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GEOLOGY OF SIERRA SANTA LUCIA AND SIERRA PAPANTON, DURANGO AND ZACATECAS, MEXICO

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ABSTRACT

Contorted, Thin-bedded limestone of early Cretaceous age is overlain unconformably by rhyolite flows and tuffs of Cenozoic age. Dikes, chiefly rhyolite, intrude the strata in the western part of the map area. Cerro Sacrificio probably is an apically-terminated stock emplaced during Laramide time. Normal faulting took place during late Cenozoic time. Copper, fluorspar, antimony, and tin prospects are within the 500-Km² map area.

INTRODUCTION

A geologic reconnaissance of a 500-Km² area (Figure 1) of the mountain range extending southeastward from Cerro Sacrificio, Durango, (23°53′ N.; 103°57′ W.) to San Martín, Zacatecas, (23°40′ N.; 103°37′ W.) was undertaken during June and July, 1971.

National highway 45 crosses the area 120 Km southeast of Durango and 120 Km northwest of Fresnillo. Unimproved pueblo and ranch roads provide access to much of the area. The Durango-Río Grande branch of Ferrocarril Nacional de México passes 15 Km south of the range.

The mountain slopes are covered in many places by pine and fir; the alluvial valleys are farmed intensively. Although the principal known mineralized areas are privately controlled, the intervening area is public land, chiefly ejidos.

No previous detailed reports have been published on Sierra Santa Lucía, but unpublished company reports exist on Cerro Sacrificio, Durango, and mining properties at San Martín, Sabinas, and La Noria, mining camps in Zacatecas, which adjoin the southeastern margin of the map area.

The range was mapped on a scale of 1:30,000 using aerial photographs flown in December, 1966 for S. R. H. D. - Pequeña irrigacción - Zona Durango. Data were later replotted on a scale of 1:50,000. Principal workings on Cerro Sacrificio were mapped on a scale of 1:500 using a Brunton compass and a metric tape.

GEOMORPHOLOGY

Elevations within the map area range from 2,400 m near La Joya to 3,300 m at the crest of Sierra Papantón. Sierra Santa Lucía and Sierra Papantón form an asymmetrical drainage divide. To the southwest, high gradient streams flow toward Río Mezquital. To the northeast, streams with a more gentle gradient flow toward Río Grande, which is a tributary of Río Aguanaval. As a result, the terrain northeast of the range is a high, flat plain, whereas that to the southwest is more intensively eroded.

The streams southwest of the range are entrenched more than 30 m in their alluvial fans suggesting recent rejuvenation resulting from uplift along the range-front fault which bounds Sierra Santa Lucía and Sierra Papantón on the southwest. Faults in Quaternary alluvium attest to the recency of movement. Exceptionally coarse fragments, including cobbles and boulders, suggest a high-energy environment where in torrential rains falling on steep

