GEOLOGY AND MINERALIZATION IN THE OCORONI DISTRICT, SINALOA, MEXICO

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RESUMEN

Las menas epitermales del Distrito Ocoroni están localizadas en el municipio de Sinaloa de Leyva al noroeste de México. Fisiográficamente el distrito descansa en los límites occidentales de la Sierra Madre Occidental en lomeríos que pasan abruptamente hacia la planicie costera.

El área tiene aproximadamente 15 km de extensión, paralelamente a una zona de fracturas con rumbo noreste. Las unidades estratigráficas inferiores que afloran son corrientes porfíricas y tobas de composición latítica a andesítica. Estas rocas están cubiertas por gruesas corrientes de riolita porfírica, de espesor variable y sub-horizontales, junto con tobas líticas y cristalinas que forman escarpes y cubren las principales características topográficas. La edad de esta secuencia volcánica es, probablemente, Terciaria temprana-media (Oligoceno?). Las lavas cubren un terreno Paleozoico metamorfozado, asignado a las facies de esquistos verdes. Sedimentos no consolidados, gravas fluviales y aluvión de edades pleistocénica y Reciente, respectivamente, cubren gran parte del extremo sur del distrito y también ocurren en los valles de la porción norte.

La mineralización está expuesta en una serie de vetas de fisura con rumbo noreste. Se han podido continuar sobre la superficie por unos 300 o 400 metros. Las vetas, por lo general, tienen un espesor de 1 a 2 metros; ocasional y localmente, alcanzan 3 o 4 metros de espesor. Las inclinaciones son frecuentemente hacia el noroeste alcanzando ángulos agudos y muy raramente son verticales o inclinadas hacia el sureste. Las vetas contienen galena y esfalerita, con cantidades menores de calcopirita, contenido todo ello en una ganga de cuarzo, exhibiendo múltiples procesos de brechamiento y relleno de cavidades.

Las rocas encajonantes adyacentes a las vetas han sido alteradas y brechadas. Los desplazamientos verticales han sido suficientemente activos para fallar normalmente las unidades riolíticas en el alto en algunas instancias. Usualmente una de las rocas encajonantes es de composición intermedia y ésta, junto con la ausencia de otras formaciones, sugiere que la mineralización está mejor desarrollada en la parte inferior de la secuencia volcánica.

Las rocas encajonantes han sido alteradas a propilita, particularmente en las lavas de composición intermedia. La clorita ha dado origen a los minerales ferrimagnesianos primarios y un conjunto de clorita, sericita, orella y epidota reemplaza a los feldespatos. La silicificación local es en vetillas aún cuando las rocas encajonantes pueden estar sumamente alteradas. Los afloramientos muestran manchones de hierro, cobre y manganeso secundarios.

Este distrito concuerda con el patrón descrito por Wisser (1966) para venas emplazadas cerca del basamento, en la Sierra Madre Occidental. La mineralización es de metales básicos y las vetas contienen menos cuarzo que las vetas de metales preciosos encontradas en elevaciones más altas en casi toda la sierra. Tales distritos usualmente muestran vetas que afloran sobre grandes distancias, con mineralizaciones distribuidas irregularmente dentro de ellas. Trabajos recientes en el Distrito de Ocoroni muestran que las mineralizaciones siguen cortos afloramientos muy resistentes y que usualmente son angostos y no muy largos, en el sentido del rumbo. Existe también una tendencia a desaparecer hacia el fondo a poca profundidad, a través de una disminución del contenido de sulfuros de metales básicos y un incremento en la mineralización de pirita.

ABSTRACT

The epithermal ores of the Ocoroni district are located in the municipality of Sinaloa de Leyva, northern Mexico. Physiographically, the district lies at the western edge of the Sierra Madre Occidental, in foothills that pass abruptly into the coastal plain.

The area is approximately 15 kilometers in extent, paralleling a zone of northeasterly striking fractures. The lowest stratigraphic units exposed are porphyritic flows and tuffs, andesite to latite in composition. They are overlain by a thick, though variable sequence of subhorizontal porphyritic rhyolite flows, crystal and lithic tuffs that form cliffs and cappings to the main topographic features. The age of this volcanic sequence is probably early middle Tertiary (? Oligocene). The lavas overlie a metamorphosed Paleozoic terrane, assigned to the greenschist facies. Unconsolidated pediment and fluvial gravels, and alluvium of Pleistocene and Recent age respectively, cover much of the southern part of the district and also occur in valley floors in the northern part.

