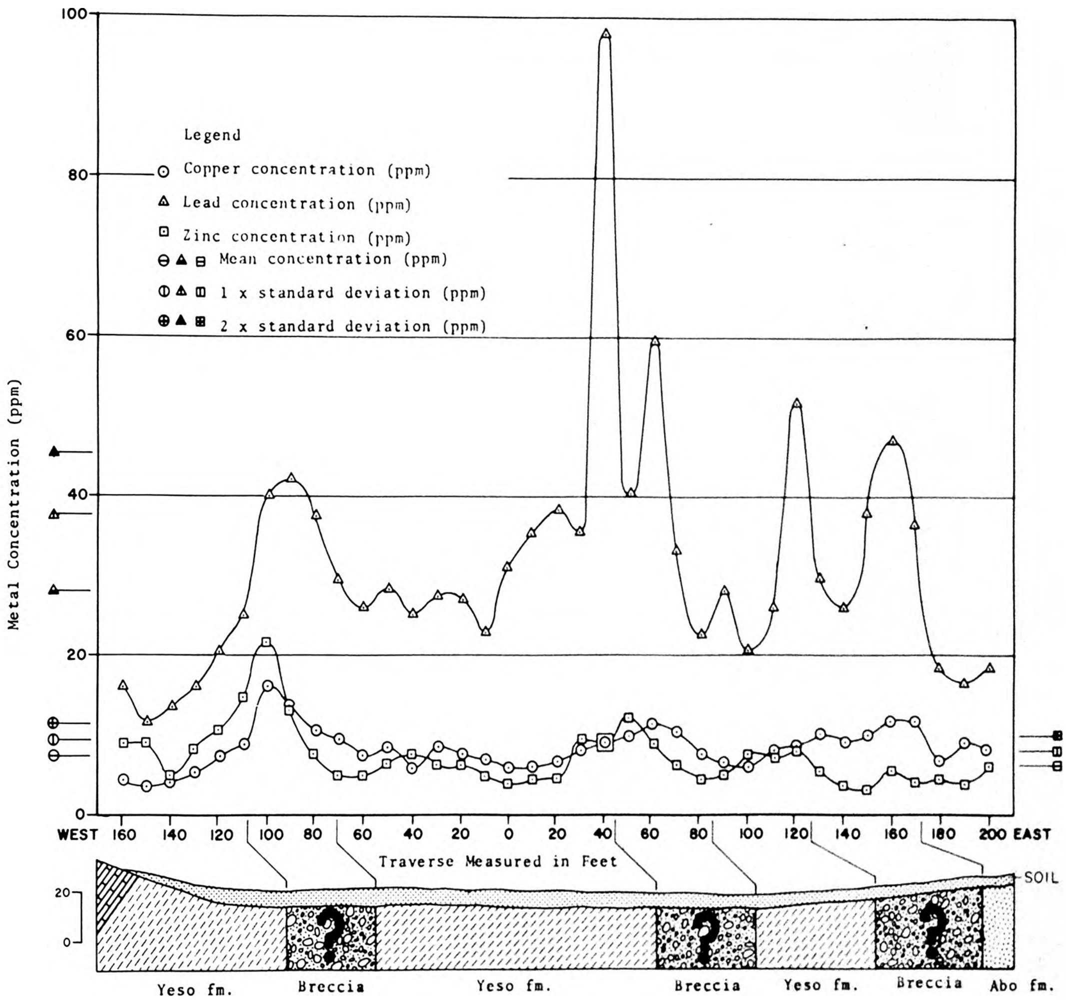

Figure 21. Copper, lead, and zinc concentrations in soil samples across the Oscura fault zone (Traverse W-E) near coordinates 11.3-22 showing related geology and possible mineralized breccia zones.

of 1,300 feet (402 m) along the Julian Arroyo, starting with the first samples at 300 feet (91 m) south of the Royal Flush mine and thence upstream to sample location eleven (See Figure 2). These samples showed heavy metal concentrations ranging from 6.8 ppm to 16.0 ppm for copper, 15.0 ppm to 36.5 ppm for lead, and 21.5 ppm to 43.0 ppm for zinc.

Copper content was highest at sample location number one with 16.0 ppm. The values gradually decreased to 6.8 ppm at location six, where copper content increased gradually to 16.0 ppm at location eleven.

Lead values also started high (36.5 ppm) at sample location one and then abruptly decreased to 16.8 ppm with no concentration above 21.8 ppm all the way to location eleven.