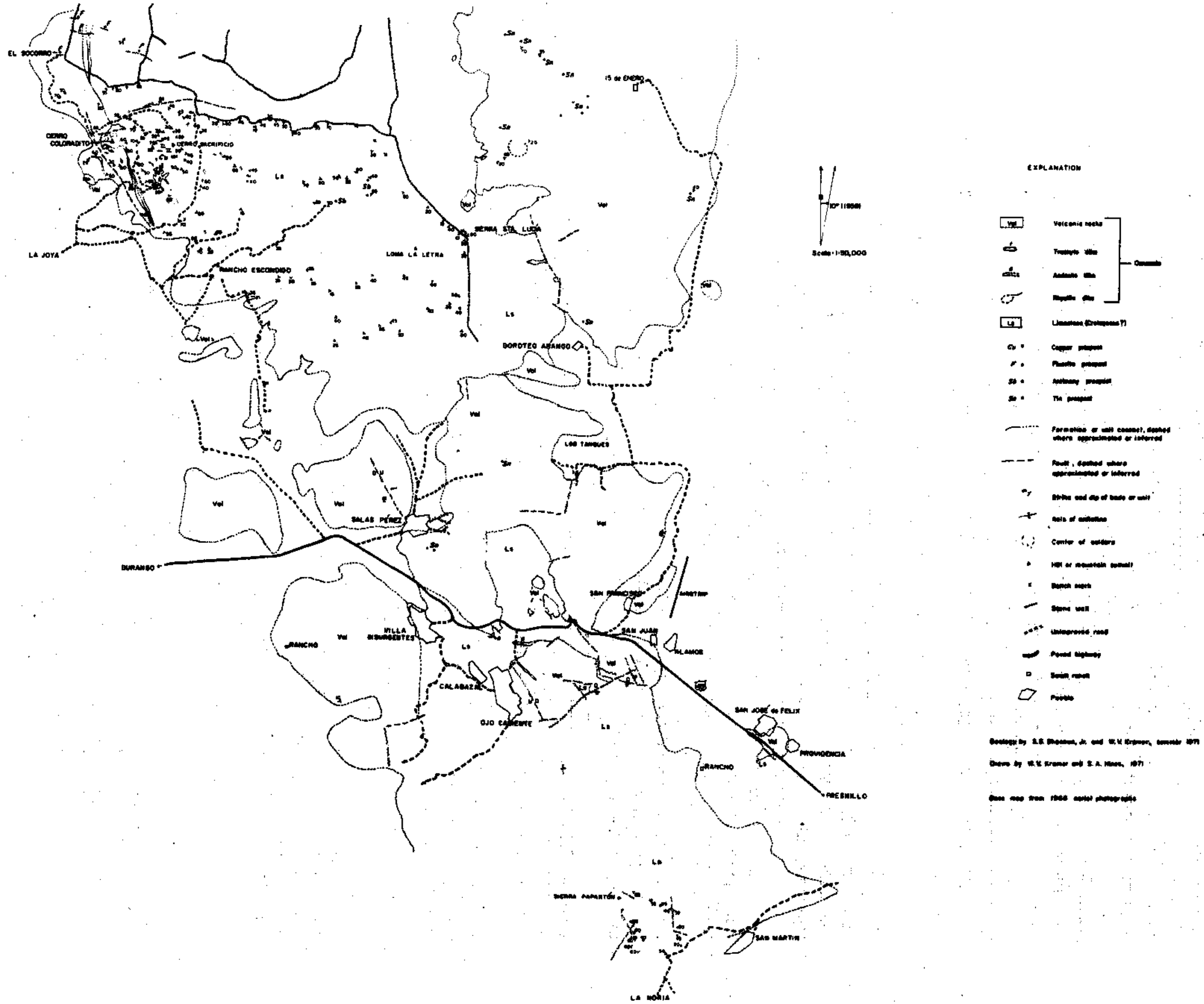

PLATE I. GEOLOGIC MAP OF SIERRA SANTA LUCIA, DURANGO-ZACATECAS, MEXICO slopes favored rapid erosion and downcutting. The depth of recent erosion is an argument against a current cycle of pedimentation. However, pediments could have formed on a higher surface before the recent episode of rejuvenation and downcutting.

Cerro Sacrificio forms a topographic high, shaped as a inverted spoon. The drainage pattern is radial from the crest of the hill to the surrounding terrain. In fact, the pattern is almost circumferential, so that Cerro Sacrificio resembles the peak of a sombrero.

The silicified rhyolite dikes, west of Cerro Sacrificio, are more resistant than the surrounding limestone and form a low ridge, which becomes much higher in the vicinity of the Cerro Coloradito pod.

The thick caliche in the area results from the alternate up-and-down movements of ground water during the wet and dry seasons. At the begining of the wet season in early June, the water table was 30 m deep in one mine shaft.

STRATIGRAPHY

Approximately 3,000 m of contorted, thin-bedded (20 to 50 cm), Lower Cretaceous (?) limestone, locally intercalated with a few thin shale beds, crops out in Sierra Santa Lucía and Sierra Papantón. The limestone is medium gray to black and weathers medium gray. The shales are red, orange, and greenish tan. On Sierra Papantón the limestone in several places contains chert eyes, as much as 30 cm thick, aligned patrallel to the bedding; elsewhere, chert fragments occur in calcilutites in a few places.