Mineralization is displayed in a series of fissure-veins that strike northeast. They have been traced at the surface for 300 to 400 meters. Veins are commonly 1 to 2 meters in thickness, occasionally and locally 3 to 4 meters wide. Dips are frequently northwest at high angles, more rarely vertical or southeast. Veins contain galena and sphalerite with lesser chalcopyrite, all in a quartz gangue, exhibiting multiple stages of brecciation and cavity filling.

The country rocks near veins have been sheared and brecciated. Vertical displacements have been sufficient to down-fault rhyolite units in the hanging wall in some instances. Usually one wall rock is of intermediate composition, and this coupled with the absence of other formations, suggests that mineralization is best developed in the lower part of the volcanic sequence.

Wall rocks have been altered to propylite, particularly in the lavas of intermediate composition. Chlorite is developed after primary ferromagnesian minerals, and chlorite, sericite, clay and epidote replace feldspars. Locally silicification is in veinlets, although wall rocks may be pervasively altered. Outcrops are stained by secondary iron, copper and manganese minerals.

This district fits the pattern described by Wesser (1966) for veins that lie close to the basement in the Sierra Madre Occidental. Mineralization is base metal, and the veins contain less quartz than the precious metal veins found at higher elevations elsewhere in the Sierra. Such districts usually exhibit veins outcropping over great distances, with ore shoots distributed irregularly within them. Recent work in the Ocoroni district shows that ore shoots closely follow resistant short outcrops and are usually narrow and short in strike length. There is also a tendency to bottom out at shallow depths through a decrease in base metal sulfides and an increase in pyrite mineralization.

INTRODUCTION

In 1969, Clark commenced geologic mapping in the Sinaloa de Leyva quadrangle, northern Sinaloa, on behalf of Instituto de Geologia. The following year, further work was done by both investigators on the immediately adjacent Ocoroni district, with Duskin paying particular attention to the economic development of the metalliferous deposits in this area. Our investigations were complete by early 1972 and a preliminary statement of the work was presented to the Geological Society of Mexico, Second Annual Convention, held in Mazatlan, May 1972.

Purpose of Study

In recent years there has been increased interest in Mexico's mineral resource wealth. In the northwestern Pacific coast area, Sonora has received most attention, whereas Sinaloa has received relatively little study. However, private enterprise investigations in Sinaloa are now being supplemented by state-wide geologic mapping which is being undertaken by Instituto de Geologia. (Universidad Nacional Autónoma de México), whereas the mineralized areas are being studied by Consejo de Recursos Naturales No Renovables, as the mapping program provides the basic regional geologic information. Undoubtedly, both these programs will further stimulate commercial ventures in coming years as basic data is distributed by publication.

We believe that by pooling industrial and governmental agency data, this report summarizes to a considerable extent, the information obtained in the Ocoroni district in the last three years. This contribution, although a very small part of the total picture, will provide specific criteria for future development in this area, while at the same time supplying a reference report for this type of deposit during future investigations in other parts of the state.

Location and Access

The Ocoroni district, located in the Municipality of Sinaloa de Leyva, northern Sinaloa, is at the western edge of the Sierra Madre Occidental, in foothills that pass abruptly into the coastal plain (Fig. 1). The district is

further defined by latitude $108^{\circ} 27''$ and longitude $26^{\circ} 03''$, and takes its name from the nearby village of 500 inhabitants. The mines are located within a 15-20 km radius north and west from the village. Ocoroni and the mining properties can be reached by unpaved roads from Estacion Naranjo, a distance of some 20 km to the south. Estacion Naranjo is connected by 23 km of paved road to a point on Federal Highway 15 near Guasave, a population center of 40,000. The total distance from Guasave to Ocoroni is 52 km.

Federal Highway 15 roughly parallels Ferrocarril del Pacifico on which Estacion Naranjo is located. These major road and rail communications link the area with Los Mochis and San Blas respectively to the north, and with Culiacan and Mazatlan to the southeast. The deep water harbor at Topolobampo is easily accessible from Los Mochis. The nearest air service is at Culiacan, although recently an air strip for light planes has been made at Ocoroni. The village is also connected to San Blas and Sinaloa de Leyva by telegraph service.

