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GEOLOGY OF THE HUAUTLA SILVER DISTRICT, MORELOS, MEXICO

By

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ABSTRACT

Base and precious metal mineralization at the Huautla district, Morelos, Mexico, is genetically related to calc-alkalic volcanism and accompanying tectonism which occurred nearly continuously throughout mid-Tertiary time. The volcanic pile is divided into five major stratigraphic units, the oldest of which, a complex of hornblende-biotite andesite and dacite flows, breccias and endogenous domes, is the only ore host. Stratigraphy and lithology had little influence on mineralization. Post-ore volcanism and faulting continued into late Tertiary time with little change in character and no additional mineralization. The younger units include dacite domes and flows which are petrologically similar to the oldest unit, and basalt flows and dikes which may be related to Pliocene and younger volcanism associated with the trans-Mexican volcanic belt to the north.

Orebodies are "epithermal type" veins occurring at intervals along laterally persistent E-W trending faults which formed due to regional and/or local magmatic doming. Early sulfide fracture filling and associated acid alteration was immediately followed by intense quartz vein filling. Supergene enrichment created significant "bonanza type" mineralization. Variations in vein textures, mineralogy and alteration, suggest the veins in the southern part of the district represent a more shallow level of exposure and possible multiple mineralization stages as compared to the single-stage veins

to the north. Hydrothermal fluids evolved from the deep circulating, acid, mineralizing solutions to an alkaline hot spring system as shown by zoning of alteration assemblages.

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INTRODUCTION

General

The Huautla district is located in southern Morelos state, Mexico, approximately 100 km south of Mexico City (Figures 1 and 3). The mining district's silver-bearing veins have been producing intermittently since their discovery by Spanish colonialists more than 3 centuries ago. The Huautla district is a small producer among the many deposits that comprise the precious metal belt that stretches 2400 km down the length of Mexico (Figure 1). This belt includes such famous districts as Pachuca-Real del Monte, Guanajuato and Fresnillo, all of which have a similar genesis and are thus identified with a limited set of mineralogical, geological, and geochemical characteristics. Numerous detailed geological and geochemical studies at these and other similar deposits have provided thorough genetic models and limiting parameters which benefit the understanding of the Huautla geology and mineralization.

Physiography and Access

Huautla is reached by year-round paved and gravel roads via Jojutla de Jaurez or Cuautla, Morelos. Both routes cross the fertile cane plantations occupying the lowlands which lie between north-south trending hogbacks, reflecting the tightly folded Cretaceous marine sediments below. The road from San Pablo Hidalgo heads southward and up into the erosional remnant of a Cenozoic volcanic field. As

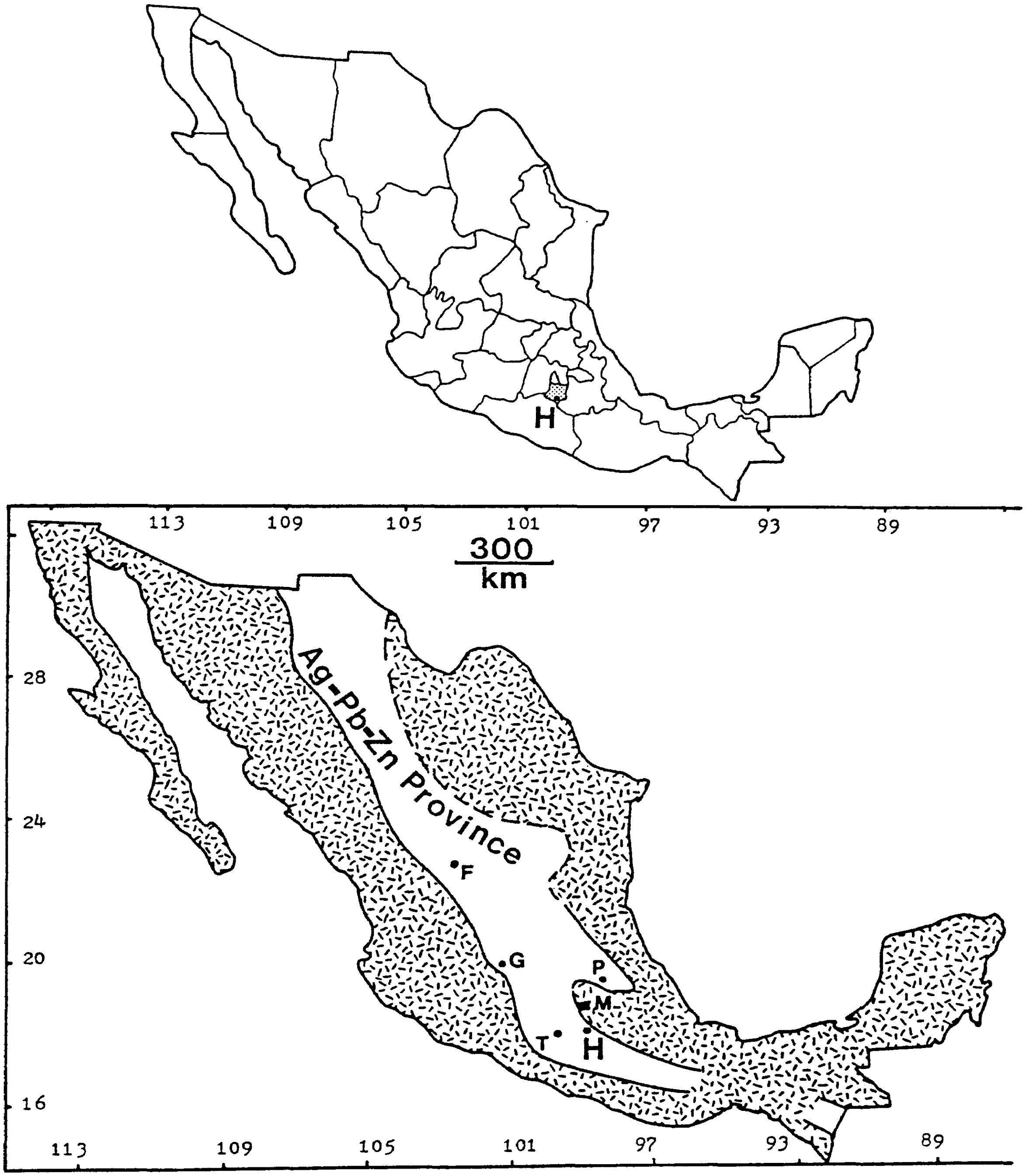


Figure 1. Location maps of the Huautla silver district (H). The upper map shows state boundaries, with Morelos state shaded. The lower map shows the silver-lead-zinc metallogenic province of Mexico (modified from Damon and others,1981), major silver districts (T=Taxco, G=Guanajuato, F=Fresnillo and P=Pachuca), and Mexico City (M).

the elevation increases the topography becomes more rugged. At the Huautla district, in the center of the present volcanic field, drainages are deeply dissected and flow southward to join with the Rio Amacuzac. The well developed, weakly rectangular drainage pattern is strongly controlled by local fault and alteration patterns. Though the canyons and valleys may contain lush groves, vegetation on the slopes is predominantly thick second growth of mesquite, and clearings for grazing and crops (Figure 2). The region is semi-arid and receives most of its approximately 100 cm/year rainfall during the summer months.

The known mineralization at Huautla occurs in veins totaling at least 20 km in length, over a 50 km² area. It is centered around the town of Huautla, which has coordinates of N18°26.5', W.99°1.5'. The study area for this report comprises 7.5 km² in the central mineralized district, immediately south and west of the town of Huautla (Figure 15). The mines are operated by Rosario Resources Mexico S.A. de C.V. The mill and mine camp are located 1 km west of town near the portal and shaft of the Santiago mine (Plate 1). Travel in the study area is by mine and drill roads, trails, and the relatively new road which roughly bisects the study area on its way to Xochipala, 1 km beyond the southwest boundary of the study area.

Mining History and Previous Investigations

The silver mineralized veins at Huautla were discovered by early Spanish colonialists, perhaps over 300 years ago. Numerous mines

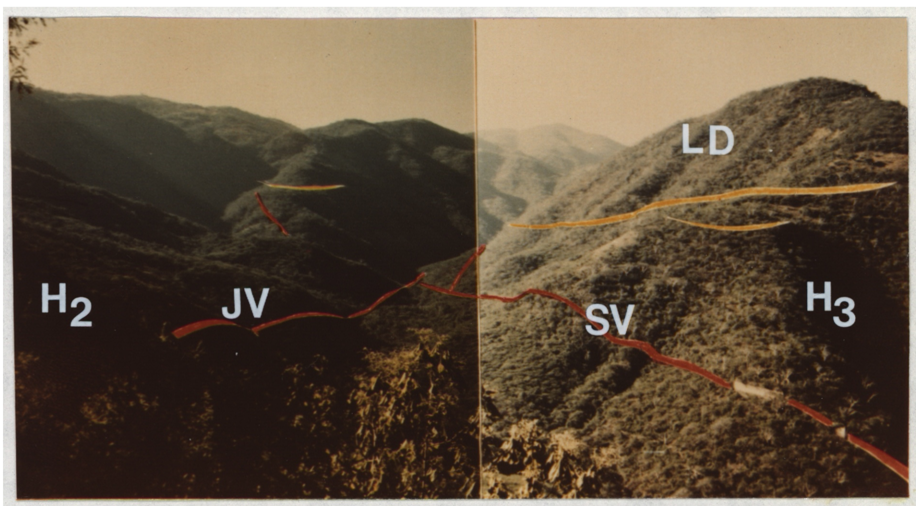


Figure 2. Panoramic view looking west up the valley of Arroyo Chico. The thin, nearly horizontal Epiclastic Group is shown by the yellow lines. Below the Epiclastic Group is the Huautla Complex, with its 2 subdivisions, Corona dome (H_2) to the left and Early Dacite Flows (H_3) to the lower right. Cutting the Huautla Complex are 2 veins (shown in red), the Santiago vein (SV) and the San Jose vein (JV). To the upper right, above the Epiclastic Group, are the Late Dacite Flows.

were developed in the extremely rich "bonanza type" oxide ores near the surface. Ruins of the stone and mortar haciendas, aqueducts, milling facilities, and fortified shafts are scattered throughout the district. The first mines were probably the Santiago, Santa Anna, and workings near Rancho Viejo. Campbell (1978) has provided the most detailed accounts of the early mine history, discerned from talks with townspeople, old mine records, interpretation of Spanish claim monuments, and overgrown mine workings.

Throughout the nineteenth and early twentieth centuries production continued sporadically. Many new mines were opened, old mines were rejuvenated, and at times pillars were high graded while waste dumps and tailings were reworked. As the rich bonanza oxide ores were depleted stoping went deeper into the leaner sulfide ores, where the high water table has continually caused production problems.

Today production comes from several mines; the Santiago, Peregrina, Plomosa, and America mines, as well as mill feed from the Tlachichilpa wastes and tailings (Figure 15 and Plate 1). The present 300+ ton/day mill produces Ag-Pb-Zn concentrate from mill feed with approximately 300 gm/ton Ag and approximately 2% combined Pb and Zn. Present production problems include low mill recovery due to loss of fine-grained silver (in gangue) to the tailings, decline in silver values at depth in the mines, and depletion of reserves faster than discovery.

Despite the long history of mining at Huautla, relatively few geologic studies have been undertaken. Most of the early literature was devoted to ore mineralogy, mining, and milling (von Egloffstein, 1864, Wittich, 1923, Brismade, 1922). At that time the lack of geological investigation was probably justified, but as the known reserves become depleted and only non-outcropping orebodies are exploration targets, new discoveries will increasingly depend upon geological models and observations.

Published literature on the local geology is limited to an investigation by Rodriguez L., and others (1962) published both as a thesis and by the supporting government agency, Consejo de Recursos Naturales No Renovables. While the subsurface maps of the San Francisco and now flooded Tlachichilpa mines are presumably correct, much of the surface mapping, volcanic stratigraphy and structural geology has been substantially modified and expanded by the author.

The unpublished company data is found in numerous mine maps, drill core logs, exploration reports (Campbell, 1978 and Malouf and others, 1973), metallurgical reports (Cyanamid, 1969), and the minds of experienced mine personnel. The reports of E.E. Campbell have been extremely helpful, particularly with respect to veining, post-ore structure, and history.

Regional investigations by Fries (1959) of the areas north and west of the volcanic field have provided the basis for the regional geologic history and regional correlation. Mexican government published geologic quadrangle maps (E-14-A-79 and E-14-A-69) have provided a regional structural pattern. The following section on regional geologic history is based on these works, as well as papers on Mexican tectonic history by Cserna (1976) and Guzman and Cserna (1963). The following discussions on mineralization at Huautla have been strongly influenced by regional syntheses by Wisser (1966) and Sillitoe (1977) and the epithermal boiling model summarized by Buchanan (1981).

Purpose and Methodology

The purpose of this investigation is to develop a more complete geologic understanding of the Huautla district. The results are intended to be applied in the local exploration for ore reserves as well as providing a data base for future detailed and regional geologic studies.

The original intention was to produce a surface geologic map emphasizing volcanic stratigraphy. This coupled with underground observations was expected to show strong stratigraphic control on ore deposition. As mapping progressed, it became apparent the volcanic stratigraphy was much different and more complex than previously believed. In fact, host rock stratigraphy will be much less useful than structural and alteration patterns as an exploration tool.

The final map boundaries were selected on the basis of abundant mineralization, stratigraphic variety, and accessibility. The approximately 7.5 km^2 area was mapped at a scale of 1 to 5,000. The partial map base was produced by Lockwood Survey Corp. (1973) from air photos and has been shown by Campbell (1978) to contain erratic coordinate errors up to 90 m. In the western portions of Plate 1 the topographic contours have been estimated from old mine maps, the government topographic sheets, and the "Lockwood" map; the surveys were not in close agreement.

Field mapping was supported by laboratory and office work. Thin sections were examined microscopically and classified based upon mineralogy using the classification system of Strekiesen (1967). Ore textures were examined on polished surfaces. Alteration mineralogy was discerned by petrographic and X-ray diffraction analyses. Selected rock specimens and thin sections are housed in a permanent reference collection. These can be made available upon request to the Petrological Reference Collection, Department of Geology, Colorado School of Mines, Golden, Colorado 80401. A list of samples within the collection is provided in the Appendix.

GEOLOGIC SETTING AND STRATIGRAPHIC CORRELATION

Regional Geologic History

The geologic evolution of south-central Mexico has undergone much the same development as the rest of the American cordillera. The basement rocks are a Precambrian to early Paleozoic metamorphic and igneous complex (Figure 3). The gneiss, schist, and intrusives of this group may directly underly the mid-Tertiary volcanic pile to the southeast of Huautla, but most of the Tertiary units are underlain by Mesozoic sedimentary rocks. Deposited unconformably on the Precambrian and early Paleozoic basement complex was a thick sequence of late Paleozoic and Mesozoic sedimentary rocks. During this period the region underwent numerous periods of uplift and associated marine transgression-regression cycles. A late Jurassic-early Cretaceous marine transgression formed a broad orthogeosyncline which obliterated early structural belts (Guzman and Cserna, 1963). The Cretaceous units deposited in this orthogeo-synclinal belt are all limestones (Xoshicalco, Morelo, and Cuautla Formations) north and northwest of Huautla (Fries, 1959). Late-Cretaceous folding and uplift resulted in accumulation of a thick clastic and shallow marine sequence of interbedded siltstone, sandstone, shale, conglomerate, and limestone beds. By the end of Cretaceous time the region was exposed to subareal erosion and was not again submerged. The early Tertiary Hidalgoan Orogeny (which is approximately correlative with the Laramide Orogeny defined in the

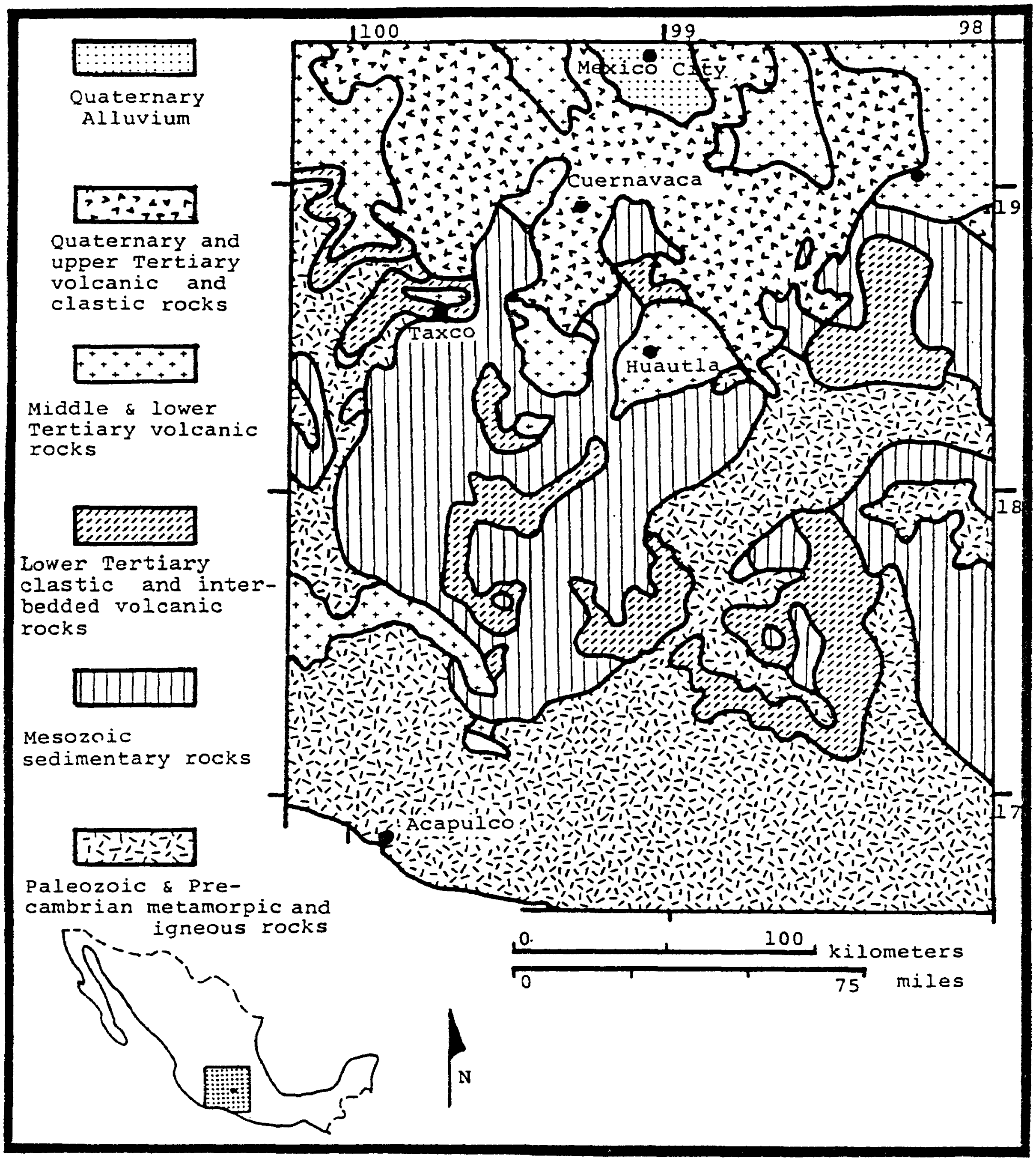


Figure 3. Generalized geologic map of south central Mexico (modified from Goddard and others, 1965), showing location of Huautla.

western U.S.A.) intensely deformed all older rocks, producing the north-northwest trending tight folds and thrust faults of the Mexican structural belt.