Zinc values along the sample traverse appeared erratic. From sample location one to location three, concentrations went from 28.5 ppm to 33.5 ppm. From location three, concentrations decreased to 21.5 ppm at location six and increased to 38.0 ppm at location eight. Zinc values then decreased to 28.5 ppm at location ten and had an abrupt increase to 43.0 ppm at location eleven.

There appears to be an increasing copper content after location six, an erratic trend of increasing zinc and about constant lead values upstream from the Royal Flush mine. No mineralization was observed up to the bombing range boundary near sample location eleven.

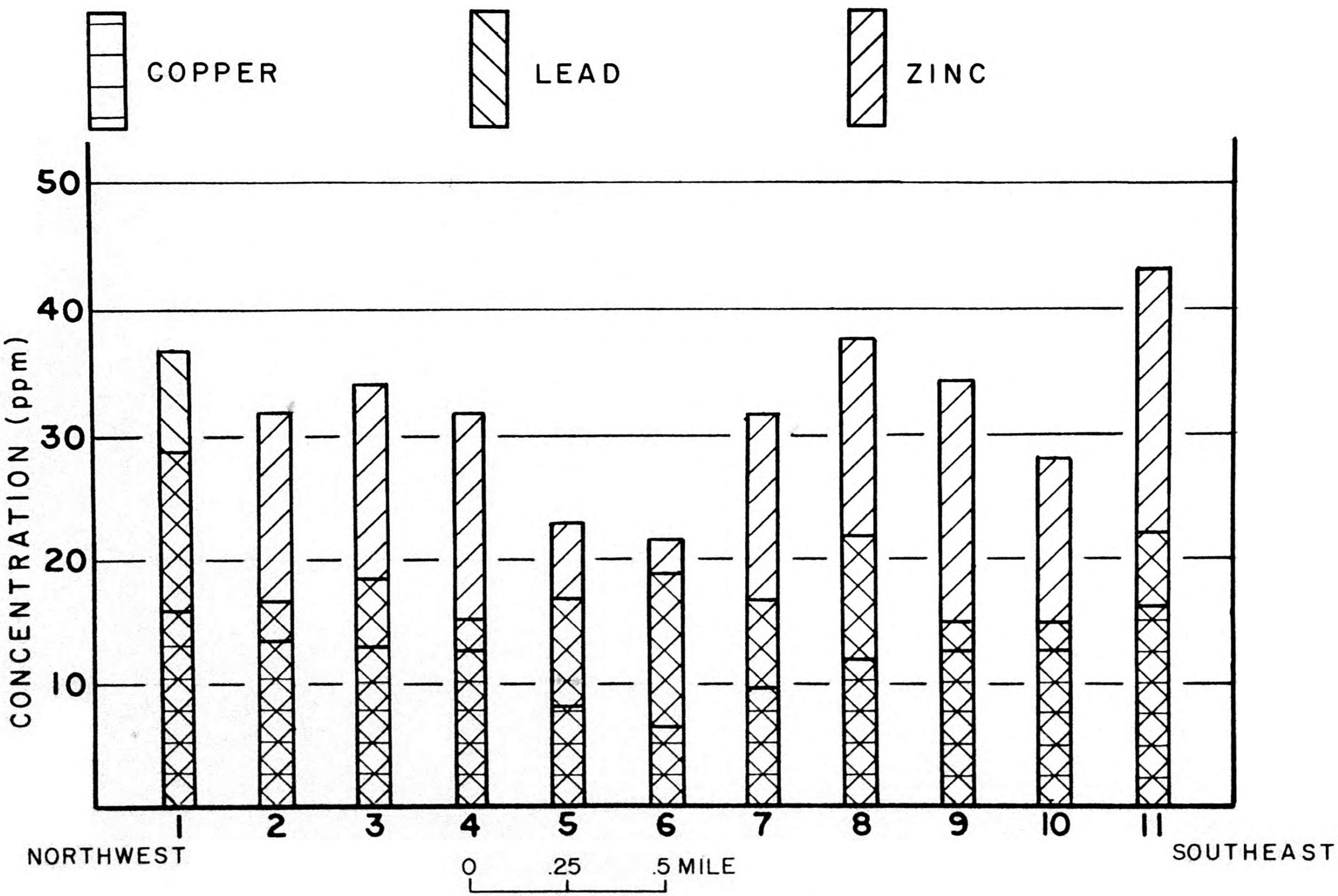

Figure 22. Distribution of copper, lead, and zinc concentrations in sediments along the Julian Arroyo.

V. CONCLUSIONS

North trending faults in the main part of the Hansonburg mining district extend northward under alluvial cover toward the northwestern part of the district. Visible mineralization occurs along some of these faults in pits and trenches in this part of the district.