The limestone commonly is unfossiliferous; however, scattered fossil fragments, including one complete cephalopod, were found on Sierra Papantón. Efforts to date the age of the limestone by studying the sutures in the cephalopod were unsuccessful because the limestone had recrystallized. A few massive beds at Cerro Sacrificio may be composed of algal remains.

It is impossible to subdivide the limestone into mappable units because the beds are so monotonous in lithology, so unfossiliferous, so uniformly thin, and so intensively deformed. If exposures were better, one or more shales or algal reefs might be broken out as marker beds. But the less-resistant, clastic units tend to be exposed only in vertical faces, such as road cuts and canyon walls. Elsewhere, more similar exposures may be obscured by caliche.

Secondary calcite veins, some containing hematite, are ubiquitous. Chert and quartz blowouts locally are common. Caliche layers 1 to 3 m thick obscure many limestone outcrops.

Around Cerro Sacrificio, some limestone beds have been altered selectively by thermal metamorphism to a skarn composed of quartz, tremolite, wollastonite, grossularite, epidote, and chlorite. Other limestone beds have been merely marmorized or silicified. The tactite zones are thin and diminish sharply a short distance away from the igneous rocks. The tactite contains no magnetite and only minor amounts of pyrite and sulfide ore minerals. A little goethite is ubiquitous; malachite and azurite are less common.

Parallel to thin, linear rhyolite dikes, even those containing goethite pseudomorphs after pyrite, alteration of limestone is limited to minimal silicification. Adjacent to fluorite and stibnite-cervantite veins, the limestone locally is intensively silicified.