Climate and Vegetation

The area is hot in summer, particularly in August and September when temperatures climb to 100°F . A period of rain extends from July to September, and this combined with summer temperatures results in high humidity. Light rains can also be expected in January and February, but winters are relatively cool. With the exception of the irrigated and cultivated areas nearer Guasave, the remainder of the coastal plain and foothills, are covered with dense scrub vegetation.

Physiography and Drainage

The main orographic unit of this region is Sierra Madre Occidental, which lies to the east of the Ocoroni district, whereas the coastal plain occupies the area immediately to the west. The low lying coastal plain is broken by a few isolated hills, such as Cerro Tetameche, Sierra d'Oro and Los Cerillos, all of which comprise sedimentary rocks (Fig. 1). These hills become more numerous and of higher elevation as the main uplift is approached. In general, surfaces are tilted away from the main welt of Sierra Madre Occidental, toward the coastal plain.

Elsewhere the transition zone between coastal plain and the mountainous area is occupied by aprons of pediment and fluvial gravels. Rio Sinaloa emerges from the mountainous area in a well defined gorge some 30 km east of Ocoroni and between Rio Sinaloa and Arroyo Ocoroni a large area is underlain by undifferentiated gravels of fluvial origin. More locally, Arroyo Ocoroni and its tributaries have carved much less spectacular southerly aligned valleys as they flow towards the coastal plain. These valleys and intervening spurs of the mountainous area are included within the province of "Cordilleras Sepultadas" of Raisz (1959).

The Ocoroni district apparently straddles the physiographic boundary between coastal plain and mountainous region. The elevation of the village, located on Arroyo Ocoroni, is only 80 m. above sea level. Gravels and alluvium underly the southeastern part of the district and are also found along valley floors further northward. The remaining areas are underlain by Tertiary volcanic rocks. The most prominent physical feature is Gran Cerron de Ramal, elevation 728 m. Other prominent hills located in interfluvial spurs in-

clude Cerro Esperanza (454 m) and Cerro de Los Chinos (478 m), all of which are capped by rhyolitic units (Fig. 2).

History and Previous Investigations

Activity in the Ocoroni district commenced in 1905 when the first denouncements were made, and in 1915 some of the veins were explored and high grade lead was exported, according to an unpublished report by Peña (1969). In the period 1928-1932, Cia. Mexicana de Minerales, S.A., developed several prospects and some lead-zinc ore was extracted. Later the depression closed those operations until Sr. Miguel Rosinach of Ocoroni denounced San Gotardo in 1940. In 1944, M.W. Hayward made a district examination for Minera de Peñoles, S.A., and more work was done in 1946-47 by Sr. Charles Pouliot and Sr. Antonio Aráezaga, with assistance from La Comisión de Fomento Minero. By 1951 Sr. Rosinach treated some ore in a small flotation plant, and in the same year El Cedro vein was developed together with El Muerto and San Gotardo. In 1953 San Luis Mining Company made their own evaluation and did some underground work at El Cedro mine, and still later, Sr. Kane, representing Exploradora de Minerales, S.A., shipped some ore. El Ramal vein was worked in a rudimentary way in the last decade. Presently the properties are owned by Cia. Minas del Codembaro, S.A., S.L.P., who acquired them in 1970. Overall production in the district has been relatively modest.

Acknowledgments

This report reflects the combined work done in the Ocoroni district by the authors through their association with Cia. Minas del Condernbaro, S.A., and Instituto de Geología, both organizations being active in the district from 1969 onwards. We gratefully acknowledge their permission to present this paper. In particular we have been advised by Zoltan de Cserna and Dewitt C. Peck on several occasions, although necessarily we accept full responsibility for the conclusions drawn herein. Patricia Clark typed the manuscript and prepared the photographic illustrations.

REGIONAL GEOLOGIC SETTING

Figure 3 shows the Ocoroni district and several other mining districts in relation to the generalized geology of Sinaloa, modified from Wissler (1966) and the Geologic map of Sinaloa (1970). The lithologic constitution of Sinaloa can be divided into a metamorphosed basement complex of Precambrian and Paleozoic age, small areas of Early and Late Mesozoic sediments, and extensive Tertiary and Quarternary volcanic terrane comprising Sierra Madre Occidental, and a coastal plain represented for the most part by Tertiary and Quarternary sediments. The major plutons in this region are granitoid in composition and several are at least sub-batholithic in size. Radiometric dating control plus stratigraphic interpretations suggest that many of these plutons were emplaced in Cretaceous through Early Tertiary time (de Cserna et al, 1962; Clark 1971; Henry and Fredrickson, 1972), although Paleozoic and Late Tertiary phases of igneous activity have been recognized by Roldan (1971).