The Hidalgoan Orogeny and late Eocene warping and block faulting produced strong relief and rapid erosion, resulting in the accumulation of enormous quantities of post-orogenic debris or molasse, represented by the Balsas Group in the region north and west of Huautla (Fries, 1959). Tertiary volcanism commenced during this episode of tectonic activity, as shown by interbedded basic composition flows, tuffs, and breccias in the Balsas Group. As Balsas deposition waned in the region, strong fault deformation (up to 2,000 m displacements) died out and has not been repeated at such magnitudes since (Fries, 1959).

The continental post-orogenic debris was then covered by a widespread composite mid-Tertiary volcanic field. The Huautla mining district is entirely located within an erosional remnant (approximately 1,500 km^2) of this thick sequence. Fries (1959) has divided the mid-Tertiary volcanic rocks (20 km or more to the north and west of Huautla) into 5 units. The earliest unit, the Tilzapotla Rhyolite was deposited in late Oligocene. This was overlain by a predominantly Miocene, thick interfingering sequence of intermediate composition volcanics, the Tepoztlan Fm., Zempala Andesite, Buenavista Group, and Nondifferentiated Group. These Miocene volcanics, though predominantly dacite and andesite, include basalts, latites, and rhyolites.

Mid-Pliocene time brought renewed faulting, erosion, and unconformable deposition of the volcaniclastic Cuernavaca Formation. At this time, large-scale basaltic volcanism associated with the trans-Mexican volcanic belt began and continued into Holocene time.

Stratigraphic Correlation

The overall geology of the Huautla district is quite simple. All lithologies exposed within the study area are mid-Tertiary porphyries of remarkably similar compositions, textures, and modes of emplacement. But it is this simplicity that has led to confusion in stratigraphic subdivision. Most subdivision has been made on rather subtle petrologic, textural, and field characteristics.

Rodriguez and others (1962) and Campbell (1978) have attempted to stratigraphically subdivide the Huautla porphyries, resulting in conflicts of nomenclature, subdivision, and interpretation. Figure 4 summarizes the stratigraphic nomenclature and subdivisions employed by Rodriguez and others, Campbell, and this study. Also shown is the regional correlation that Rodriguez has made between the Huautla volcanics and the Buenavista Group as described by Fries (1959).

AGE	Fries,1959	Rodriguez,1962	Campbell,1978	This Study,1981	
Pliocene?				Basalt Flow & Dikes	
Miocene	Buenavista Volcanic Series	Tuff	Tuff-Aglomerate	Late Dacite Flows	
				Center / Border	Barriga Dacite
		Dacite Trachyandesite	Dacite-Tuff	Epiclastic Group	
				Early Dacite Flows	Huautla Complex
		Tlachichilpa Andesite	Andesite-Tuff	Corona Dome	
				Undifferentiated	
Oligocene	Tilzopotla Rhyolite				
Eocene	Balsas Group				

Figure 4. Tertiary stratigraphic nomenclature and correlation chart for this study and previous investigations of the Huautla district and surrounding region. Ages of the units are based on regional stratigraphic correlation with units defined by Fries,1959. (See also Figure 5).

Regional Mineralization

The Huautla silver deposits lie in the southern portion of the Mexican silver belt (Figure 1), a broad zone of similar epithermal Pb-Zn-Ag deposits. The similar deposits of the region are all late Cretaceous and Cenozoic in age occurring in Tertiary subareal calc-alkalic volcanic rocks or in the subvolcanic basement. Huautla is separated from the major Ag deposits to the north (e.g. Guanajuato, Pachuca, and Fresnillo) by the trans-Mexican volcanic belt. This volcanic belt reflects a major strike slip fault which seems to have offset the precious metal belt (Salas, 1975 and Gastil, 1973). The silver and other hydrothermal mineral deposits in south central Mexico show a broad east-west (N70W) alignment, particularly in a 300 to 400 km radius of Huautla. Sixty km east of Huautla are located the famous silver mines of Taxco, Guerrero. The mineralization at Taxco is similar to that at Huautla, though most orebodies are in the subvolcanic basement, with only minor mineralization in the overlying volcanic rocks (Salas, 1975). Forty km southwest, mercury-antimony mineralization occurs in Cretaceous sediments (Maria, 1963). Stretching more than 100 km across southern Puebla, due east of Huautla, are numerous copper, lead, antimony, and silver deposits (Ugalde, 1972).

VOLCANIC STRATIGRAPHY

General

The exposed mid-Tertiary volcanic pile at Huautla is subdivided here into five major units and several additional subunits (Figure 5). Stratigraphic discrimination has been made on the basis of age relations, petrographic composition and field characteristics such as volcanic structures and alteration. Further subdivision is desirable in the vicinity of mineralized veins, though previous attempts met with little success (Campbell, 1978). Investigations of the stratigraphic controls on ore deposition at Huautla must be approached in the context of the district's overall stratigraphy. The recent mapping suggests the stratigraphic ore controls are much more complex than suggested by previously presented stratigraphic models (Rodriguez and others 1962, Campbell 1978).

Volcanism in the central Huautla district can be divided into four stages. The earliest stage of volcanism (#1) is uncertain as no base of the volcanic pile is observed in the study area. Regional mapping to the northwest (Fries, 1958) suggests the exposed Miocene intermediate composition volcanics are underlain by the late Oligocene Tilzapotla Rhyolite. The exposed volcanic pile includes two stages (#2 and #3) of intermediate composition dome-flow complexes separated by a volcanic hiatus (Figure 5). The Stage 2

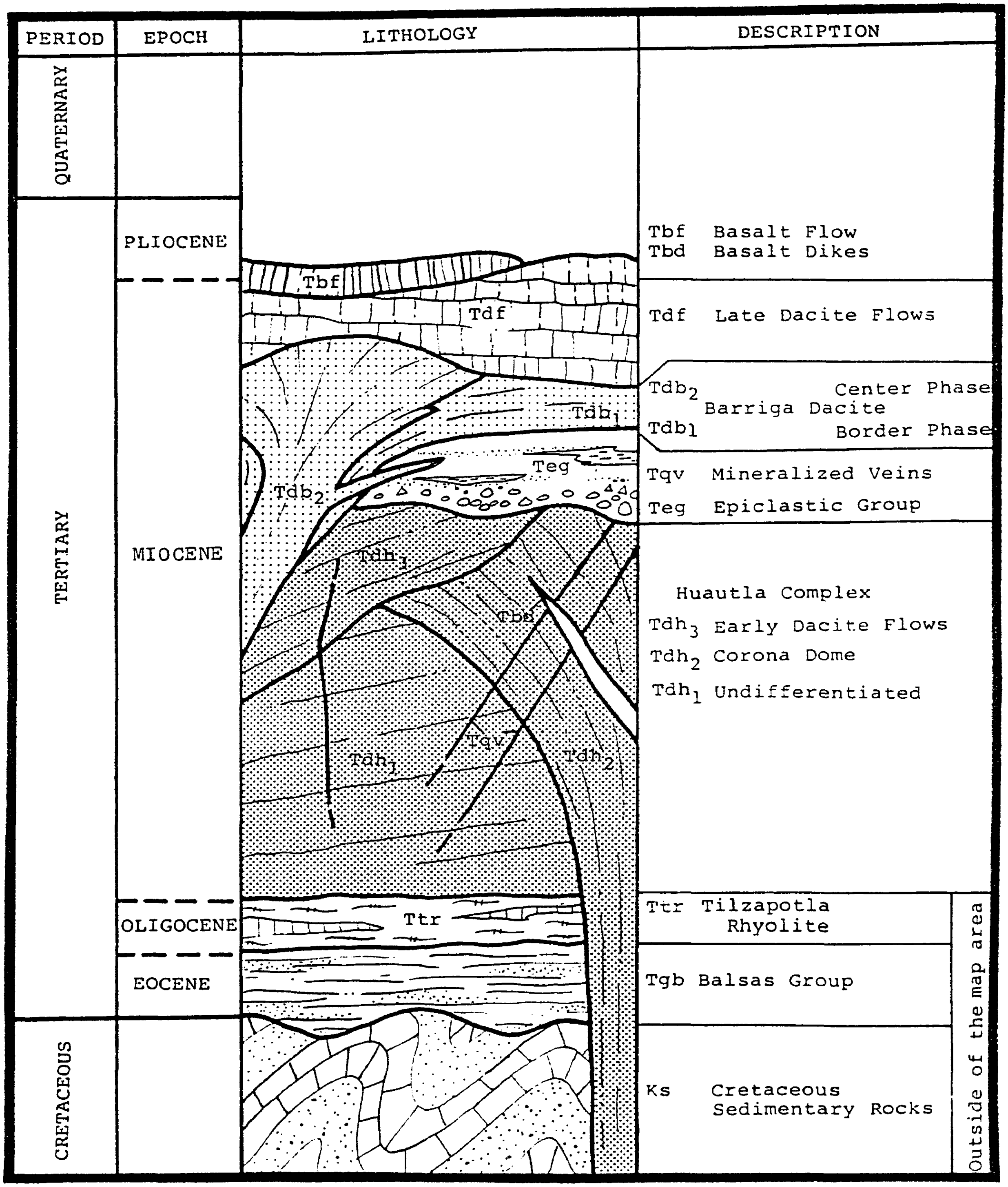


Figure 5. Generalized stratigraphic column of the Huautla district, Morelos, Mexico. The lower 3 units are not seen in the district, but are inferred by regional studies (Fries, 1959) to underlie it.

volcanics are both andesite and dacite compositions, while the Stage 3 units are only of dacite composition. The volcanic hiatus between Stages 2 and 3 is characterized by a thin group of volcaniclastic sediments. The final fourth stage of volcanism consists of strikingly different basaltic dikes and flows. Each of the three stages exposed at Huautla is discussed individually with their respective geologic units. The author has given informal stratigraphic names to the units defined in this study. The new stratigraphic designations are capitalized in this report for clarity. The major units are: the Huautla Complex, Barriga Dacite, Epiclastic Group, Late Dacite Flows, and Basalt Flow.

Huautla Complex

The products of the second stage of volcanism are grouped into a thick extrusive and shallow intrusive unit designated the Huautla Complex in this report. This unit has previously been named the Dacite, Trachyandesite, and Tlachichilpa Andesite (Rodriguez and others, 1962), Andesite Tuffs, and Dacite Tuffs (Campbell 1978) and frequently referred to as graywacke in drill logs.

Because it is the only ore host, subdivision of the Huautla Complex is important. Earlier investigators believed it was composed of nearly horizontal interstratified flow and tuff units. The steep flow banding characteristic of much of the Huautla Complex necessitated either extreme structural deformation or a reinterpretation of volcanic structures. The recognition of the shallow intrusive nature of much of the complex and resultant steep contacts solved the improbable structural constraints imposed by an interpretation of tilting of originally horizontal flow banding. Only three subdivisions were recognized with enough certainty to be presented in Plate 1. Field observations show there are undoubtedly more individual volcanic units (Figure 6). Their discrimination has been retarded by 1) rapid lateral variations in volcanic structures and textures due to multiple source vents, 2) complex faulting, 3) erosion and cover by younger units and 4) vegetation cover. Though the pervasive hydrothermal alteration has obscured field relations, it is also a positive indicator of the more altered Huautla Complex, as compared with the fresher, younger volcanic units.

Lithologic map symbols used in the plates and figures are abbreviations for age, predominant composition, unit name, and subgroup. For example, "Tdh_2" refers to Tertiary age, dacitic, Huautla Complex of the Corona dome subdivision.

The most easily recognized unit of the Huautla Complex is the truncated endogenous dome root exposed on the south side of the Arroyo Chico valley; hereafter called the Corona dome (Tdh_2) after the nearby Corona mine. The original Corona dome undoubtedly possessed high relief, surrounded by talus aprons, lava flows, and breccia flows. The shallower portions of the dome have not been recognized, and if preserved are probably included in the Undif-

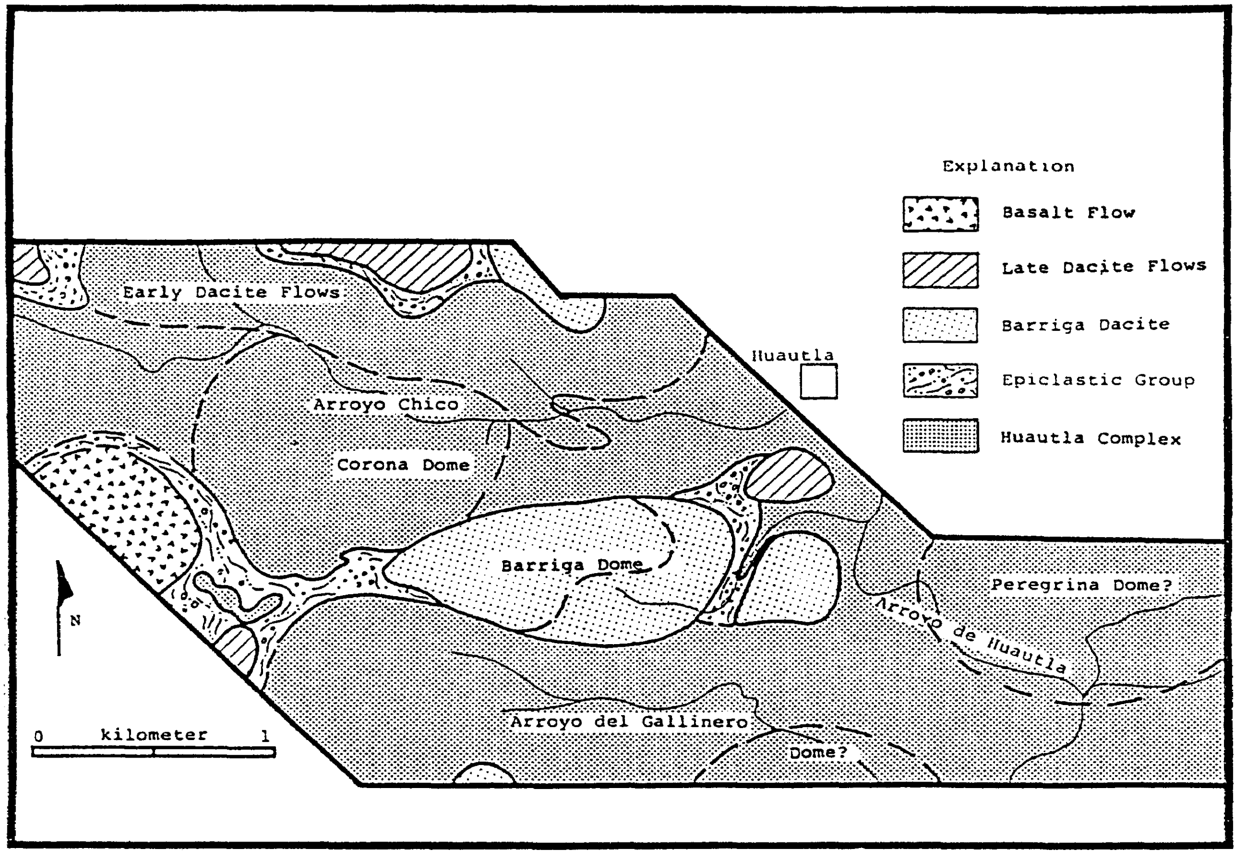


Figure 6. Simplified lithology map of the Huautla district, with structure and alteration features omitted.

ferentiated Huautla Complex (Tdh_1). Alteration and faulting have changed the originally grey porphyritic dacite to a variety of textures and an assortment of colors (e.g., green, purple, brown). Thus, it was the regular concentric flow banding pattern by which the unit was recognized (Figures 7 and 17). The flow banding steepens toward the southeastern corner of the dome's outcrop (Plate 1) suggesting the vent's center may have been the same as that of the younger dome at Cerro de Barriga de Plata. The southeastern corner of the dome's outcrop which is obscured by faulting and intense alteration may have been destroyed by post-emplacement gaseous explosions associated with either the Corona dome or the younger Barriga dome.

