

# **GEOLOGY AND PRECIOUS METALS MINERALIZATION OF THE OCAMPO DISTRICT, WESTERN CHIHUAHUA**

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## **ABSTRACT**

The Ocampo Mining District, in a remote canyon in western Chihuahua, is a substantial low-sulfidation epithermal mining district that is presently being exploited by open pit and underground methods. The historic production from the district is unknown as much of it went unrecorded in this remote location. In the past three years, the present operator, Gammon Gold Inc., has produced over 255,000 oz Au and 8,750,000 oz Ag from the mines here. Ocampo stratigraphy is typical of much of the Sierra Madre Occidental geomorphic region with a basal Eocene (?) Navosaigame Fm conglomerate, that is overlain sequentially by the El Salto Fm. (variably welded dacite ash flow tuff), the Ocampo Andesite (flows and flow breccias), the San Ramon Fm. (volcaniclastic sandstone), and the Sta. Eduvigis Fm. (porphyritic dacite flow breccias). These units comprise the local components of the "Lower Volcanic Sequence" (LVS). The LVS units are overlain disconformably by a series of thick quartz-porphyry rhyolitic tuffs and volcaniclastics that comprise the local component of the Miocene "Upper Volcanic Sequence" (UVS). The district has been deformed by a series of NW-striking oblique-normal faults that have left the stratigraphy tilted north-eastward. Mapping has shown that the basal contact of the UVS is deformed similarly; indicating that at least some of the district tilting is post-UVS. In addition to the predominant NW faults, there is a major WNW-striking normal fault system (PGR Fault) that intersects and cuts the NW-striking system. N20°E striking brittle structures are also common, and appear to be extension fractures. Mineralization is characterized by low-sulfidation epithermal mineralization that in many ways is typical of the Sierra Madre Occidental province. Ore is controlled by all three faults systems: NW, WNW, and NNE. The WNW and NNE systems dip steeply south, but the NW-striking system dips both NE and SW forming complex intersection relationships with the other vein systems. Veins consist of a gangue of drusy quartz, white sugary-textured quartz, amethyst quartz, adularia, and calcite, with ore-bearing phases of argentite – electrum – argentiferous galena, pyrite, galena, sphalerite, and rare chalcopyrite. Most of the vein mineralization consists of planar arrays of hydrothermal breccias and sheeted to networked arrays of veinlets, although some classic fissure veins occur to a lesser extent. Delicately banded multi-stage fine-grained quartz and quartz-chalcedony are rarely found, and only in the uppermost elevations. The present mines comprise a 3.5km long series of four open pits (where NW-striking veined zones intersect the WNW-striking PGR trend), and a 0.8km diameter underground mine complex that extracts ore from six major veins and numerous smaller vein splits. Ore grade mineralization is restricted to the stratigraphic interval from Sta. Eduvigis Fm to the base of the Ocampo Andesite. The highest outcrops of veins are at 2150m elevation, and the lowest known mineralization at present is at 1450m – thus there is a 700m vertical interval of known mineralization, although no one ore shoot has more than a 400m vertical interval. Ore grade veins outcrop at 2150m, so the distance to the top of the pre-erosion ore shoots is unknown. Tilting of the UVS rocks northeastward suggests that the favorable ore horizon is probably also tilted eastward and preserved underneath post-mineral UVS volcanics.