STRATIGRAPHY

Basement Complex

Plate 1 shows the distribution of the lithologic units of the Ocoroni district,

Fig. 2. PANORAMIC VIEW OF OCORONI DISTRICT.

This view accentuates principal physiographic features. Note the rhyolite capped hills.

an area approximately 15 by 10 km in extent. Basement rocks are found in the southwestern and northwestern parts of the district.

Metamorphic rocks are but poorly exposed 2 km south of Chapote at an elevation of approximately 80 - 100 m. There, greenschists are the most common rock type, although areas of amphibolite associated with red soils have been noted. Both units are cut by thin calcite stringers. In addition, a single exposure of quartzite was found in this area. Meager information on the structural attitude of the schists suggests that the plane of foliation strikes north-northeast.

In the northwestern corner of the district, immediately adjacent the Tasa-jara prospect, there is a 70 - 100 m wide ridge of quartzite. The ridge makes a distinct physiographic feature in contrast to the immediately adjacent hills of lava. The quartzite shows little of its original sedimentary structures other than displaying rounded fragments which are tightly welded together in a tough siliceous matrix. The contact with the nearby rhyolite is unconformable, but poorly exposed, and the trend of the quartzite is approximately east-west at this locality.

These metamorphic units, and others found in the Sinaloa de Leyva quadrangle, have been assigned to the greenschist facies by Clark (1971). They were tentatively correlated with the Sonobari Complex of de Cserna and Kent (1961) in the San Blas and El Fuerte areas. Recent mapping by Roldan (1971) in the adjacent Yecarato quadrangle and by Mullan (1972) in the Rio Fuerte region have revealed similar metamorphic units. Roldan has assigned to the lowermost units an Early Paleozoic age, whereas the upper unit is considered Late Paleozoic. Consequently, by lithologic correlation alone, the quartzite of the Ocoroni district, at least, is most easily considered as Early Paleozoic.

Andesite Series

In the restricted area of the Ocoroni district, no other units are recognized in the time interval between the Paleozoic basement rocks and the extrusion of the Tertiary volcanic rocks. However, in adjacent areas Cretaceous limestone-gypsum and indurated red mudstone sequences occur together with a small exposure of a "Laramide" granite at Cerro Tetameche.

Early Tertiary volcanic materials form the hilly parts of the district at the western margin of the Sierra Madre Occidental terrane. Two lithologic units are recognizable; andesite at the base of the sequence overlain by cliff-forming rhyolite. The lowest units are red, purple or gray porphyritic flows and tuffs whose composition, as identified in thin section, varies from andesite and trachyandesite to latite. Exposures are sporadic and are confined to bases of hills or low stream divides. From evidence obtained south of the district, the andesitic unit is believed to overlie the basement with angular unconformity.

The andesites contain phenocrysts of plagioclase (oligoclase) which are partly saussuritized. Potash feldspar has not been positively identified. Biotite is the principal ferromagnesian mineral, whereas amphibole and pyroxene occur less frequently. Quartz occurs in irregular (?) secondary grains. Accessory minerals include apatite. The groundmass is made up of sericitized feldspar and lesser amount of iron oxides, quartz and alteration materials after ferromagnesian minerals.

Included in the andesite series are porphyries and tuffs which are closer to latite in composition. The main constituents are plagioclase, quartz, in rare subhedral crystals; biotite and on occasion, altered potassic feldspar prisms.

The groundmass contains these minerals in addition to apatite and alteration products. Epidote may also be present. Tuffaceous varieties contain lithic fragments with a trachytic fine grained groundmass and more rarely quartz-mica schist, caught up from the underlying metamorphic complex.

Another lithologic variety included here are the trachyandesites. Their mineralogic composition is similar to the andesites described previously, plus the addition of potash feldspar. They are characterized by the alignment of minerals in the groundmass (Fig. 4A).

Rhyolite Series

The upper unit of the Tertiary volcanic sequence is predominantly light colored rhyolite which caps the main topographic features at Gran Cerron de Ramal, Cerrito La Pila, Cerro Esperanza, Cerro de Los Chinos (Fig. 2) and elsewhere. The rhyolite unit is made up of porphyritic flows, crystal and lithic tuffs. A pinkish massive variety commonly forms the base of the capping.