The Corona dome dacite is mineralogically typical of the Huautla Complex as a whole. The highly altered dacite usually contains 10% to 30% phenocrysts, of which at least 90% are zoned and altered plagioclase often totally replaced by clays. Alkali feldspars have not been recognized as phenocrysts. Biotite (1-6%) often occurs as fresh black phenocrysts even when the groundmass is extremely altered (Figure 24). Hornblende phenocrysts (0-3%) are more frequently altered. Quartz phenocrysts (0-3%) are always corroded or embayed and in cases of extreme alteration, may be the only hint of the original porphyritic textures. The groundmass of plagioclase laths in a fluidal texture has minor iron oxides, pyroxene, and possibly altered alkali feldspar and glass. The flow banding visible in hand

Figure 7. Outcrop of the central portion of the Corona dome of the Huautla Complex, exhibiting vertical flow banding which strikes toward the observer. The mortar and stone monument at the top is an old Spanish mining claim marker, near the Corona mine, west of the present mill and mine camp.

sample and outcrop appears to be due to fluctuating amounts of glass in the groundmass, with a weak color contrast caused by differential oxidation. Photomicrographs of Corona dome dacite and other Huautla Complex porphyries are included in the alteration section (Figures 22 and 24).

North of the Corona dome, across Arroyo Chico, is a second lithologic unit of the Huautla Complex. Lithologically similar to the older Corona dome, identification of these Early Dacite Flows (Tdh_3) has relied primarily on poorly exposed contact breccias and the consistent moderate angle (30°) north-dipping flow banding. Once again textures, composition, and colors vary considerably. The freshest rock is dark purple-grey and quite dense. Biotite and hornblende occur as phenocrysts, but their proportions vary and they may be absent megascopically. Flow breccias of conformable dip are frequently interstratified. Large volumes of these Early Dacite Flows are strongly altered to pale green-grey matrix with chalky plagioclase phenocrysts. Propylitic alteration is strongest in the flow breccia units, which were presumably more permeable, as well as in surface and subsurface exposures near the Santiago vein. The source of this massive pile of flows (200+ meters thick) is unknown. A source vent immediately north of the study area is likely, as shown in Plate 2.

Unfortunately, the majority of outcrops of the Huautla Complex could only be mapped as a unit collectively named the Undifferentiated Huautla Complex (Tdh_1). The Undifferentiated group comprises a large variety of compositions and textures. All are of intermediate composition and most are intensely altered. Original compositions include dacite, quartz-andesite, andesite, and trachyandesite. Frequently, distinct lithologies or textures were found separated by a contact or fault. Attempts at following these contacts frequently turned up only facies changes or alteration differences.

Even though the Undifferentiated Huautla Complex did not lend itself to mappable units, some speculations as to its morphology are warranted. Some units are structureless porphyries, which are difficult to decipher. But other areas include more diagnostic volcanic structures. Campbell (1978) described portions of the Huautla Complex as stratified tuffs of the older "Andesite series." Due to the abundance of large (2-20 cm) rounded lithic inclusions in the steeply banded unit, he referred to it as the "baseball tuff" (Figure 17). Field observations by the author showed the "tuff" to be steeply flow banded dacites and andesites of endogenous domes and their roots. This steep flow banding observed in Arroyo Chico is here interpreted as the northern edge of the Corona dome. Identical lithology and structures have been mapped in Arroyo Huautla, in front of the portal of the San Francisco and Perigrina mines, as well as in the western edge of the map area along Arroyo Saltire, near the Santa Cruz mine. These observations suggest that the remnants of another dacite-andesite dome, the "Peregrina dome", are centered approximately 250 meters south of the top of Cerro Peregrina (Figure 6).

The eastern edge of the approximately 1 square kilometer Perigrina dome is probably at the San Francisco mine on the steep hillside above the portal on Arroyo Huautla. One hundred meters north of the San Francisco vein are cliffs exposing coarse dacite breccia, and just south of the vein flow banding occurs in a random fashion suggesting a mega-breccia. Both breccia types may have resulted from the large talus fields that typically cover endogenous domes (Williams, 1932). If this is so, then the paleosurface at the time of formation of the Peregrina dome would be near the present surface, though relief above the dome center could have been several hundred meters higher. Steep flow banding and breccias suggest yet another dome may exist, centered below the southern map edge at Arroyo del Gallinero (Figure 6). Additional surface and mine mapping are necessary to confirm the limits of the dome structures.

Other areas of the Undifferentiated Huautla Complex are of even less certain origin. In the valley south of Cerro de Barriga de Plata, around the ghost town of Tlachichilpa (Plate 1), the low angle flow banding is irregular, but generally dipping at moderate angles to the north. These units may correlate with the Early Dacite Flows (Tdh_3) found on the slopes of Cerro de la Cienega north of Arroyo Chico. If this is so, then a large block comprising most of the southern study area was downdropped. The suspected preservation of the shallow talus apron at the Peregrina dome (as well as the vein character discussed later) supports the theory of major down dropping to the south. Insufficient mapping and intense alteration at the San Esteban Vein and around the town of Huautla did not allow the Huautla Complex to be differentiated further.

In summary, Stage 2 volcanism represented by the Huautla Complex has received a variety of designations by previous investigators (Figure 4). Many of the Huautla Complex's lithologies are porphyritic volcanic rocks of strikingly similar compositions and textures, which has led to confusion in field designation. Petrography has been less useful than volcanic structures in subdividing the complex. Total thickness of the complex is at least 600 meters, but may be considerably more. The formations below remain a mystery as the abundant lithic clasts, inclusions, and breccia fragments in the Stage 2 volcanic rocks are all of similar intermediate compositions. After the deposition of the Stage 2, Huautla Complex andesites and dacites, volcanism continued to Stage 3, but only with dacitic composition flows and domes. Topographic expression of the Huautla Complex is controlled more by post-depositional faulting and alteration than by volcanic stratigraphy. The Huautla Complex forms the lower half of most major valleys (Figure 2), with excellent exposures in most stream channels, but it also occurs as a hill and cliff former. As the Huautla Complex is the most intensely altered and faulted unit, and the only ore host in the mining district, it receives more attention in the following chapters.

Epiclastic Group

During deposition of the Huautla Complex there existed rugged hills representing the volcanic domes and lowlands covered by talus aprons and volcanic flows. The local district then experienced a period of volcanic quiesence accompanied by erosion and the unconformable deposition of volcaniclastic sediments, hereafter called the Epiclastic Group (Teg).

The duration of this period of quiesence is not known. It must have been long enough for several hundred meters of the top of the Corona dome to have been removed by erosion, before unconformable deposition of the Epiclastic Group. In other locations, such as Cerro Frio to the west and Cerro de la Cienega to the north, epiclastic deposition is still unconformable as shown by differences in dip between the older volcanic flow layering and younger sedimentary bedding, but amount of erosion cannot be estimated.

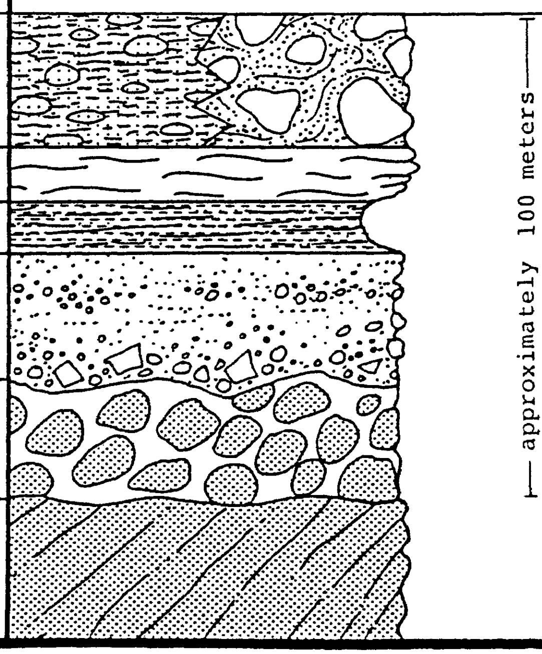
The Epiclastic Group is not important volumetrically (2 to 100 meters thick), but it is very important as a stratigraphic marker. Where this unit is found, it separates the potentially mineralized Stage 2 volcanics (Huautla Complex) from the lithologically similar third stage volcanics. Unfortunately, it has not been found in the southern map area where the stratigraphic control would be additional evidence for (or against) large scale down dropping discussed more in the structure section.

It would be expected that deposition of the many clastic facies would have been controlled by the extreme topography that usually exists in new volcanic fields. But in three sides of the Arroyo Chico valley (Cerro Frio, Cerro de la Cienaga and west Cerro de Barriga de Plata) the sediments occur at the same elevations (±50m) suggesting a subdued topography. East of Cerro de Barriga de Plata the clastic rocks appear again, though at a lower elevation and composed of different facies, they are correlated with the Epiclastic Group. This is justified due to their occurrence at the same stratigraphic horizon, between the Stage 2 volcanics (Huautla Complex) and younger Stage 3 volcanics. The Epiclastic Group thickens to the southwest as shown clearly in the road cuts of the new road to Xochipala. Though the exposure is excellent, it is not a good type locality. The clastic rocks are thick, up to 100 meters, in places steeply dipping and interbedded with small intermediate composition flows. The steep dips (70°) of the flow breccias, laharic breccias and conglomerates may be primary. Their dip away from the Corono dome and the dacite-andesite composition of the altered clasts in the monolithic breccias and lahars suggests their source may have been the talus apron which surrounded the Corona dome high. Large outcrops of Huautla Complex dacites and andesites in this area represent the remains of "islands" which rose above the epiclastic deposition.

It has been difficult to define the top and bottom of the Epiclastic Group, and which units are a facies of older or younger volcanics. The Epiclastic Group as here defined does contain occasional flow and flow-breccia units, as well as the more diagnostic volcaniclastic shales, sandstones, conglomerates, lahars and a thin tuff horizon (Figures 8 and 9). The monolithic flow breccias of andesite and dacite that occur at the Xochipala road cut to the west and the mine camp road cut (east of Barriga de Plata) are the best example of confusion in defining the bottom of the Epiclastic Group. The top of this group is clear at every occurrence except the western map area where the clastics are overlain not by the Stage 3 dacites, but instead by a Stage 4 basalt flow. Below the seemingly conformable basalt flow is a laharic breccia which probably had a source outside the map area. The conformity suggests this upper volcaniclastic unit could have been deposited anytime after Stage 2 volcanism and before Stage 4.

The field data are summarized in Figure 8 which provides an idealized detailed stratigraphic column of the Epiclastic Group along with a table illustrating which horizons were observed at the five major exposures.

The Epiclastic Group as a whole is less resistant than the volcanic rocks above and below. The wide expanses shown on the



Description	Lithology	Cerro Frio	Cerro de la Cienega	Xochipala road cut	west Barriga de Plata	east Barriga de Plata
Basalt Flow , Late Dacite Flows or Barriga Dacite						
Laharic Breccias & Flow Breccias (age uncertain)		X		X		
Thin Tuff		X	?	X	X	?
Shale & Sandstone		X	X	X	X	
Conglomerates, Fluvial & Laharic Breccias		X	X	X	X	X
Monolithic Flow Breccias				X		X
Huautla Complex						

Figure 8. Detailed stratigraphy of the Epiclastic Group, showing the complete sequence and mode of occurrence at each field locality.

Figure 9. Epiclastic Group outcrop (upper) near Cerro Frio showing the contact between tuff (T) and shale (S) members. Hand samples (lower) of the Epiclastic Group breccias show both volcanic (v) and sedimentary (s) textures. The scale is 15 cm long.

bedrock geology map (Plate 1) are misleading since the Epiclastics typically form the flatter topography on slope sides or ridge saddles with thicker alluvium and soil cover. Mapping contacts depend much on exposures in ravines, below protecting cliffs, float, and road cuts. Though this thin unit is easy to miss in the field, it will be important to note any new exposures, as a stratigraphic marker for lithology discrimination and interpreting later structural adjustments.

Late Dacite Volcanism and Intrusion

The third stage of volcanism and intrusion at Huautla consists of dacite domes, flows, and dikes. No andesites were deposited at this or later times. Once again the author has changed the terminology of the previous investigators. The Tuff of Rodriguez and others (1962) and the Tuff Agglomerate of Campbell (1978) are referred to here as the Barriga Dacite (Tdb), the Late Dacite Flows (Tdf) and the Intermediate Dikes. Each is distinct texturally and in volcanic structures. The Barriga Dacite and the associated Intermediate Dikes are thought to be oldest due to their greater degree of alteration, but no overlap exists between the exposures and they may in fact be contemporaneous. All of the units are less altered in general compared with the Huautla Complex.

Both the Barriga Dacite and Late Dacite Flows are identical mineralogically. Both are porphyritic-aphanitic, biotite-hornblende dacites. Compared to the Late Dacite Flows, quartz phenocrysts are larger and more abundant in the Barriga Dacite. Hornblende, biotite, and plagiclase phenocrysts are generally larger, more abundant, and more altered in the Barriga Dacite. The groundmass (of plagioclase, quartz, iron oxides, and glass) is glassier, darker, denser, and fresher in the Late Dacite Flows.

Barriga Dacite

The Barriga Dacite is named for its major outcrop and source vent at Cerro de Barriga de Plata. The name of this hill (Barriga de Plata; in English, Belly of Silver) is somewhat over optimistic. Age relations suggest the Barriga intrusion (before it broke the surface) or its deeper source pluton may have provided the heat which drove circulation of ore-bearing solutions.

The Barriga Dacite dome is a multiple dome, with two intrusive pulses using the same vent. The first phase, here called the Border phase (Tdb_1) occurs as the upper portions of a steeply flow-banded endogenous dome on the eastern half of Cerro de Barriga de Plata (Plates 1 and 2). This early dome had an extensive outflow facies, now preserved on hill tops to the north (Cerro de la Cienega), south and slopes to the east of the vent.

The second phase, or Central phase (Tdb_2), occurs only on the hill's rounded top (Plates 1 and 2). The well developed flow banding (Figure 10) shows clearly the steep interior flow banding which

0.5 mm

crossed polars

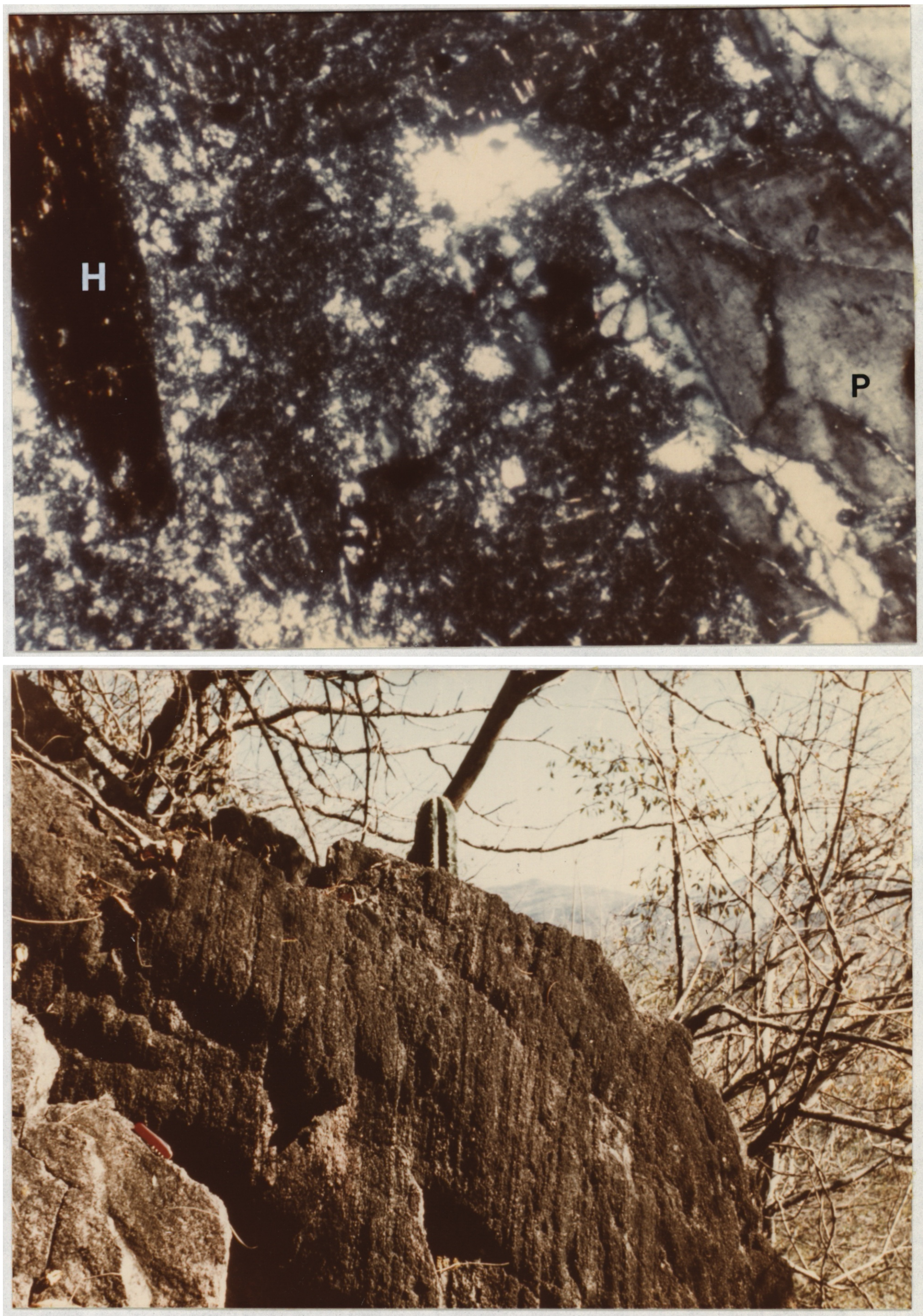


Figure 10. Barriga Dacite: photomicrograph (upper) with fresh plagioclase phenocryst (P) and altered hornblende (H), the blue color is due to a filter. outcrop (lower) of the steeply flow banded Central phase of the dacite dome at Cerro de Barriga de Plata.

flattens towards the outer margins reflecting lateral flow; an excellent example of an endogenous dome. On the northern contact with the Huautla Complex the Central Barriga Dacite contains breccia clasts of the Huautla Complex and possibly the Border phase.