## **RESUMEN**

El distrito de Ocampo, ubicado en un apartado cañón del oeste de Chihuahua, es un substancial distrito minero de tipo epitermal de baja sulfatación actualmente explotado a tajo abierto y subterráneo. La producción histórica del distrito esta desconocido debido a su ubicación. En los últimos tres años el operador actual, Gammon Gold Inc., ha producido más de 255,000 onzas de oro y 8,750,000 onzas de plata. La estratigrafía de Ocampo es típica de gran parte de la región geomorfológica de la Sierra Madre Occidental. Las rocas mas antiguas están representadas por el conglomerado Eoceno de la formación Navosaigame que lo sobreyacen las formaciones Oligocénicas El Salto (toba de flujos de ceniza dacítica parcialmente soldados), la andesita de Ocampo (flujos y brechas de flujo), la formación San Ramón (arenisca volcánica), y la formación Sta. Eduvigis (brechas de flujo de dacita porfídica). Estas unidades incluyen los componentes locales de lo que se conoce como "grupo volcánico inferior" (GVI). Las unidades del GVI están cubiertas irregularmente por una serie de gruesas tobas volcánicas riolíticas cuarzo-porfídicas que incluyen el componente local del "grupo volcánico superior" (GVS) del Mioceno. El distrito ha sido deformado por una serie de fallas normales oblicuas con rumbo noroeste y que han dejado la estratigrafía inclinada hacia el noreste. El mapeo ha mostrado que el contacto basal del GVS está deformado de manera similar, lo cual indica que por lo menos una parte de la inclinación del distrito es posterior al GVS. Además de las predominantes fallas del noroeste, hay un sistema principal de fallas normales con rumbo oeste noroeste (sistema PGR) que se intersectan y corta el sistema con rumbo noroeste. También son comunes las estructuras quebradizas con rumbo N20°E y parecen ser fracturas de extensión. La mineralización es similar a otros distritos mineros de tipo epitermal de baja sulfatación típicos de la Sierra Madre Occidental. El cuerpo mineralizado esta controlado por tres sistemas de fallas: noroeste, oeste-

noroeste y nor-noreste. El sistema oeste-noroeste y el sistema nor-noreste tienen un echado muy inclinado hacia el sur, pero el sistema con rumbo noroeste se inclina tanto al NE como al SO, formando complejas relaciones de intersección con los otros sistemas de vetas. Las vetas consisten de una ganga de cuarzo con estructuras de drusa, cuarzo blanco de textura azucarada, amatista, adularia y calcita, con fases con argentita (electrum), galena argentífera, pirita, galena, esfalerita y trazas de calcopirita. La mayor parte de la mineralización de la veta consiste en arreglos planares de brechas hidrotermales y arreglos de vetillas laminares, aunque algunas vetas de fisura clásicas ocurren en menor grado. Es raro encontrar cuarzo con bandeado multi-fase de grano fino cuarzo-calconita; sólo se encuentran en las elevaciones más altas. Las minas actuales comprenden una larga serie de cuatro tajos abiertos con una longitud total de 3.5 km (donde las zonas de vetilleo con rumbo noroeste cruzan con el *trend* PGR de rumbo oeste-noroeste), y un complejo minado subterráneo de 0.8 km de diámetro y 35 km de desarrollo, de donde se extrae mineral de seis vetas principales y muchos otros ramales de vetas más pequeñas. La mineralización está restringida al intervalo estratigráfico de la formación Sta. Eduviges a la base de la andesita Ocampo. El afloramiento de vetas más alto está a 2150 m de elevación, y la mineralización más baja conocida en el presente está a 1450 m. Hay un intervalo vertical de 700 m de mineralización conocida, aunque ningún clavo de mineral tiene más de 400 m de intervalo vertical continuo. Las vetas mineralizadas afloran a 2150m, así que se desconoce cuál es la distancia a la cima de los cuerpos minerales antes de la erosión. La inclinación de las rocas del grupo volcánico superior hacia el noreste sugiere que probablemente el horizonte favorable de la mena también esté inclinado hacia el este, preservado bajo el material volcánico del GVS post mineral.

## LOCATION AND ACCESS

The Ocampo Mine is located at approximately 28°12.5' Latitude and 108°25' Longitude in western Chihuahua, Mexico. The property lies 235km SW of the capital city of Chihuahua, and is accessed from Chihuahua by driving 310kms on Federal Highway 16 (the main highway that crosses the Sierra Madre) to Cahuisori, then 25km south on a government-maintained gravel road.

## INFRASTRUCTURE, CLIMATE, LOCAL RESOURCES

The small town of Ocampo, population 1500, was built over the eastern portion of the mining district and has only minor services available. The town is connected to The National Electrical grid (CFE), and the Ocampo Mine has recently connected to the grid. Apart from mining the only other industries in the area are forestry, ranching, and farming. An adequate workforce that is familiar with mining is present in the region.

## Topography and climate

The Ocampo Mine lies within the Sierra Madre Occidental physiographic province, a rugged incised plateau with deep canyons. Relief is rugged with elevations ranging from 1,600m to 2,400m. The climate is moderate with typical winter temperatures of -3°C to +10°C and summer temperatures of 10°C to 35°C. Rainfall is erratic and mainly occurs during the summer monsoon season. Snow occurs sporadically in the winter. Average annual precipitation is approximately 800 mm. Vegetation in the area consists of pine and mixed pine and deciduous stands of trees. The Ocampo Mine gets its water from dams, underground mine water, recycled water and from ground water wells.