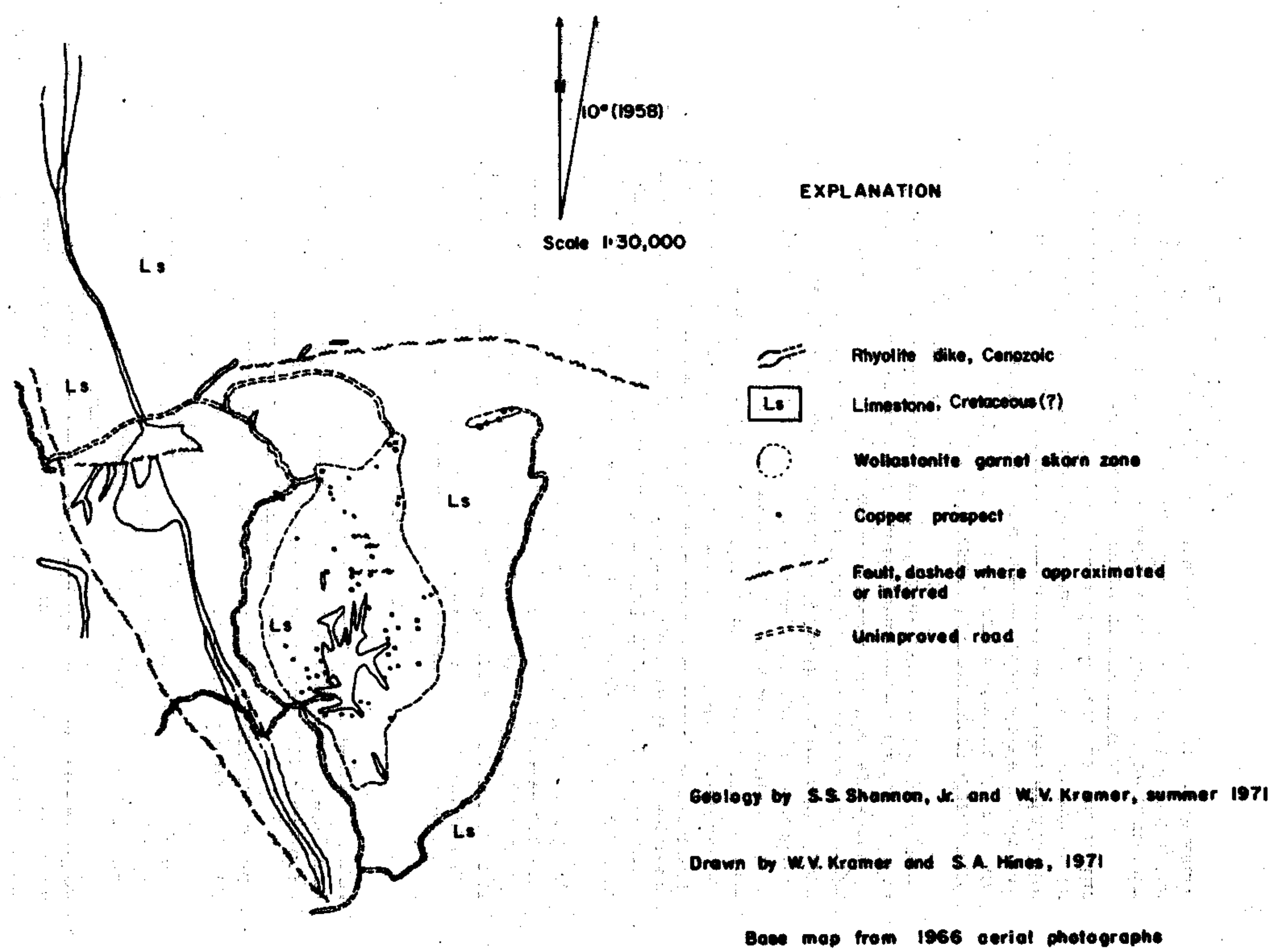

PLATE 2. GEOLOGIC MAP OF CERRO SACRIFICIO, DURANGO, MEXICO.

VOLCANIC ROCKS

Consanguineous rhyolite flows and tuffs, of probable mid-Cenozoic age, occur as nearly flat-lying units in down-thrown blocks in Sierra Santa Lucía.

The rhyolite flows are light gray to reddish brown. They contain phenocrysts of sanidine and quartz, as much as 2 mm in diameter, in a very fine holocrystalline groundmass, composed of potassium feldspar, quartz, and minor biotite. The rhyolite tuffs vary in color from light gray to yellowish brown to pale reddish brown. They contain phenocrysts of sanidine and quartz and rock fragments as much as 5 mm in diameter in a hypohyaline groundmass of potassium feldspar microlites and volcanic glass.

The general sequence of volcanic units was examined in three places. South of the highway pass, de basal 3 to 30 m of rhyolite tuff, pitchstone, and obsidian are overlain by 300 to 600 m of rhyolite flows and tuffs. In the pass, folded Cretaceous strata are overlain by an equally contorted reddish-brown rhyolite flow, which is the only volcanic rock known to be involved in the same episode of deformation as the underlying limestone beds. These folded units are truncated by an unconformity. Above the unconformity, is a nearly flat-lying sequence, comprising a baseball-spherulitic rhyolite, overlain, in turn, by jointed massive rhyolite tuff and volcanic breccia. In an arroyo south of Cerro Sacrificio, a sequence of alternating fine- and coarse-grained light-gray rhyolite flows is overlain by a yellowish-gray rhyolite tuff. Except for some glassy flows near 15 de Enero, outcrops of vitrophyres are confined to the general vicinity of the highway.

Approximately 4 Km southwest of 15 de Enero is a shallow, circular depression, 500 m in diameter, containing many thin (30 cm), steeplydipping rhyolite flows. This structure is interpreted to be a small caldera.

DIKES

Rhyolite. Almost all dikes in the Sierra Santa Lucía map area are composed of rhyolite. The grain size of the phenocrysts and groundmass commonly increases with the thickness of the dikes.

Many thin (<10 m) dikes, especially the 7Km long set trending 345°through Cerro Coloradito, contain 1 to 2 mm euhedral phenocrysts of quartz, sanidine, and goethite (pseudomorphic after pyrite) set in a very fine porcellanic groundmass composed of quartz, sanidine, and minor biotite.