Aphanitic dacite dikes and dikelets were intruded into the surrounding volcanics before and during emplacement of the Barriga dome. Ranging from 1.5 meters to 1 cm in width, the dikes and dikelets are abundant in the Huautla Complex (Tdh_1 and Tdh_2) and the Epiclastic Group. They are rarer in the Border phase (Tdb_1) and do not occur at all in the Central phase (Tdb_2) suggesting emplacement early in the dome forming process. The dike distribution shows a clear concentration within 350 m of the Barriga dome boundaries, which coincides with a propylitic alteration halo (Plate 1). The larger dikes (~1 m) are typically straight with numerous angular blocks of wallrock and stoped walls with irregular offshoots, suggesting forceful emplacement. The very abundant dikelets (average 5 cm) typically have irregular paths (Figure 11).

Mineralogically the Barriga Dacite is porphyritic-aphanitic biotite-hornblende dacite, and the Intermediate Dikes though aphanitic are thought to be the same dacitic composition. Phenocrysts are rounded and embayed quartz (2%), zoned plagioclase up to 1 cm long (10%), hornblende (2%), and biotite (2%), which are often altered to iron oxides (Figure 10). The groundmass is fluidal textured, with plagioclase laths, minor quartz, alkali feldspar(?),

Figure 11. Intermediate composition dikelet (D), cutting the Huautla Complex, in an irregular path. The exposure is a road-cut just north of Cerro de Barriga de Plata, and within the zone of intense dike intrusion and alteration that surrounds the Barriga dome. White altered plagioclase phenocrysts and fresh hornblende and biotite phenocrysts can be seen as white and black dots in the Huautla Complex. Note the chloritic selvage (C) above and to the right of the 15 cm scale.

iron oxides, and glass. Compared with similar dacites of other ages, the Barriga Dacite is lighter in color, light grey to pink, and with larger and more abundant phenocrysts.

Late Dacite Flows

The Late Dacite Flows receive only cursory description as they are neither complex nor associated with significant structure, alteration or mineralization, as are the Barriga Dacite and related Intermediate Dikes.

The Late Dacite Flows cap the ridges at Cerro de la Cienega, Cerro Frio and hills in the southwestern map area. Topography and vegetation suggest they also cap many of the hills in the surrounding countryside outside the study area. Just south of the town of Huautla is a low knoll, mapped as Late Dacite Flows based on textures, mineralogy, and lack of alteration. Flow banding suggests the knoll is a small vent though it may be a flow remnant.

The Late Dacite Flows are typically dense, fresh porphyries of dark purplish-grey hornblende dacite or hornblende-biotite dacite. Alteration is limited to hematite banding in the trachytic, hypo-crystalline groundmass and quartz fillings in the base of horizon-tally-elongate 2 cm vesicles. The phenocrysts are plagioclase, biotite, and hornblende, as in the Barriga Dacite, but fresher. Volcanic structures consist of nearly horizontal flow banding and rare columnar jointing (Figure 12). Late Dacite Flows form stepped

Figure 12. Late Dacite Flows exposed in an outcrop on Cerro de la Cienega, showing columnar jointing and nearly horizontal flow banding.

cliffs; each step representing a flow unit. At Cerro de la Cienega five or more flows are stacked; other exposures contain less. To the north and west, outside of the map area, flow breccias of similar composition and textures overly the stacked flows.

Basaltic Volcanism

The youngest and freshest volcanic unit in the Huautla district is the Stage 4 Basaltic Flow (Tbf) and associated dikes (Tbd). A Basalt Flow occurs in the southwestern portion of the study area, and is exposed best in the roadcut on the new road to Xochipala (Figure 19). This fresh, grey, nearly horizontal basalt flow is less than 30 m thick and rests conformably on the flows, lahars, and breccias of the Epiclastic Group. The age is presumably early Pliocene or late Miocene, though the basalt could be even younger and related to Pleistocene basaltic volcanism associated with the trans-Mexican volcanic belt to the north.

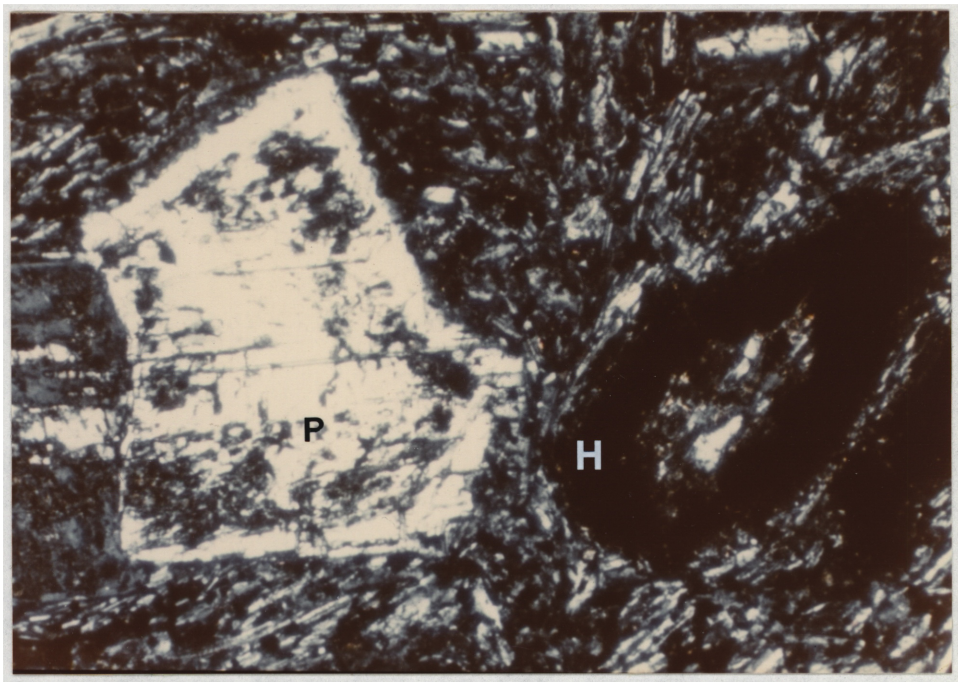
The Basalt Flow forms a broad, smooth, roughly synform saddle now covered with soil and under cultivation. The roadcut shows horizontal flow banding and numerous east-west trending faults with envelopes of strong jointing and weathering (Figure 19).

Basalt Dikes are observed in the workings at the Santa Anna mine (Figure 13) reportedly at the Santiago mine and at the America mine 3 km north of the study area (Campbell, 1978). The near vertical dikes are typically 1 m wide, cutting the veins and faults with their

Figure 13. Basalt Dike exposed in old workings of the San Francisco mine. The dike is 1 m wide with horizontal columnar jointing. The right side of the dike is altered and friable, which in the workings below, is shown to result from calcite and zeolite saturation.

north-south trend, which suggests emplacement under a very different structural regime. The basalt dikes show greater alteration than the flow. The host Huautla Complex exhibits minimal dike-related alteration, though the dikes themselves are saturated with calcite (and zeolite?) and cut by numerous calcite veinlets.

The Basalt Flow is porphyritic with distinctive altered hornblende phenocrysts (7%), twinned, normal and reversed zoned plagioclase phenocrysts (2%), and a groundmass of plagioclase laths forming a fluidal texture with interstitial pyroxene, glass, and iron oxides. The hornblende phenocrysts are obvious on weathered surfaces as dark hollow rods or loop shapes. Under magnification (Figure 14) they can be seen as extremely altered hornblende centers surrounded by opaque reaction rims probably a mixture of pyroxene, magnetite, feldspar, and indeterminate mineral. Moorhouse (1959) suggests this type of alteration is deuteric rather than hydrothermal, related to rapid temperature change resulting from degassing of the lava upon extrusion.



0.5 mm crossed polars

Figure 14. Photomicrograph of the Basalt Flow, showing a zoned plagioclase phenocryst (P) and an altered hornblende phenocryst (H) with opaque reaction rims, probably a mixture of pyroxene, magnetite, feldspar and indeterminate mineral. The trachytic groundmass of plagioclase laths is blue because a filter was used during picture taking.

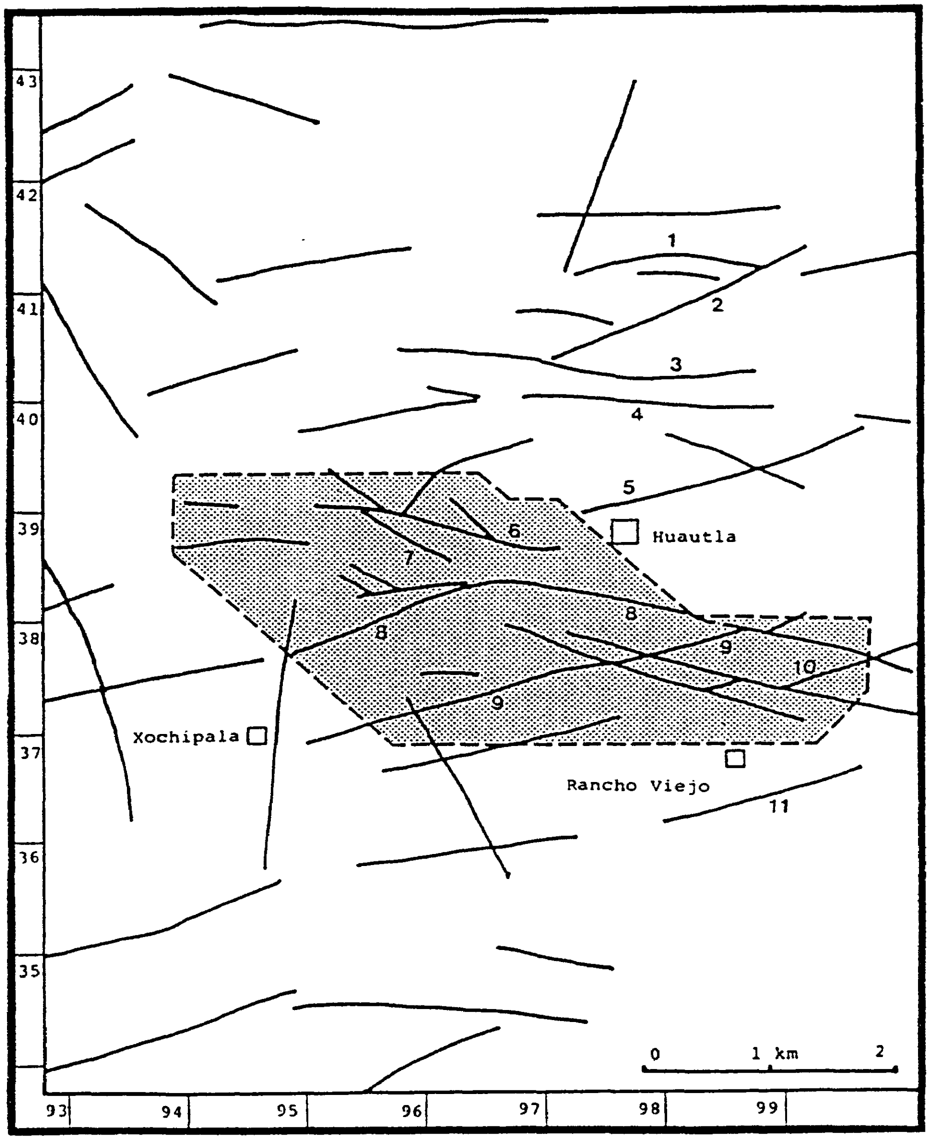
STRUCTURAL GEOLOGY

General

Throughout Tertiary time both tectonism and volcanism were active in southern Mexico. The Huautla district underwent a structural history much the same as the other deposits of the silver belt extending northward into the western United States. Simply stated, the common model begins with the rise of a deep batholith along zones of crustal weakness and results in repeated volcanism and intrusion. Local arching of the host rock by intrusion created tensional fractures and normal faults. Based on isotopic and fluid inclusion studies at similar deposits, an inference can be made that these structures provided the channelways for deep circulation and heating of meteoric waters, which in turn formed wallrock alteration and vein filling. Before the Huautla structures are described in detail, the structural model is examined as it applies to the Huautla region in general.

As Figure 15 shows, the Huautla region exhibits a very definite east-west structural trend, which is actually composed of two persistent fault sets trending N70E and N70W. This trend is as consistent over time as it is space. It persisted over the entire span of volcanism, implying that once the fracture pattern was initiated (possibly by basement trends) all succeeding structural adjustments took place along the established planes of weakness.

The fracturing pattern of the older units of the volcanic pile suggest tensional tectonics, which were possibly created by crustal extension due to regional uplift by a buried pluton and local uplifting by intrusions such as the Corona and Barriga domes which reached the surface. Localities showing similar volcano tectonic structures and mineralization include Ocampo, Chihuahua, (Clark and others, 1979), Julican, Peru (Peterson and others, 1977), and Bodie, California (O'Neil and others, 1973). The tensional fractures at Huautla are similar to longitudinal and transverse fractures that formed over elongate uplifts such as described at Bodie and Ocampo by Wisser (1960). As volcanism continued at Huautla the initial tensional fractures experienced numerous periods of normal movement, the creation of parallel and antithetic faults, the propagation of the same faults into post-arching overlying volcanic flows and the formation of major late faults following the same east-west trend. The faults belong to two sets, ore-stage and post-ore, both with east-west trends and post-ore, north-south trending faults. The east-west faults extend many kilometers north and south of Huautla. The known mineralized faults extend from the America Vein (north) to the Victoria vein (south) (Figure 15). The structural observations for this study were only made in the central Huautla district (Figure 15), but probably typify the area as a whole.



1. America Vein
2. Povorines Fault
3. Las Animas Vein
4. El Clarian Vein
5. La Union Vein
6. Santiago Vein
7. San Jose Vein
8. Huautla Fault
9. Santa Anna Vein
10. Plomosa Vein
11. Victoria Vein

Figure 15. Regional fault pattern at Huautla, showing the major faults and veins. The shaded region represents the study area, for which detailed structure is presented in Figure 16 and Plate 1. The structural pattern outside the study area is derived from the Mexican government map (E-14-A-69) and from Rosario Resources files.

Ore-Stage Faults

The group of ore-stage faults include faults and fractures that formed during and after deposition of the Huautla Complex, but before mineralization had ceased. All known ore-stage faults have an east-west trend, and contain vein material. Rodriguez and others (1962) have referred to pre-ore or ore-stage faults with a north-south trend in the Huautla district, but no such early north-south faults were observed by the author. As the individual structures are discussed in the text, the numbers which follow refer to their locations on Figure 16. Within the map area the veins (ore-stage faults) can be divided into four major systems; the Santiago (2-5), the San Jose (1, 6, 7), the Santa Anna (9, 10, 11, 12), and the Reforma (13, 14) systems.