Mineralization may be present in fault breccia zones to a depth of at least thirty feet as observed in a prospect shaft in the Oscura fault zone and as bedded replacement and fissure filled bodies at depth in both the Council Spring limestone and possibly other Pennsylvanian formations.

Some areas outside the western edge of the district have minor barite, fluorite, and galena mineralization spacially related to folded and/or faulted rock.

Significant differences occur in heavy metal means, standard deviations, and threshold values between the dark red soil and the white gypsiferous soil of the northwest part of the district. Some of the differences may be the result of the original variation in the metal content of members of the Yeso formation. Another possibility is the lead, being less mobile than either copper or zinc, became trapped as a result of the sealing of mineralizing channel ways by the impermeable plastic gypsum members.

Four distinctly anomalous heavy metal areas occur in the northwestern part of the district. One anomalous area definitely relates to underlying faults while three others probably relate to nearby fault zones or their projections.

Both visible and mathematical trend surface analyses of the geochemical data indicate north-south and east-west regional trends among the copper, lead, and zinc concentrations in the soil. A trend of high copper, lead, and zinc values is located along the western margin of the northwestern part of the district while only high copper and zinc values occur along the northern margins. High lead values exist over the Oscura fault zone from coordinates 27-26 to the northern margin of the area.

Heavy metal analyses of Creosote bushes along detailed biogeochemical traverses show distinct relationships to mineralization in certain areas. However, in other localities the relationships are less distinct but still visible.

Copper uptake in the Creosote bush is greatest of the heavy metals and ranges to 65.0 ppm over known mineralized zones and 50.0 ppm in areas of possible mineralization while, for areas away from known mineralization, copper ranges to 26.5 ppm. In only one case did copper content fall below lead for the same sample.

The significant heavy metal uptake in the Creosote bush suggests that further study is needed to establish: 1) the most favorable season for collecting samples and, 2) the best part of the plant (leaves, stems, flowers, etc.) to sample. Additional work is needed to determine relationships between the bush and soil metal concentrations in mineralized and nonmineralized areas on regional and local scales at other localities in the southwestern United States. The deep root system of the plant makes it especially suited as an indirect means by which soil can be sampled at depth for heavy metals.

Heavy metal analyses of soil in this shallow soil area more clearly define anomalous areas than that of the Creosote bush. A combination of both soil and Creosote bush heavy metal analyses are more definitive for anomalous areas.

A trend of rising copper and zinc values coupled with fairly constant lead values in the sediments of the Julian Arroyo, upstream from the Royal Flush mine, suggests possible mineralization within the Alamogordo Bombing Range property.

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VITA

The author was born February 26, 1948 in Washington, D. C. In 1950 he moved to Silver Spring, Maryland, a suburb of Washington. He attended Northwood High School in Silver Spring and Montgomery College in Takoma Park, another suburb of Washington. After attending Montgomery College from 1966 to 1968, he transferred to the University of Missouri-Rolla. There he received his Bachelor of Science degree in 1971. From September to December 1971, he traveled to the Middle East, Africa, and Australia and returned to the United States by working on a ship. He arrived in time to enter the Spring 1972 semester at his Alma Mater as a graduate student. He has membership in the Geological Society of America, Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., American Association for the Advancement of Science, and the National Speleological Society. His hobbies are camping, mineral collecting, hiking, and spelunking.

APPENDIX

Heavy Metal Soil Survey Values

Table V. Heavy metal soil survey values.