The size of the phenocrysts is greater in the rhyolite near the centers of the Coloradito and Sacrificio pods. Here, phenocrysts of quartz and sanidine, 2 to 10 mm in diameter, occur in a more nearly serial porphyritic groundmass containing sanidine, plagioclase, magnetite, and biotite. The cores of the pods contain as much as 30 percent plagioclase, thus approaching the composition of latite. However, the margins of the pods have the same texture and mineralogy as the dikes noted avove. Hence, the pods are composed of rhyolite.

On the southeastern slope of Cerro Sacrificio, a small rhyolite flow contains quartz and sanidine phenocrysts as much as 0.5 mm in diameter in a groundmass of quartz, sanidine, and biotite.

East of Cerro Sacrificio, thin, fine-grained rhyolite aplite dikes and sills occur in limestone. Phenocrysts of quartz and sanidine to 0.5 mm in diameter are set in a serial porphyritic groundmass of quartz, sanidine, and a little biotite. Superficially, these rocks resemble tuffs; however, close inspection discloses that they have flow texture and cut across the strata. Because these dikes have the same mineralogy and texture as the rhyolite flow, noted in the previous paragraph, they may have served as feeders for it and other flows.

Andesite. Two medium-gray andesite dikes were noted in the limestone terrane, a 70-m thick unit north of Ojo de Agua and a much thinner one north of Villa Insurgentes. The andesite, which has a poikilitic texture, is composed of phenocrysts of plagioclase and clinopyroxene as much as 5 mm in diameter in a groundmass containing plagioclase, potassium feldspar, and magnetite.

Trachyte. A single outcrop of trachyte was noted near the top of Sierra Papantón. It is composed of phenocrysts of sanidine and perthite in a hypohyaline groundmass containing some potassium feldspar and magnetite microlites. The rock has definite trachytic flow structure.

STRUCTURAL GEOLOGY

Efforts to map all fold axes and rock attitudes were abandoned for three reasons: First, it is impossible to subdivide the limestone into mappable units. Second, useful vertical exposures are limited to a few road cuts and canyons. Third, the strata are so contorted, possibly by multiple deformations, that measurements of individual attitudes are meaningless for distances of more than a few feet.

Limestone beds have been deformed intensively (perhaps in more than one event) into similar isoclinal folds, having thickened troughs and crests. In places, the overturned limbs are broken by minor thrust faults, Elsewhere, strata have been compressed into chevron folds, some of which have nearly flat axial planes.

Linear veins and rhyolite dikes, which formed later than the folding of the limestone beds, cut across the bedding and fold axes. In places, small dikes follow minor fold axes. Also, the stibnite-cervantite veins are aligned parallel to minor anticlinal axial planes.

Sierra Santa Lucía and Sierra Papantón are individual limestone horst blocks, separated by small grabens containing downthrown volcanic rocks, but bounded on the northeast and southwest by large grabens. All rocks, including the contorted Cretaceous limestone and the nearly flatlying Cenozoic volcanic rocks, have been involved in basin-and-range-type deformation. In fact, displacement of Quaternary alluvium suggests that the range-front faults are currently active. The Santa Lucía horst is bounded, on the west near Cerro Sacrificio and on the east near Doroteo Arango, by a pair of normal faults which strike 350°. Along highway 45, the northern block is downthrown at SalasPérez and in the highway pass by subparallel normal faults which strike 260°.

Cerro Sacrificio may be an apically terminated stock. Although no definitely plutonic rocks are exposed at Cerro Sacrificio, the probable existence of a pluton, concealed at shallow depth, may be inferred from several lines of evidence. First, texture of the igneous rock coarsens toward the center of the Sacrificio pod. Second, the extent of the wollastonite-tremolite-garnet skarn zone is limited to Cerro Sacrificio and the immediately surrounding area. The intensity of thermal metamorphism decreases sharply away from Cerro Sacrificio. No similar metamorphic halo surrounds Cerro Coloradito. Third, at Cerro Sacrificiio the regional structural pattern of intricately folded limestone beds in interrupted by a rigid, upthrown mass of faulted limestone blocks. Also several joint sets cross the skarn zone and limestone beds in the vicinity of Cerro Sacrificio whereas elsewhere in the map area they are less obvious. This type of deformation may have been caused by upward stoping or injection of a concealed pluton. Finally, the hill has the topographic form and radial drainage pattern characteristic of an isolated plug.