Faulting was continuous throughout the period of mineralization. This is evident in the north where the San Jose vein system (1, 6) is offset by the Santiago vein system (2, 4), which in turn is offset by the El Loco vein (3). The southern vein systems, the Santa Anna, and Reforma, do not show patterns of veins offsetting veins. Instead, displacements during mineralization occurred along the same fault planes as shown by vein textures with at least four periods of vein filling separated by periods of brecciation (Figure 23). The greatest principle stress axis was nearly vertical due to structural doming and intrusion. The nearly horizontal intermediate and least principle stress axes may have locally rotated counter clockwise

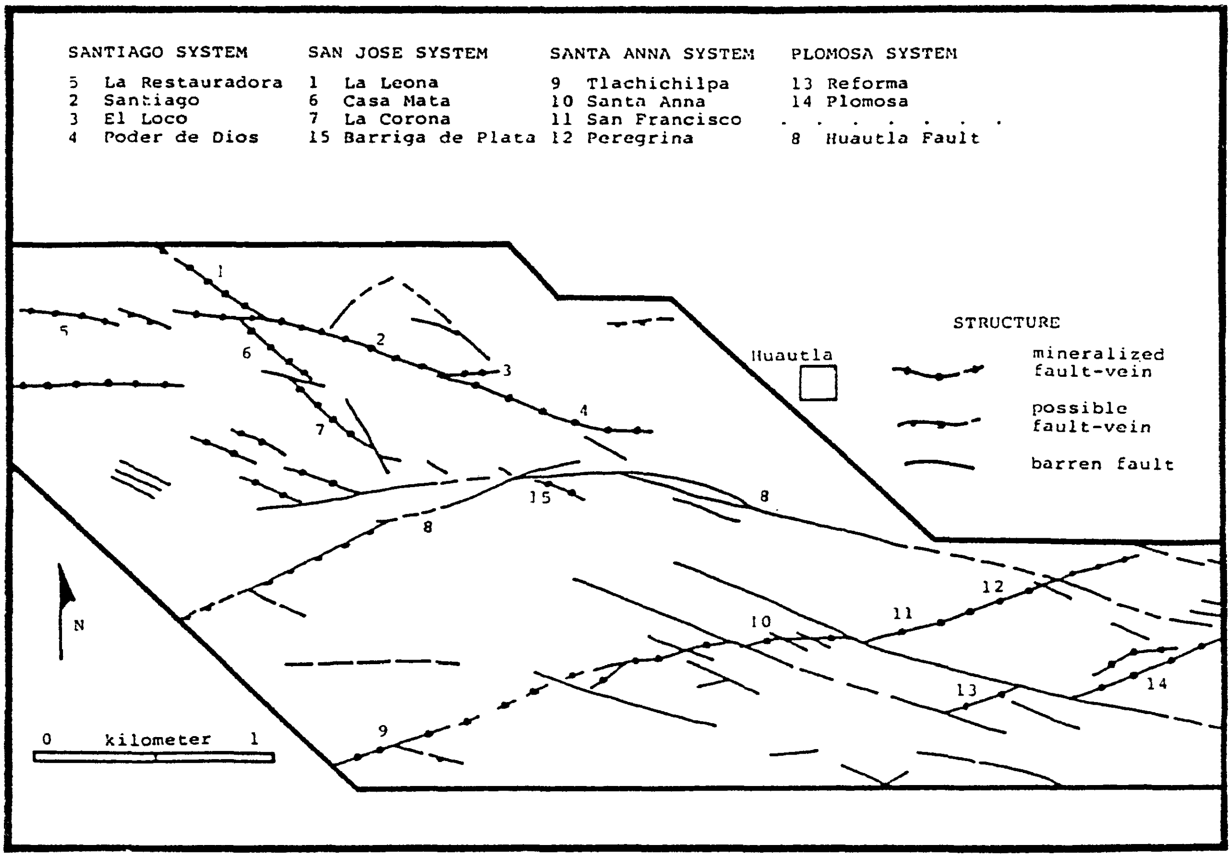


Figure 16. Generalized fault and fracture map of the Huautla district, showing the major vein systems.

during mineralization as suggested by the changing strikes over time of the San Jose, Santiago, and El Loco veins.

The ore-stage faults are characterized by persistent strikes (N70W and N70E), south dips (50-80°), thick breccia and gauge zones (1 to 3 m wide), frequent fault branching, parallel faults, and strong alteration envelopes. Perturbations in fault strike and dip increase the thickness of brecciation in one or both fault walls, but with no consistent pattern. Usually the hanging wall shows intense oxidation and brecciation which grades over a distance of 1 to 4 m into unfractured wall rock. The more confined foot wall generally is a sharply defined fault plane. Changes in vein attitude have often reversed this relationship, sometimes repeatably in the same fault (or vein).

Numerous small scale structures were formed during emplacement of the Huautla Complex domes. These features are similar to those described by Williams (1932) at the domes of Lassen Peak, California. Slickensides paralleling flowbanding or in seemingly random orientations near the margins of dome roots indicate there was considerable movement of the viscous lavas during solidification. Figure 17 illustrates another small-scale deformation feature that presumably formed during dome emplacement. Here a brittle xenolith is fractured and displaced while the porphyritic host, which was more plastic, is not offset.

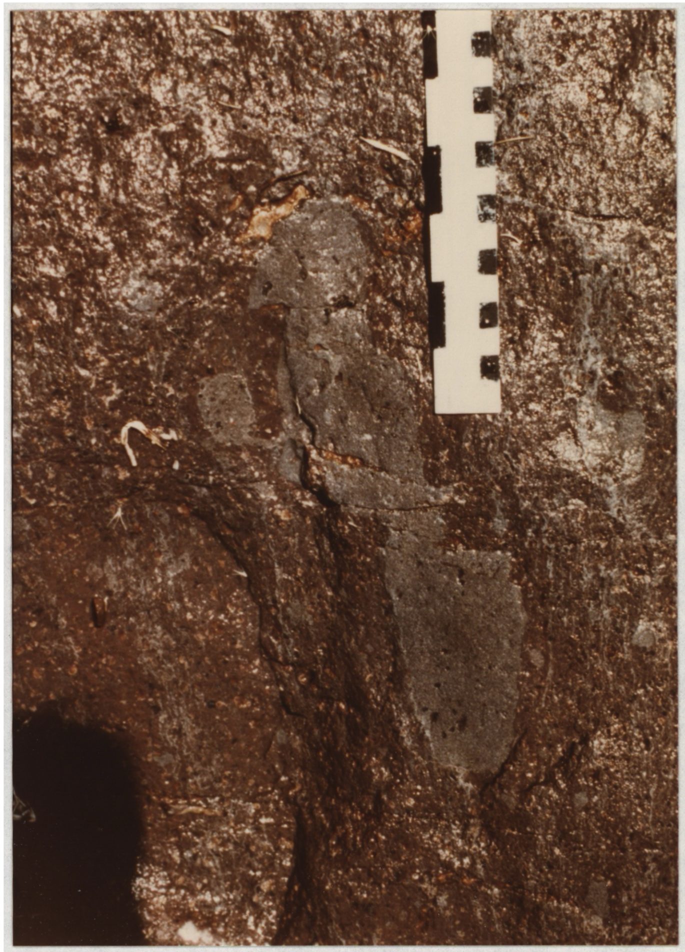


Figure 17. A lithic inclusion in the steeply flow banded Huautla Complex in Arroyo Saltire, showing displacement by small-scale faults. The steep flow banding (vertical in the photograph) is paralleled by specular hematite and silicification (not visible). The scale is 15 cm long.

Post-Ore Faults

The post-ore structures consist of three varieties: persistent N70W and N70E faulting formed during emplacement of the Barriga dome, weak north-south faulting and basalt diking and rejuvenated N70W faulting in the young basalt flows. Cross-cutting features at Cerro de Barriga de Plata show the first post-ore faults formed during and possibly due to the rise of the Barriga dome, but before the final Central phase Barriga Dacite broke the surface. Their persistent strike shows the identical trends observed in the pre-ore faults (N70E and N70W), suggesting influence by the same tectonic forces or basement trends. A curious pattern has developed though, in the north where the veins trend N70W, the later faulting trends the opposite N70E (Figure 16). The reverse relationship is seen in the south where the N70E vein trend is offset by N70W faults. The faults of this group typically have clean polished slickensided fault planes. A typical exposure, in Figure 18, shows characteristic low angle slickensides and strong hematite. The fault breccia and gouge is usually oxidized and less than 1 m wide.

A major fault of this episode stretches east-west across the entire map area (8). The extreme length and width of this diffuse fault zone has inspired the author to name it the "Huautla Fault." In the west, alteration and quartz filling indicates the Huautla Fault may follow an ore-stage fault, but along most of its length it traverses typical unmineralized pervasively altered dacites and

Figure 18. A post-ore fault outcrop, cutting the Huautla Complex-Early Dacite Flows, 300 m west of the Santiago mine shaft. The slickensided, hematite-rich fault plane is typical of the post-ore faults. The moderate propylitic alteration visible in the wall rock results from the nearby Santiago vein.

andesites of the Huautla Complex. The Huautla fault zone shows numerous branching and parallel fractures with slickensides of every orientation. The timing of its formation, between phases of Barriga dome emplacement, and its curve paralleling and dipping into the Barriga dome contact infer its sense of displacement to be reverse, uplifted by the rising dome.

The other post-ore faults formed much later (perhaps as young as the Pliocene) and are associated with basaltic volcanism. Basalt Dikes cut veins and fill north trending fractures in the San Francisco (11), Santiago (2), and America veins (Figure 13). Rodriguez and others (1962) mention this late N-S fault trend, but the many N-S faults they mapped could not be substantiated, though the topography and joint patterns do support their existence. The Basalt Flow in the western map area is cut by several parallel N70W faults (Figure 19) which are presumably the earlier structures propagated upward into the younger units, and show very little displacement.

Structural Summary

The major faulting in the Huautla District referred to as east-west trending, is actually two sets dipping south and trending approximately N70E and N70W. Though possibly initiated by a pre-volcanic deep-seated crustal weakness, once initiated the trends continued to be reactivated throughout mid- and late Tertiary

Figure 19. Basalt Flow exposed in the Xochipala roadcut, at the western margin of the map area. The horizontally flow banded outcrop is cut by a vertical fault (center), which contains argillic altered breccia (X), is surrounded by weathered, vertical joints.

volcanism and tectonism. Fault patterns suggest the ore stage faults may have formed by regional arching and tensional forces. Before, during, and after mineralization movement continued on these faults. Alteration accompanying mineralization frequently included silicification which produced linear resistant outcrops resulting in drainage patterns running parallel to but not on the structures. Post-ore faults are recognizable by distinctly different outcrop (competent walls) and lack of alteration. Discriminating between the similarly trending fault types is important in recognizing veins or faulted orebodies.

Displacement along individual structures has been difficult to estimate due to the similar lithologies. Also, when slickensides do occur, they show a variety of directions resulting from the numerous faulting episodes. Most ore-stage faulting is thought to have normal movement, which with the general south dips of the E-W faults, leads to a gradual down dropping to the south. The post-ore faults probably also had normal movement, but with a strong strike-slip component. Though earlier workers (Malouf and others, 1973) have suggested a strike-slip displacement of over 3 km, the author's observations infer most separation is due to slip from vertical displacement, not strike-slip displacement. The vertical stresses acting on normal faults have lowered and possibly tilted the southern study area as inferred by volcanic stratigraphy, vein mineralogy, and types of hydrothermal alteration.

MINERALIZATION AND ALTERATION

General

The mineralization at the Huautla silver district is in many respects typical of Mexican epithermal precious metal deposits. Characteristics of a "typical" epithermal deposit have been summarized by Wisser (1966), Sillitoe (1973), and Buchanan (1981). An abbreviated list of their characteristics is presented in Table 1, with the characteristics of the Huautla district. The deposits are classified as "epithermal" in a genetic sense, rather than the strict temperature-depth definition originally proposed in Lindgren's classification (1933).

Huautla mineralization closely resembles that found in other districts where more complete geochemical studies have been done. This suggests that the genetic and geochemical models, developed at these similar, but well studied deposits, may also apply to the Huautla district. The model is described by numerous authors, such as Sillitoe (1973) and Buchanan (1981).

A very brief summary of the mineralization model is as follows: Ore and gangue minerals are precipitated from low temperature (200-300°C) hydrothermal solutions, of meteoric origin, with or without significant magmatic water contribution. Driven by the heat from adjacent intrusion, the ore-bearing fluids rise through fractures, depositing ore due to change in character of the fluid and its con-

CHARACTERISTICS OF EPITHERMAL AG-DEPOSITS

A.	Ore Host	1)	Early to Late Tertiary in age	-
		2)	calc-alkaline volcanic pile	-
		3)	local anticline or doming associated with ore	?
B.	Ore Shoots	1)	occupy pre-existing fractures	-
		2)	occupy isolated zones within veins	-
		3)	more structurally constricted with depth	-
		4)	end at definite upper and lower elevations	-
		5)	more persistent laterally than vertically	-
		6)	deposited 100 to 600 m below paleosurface at time of formation	-
		7)	base metals and gangue persist below ore-zone	-
		8)	brecciation occurred during vein formation	-
		9)	vein textures (crustified, colloform, drusy) indicate low confining pressures	-
C.	Mineralogy	1)	ore minerals are acanthite and sulfosalts	x?
		2)	gangue is mostly quartz with minor calcite	-
		3)	gangue also includes adularia, barite, fluorite, pyrite	x
D.	Alteration	1)	wide propylitic alteration	-
		2)	sericitic, alunitic, potassic alteration close to veins	x
		3)	argillic, silicic (chloritic) alteration close to veins	-

Table 1. The general characteristics of epithermal silver deposits are summarized from published syntheses by Wisser (1966), Sillitoe (1973), and Buchanan (1981). Characteristics not present at the Huautla silver district are marked with an "x" or a "?".

stituents. Solution cooling, mixing, and reaction with wall rocks cause the change in character of the fluids. A more rapid change in the fluids and possible concentration of ore will occur at a physio-chemical barrier, such as a level of boiling.

Though there is no direct evidence for boiling at Huautla, speculation of how the above model might apply to the Huautla deposits is discussed, after presentation of the field and laboratory observations.

In this section, descriptions of orebody form and primary mineralization are followed by descriptions of ore-stage hydrothermal alteration, post-ore hydrothermal alteration, erosion, weathering, and secondary enrichment of orebodies. The mineral paragenetic sequence, in Figure 20, provides a graphical summary of the mineralization and alteration process at Huautla.

The alteration types (propylitic, argillic, zeolitic, and silicic) can be distinguished at the scale mapped, but too often their discrimination is tenuous, due to their gradational contacts and superposition. The relative homogeneity of the Huautla Complex lithologies leads to only weak stratigraphic control on alteration products. Future exploration-oriented studies should concentrate on the vein-related, ore-stage alteration, as distinct from the post-ore Barriga dome-related propylitization and hot spring alteration products.

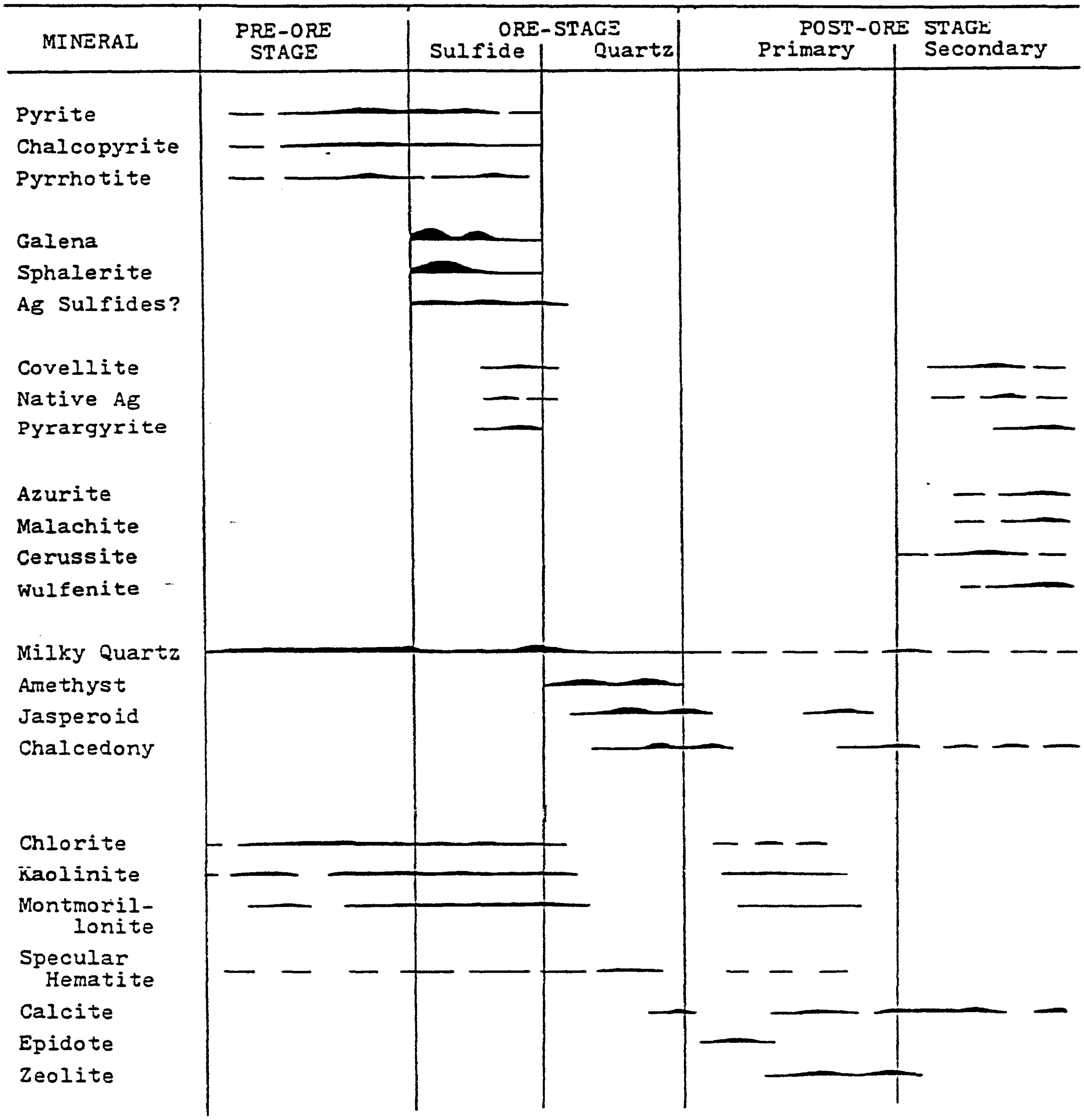


Figure 20. Mineral paragenesis diagram for the Huautla silver district.

Orebodies

The form of the orebodies is generally tabular with persistent strikes (N70E to N70W) and moderate dips (50°-70°) to the south. The appropriately named "El Loco" vein, with its steep north dip, is the major exception. The faults containing the orebodies are extremely persistent in strike, greater than 5 km in the Santa Anna system, and consist of numerous parallel, branching, and intersecting structures (Figure 16 and Plate 1). Usually only one vein in a fault zone is significantly mineralized and not all of this contains mineralization. Orebodies occur intermittently along the veins, which are presumably interconnected at depth.