(*) White gypsiferous soil

Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn
7-23	8.3	11.8	10.5	19-5 *	3.3	14.0	2.8	20-8	4.0	12.0	4.5	21-9 *	4.8	18.0	2.0
8-22	13.8	11.8	9.8	19-6 *	4.0	15.3	2.8	20-9 *	5.5	16.5	2.8	21-10*	4.8	16.5	2.0
8-24	6.0	15.3	14.3	19-7 *	3.3	16.8	2.8	20-10	6.5	8.8	8.8	21-11*	5.5	18.0	3.5
9-22	11.5	10.5	11.3	19-8 *	4.0	14.0	4.3	20-11	5.5	8.5	9.3	21-12	7.5	11.5	5.5
9-23*	4.5	15.3	6.8	19-9 *	4.0	14.0	2.8	20-12	7.0	8.8	11.8	21-13	5.5	8.5	7.0
9-24	6.8	11.8	19.5	19-10*	4.0	15.3	2.8	20-13	6.8	20.0	10.8	21-14	3.5	6.5	5.8
9-25	5.0	8.3	13.5	19-11*	3.3	14.0	2.8	20-14	4.0	16.5	10.3	21-15*	4.8	16.5	5.5
10-21*	5.0	17.5	7.5	19-12*	5.0	16.8	2.8	20-15	9.5	6.5	20.0	21-16*	52.0	91.5	33.5
10-22	14.3	15.3	18.3	19-13	8.0	12.5	12.3	20-16	17.0	21.5	29.3	21-17	5.8	14.3	6.0
10-23	13.3	15.3	20.3	19-14*	3.3	16.3	2.8	20-17*	5.8	16.0	4.3	21-18	4.8	13.3	6.0
10-24	11.5	19.0	12.0	19-15	15.5	17.8	30.0	20-18	4.5	7.0	7.0	21-19	10.8	17.5	27.3
10-25	6.0	17.5	11.3	19-16*	4.0	28.8	8.5	20-19	4.0	8.3	7.8	21-20	4.0	16.5	4.5
11-21	8.3	21.5	10.5	19-17	12.0	18.8	24.3	20-20	9.0	12.5	17.0	21-21	4.0	16.5	6.0
11-22	11.5	16.5	12.8	19-18	4.5	20.3	6.0	20-21*	4.0	16.0	3.5	21-22	3.0	5.5	11.8
11-23	11.0	10.5	20.3	19-19	7.5	12.5	7.8	20-22*	5.0	13.8	7.0	21-23	9.0	12.0	19.3
11-24	18.8	14.0	19.5	19-20	9.0	12.5	7.8	20-23	9.5	13.8	11.3	21-24	4.8	7.8	14.8
11-25	5.0	11.8	11.3	19-21	7.5	8.8	9.5	20-24	10.8	8.3	10.5	21-25	5.8	9.8	9.5
18-5	11.5	15.0	20.3	19-22	5.0	15.0	7.0	20-25	8.0	13.8	8.5	21-26	4.0	12.0	10.3
18-6 *	3.8	10.0	3.0	19-23	7.5	17.8	11.3	20-26	8.0	10.3	8.5	21-27	5.8	12.0	13.8
18-7 *	2.8	10.0	3.8	19-24	5.8	11.3	19.0	20-27	10.8	13.8	15.5	24-17	10.0	17.5	18.5
18-8	8.3	10.0	19.0	19-25	15.5	15.0	19.0	21-1	13.0	25.0	10.8	24-18	6.5	14.3	25.8
18-9 *	3.3	15.0	3.8	19-26	7.5	13.8	13.0	21-2	4.8	20.0	3.5	24-19*	4.0	14.3	5.3
18-10*	4.5	14.0	6.0	19-27	8.0	16.3	16.5	21-3	5.5	20.0	4.3	24-20*	4.0	15.3	5.3
18-11	2.8	7.0	8.3	20-3	8.8	11.5	5.5	21-4	4.8	18.0	3.5	24-21*	4.8	17.5	5.3
18-12*	3.8	9.0	3.0	20-4	4.8	16.5	4.3	21-5 *	5.5	20.0	3.5	24-22*	3.5	14.3	5.3
18-13	8.8	9.0	12.8	20-5 *	4.8	16.5	3.5	21-6 *	4.0	16.5	3.5	24-23	4.0	16.5	7.5
18-14	5.0	6.0	12.0	20-6 *	4.0	16.5	4.3	21-7	9.5	11.5	11.5	24-24	5.8	19.8	7.5
18-15*	3.8	10.0	3.0	20-7 *	3.5	15.0	2.8	21-8 *	4.8	18.0	2.0	24-25	4.0	14.3	5.3

Table V. (continued)

Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn
24-26	7.0	14.3	13.8	27-19	4.8	10.5	8.5	29-24*	2.8	19.3	1.3	31-28	5.0	12.0	16.8
24-27	7.0	8.8	12.5	27-20	4.8	10.5	11.0	29-25*	5.5	15.5	1.3	31-29	5.8	21.0	15.7
24-28	4.8	11.0	8.0	27-21	5.2	16.0	9.7	29-26*	4.8	19.3	3.8	31-30*	5.8	19.0	6.3
25-17	12.5	16.0	22.2	27-22	3.3	19.5	---	29-27	6.5	15.5	5.0	32-19	8.0	17.3	12.5
25-18	10.0	12.5	13.8	27-23	8.3	14.3	18.0	29-28	9.3	15.5	12.5	32-20	9.8	15.5	20.9
25-19	4.8	10.5	11.0	27-24	9.0	14.3	23.2	29-29	8.5	16.8	15.0	32-21*	5.0	19.0	4.3
25-20	5.8	7.0	12.5	27-25*	5.8	21.5	---	30-18	5.5	11.5	10.0	32-22*	4.0	21.0	3.2
25-21*	19.3	12.5	17.0	27-26	4.8	8.8	11.5	30-19	3.8	11.5	8.8	32-23	7.0	14.3	15.3
25-22	3.5	7.8	9.5	27-27	9.0	19.5	---	30-20	10.5	11.5	11.3	32-24	4.5	12.5	10.8
25-23	7.0	13.3	13.8	27-28	6.5	16.0	11.5	30-21	3.8	19.3	---	32-25*	4.5	12.5	3.3
25-24	7.0	14.3	13.3	28-18	11.5	21.5	21.2	30-22	4.0	6.8	12.5	32-26	7.0	12.5	31.5
25-25	10.8	15.3	20.0	28-19	4.5	8.8	8.5	30-23	7.3	19.0	15.7	32-27	7.0	14.3	21.0
25-26	4.0	6.5	8.0	28-20	6.5	8.8	13.8	30-24	8.0	17.3	18.8	32-28	7.0	9.0	16.5
25-27	7.0	34.0	20.0	28-21	7.5	8.8	11.5	30-25	7.3	12.0	20.9	32-29	5.3	9.0	16.5
25-28	4.8	7.8	6.5	28-22*	4.8	15.5	1.3	30-26*	5.8	22.5	4.3	32-30	10.5	14.3	15.3
26-17	4.0	10.5	12.5	28-23	6.5	11.5	16.3	30-27	5.8	19.0	13.5	33-19	5.3	10.8	17.5
26-18	7.5	16.0	14.8	28-24	4.8	15.5	---	30-28	9.8	19.0	18.8	33-20	7.0	43.0	12.5
26-19	10.0	16.0	20.2	28-25	4.8	15.5	3.8	30-29	5.8	12.0	15.7	33-21	3.5	9.0	14.0
26-20	4.8	7.0	11.0	28-26	10.5	15.5	12.5	30-30*	4.0	22.5	5.3	33-22	5.3	16.3	10.8
26-21	8.3	12.5	20.2	28-27	6.5	11.5	7.5	31-19	9.8	29.3	20.9	33-23	5.3	10.8	16.5
26-22	4.8	10.5	7.5	28-28	8.5	15.5	20.0	31-20	9.8	24.0	12.5	33-24	5.3	10.8	17.5
26-23	9.0	16.0	17.0	28-29	11.3	11.5	21.3	31-21	5.0	10.3	16.8	33-25	5.3	9.0	17.5
26-24	9.0	21.5	12.5	29-18	9.3	19.3	15.0	31-22	5.8	15.5	15.7	33-26	7.0	14.3	19.5
26-25	10.0	10.5	20.2	29-19	4.8	7.5	1.3	31-23	5.8	10.3	12.5	33-27*	3.5	9.0	5.3
26-26	4.0	17.8	---	29-20	4.8	15.5	7.5	31-24	5.0	5.3	16.8	33-28	14.0	18.0	16.5
26-27	8.3	14.3	20.2	29-21*	3.8	15.5	1.3	31-25	9.0	17.3	16.8	33-29	9.5	16.3	22.8
26-28	10.0	23.0	8.5	29-22	8.5	11.5	16.3	31-26*	5.0	19.0	4.3	33-30	8.0	9.0	15.3
27-18	6.5	7.0	12.5	29-23*	4.8	19.3	2.8	31-27	5.0	10.3	14.6	34-19	4.5	10.8	16.5

Table V. (continued)

Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn	Sample	Concentration Cu	Pb	Zn
34-20	22.8	19.8	40.0	34-26	12.3	15.5	24.8	35-20	9.3	13.5	26.0	35-26	7.5	13.5	11.8
34-21	10.5	19.8	23.8	34-27	11.5	13.5	19.5	35-21	10.0	15.5	20.2	35-27	12.3	15.5	24.8
34-22	4.5	7.8	12.3	34-28	8.5	15.5	13.0	35-22	8.5	55.8	22.2	35-28	10.0	15.5	21.5
34-23	3.8	11.5	13.8	34-29	7.0	13.5	17.0	35-23	6.0	11.5	20.2	35-29	7.5	17.3	15.0
34-24	6.0	9.5	15.0	34-30	7.0	21.0	15.8	35-24	9.3	15.5	20.2	35-30	6.0	11.5	15.8
34-25	9.3	21.0	17.0	34-31	9.3	15.5	20.2	35-25	10.0	15.5	19.0	35-31	7.5	15.5	17.8