The phenocrysts of the rhyolitic varieties include subrounded grains of quartz, potash feldspar and plagioclase together with biotite. Quartz grains are partially resorbed, whereas feldspars show moderate alteration to sericite. Biotite is altered to iron oxides; it commonly occurs in subhedral grains or shreds. The mineralogy of the groundmass is similar although very fine grained to cryptocrystalline in texture. Spherulites (Fig. 4B) up to 1.0mm in size are fairly common in partially devitrified material.

The age of this volcanic sequence is probably early Middle Tertiary (? Oligocene) and its stratigraphic position indicates that the sequence is the lower part of the volcanic terrane. This supposition is based on proximity to the basement, and the structural dislocation to which the sequence has been subjected. The stratigraphic position of the andesite-rhyolite contact above the basement is approximately 130m near El Cedro Mine, agreeing rather well with structure section predictions of the andesite unit thickness in this general area.

The andesitic unit is correlateable with the San Blas Formation of de Cserna and Kent (1961) and Roldan (1971) in the Yecorato quadrangle. The overlying rhyolite, at the elevation of Gran Cerron de Ramal (728m) is some 500 to 600 m thick. This unit is tentatively correlated in part with the Fuerte Formation of the type locality of the same name.

Sinaloa Gravels and Alluvium

The remaining surface area of the district is covered by undifferentiated pediment and fluvial gravels and by alluvium of Pleistocene and Recent age respectively. These unconsolidated materials are confined to stream valley floors in the hilly northern part of the district, but in the southeastern part they are widespread where Arroyo Ocoroni emerges from the mountain front.

STRUCTURAL EVOLUTION

At least three major tectonic events are apparent in the district; they vary in age from Paleozoic to Tertiary. The mineralization at Ocoroni is associated with the later disturbances.

The earliest recognizable event imparted the regional grain to the basement rocks, swinging from northwest to northeast in a belt of isolated exposures south of the district. This foliation was impressed by regional metamorphism by a post Early Paleozoic event. De Cserna (1960) suggested a

PHOTOMICROGRAPHS OF TERTIARY VOLCANIC UNITS.

Figure 4

Fig. 4A. Trachytic texture of ground-mass microlites in comparison to phenocrysts (X 36).

Fig. 4 b. Spherulitic rhyolite (X 36).

Fig. 4C. Quartz veinlet (Q) in footwall rock of El Cedro mine is flanked by silicified and chloritized (C) andesite (X 36).

Mid-Paleozoic age of metamorphism in the San Blas - El Fuerte area, presumably due to his Jaliscoan tectonic cycle.

Evidence for sediment accumulation in the Early to Middle Cretaceous interval is forthcoming from the Sinaloa de Leyva quadrangle. But these sediments as well as other Mesozoic units in adjacent areas have been deformed, suggesting a second major period of dislocation. At Cerro Tetameche, an intruding granite has been tentatively correlated with the Capomos quartz monzonite of the Yecorato quadrangle that has been dated as 75 m.y. (de Cserna, et al 1962). Laramide events are clearly recognizable in parts of northern Sonora (United Nations Report, 1969) and several age determinations of the batholithic granodioritic rocks of Sinaloa span the same time interval (Henry and Fredrikson; 1972).

A Middle to Late Tertiary period of deformation in the district is indicated by high angle faulting that cuts the volcanic units. Dislocation must also have taken place in latest Tertiary time as indicated by tilting of the olivine basalt cappings of the Hornillos Formation of Pliocene age. The nearest outcrops of this unit are located in Mochobampo, 10 km southwest of the district.

The high angle faults mapped in the district are strongly aligned southwest-northeast. Apparently they controlled the distribution of the mineralizing fluids that were necessarily no earlier than early Middle Tertiary time. Farther north, in the Yecorato quadrangle, fracturing is oriented in a more northerly direction, whereas to the east and northeast a subsidiary (?) later fault-set has a northwest trend. The northwest trend has been located only at El Cajon in this district. Apparently the vertical displacement on all these faults is less than 130 m., otherwise the basement complex would have been exposed.