The character of ore deposits change from north to south in the central mining district. Ores in the northern veins have simpler mineralogy, are finer grained, and occur in gouge zones. The southern ores consist of complex breccias with very strong silicification and open-space quartz of numerous generations. Secondary mineralization in the north is apparently not substantial and what existed is mined out. The secondary mineralization in the south is a much more complex assemblage and shows open space textures.

The ore occurs in silicified fault breccias or in lenses on the shattered walls of the main or subsidiary veins. Replacement of wallrock by mineralization is very minor. Often one of the walls is competent, while the brecciated opposite wall contains mineralization in fractures resembling a stockwork. This brecciation resulted from movement, at changes in the fault-plane strike or dip. The width of individual ore shoots range from 1 cm to possibly as much as 10 m, but most deep economic zones are 1 m wide (Figure 21). The orebodies are more persistent laterally than vertically. The vertical productive range of ore shoots has been over 200 m, but is usually less due to loss of silver values with depth or flooding of the workings with water. Laterally, orebodies can be several hundred meters long (as at the Peregrina mine). But these are often shorter due to pinching out or offset (1 to 100 m) by post-ore faults, as at the Santa Anna/San Francisco mines.

Primary mineralization has been richest at changes in vein attitude and at vein intersections. Secondary enrichment has increased ore grade, particularly near the surface and at channels of permeability such as intersections of veins and post-ore faults. The oxidized "bonanza" ores worked since colonial times were noted for their richness. According to Brinsmade (1922) 10 kg/ton (320 oz/ton) Ag was often attained by hand sorting and 60 to 80 kg/ton (1927 to 2569 oz/ton) Ag was occasionally reached in the Santa Anna mine as late as 1900. Today at the Victoria vein, located 1 km south of the map area, similar supergene ore with at least 1 kg/ton (32 oz/ton) Ag is being extracted. Oxides, sulfides, and visible native silver occur together.

The present mill feed is a mixture of ores from several mines and old tailings. The ores, whether they are dark green gouge or

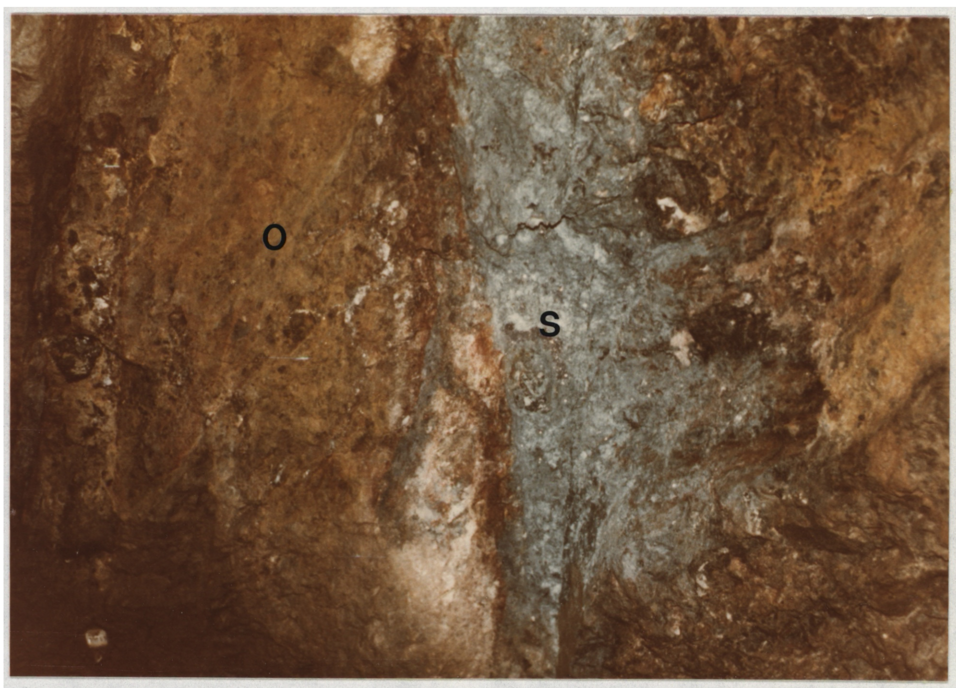


Figure 21. Underground view of the vertical Santiago vein. The field of view is approximately 2 m across. The wall rock to the left is competent, while the right wall is brecciated and mineralized. The green, chlorite-rich, sulfide ore (S) and the yellow-brown, oxidized ore (O) both contain several kg/ton silver.

brecciated and enclosed in quartz or even thoroughly oxidized often contain several kg/ton silver, although it is rarely visible. The presently active mines are the Peregrina and San Francisco on the Santa Anna system, the Santiago mine, the Victoria mine, and mines north of the map area on the America vein.

Veins are expressed at the surface either as shallow depressions with quartz float and hematite staining, or as resistant quartz breccia outcrops. Most veins are marked by pits, trenches, and collapsed shafts. In drill cores, the massive grey "fresh" dacite porphyry grades into dark red to brown, heavily fractured porphyry with increasing amounts of calcite and hematite on fractures as the vein is approached. Though core recovery is usually low at structures, green chlorite, quartz breccia, and sulfides are encountered at the vein.

Mineralization and Ore-Stage Alteration

All mineralization in the Huautla district occurs in the dacites and andesites of the Huautla Complex. This unit is the host rock not because of favorable chemical composition, but because of strong structural preparation and the fact that it was the only lithology present during mineralization. The Huautla Complex exhibits pervasive propylitic alteration from two periods, during Huautla Complex deposition and during Barriga dome emplacement (Figure 27). The early propylitic alteration, though not zoned about veins, was controlled by volcanic structures such as contacts or permeable breccia horizons. The mafic minerals, particularly the amphiboles and pyroxenes, were altered to chlorite and iron oxides, and the plagioclases were altered to clay minerals.

The fractures created by intrusive and volcanic doming were filled with vein material as the zoned alteration envelopes formed. Large- and small-scale cross-cutting relationships, including numerous brecciation episodes, show the formation of ore, gangue, and alteration went through several stages. Different fractures and parts of fractures were open for various episodes of the vein filling. In general, the Santiago system best shows the early stages (Figure 21) while the Santa Anna vein system has a more complete record of the later stages of vein filling (Figure 23). The general sequence is one of coarse-grained base metal sulfide deposition followed by brecciation and deposition of fine-grained sulfides (and native silver?), followed again by brecciation and quartz gangue. The quartz is of multiple generations in banded veins of amethyst, chalcedony, jasper, and milky quartz, in a variety of textures (Figure 23).

Mineralization began with precipitation of intergrown galena, iron-poor sphalerite, and minor quartz. Covellite is commonly intergrown with galena. A silver mineral tentatively identified as pyrargyrite occurs as inclusions in galena. Metallurgical flotation testing has shown the galena to be low in silver (Cyanamid, 1968). The early coarse-grained lead, (copper) and zinc deposition was immediately followed by deposition of fine-grained iron, copper, and silver sulfides, quartz, chlorite, and clays. Identification of sulfides in this late grey-green ore is difficult due to their fine-grained nature, but tentative identification of minerals and their zoning patterns is possible. The central portions of the veins are friable. The outer portions are silicified with weak disseminated iron and iron-copper sulfides: fine-grained pyrite, pyrrhotite, and chalcopyrite. Pyrite is absent in the main mineralized zones. The friable central mineralization contains the copper and silver sulfide ores. Copper sulfide (covellite) was observed in polished section. Other than pyrargyrite and native silver, no silver minerals could be identified. The copper-silver sulfide, stromeyerite, has been reported (Wittich 1923, Malouf and others, 1973) though not substantiated, and it very possibly occurs in this episode of vein filling. Silver sulfide (acanthite) could not be identified in polished sections.

The deposition of sulfides and gangue was accompanied by intense wall rock alteration. Gangue in the central vein consist of chlorite, kaolinite, specular hematite, and altered rock flour from fault gouge. X-ray diffraction was used to identify the clay minerals. The kaolinite-chlorite gangue grades outward to quartz-chlorite altered wall rock with minor disseminated pyrite, and then to a wide zone, (up to 100 m) of montmorillonite and quartz (Figure 22). The central argillic alteration, just described, grades outward into propylitized and silicified wall rock. The ore-stage propylitic alteration often grades imperceptibly into rock which was subject to propylitic alteration during subsequent events. The silicification, when it is present, gives the rock a fresh appearance and its resistance to weathering results in cliffs or topographic highs paralleling veins. Though wall rocks have been intensely altered, mineralization is by open-space filling, and not by wall rock replacement.

Immediately following sulfide ore deposition was a period of brecciation and intense quartz gangue deposition. The ore brecciation occurred in all vein structures. The thick quartz vein filling occurs mostly in the southern veins (Santa Anna system) which were open, while the Santiago system remained sealed with gouge and ore. The brecciated ore occurs both as blocks (2-30 cm) surrounded by quartz and as milky quartz darkened by microscopic and larger fragments of galena, sphalerite, and fine-grained chlorite and clays. At times the silicified wall rock and milky quartz-pyrite margins of the veins form quartz-"marbles", i.e., resistant fragments rolled along the walls of faults and now contained in a gouge matrix.

The quartz episode of vein filling resulted in deposition of a remarkable variety of quartz types. Textures include; crustified, drusy cavities, comb and cockade textures, amethyst, crypto-crystalline quartz or jasper, and chalcedony. Brecciation continued

0.5
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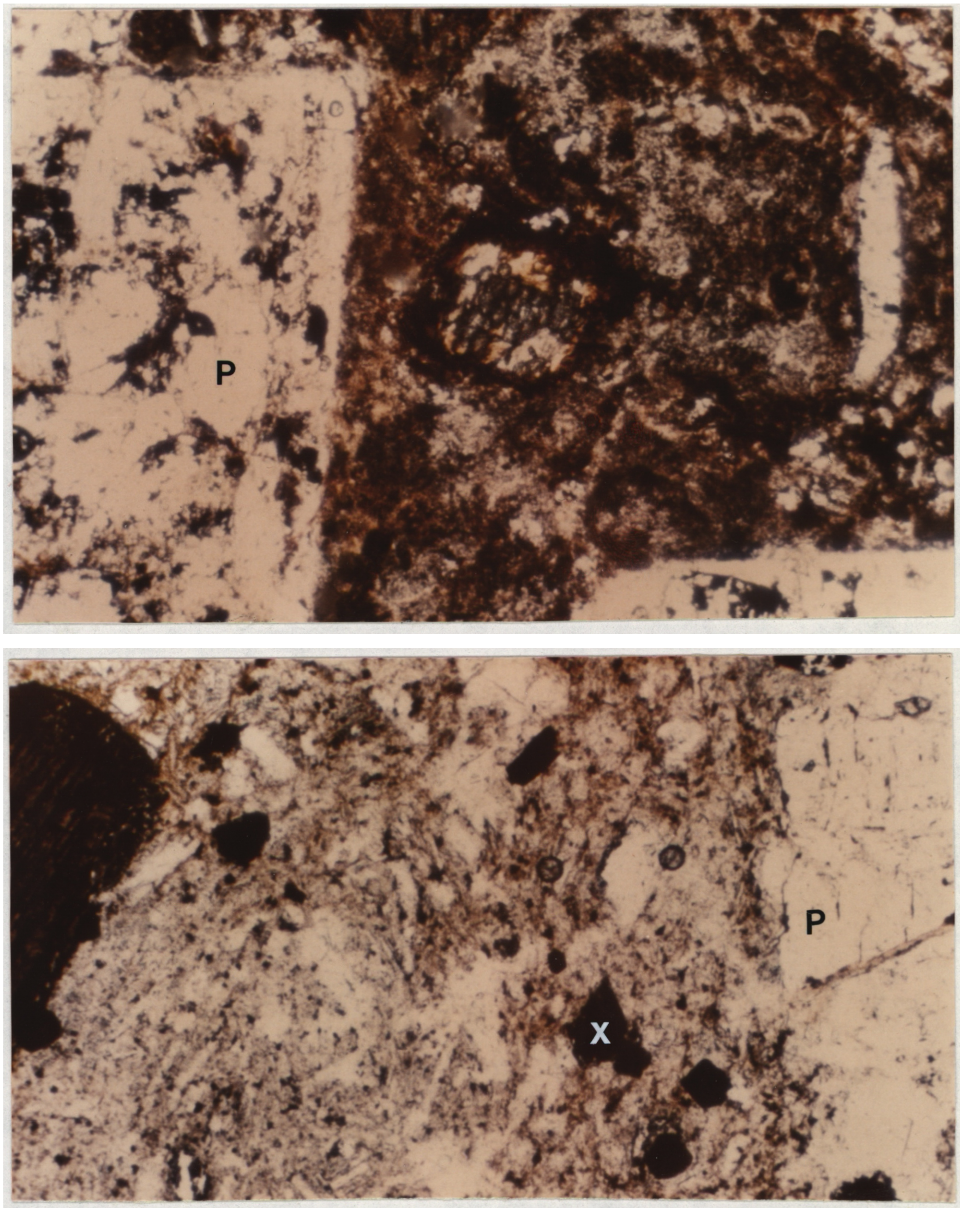


Figure 22. Vein-related alteration of the Huautla Complex: argillic alteration (kaolinite and montmorillonite) replaces the original trachytic groundmass and plagioclase phenocrysts (P) in both photomicrographs. In the lower view, the argillic alteration is overprinted with silicification and disseminated pyrite (X). Both samples are from near the Santiago vein.

throughout the deposition of the quartz varieties. Figure 23 illustrates the quartz relations exceptionally clearly. The early dark-green mineralized fragments were first coated with thick bands of amethyst and then by several 1-cm bands of euhedral milky quartz. Upon this was deposited either thin bands of specular hematite and quartz or cryptocrystalline dark brown quartz. Thin bands of · chalcedony followed. The open spaces were again filled with a dark brown cryptocrystalline quartz or jasperoid. Euhedral calcite seems to have been deposited at the end of the quartz episode, but this may be a product of a much later period of calcite deposition. The vein textures such as drusy, banded quartz simultaneously deposited on both walls and non-crushed quartz breccia fragments in cryptocrystalline vein filling suggest the fissures were opening faster than veins could fill.

No important alteration types are identified with the quartz episode of vein filling. Numerous parallel and offshooting veinlets of identical amethyst and chalcedony show hydrothermal solutions did travel widely, but only thin chloritic selvages resulted.

Post-Ore Alteration

Following mineralization, during and after the quartz episode of vein filling the Huautla Complex was uplifted and eroded several hundred meters. Any weathering and supergene enrichment that formed was largely destroyed at this time. The argillic alteration and

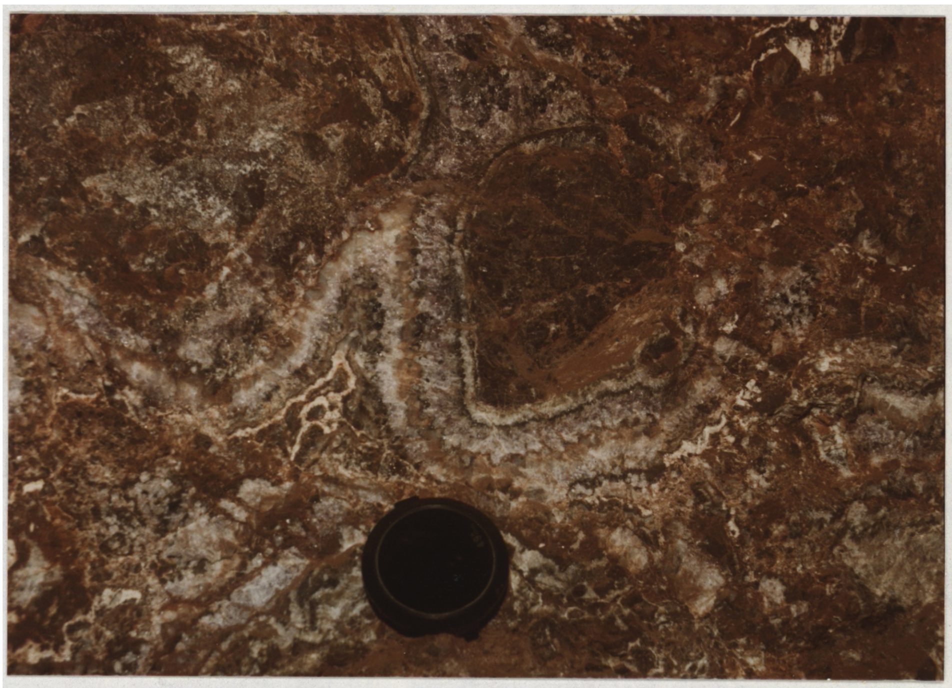
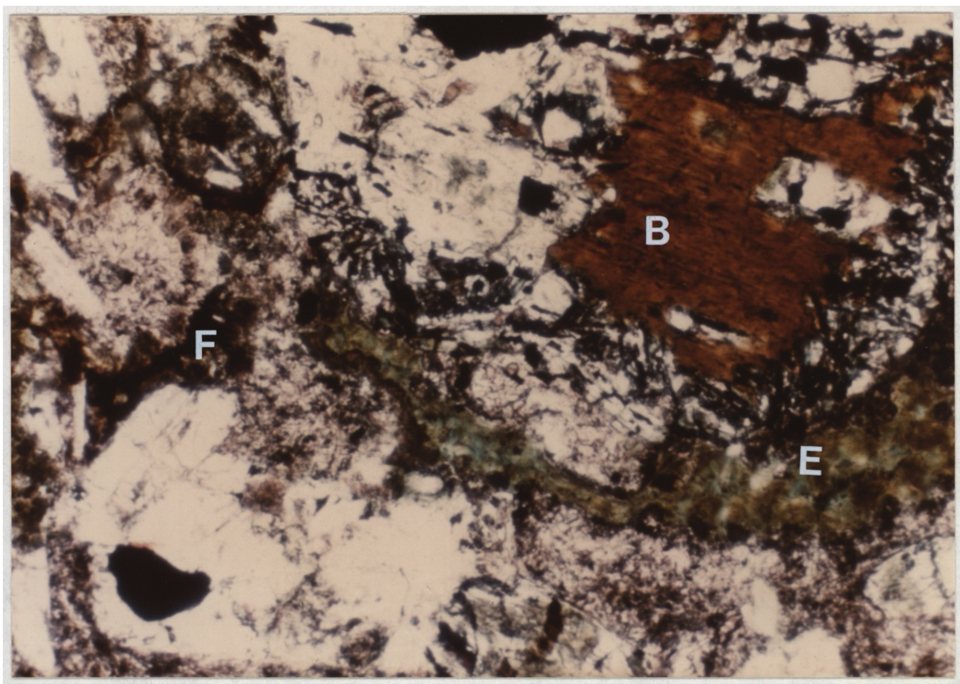


Figure 23. Banded textures of the quartz episode of vein filling, in the San Francisco mine, on the Santa Anna vein system. Dark fragments at the upper left and right-center are wall rock and sulfide ore, which are coated with numerous generations of quartz (amethyst, jasper, and chalcedony). Vein brecciation and quartz filling continued after this pulse of vein filling.

bleaching of andesites and dacites in the vicinity of the town of Huautla (Plate 1) may result from this period of exposure. The Epiclastic Group was deposited atop this erosion surface.