## Present Operations

Gammon Lake de Mexico, S.A. de C.V., a wholly-owned subsidiary of Gammon Gold Inc. operates the Ocampo mine and mill complex which lies within 61 concessions that cover 11,822 hectares. Gammon began commercial production in 2006, and in 2008 produced 115,600 oz Au plus 3,996,000 oz Ag. The operation consists of an open pit mine complex (with four individual pits) that produces presently produces 6000 tpd of ore, an underground mine complex that produces 650 tpd of ore, a mill complex with Merrill-Crowe recovery that is processing 3000 tpd, and a heap leach complex. Published reserves at year-end 2008 were 53.8 Mt grading 0.62 gpt Au + 24 gpt Ag in the open pits complex, and 2.85 Mt grading 3.02 gpt Au + 170 gpt Ag in the underground vein system.

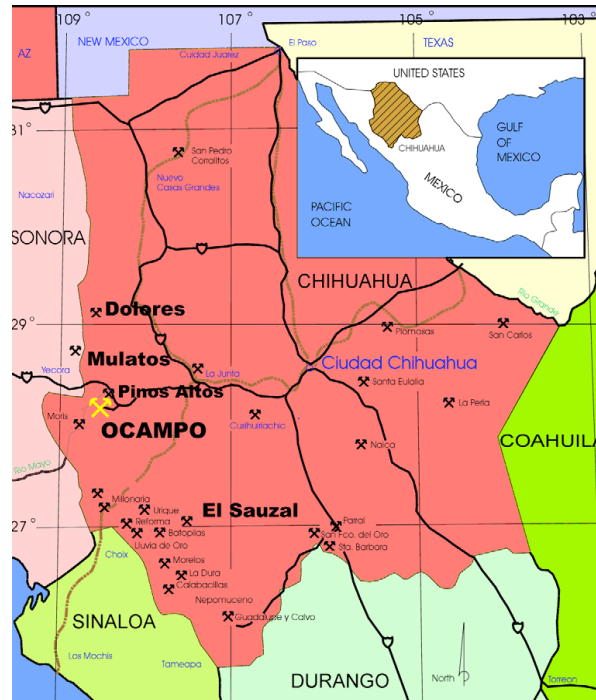


Figure 1. Location of Project

## History

The Ocampo area has been explored and exploited over the last 200 years. Most of the production has been poorly reported or unreported, hence the actual historic past production is hard to estimate. Typical Ag:Au ratios for the district are on the order of 40 to 70, thus the district's ore values are nearly equivalent in gold and silver. Cárdenas Vargas et al. (1994) estimated that the district had produced at least 450,000 tonnes of ore from the three largest ore shoots, although anecdotal comments suggest total production before the Revolution was as much as US\$ 100M (which would suggest a production on the order of 2.7 Moz Au and 125 Moz Ag). Further anecdotal evidence indicates that one high grade ore shoot at Sta. Eduviges produced on the order of 100,000 oz Au and 2 Moz Ag. The true historic production is unknown.

Ocampo mineralization was discovered in 1804 when a local herder discovered gold in the Rosario vein outcropping along the Ocampo River, and soon thereafter other veins. Exploitation of the area was curtailed during the Mexican War for Independence from 1810 to 1820, but after the war, French and English interests made significant investments in the Refugio and Plaza de Gallos mines in the western part of the district. By the mid 1800's the district was idle due to the political unrest and problems with water in the mines. In the late 1800's the government again encouraged foreign investment and Ocampo was reactivated. From the 1880's to 1912 was Ocampo's greatest period of development, after which the Mexican Revolution caused the mines to close.

Mining activity increased in the 1930's when the price of gold rose, and small operators and gambusinos continued to operate in the area through the slow periods over the following four decades. In the 1980's the Consejo de Recursos Minerales (CRM), an agency of the Mexican Government, financed the construction of a 100 tpd flotation mill. In 1994, the Mexican mining laws were changed to allow 100 percent foreign ownership of mining properties, after which the Ocampo area became active soon thereafter.