If the ore mineralization be genetically related to the pluton, then the relative age of its injection becomes important. The pluton is older than the linear dikes and younger than the limestone. It may be Laramide in age. Perhaps the same stresses which accompanied the intrusion of the pluton also caused the folding of the surrounding strata. Or perhaps the pluton was injected before the folding took place and acted as a buttress inhibiting the strata in the immediate vicinity of Cerro Sacrificio from further deformation during any subsequent episodes of compression.

MINERAL DEPOSITS

Copper. Copper sulfide and secondary copper carbonate minerals are restricted to the 3.5-Km^2 wollastonite-tremolite-grossularite skarn zone of Cerro Sacrificio and to the 0.1-Km^2 similar skarn zone 600 m to the northeast at Guadalupana. These tactites may be related to a buried apically-truncated stock. The distribution of known copper mineralization is shown in Figure 2. Surficial pits contain quartz, some malachite, and minor amounts of bornite and chalcopyrite in narrow skarn zones aligned parallel to the the contacts between rhyolite dikes and limestone. The most thorough descriptions come from the accessible underground workings.

In the upper mine southeast of the watchman's home, three 3-cm veins, containing bornite and tetrahedrite in azurite-and malachite-stained quartz and calcite gange, can be followed for 27 m from the portal. A few specks of bornite occur in the wallrock skarn along the margins of a southeasterly-trending stope along the entire 23-m distance to its face. At 6 to 8 m from the face, three calcite veins containing chalcopyrite and tetrahedrite strike 295° and dip 85° NE. The largest vein, which is 3 cm thick, contains the most chalcopyrite. The other two veins are each 2 cm thick. Three other veins occur within 2 m of the face. The largest, which is 8 to 18 cm wide, strikes 315°. It contains much tetrahedrite and chalcopyrite in a gangue composed of abundant garnet plus some pyrite, calcite, and quartz. Normal to this vein is a 5-cm vein containing abundant tetrahedrite. Another 8-cm striking 280° contains tetrahedrite, chalcocite, chalcopyrite, and molybdenite in a gangue composed chiefly of garnet with some calcite and quartz. At the face is a little disseminated bornite and tetrahedrite.

In the 44-m long, 155°-trending adit east of the watchman's home on the northwestern flank of Cerro Sacrificio, copper carbonates and sulfides occur in several veins and disseminated zones. At the portal, a 1-cm vein contains galena and bornite. At 1 m from the portal, a 1-cm vein striking 060° contains malachite and azurite. At 3 m, an 8-cm quartz-calcite vein containing some malachite staining strikes 055° and dips 85°SE. At 5 m, a 3-cm hematite-stained quartz-calcite vein containing bornite, malachite, and azurite strikes 090° and dips 75°N. At 7 m, a 14-cm quartz-calcite vein is stained with hematite, malachite, and azurite. This vein strikes 275° and dips 70°NE. At 9 m, bornite and malachite- and azurite-stained quartz occur in a few small discontinuous pockets between two fractures, 1 m apart, both of which strike 065° and dip 70°SE. At 15 m from the portal, a little bornite, malachite, and azurite occur with hematite, calcite, and quartz in a fault zone which strikes 080°. A few flecks of malachite and bornite occur in the west wall for the next meter to a 1-cm chalcopyrite-bearing calcite veinlet which strikes 090° and dips 80°S. At 19 m, malachite stains a 2-cm pyrite-quartz-calcite vein which strikes 075° and dips 70°SE. At 23 m, bornite is disseminated in a wollastonite skarn.

Along the southwestern flank of Cerro Sacrificio part way up the stone trail to the stock tank, an adit extends for 53 m almost due north(355°) .At 41 m, from theportal, sparse malachite occurs with limonite in a 20-cm calcite vein which strikes 065° and dips 75°SW. At the face, two veins contain chalcopyrite, sphalerite, and galena in a quartz calcite gangue. One vein varies in thickness from 1 to 7 cm and strikes 285°; the other is 1 cm thick and strikes 265°. Both have southerly dips of 70°.