Table 1. Composite Stratigraphic Column and Summary of Geologic History

Era / Period		Map Symbol	Major Event	Geotectonic Cycle / Orogeny
Quaternary	Recent	Qal	Formation of coastal plain by coalescing alluvium. Lateral Planation by Rio Sinaloa and tributaries	MEXICAN Taphrogenesis (Tertiary)
	Pleistocene		Gravel accumulation of Sinaloa Fm.+ Uplift and erosion of Sierra Madre Occidental. entrenchment of Rio Sinaloa ----- Tilting -----	
Tertiary	Pliocene	Tr	Olivine basalt extrusion of Hornillos Fm. ----- Angular Unconformity -----	
	Miocene		Faulting. Mineralization+	
	Oligocene		Emplacement of Rhyolite Series+ (Fuerte Fm.?)	
	Eocene	Ta	Interbedded minor sediments and deposition of Maune Fm.	
			Extrusion of lower Andesite Series+ (San Blas Fm.) ----- Angular Unconformity -----	
	Cretaceous		Intrusion of Tetameche granite ----- Folding -----	LARAMIDE Orogeny (Late Cretaceous-Early Tertiary) Miogeosyncline (?)
	Paleozoic	Pm	Deposition of limestones, mudstones and gypsum of Tetameche Fm. ----- Erosion ----- Extrusion of lavas of basic and intermediate composition Accumulation of arenaceous and pelitic sediments+, associated with lavas and intrusive igneous rocks.	JALISCOAN Orogenesis and metamorphism (Mid-Late Paleozoic) Eugeosyncline

+ Recognizable events in Ocoroni district

GEOLOGIC MAP
EL CEDRO MINE
OCORONI, SINALOA

(Shown only for 0 and 50 levels)

The regional tectonic fabric is aligned northwest and parallels Sierra Madre Occidental and the coast line. This grain is reflected in overall distribution of major lithologic units and faults (Fig. 3). But in the Ocoroni district, as well as further north in the Yecorato quadrangle, local structures cut across the regional trend. The significance of crossing fracture systems in relation to igneous centers of activity and associated mineralization in other parts of the western Cordillera have been well documented by Billingsley and Locke (1941) and Clark (1972), to name but a few. Their probable importance in Mexico cannot be overemphasized.

MINERALIZATION

Lead-zinc mineralization occurs in two principal areas about 9 kilometers apart within the volcanic rocks along the strike of the fault system. The southwestern area contains the San Gotardo and El Ramal mines, plus the Anberes, Plomosa and El Muerto prospects. The Sara and El Cedro mines and the San Judas prospect are in the northeastern area. The Tasajera, El Triunfo and La Fortuna prospects occur at separate localities in the northern part of the district. The locations of all of these are shown on the district geological map, Plate 1. Plates 2 and 3 show the principal veins in greater detail.

Controls

Almost all of the workings are on veins that occur within northeasterly striking faults that in some cases can be related directly to the major faults of the system. These mineralized faults all appear to be of the normal type, with dips most commonly steeply northwest. Vertical and southeast dips also occur, and one vein, at La Plomosa, strikes northwest in contrast to the usual pattern for the district. Small changes of strike and dip in a few cases seem to control the mineralization within the controlling faults, but in most cases this subtle secondary control is not evident. Although the controlling faults cut both volcanic rock types, the strongest vein development seems to occur where they have brought rhyolite into contact with andesite. This suggests and additional physico-chemical control that is not yet understood.

Mineralogy

One of the largest veins of the district is of the type where andesite forms one wall and rhyolite forms the other. This is the Cedro vein, shown in outcrop in Figure 5A. It is the most extensively developed of all the veins in the district, and can be considered a typical example of their occurrence and mineralogy. Mineralization in this vein and in the rest of the veins in the district consists of galena and sphalerite with minor chalcopyrite and varying amounts of pyrite, all in a quartz gangue. The mineralization is clearly of the cavity filling type, usually exhibiting multiple stages of brecciation and deposition (Fig. 5B). Strong colloform banding of quartz and sulfides is characteristic of the richest ore zones. Figure 6 shows typical polished sections of the ore, showing sulfide replacement of early quartz. In the Cedro vein the zinc to lead ratio is about 2:1. In other veins zinc and lead occur in roughly equal proportions, and in some, lead predominates. The galena is very weakly argentiferous; silver is only a minor value of the ores of this district. Pyrite distribution is erratic, but there is some evidence from mine sampling that it increases with depth at the expense of base metal sulfides.