In 1999, Gammon executed an option to purchase some key concessions in the district and by 2000 had consolidated most of the district for the first time since Mexican Revolution of 1912. In 2000 Gammon completed a total of 31,046m reverse circulation and diamond drill holes. Metallurgical studies began in

2000, and by March 2001 a preliminary design was completed for a heap leach pad and ponds and a geotechnical evaluation on the stability of potential open pits. Gammon and one partner continued exploration on the property until a positive feasibility study was completed in November 2004. Construction began in March, 2005 and commercial production was achieved in January 2007. Production since start-up of Gammon operations has been:

2006:	51,790 oz Au	1,303,100 oz Ag
2007:	87,687 oz Au	3,453,400 oz Ag
2008:	115,656 oz Au	3,995,700 oz Ag
Total	255,133 oz Au	8,752,200 oz Ag

## REGIONAL GEOLOGY

The Ocampo project occurs within the Sierra Madre Occidental Province. This extensive physiographic province extends from southwestern Mexico to the Arizona border and is host to many precious and base metal deposits (Wisser, 1966), and the deposits appear related to underlying basement composition (Campa & Coney, 1983). Regionally it is a relatively undeformed high plateau. The main feature of the province is the thick sequence of Tertiary volcanic flows, tuffs, agglomerates and related intrusives of andesitic to rhyolitic composition. These Tertiary volcanic rocks overlay a basement of Precambrian to Jurassic rocks. Uplift and erosion have created deep incised canyons. The basement rocks are found only in isolated windows. The stratigraphy of the area has been divided into two main groups, the Lower Volcanic Series (LVS) and the Upper (UVS). The LVS is the host to the majority of the Au-Ag deposits exploited in the Sierra Madres and is a calc-alkaline igneous series of volcanics (Cameron, et al., 1980; Camprubí, et al., 2003). The UVS is comprised primarily of a <1000m thick sheet of rhyolitic ash flow tuff – perhaps the largest ash-flow tuff field on earth, and several authors have proposed a series of large calderas to explain their presence, including the proposed Ocampo Caldera Bockhoven (1980), McDowell & Claybaugh (1979), Swanson & McDowell (1985), Wark, et al., (1990). Our work has not proven the existence of this proposed caldera.

The regional structural fabric has a general northwest trend related to the underlying Jurassic Mojave Megashear, as well as later extensional and transtensional deformation in the late Tertiary (Anderson & Silver, 1979).

## LOCAL GEOLOGY

### Ocampo Stratigraphy

Ocampo stratigraphy has been described by Bockhoven (1980), Byington & Bybee (2000) and Lewis (2009). These workers and our mapping have defined six informal formations within Lower Volcanic Series rocks. In general, these strata dip gently to moderately eastward, and consequently deeper stratigraphic levels are best exposed along the western edge of the property.

### Navosaigame Formation

Navosaigame Formation strata at Ocampo occurs in the northwestern part of the property, where the type section of the formation is well-exposed in roadcuts descending to the Rancho Navosaigame (Bockoven, 1980). Our observations show that the upper part of the sequence there is dominated by clast-supported conglomerates with rounded, polyolithic cobbles and a sandstone matrix. Green to brown, fine- to medium-grained sandstones are volumetrically minor in the upper part of the unit. The Navosaigame Formation is several hundreds of meters thick in its type locality. An unnamed sandstone - tuff unit of crystal-rich sandstones and volcanoclastic breccias/tuffs overlie the Navosaigame Formation along a sharp contact. The upper part of the sequence here contains poorly-stratified fragmental layers with quartz-phyric angular volcanic clasts and common fiamme textures. Flow-banded, quartz+biotite phyric lavas and autoclastic breccias exposed in the southern part of the property occur at the same stratigraphic position as the unnamed sandstone/tuff unit, and may represent its lateral, source-proximal equivalent.

## Victoria Formation

Thick sequences of flow-banded rhyodacite lavas and monolithologic breccia underlying the El Salto formation in the main arroyo south of Ocampo are interpreted as a flow/dome sequence assigned to the Victoria Formation (which is more prominently developed in the Pinos Altos district, 12 km to the NE; Lewis, 2009). The only other known exposure of Victoria Formation at Ocampo is in the NW part of the property where it lacks this vent-proximal unit but contains compositionally equivalent pyroclastic and epiclastic strata at the same stratigraphic level.