Near the crest of Cerro Sacrificio, a north-trending stope is inclined 60°E. The stope is 25 m long, 3 m wide, and 20 m high. A small amount of tetrahedrite, galena, bornite, and chalcopyrite occurs within a few veins, 1 to 4 cm thick, along fractures in an epidote-grossularite-calcite-quartz skarn.

Fluorspar. Thin breccia veins containing fluorite occur along northwesterly fractures in limestone 2.5 to 4 Km northwest of Cerro Sacrificio. The veins are exposed only in old workings where they are capped by 2 to 4 m of caliche. Most of the area is covered and specific attitudes are doubtful. The deposits will be described in a clockwise sequence.

El Socorro fluorite prospect is 4 Km west-northwest of Cerro Sacrificio. Fluorite occurs in intensively hematite-stained silicified calcite-quartz breccia,20 to 30cm,thick,which follows a 270°-trending fracture in limestone for 150 m. In June, 1971, a 1.5-m² prospect shaft had been sunk 10 m by Minerales Industriales Mexicanas of Tlalnepantla, México. The results were discouraging and the engineer in charge was ready to abandon the camp.

Northwest of Cerro Sacrificio 4 km, a line of quartz blowouts containing minor amounts of fluorite trends 280° for 900 m.Elsewhere,a line of workings follows a narrow fluorite vein and quartz blowouts in limestone 3.5 km north-northwest of Cerro Sacrificio. Finally, north of Cerro Sacrificio 2.5 km, old workings, including a shaft and an adit, follow for 900 m along a narrow fluorite vein which strikes 280° to 300° in limestone. Many quartz blowouts occur along the strike of the vein.

Antimony. A small amonunt of cervantite and stibnite occurs in narrow, dfiscontinuous quartz-calcite veins in folded, black thin-bedded limestone 5.5 to 7 Km east-southeast of Cerro Sacrificio. The limestone is fractured and contorted; locally, minor anticlines control the loci of mineralization. Adjacent to the veins, the limestone is silicified in places. Surronding the workings, the limestone is intensively fractured and cemented with calcite. One set of veins strikes 290° to 315° ; another set strikes 030° to 050°. The maximum traceable strike length of individual veins is 40 m, but most veins can be followed for only a few meters. The average width of the veins is 2 cm. Shallow shafts and short, narrow (1 m²) flat and inclined adits (the longest of which extends fot 30 m) were dug to explore the antimony prospects. The most recent effort to develop the deposits was abandoned as a failure in 1970.

Tin. Cassiterite occurs sparsely with specularite in ribbon veins and pockets in rhyolite and in small, shallow eluvial and alluvial placers.

Workings as much as 30 m deep occur in an abandoned mine 4.2 Km westnorthwest of 15 de Enero. Cassiterite and botryoidal specularite are in a narrow vein which strikes 005° for 300 m. Minor prospects 3.9 and 4.5 Km west-northwest of the same village contain similar mineralogy, as does another prospect 4.5 km west-southwest of the village. Cassiterite occurs in 1-cm veinlets and in 30-cm^3 bolsas in four prospects 1.5 to 2.5 km west-southwest of 15 de Enero.

Small quantities of placer cassiterite occur along hillsides and in stream beds in a 1-m thick zone of colluvium and alluvium in three prospects, respectively 2.4 Km west of 15 de Enero and 1.5 and 2.1 Km west-northwest of the village.

A few fine crystals of cassiterite occur along a fracture in rhyolite in a prospect 900 m east-northeast of Doroteo Arango. Minor cassiterite also occurs in a 1-cm thick veinlet striking 325° in rhyolite 6.5 Km northeast of Doroteo Arango.

A little cassiterite occurs in hairline fractures in rhyolite in a prospect 600 m south-southeast of Salas Pérez. Another prospect containing a few grains of cassiterite is 3.3 Km northeast of Salas Pérez.