The intrusion of the Barriga dome and related dike intrusion renewed the shallow geothermal system. Resultant hydrothermal alteration includes strong propylitic and zeolitic zones corresponding with the zone of strong dike intrusion, which extends 300 m and more from the dome border (Plate 1). This propylitic assemblage is superimposed upon the earlier pervasive and vein-related propylitic alteration. It is characterized by epidote, calcite, montmorillonite, chlorite, and quartz (Figure 24). Alteration textures, colors, and intensity vary considerably. Areas of intense dike intrusion typically show intense chlorite and epidote green alteration envelopes replacing the host groundmass, and bleaching of plagioclase phenocrysts. Biotite and hornblende phenocrysts generally retain a fresh appearance (Figures 9, 11, and 24).

Calcite and zeolites were the last minerals, and sometimes the only minerals to be deposited (Figure 25). The zeolite-calcite alteration formed primarily in open spaces in the shallower portions of the system, though calcite and to a lesser extent, zeolites and epidote, all may flood the groundmass. Stilbite is the only zeolite positively identified (by X-ray diffraction). It forms coarse euhedral void fillings by itself, coarse intergrowths with calcite



0.5 mm plain light

Figure 24. Propylitic alteration, related to the intrusion of the Barriga dome. Mafic phenocrysts, such as the biotite (B) at the upper right, are usually fresh, while the groundmass is often completely replaced by clay minerals, calcite, iron oxides (F) and epidote (E).

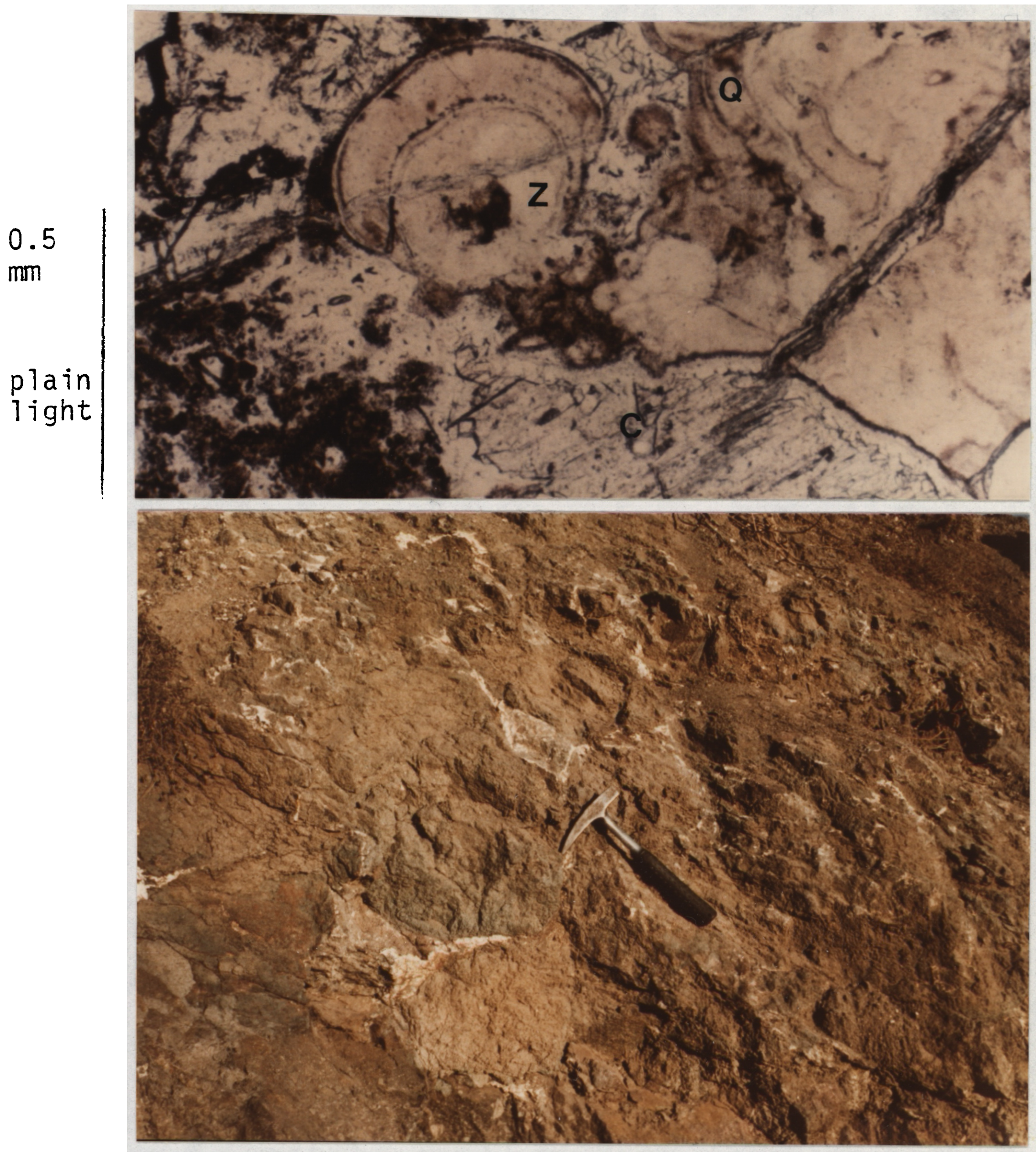


Figure 25. Zeolitic alteration: photomicrograph (upper) of the same alteration visible as the white open space fillings exposed in the outcrop (below). Quartz (Q), calcite (C), and zeolite (Z) were deposited in rapid succession, probably by alkaline ground waters mixing with hydrothermal solutions. This roadcut exposure is located .5 km south of the town of Huautla.

and opal in epiclastic breccias (Figure 25), and fine-grained, lustrous fracture fillings in the intermediate volcanics, faults, and veins. Field identification of the fine-grained variety is difficult and minor zeolites may be more common and widespread than the Barriga dome zoning pattern suggests. Minor brecciation continued throughout post-ore alteration resulting in every conceivable color combination of clasts and groundmass (Figure 9).

A third type of post-ore alteration, silicification to jasper, was observed, but its age and chemical relations to the other alteration types and volcanic events are uncertain. Though composed of resistant minerals, this alteration type never outcrops. It has been mapped in three locations by concentrations of float (Plate 1). All three locations are within the Epiclastic Group only, suggesting this type of silicification may be of that age, older than Barriga dome emplacement and younger than or contemporaneous with the quartz-episode of vein filling. Two occurrences are in grassy saddles on the ridge west of Cerro de Barriga de Plata and one occurrence is across the valley on the slopes of Cerro de la Cienega (Plate 1).

The silicified dacites (jasper rocks) show nearly complete replacement of groundmass and phenocrysts (Figure 26). Relict porphyritic textures are visible in the less altered centers of larger fragments. Relict quartz phenocrysts in the jasper rock give the appearance of a fine-grained rhyolite with quartz phenocrysts.

The jasper rocks are always brecciated; showing light jasper in a darker silicified matrix, or in one interesting boulder, jasper fragments in a specular hematite matrix.

Following the jasper formation, propylitic alteration and zeolitic alteration, the Late Dacite Flows, Basalt Flow, and Basalt Dikes were deposited and intruded. The only alteration that occurred during this time was the minor calcite veinlets that generally fill north-south trending fractures and cut the Basalt Dikes (Figure 13) and older units.

Weathering and Supergene Enrichment

The final geologically important stages at Huautla were erosion, weathering, and supergene enrichment. A similar supergene stage occurred during the post-Huautla Complex hiatus. Remnant products of this early stage were similar and may be included in the last supergene stage.

The topography has been strongly influenced by hypogene alteration, such as vein-related silicification, and the lack of alteration such as in the resistant, fresher Barriga Dacite and Late Dacite Flows. This final stage supergene alteration included argillization, leaching, and oxidation of the intermediate composition volcanics, as well as the important enrichment of orebodies.

Figure 26. Hand samples of 'jasper rocks' formed by silicic alteration. Faint relict dacite-porphyry textures are visible in the less altered centers of breccia fragments. The breccia matrix is usually also dark silica, but may be specular hematite as seen in the lower left sample.

Those veins which were sealed during the quartz episode of vein filling (e.g. Santiago) remained relatively impermeable to surface waters compared with the permeable brecciated quartz veins (e.g. Santa Anna). But virtually all structures show some degree of oxidation (Figures 21 and 18). The abundance of secondary minerals in the southern veins suggest they have been down dropped and eroded less than the northern veins. Unfortunately, the shallower oxidized orebodies have largely been mined out. The Peregrina and San Francisco mines provide the best opportunity to study the supergene enrichment.

Oxidation of sulfides by surface and groundwaters resulted in percolation of acidic solutions down vein structures. Base and precious metal sulfides caught in the zone of oxidation went into solution and were repeatably redeposited with enrichment near the top of a paleo-reducing zone.

Copper has been redeposited as malachite, azurite, chrysocolla, and possibly chalcocite and covellite.

Lead has been redeposited as the carbonate: cerrusite, and the yellow molybdate; wulfenite. According to Wilt and Keith (1980), wulfenite commonly occurs later than cerrusite in veins where no molybdenite was reported in the sulfide zone, and is a negative clue to the contemporaneous Cu or Cu-Mo porphyry mineralization.

Silver was redeposited in several forms, but the main mineralogy of the ore is unknown. Native silver occurs in visible flakes and wires on oxidized surfaces, and as micron-size inclusions in quartz gangue (Cyanamid, 1969). Hematite was often present as inclusions with the silver. Dark ruby silver, pyrargyrite, was deposited very late in the sequence as open space fillings. Another potential site for the silver is incorporation in the lattices of the ubiquitous iron oxides, cerussite, or copper carbonates which can contain up to 1,000 ppm Ag. (Boyle, 1968 and Shcherbina, 1972).

Gangue minerals are vuggy quartz, calcite, and iron oxides. The iron oxides occur disseminated throughout wall rock, on fracture surfaces, and as thick gouge zones with a marked color contrast to the sulfide ore (Figure 21). Cellular boxworks are frequent in the upper leached zones and as float. Boxworks consisting of fragments from the early quartz episode with small sulfide breccia fragments are particularly recognizable. Managanese oxides are noteably absent in the group of supergene minerals. Secondary zinc minerals were not observed.

Summary of Mineralization and Alteration

This section summarizes a model of the mineralization and alteration at Huautla. Discussion of ore controls is based on field observations. Discussion of hydrothermal fluid chemistry is based primarily on the zoning of alteration mineral assemblages. The discussion of the application of the boiling model to the Huautla district is speculative. Application of the boiling model is not based on geochemical evidence, rather it is based upon the similarities of the Huautla mineralization, structural setting, and zoning patterns, to similar, better studied deposits where boiling has been shown to have occurred. Figure 27 is a schematic summary of the Huautla mineralization model.

The early hydrothermal solutions which created the mineralization and vein-related alteration were acidic, as indicated by alteration assemblages. The zoning outward from the chlorite-rich orebodies, to an intense argillic altered zone with kaolinite, and further out to montmorillonite, infer acid solutions passed through the major fractures. As the acid solutions permeated the fractured wall rocks they were buffered to moderate acidity where the montmorillonite was stable. Similar moderately acid solutions circulated much later, during the emplacement of the Barriga dome, as shown by the montmorillonite-rich propylitic alteration halo around the dome. Future exploration-oriented mapping should take care not to confuse the important vein-related (propylitic and argillic) alteration with the dome-related propylitic alteration, which is richer in calcite and epidote.

The zeolite-rich alteration assemblage which is distributed around the Barriga dome was deposited from low temperature, alkaline solutions close to the surface. Stilbite, which is characteristic of this assemblage, is stable in low temperature, low pressure, alkaline environments. The rapid precipitation of zeolite, calcite and

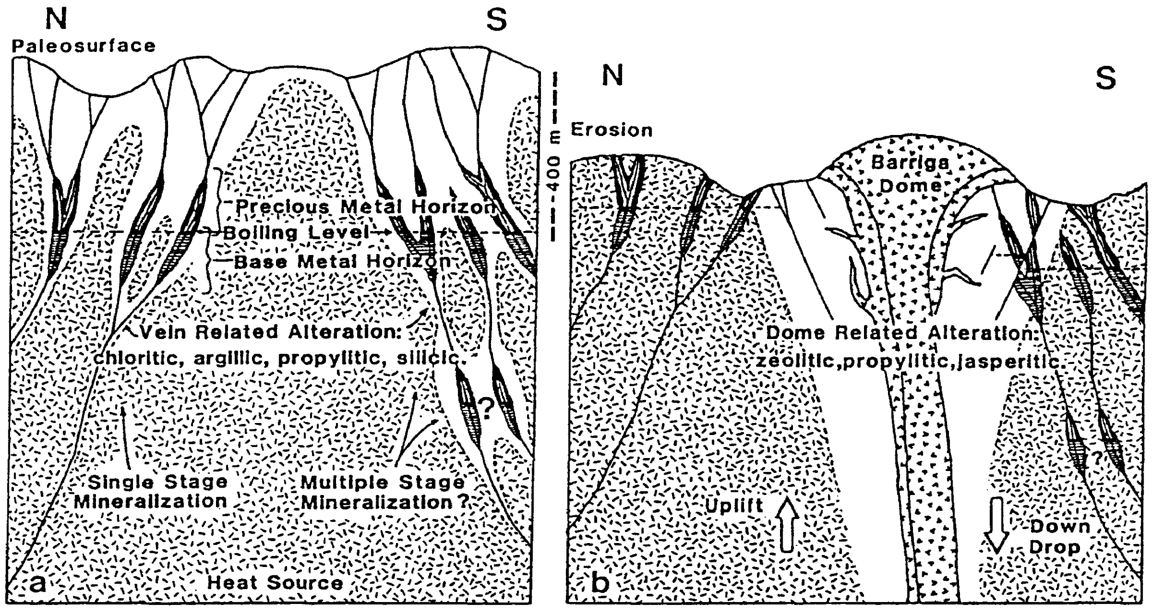


Figure 27. Schematic mineralization and alteration model for the Huautla silver district.

Cross section "a" (left) represents the district immediately following deposition of the Huautla Complex. Ascending hydrothermal fluids produced vein-related alteration envelopes. Precipitation of base metals, possible fluid boiling, and deposition of precious metal-rich ore, produced rough vertical zoning in orebodies. Post-ore quartz gangue followed, as the speculated boiling level migrated downward, possibly producing stacked orebodies in the southern veins.

Cross section "b" (right) represents the district following emplacement of the Barriga dome. Intrusion created an alteration halo around the vent, and faulting, which offset orebodies. Following relative uplift to the north, erosion exposed deep, base metal-rich ore in the northern veins. Less erosion at the southern veins preserved upper, precious metel-rich ore, and supergene enrichment.

quartz, each which is stable under different chemical conditions, suggests two solutions mixed. These may have been acid solutions which created the deeper propylitic alteration and shallow alkaline groundwater. The thick open-space fillings of the zeolite-rich assemblage, within voids of an epiclastic breccia, infer a shallow hot spring system existed during emplacement of the Barriga dome.

Structural controls on ore localization are obvious in the Huautla district. Primary mineralization is concentrated at structural intersections and changes in vein attitude. Ore occurs at a laterally continuous level within the structures, and was previously suspected as being lithologically controlled, by horizontal volcanic stratigraphy. But lithologic and stratigraphic controls on mineralization and accompanying alteration are weak. Because much of the horizontal stratigraphy has been disproven by recent mapping, another mechanism is needed to explain vertical control on ore deposition. The author prefers to call on the boiling model for this.