EL CEDRO MINE**Figure 5** **Fig. 5A. Headframe and dipping vein outcrop.** **Fig. 5B. Banded and brecciated ore, Zero level.** **Fig. 5C. Boxworks developed in gossan.**

PHOTOMICROGRAPHS OF ORE, EL CEDRO MINE

Figure 6

Fig. 6A. Idiomorphic quartz (Q) replaced by pyrite (P), both of which are replaced by later sphalerite (S) (X 36).

Fig. 6B. Remnant quartz (Q) surrounded by galena (G) showing triangular cleavage pits and sphalerite (S) (X 36).

Fig. 6C. Dark idiomorphic quartz (Q) and light pyrite (P) are earlier than galena (G) and sphalerite (S) (X 36).

Alteration

Hydrothermal alteration of enclosing rhyolitic wallrocks is generally slight, limited to silicification and weak to moderate kaolinization of feldspars. However, alteration of andesitic wallrocks is commonly well developed. Besides abundant silicification and pyritization, the andesitic rocks usually display a strong propylitic assemblage consisting of chlorite, epidote and calcite, with minor amounts of sericite and clay. Figure 4C shows a thin section of altered andesite from the footwall of the Cedro vein, displaying the typical propylitic alteration. As shown in Plate 2, this alteration of andesitic wallrock often extends outward from the veins for several meters. There appears to be a direct relation between the size and strength of the veins and the extent of wallrock alteration. The strongest veins also show the best developed alteration.

Oreshoots

The alteration associated with the veins of the Ocoroni district often enhances the effect of weathering so that the resistant quartz veins stand out prominently. The outcrops can be sometimes traced for 300 to 400 meters, but are usually much shorter. Widths are commonly 1 to 2 meters and occasionally reach 3 or 4 meters. These outcrops display varying degrees of iron staining and limonite boxworks as gossan (Fig. 5C) indications of sulfides below. Sulfide mineralization is confined to steeply raking oreshoots that closely correspond to the limits of quartz deposition in the veins. El Cedro is a good example in this regard. Plate 2 shows the underground geology and surface outcrop of the Cedro vein. The quartz outcrop near the shaft shown in Figure was traced along strike to the northeast, where it gradually disappeared. Geochemical sampling near the vein outcrop yielded values in excess of 1000 ppm Pb and Zn, but beyond the last quartz outcrop indications, the soil sampling gave values in the 40 to 100 ppm range. These low geochemical results were later confirmed by driving the Zero level adit northeastward along the vein. As can be seen from Plate 2, the vein gradually turned to gouge and unmineralized alteration at the point in the fault that corresponds to the disappearance of the surface outcrop. A similar phenomenon occurs on the southwest end of this oreshoot. The veins elsewhere in the district appear to exhibit a similar characteristic, with oreshoots confined to those areas of the controlling faults that show strong quartz outcrop development, presenting rather well defined lateral oreshoot limits. Although the present workings on the various veins are not very deep, there is some evidence, as mentioned, that vertical oreshoot limits are provided at relatively shallow depths by increasing pyrite content.

Summary and Conclusions

The origin of the mineralization at Ocoroni appears to be similar to that of many other mining district in the Sierra Madre Occidental. Vertical faulting and concurrent post-Middle Tertiary intrusive activity probably provided both the channelways and source, respectively, for the mineralized solutions. Although no intrusive outcrops within the district itself, the presence of the nearby post-Middle Cretaceous granite pluton at Cerro Tetameche to the west suggests that intrusive rocks may be found at shallow depths below the volcanics around Ocoroni. Because of close proximity to the probable source, the mineralization here is base metal, and fits the pattern described by Wisser (1966) for veins that lie close to the basement in the northwest Mexico

metalogenic province. The veins here contain less quartz than the precious metal veins found in mining district elsewhere in the Sierra at higher elevations. Such districts usually exhibit quartz veins outcropping over relatively great distances, with oreshoots distributed irregularly within them through secondary structural controls. Veins in the Ocoroni district are generally narrower than the veins of many of the precious metal districts, and oreshoots are closely linked to resistant quartz outcrops that are relatively short in strike length. It is believed that the characteristics of the Ocoroni district as described here can be profitably applied to the exploration and evaluation of other district in similar environments elsewhere along the western edge of the Sierra Madre Occidental.

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