During their ascent through the fracture system, hydrothermal solutions formed the widely recognized vertical and temporal assemblage of minerals and textures characteristic of epithermal deposits. Limited fluid inclusion data (4 readings) on the post-ore amethyst give homogenization temperatures of 230° to 240°C. This implies the ore-depositing solutions were possibly in the range of 240° to 300°C. If these solutions had boiled at a critical depth below the Huautla

Complex paleosurface, then ore precipitation could have been localized at this laterally persistent physio-chemical barrier.

In this way, the boiling model may explain the consistent vertical level of mineralization. The depth of boiling has been estimated for other districts as being approximately 350 meters or more below the paleosurface, at the time of mineralization (Buchanan, 1981). For the Huautla district this depth estimate is consistent with stratigraphically derived erosion estimates. At the margins of the Corona dome, of the Huautla Complex, the flow banding is steep (55°-75°) suggesting the upper dome portions, with low-angle flow banding, have been eroded. Better preserved hornblende-mica dacite domes at Lassen Peak, California, have been estimated by Williams (1933) as having stood 400m to 800m above the surrounding volcanic rocks. Though precise erosion estimates are not possible, 300m to 500m of erosion may have occurred in the northern Huautla map area, since the Huautla Complex was emplaced. The speculated level of boiling was presumably at a level intermediate between the lower base metal-rich horizon and the upper precious metal-rich horizon. As hydrostatic and temperature gradients shifted, and as the veins were repeatedly sealed and refractured, the boiling depth may have dropped. At Guanajuato, Mexico this mechanism has formed three vertically stacked orebodies separated by the barren vein (Gross, 1975 and Buchanan, 1981).

With this model in mind, some speculations can be made as to the origin of the different vein types at Huautla. The Santiago vein system is structurally constricted, has strong fault gouge with little wall rock brecciation and has pyrite present, though not much. This suggests the Santiago vein system represents a deep level in the mineralization model. In contrast, the Santa Anna vein system with its more prominent stock work-textured orebodies, and post-ore breccia textures, suggests a shallower level in the mineralizing system. As shown in Figure 27, the two levels of mineralization have been exposed by differential uplift (along numerous faults) and erosion. In the southern veins the strong post-ore brecciation was accompanied by intense gangue filling of numerous generations of quartz, each forming under progressively lower temperatures and pressures (milky bull quartz-amethyst-chalcedony-opal). The mineralogy and tectonic history, as interpreted from vein textures, suggest the quartz episode of vein filling may represent the upper, distal portions of a mineralizing system. Thus, there exists a possibility for one or more stacked levels of precious metal deposition deep below the Santa Anna vein system, and probably not below the Santiago vein system.

The orebodies of the Huautla silver district lack some common characteristics of epithermal silver deposits, such as the presence of sericite, alunite, adularia, pyrite, and obvious acanthite. But overall, the mineralizing system is typical of epithermal precious metal deposits across the western cordillera.

SUMMARY AND CONCLUSIONS

The Tertiary geologic history of the Huautla silver district is reconstructed in the following short summary:

1. Unconformable deposition of rhyolite and volcaniclastic sediments upon folded Cretaceous sediments is inferred from regional studies.

2. Emplacement of the Huautla Complex, a thick sequence of andesitic and dacitic endogenous domes, flows, and breccias and concurrent pervasive propylitic alteration.

3. Formation of east-west trending tensional fractures and faults, possibly related to regional and local arching of the volcanic pile .

4. Mineralization of fractures with Pb and Zn sulfides followed by Ag and Cu sulfides, accompanying low pH alteration assemblage. Continued faulting and uplift.

5. Intense quartz vein filling in some veins may represent waning stages of mineralization or a distal fingerprint of a deeper mineralizing system. Continued faulting.

6. Uplift and erosion of 200-400m of the Huautla Complex, probable supergene enrichment.

7. Deposition of Epiclastic Group sediments, breccias, lahars, and minor volcanism.

8. Intrusion of numerous small intermediate composition dikes accompanied by local propylitization of Huautla Complex, and strong silicification(?) in the Epiclastic Group.

9. Extrusion of the Border phase of the Barriga dome and outflow facies.

10. Continued faulting on the established east-west structural trend. Offset of orebodies. Hot spring activity and zeolitic alteration.

11. Extrusion of the Center phase of the Barriga dome.

12. Extrusion of the Late Dacite Flows.

13. Minor north-south faulting and offset of orebodies.

14. Extrusion of the Basalt Flow and intrusion of Basalt Dikes.

15. Minor east-west faulting, erosion, supergene alteration, and enrichment of orebodies.

Throughout mid-Tertiary time, volcanism and tectonism were nearly continuous in the Huautla district. The volcanic character changed little during the formation of the complete volcanic pile. Though volcanism may have begun with rhyolitic composition and ended with basaltic composition, almost all of the exposed volcanics are of intermediate compositions. Tectonism included repeated uplift (with erosion) and recurrent movement along a temporally and spacially persistent east-west fault trend. The structural pattern may be inherited from pre-existing structural patterns. The dominant mid-

Tertiary stresses were vertical, probably due to both regional and local arching of the volcanics by intrusion.

The fracturing and volcanism provided the channelways and heat which drove the geothermal system, the oldest part of which created the known mineralized fissure veins. The geothermal waters changed character over time and space resulting in a variety of alteration assemblages. The post-ore alteration resulted from a shallow, hot spring environment (jasper, zeolite, calcite, quartz) and dome intrusion (chlorite,clays,epidote). The pre-ore pervasive propylitization is strongly overprinted by vein-related argillic (kaolinite, chlorite, montmorillonite) and silicic alteration. Due to the lack of previously suspected stratigraphic ore controls, detecting locations of orebodies within the veins will be greatly aided by detailed mapping of ore-stage alteration patterns both vertically and laterally along structures.

This study of the central Huautla silver district has resulted in a beginning at deciphering alteration patterns and an improved understanding of the volcanic history and structure, which are best summarized in the geologic map (Plate 1). Despite the district's long history of production, continued exploration and geologic investigations will likely lead to discovery of additional orebodies.

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APPENDIX

The following samples are housed in the Petrological Reference Collection, Department of Geology, Colorado School of Mines, Golden, CO, 80401.

Sample Number		Sample Description
179-1	Hand sample and Thin section	Huautla Complex, andesite porphyry
179-2	Hand sample and Thin section	Huautla Complex, dacite porphyry
179-3	Hand sample and Thin section	Huautla Complex, argillic altered
179-4	Hand sample and Polished section	Santiago vein, sulfide ore
179-5	Hand sample and Polished section	Santa Anna vein, sulfide ore breccia
179-6	Hand sample and Thin section	Barriga Dacite, Central phase, dacite porphyry
179-7	Hand sample and Thin section	Late Dacite Flows, dacite porphyry
179-8	Hand sample and Thin section	Basalt Flow

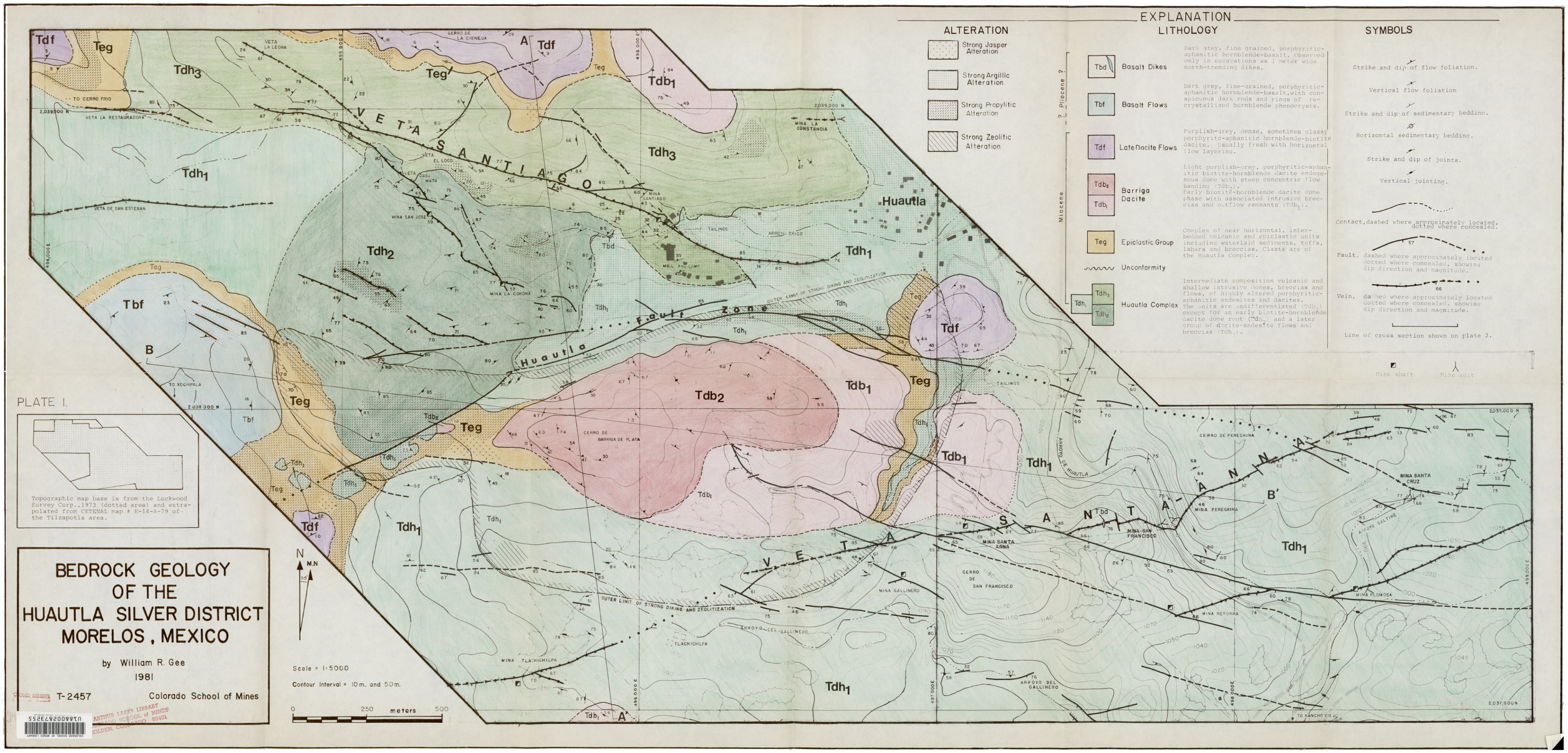


PLATE I.
BEDROCK GEOLOGY OF THE HUAUTLA SILVER DISTRICT MORELOS, MEXICO
by William R. Gee
1981
T-2457
Colorado School of Mines
Topographic map base is from the Lockwood Survey Corp.,1973 (dotted area) and extrapolated from CETENAL map # E-14-A-79 of the Tilzapotla area.
EXPLANATION
ALTERATION
Strong Jasper Alteration
Strong Argillic Alteration
Strong Propylitic Alteration
Strong Zeolitic Alteration
LITHOLOGY
? Pliocene ?
Miocene
Tbd Basalt Dikes
Dark grey, fine grained, porphyritic-aphanitic hornblende-basalt. Observed only in excavations as 1 meter wide north-trending dikes.
Tbf Basalt Flows
Dark grey, fine-grained, porphyritic-aphanitic hornblende-basalt, with conspicuous dark rods and rings of re-crystallized hornblende phenocrysts.
Tdf Late Dacite Flows
Purplish-grey, dense, sometimes glassy porphyritc-aphanitic hornblende-biotite dacite. Usually fresh with horizontal flow layering.
Tdb2 Tdb1 Barriga Dacite
Light purplish-grey, porphyritic-aphanitic biotite-hornblende dacite endogenous dome with steep concentric flow banding (Tdb2).
Early biotite-hornblende dacite dome phase with associated intrusive breccias and outflow remnants (Tdb1).
Teg Epiclastic Group
Complex of near horizontal, interbedded volcanic and epiclastic units including waterlaid sediments, tuffs, lahars and breccias. Clasts are of the Huautla Complex.
Unconformity
Tdh1 Tdh3 Tdh2 Huautla Complex
Intermediate composition volcanic and shallow intrusive domes, breccias and flows, of highly altered porphyritic-aphanitic andesites and dacites. The units are undifferentiated (Tdh1) except for an early biotite-hornblende dacite dome root (Tdh2) and a later group of dacite-andesite flows and breccias (Tdh3).
SYMBOLS
Strike and dip of flow foliation.
Vertical flow foliation
Strike and dip of sedimentary bedding.
Horizontal sedimentary bedding.
Strike and dip of joints.
Vertical jointing.
Contact, dashed where approximately located, dotted where concealed.
Fault, dashed where approximately located dotted where concealed, showing dip direction and magnitude.
Vein, dashed where approximately located dotted where concealed, showing dip direction and magnitude.
Line of cross section shown on plate 2.
Mine shaft
Mine adit
N
M.N
Scale = 1:5000
Contour Interval = 10m. and 50m.
0 250 meters 500
VETA SANTIAGO
Huautla Fault Zone
VETA SANTA ANA
Huautla
OUTER LIMIT OF STRONG DIKING AND ZEOLITIZATION
CERRO DE BARRIGA DE PLATA
CERRO DE SAN FRANCISCO
CERRO DE PEREGRINA
MINA SANTA ANNA
MINA SAN FRANCISCO
MINA PEREGRINA
MINA SANTA CRUZ
MINA PLOMOSA
MINA REFORMA
MINA GALLINERO
MINA TLACHICHILPA
MINA LA CONSTANCIA
MINA SAN JOSE
MINA LA CORONA
MINA SANTIAGO
MILL AND CAMP
TAILINGS
ARROYO DE HUAUTLA
ARROYO DEL GALLINERO
ARROYO BEL GALLINERO
TO CERRO FRIO
TO XOCHIPALA
TO HANCHO VIEJO
VETA LA RESTAURADORA
VETA DE SAN ESTEBAN
VETA LA LEONA
CERRO DE LA CIENEGA
2,039,000 N
2,038,000 N
2,037,000 N
A
A'
B
B'
Tdf
Teg
Tdh3
Tdh2
Tdh1
Tdb1
Tdb2
Tbf
Tbd

CROSS SECTION B-B', Striking N82W, Looking North

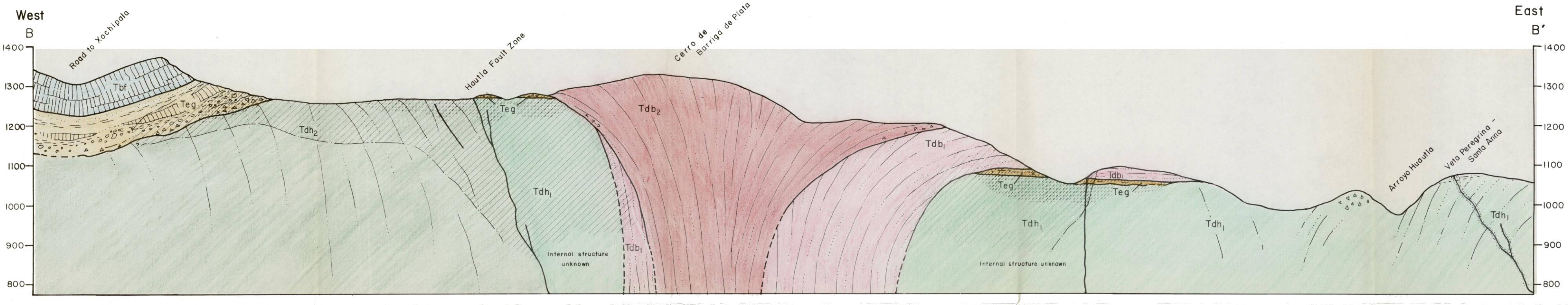


PLATE 2.

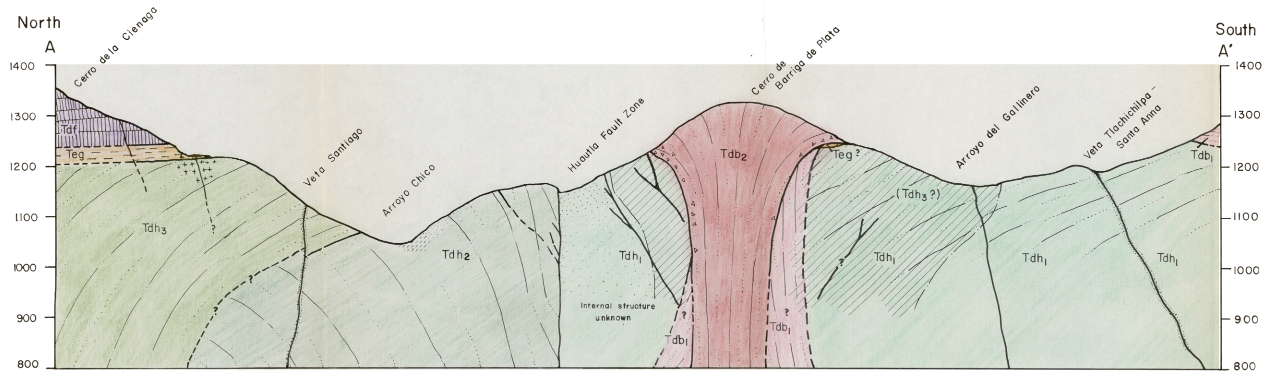
Scale = 1: 5000

Vertical = Horizontal

See plate I for explanation of symbols.

0 250 meters 500

CROSS SECTION A-A', Striking N6W, Looking East



GEOLOGIC CROSS SECTIONS OF THE HUAUTLA SILVER DISTRICT MORELOS, MEXICO

by William R. Gee

1981

Colorado School of Mines