## El Salto Formation

A thick sequence of volcanic breccia and lithic tuff of the El Salto Formation overlies the Navosaigame Formation and unnamed sandstone/tuff unit, and is exposed over large areas in the western and southern portions of the Ocampo Property (Lewis, 2009). The El Salto Formation is lithologically varied, with the lower portion dominated by stratified volcanic breccias, and the upper portion containing multiple ignimbrite cooling units with well-defined fiamme texture. The breccias are characterized by abundant, finely flow-banded volcanic fragments, and contain minor fiamme. The phenocryst assemblage within it is dominated by plagioclase and hornblende, and quartz is rare or absent; therefore, a dacitic composition is inferred. The total thickness of the El Salto Formation has not been established, but its recognized distribution indicates several hundred meters are present.

## Ocampo Andesite

The Ocampo Andesite unit comprises lithologically-varied coherent and fragmental volcanic rocks and possible high-level intrusions that are widely exposed through the central part of the Ocampo camp. Most of the unit consists of either massive porphyritic (plagioclase, hornblende) lavas, or monolithologic clast-supported breccias that are compositionally and texturally similar to the lavas and likely originated as autoclastic breccias. Coherent facies in the northern part of the property include a strongly flowbanded porphyritic unit that may have originated as a dome complex. Well-stratified, epiclastic andesitic sandstone and conglomerate/breccia layers are locally interstratified with the coherent facies and monolithologic breccias, but form a volumetrically minor part of the Ocampo Andesite. The total thickness of the unit in the mine area is approximately 250 - 300 meters.

## San Ramon Formation

Epiclastic sandstones and breccias assigned to the San Ramon Formation form a discontinuous map unit up to approximately 50 meters thick overlying the Ocampo Andesite. In the mine area, the San Ramon Formation consists mainly of medium-grained, feldspathic arenite forming thick layers to massive deposits with fine internal laminations and local cross stratification. Elsewhere on the property, volcanoclastic breccias to conglomerates with andesite clasts form a significant part of the unit, occurring either as lenses within the sandstone, or as medium to thick beds with little or no interstratified sandstone.

## Santa Eduvigis Formation

The uppermost unit within the LVS at Ocampo consists of a thick sequence of nonstratified porphyritic breccia, assigned to the Santa Eduvigis Formation. Both the matrix and a majority of clasts in this unit contain abundant plagioclase, biotite, hornblende, and quartz suggesting a dacitic composition. However, the unit also contains conspicuous subrounded to irregular clasts of fine-porphyritic andesite or possible microdiorite, commonly with diffuse, irregular margins. The Santa Eduvigis Formation shows drastic variation in thickness: just north of the mine, it is up to 200 meters thick, but in the northwest part of the property the unit is completely absent, and rocks of the UVS directly overlie the Ocampo Andesite. It is uncertain whether the Santa Eduvigis Formation was preferentially eroded from, or was never deposited where it is missing from the sequence.

## Upper Volcanic Series tuffs

The Upper Volcanic Series at Ocampo has not been describe in detail, but in general consists of a basal breccia, a crystal-lithic tuff-breccia member (well-stratified volcanoclastic sandstone, poorly- to moderately-

welded crystal-rich matrix supported tuff breccia), a glassy vitrophyre member, an minor andesite member, and an upper dacitic flow unit.

## STRUCTURAL GEOLOGY

Structural features in the Ocampo District are primarily brittle faults characteristic of the northern Sierra Madre. Mapping in the mine area documents a high density of closely-spaced faults, some of which host the epithermal gold-silver mineralization. These faults include some with substantial normal offsets in the range of 50 to 200m, but there are dozens of minor faults and fracture zones that have negligible offset. Byington & Bybee (2000), Thorton & Arik (2004), Arik & Fest (2006), Lewis (1998), and Lewis (2009), in combination with our work, have recognized the complex system of faults as a cogenetic system of NW, WNW, NNE, and N-S faults related to extension, as follows:

### NW Faults

The predominant fault system in the district is a series of N40°- to N55°W striking normal or oblique faults that dip both SW and NE, although SW dips are predominant. This fault system is perpendicular to the general orientation of bedding, and is considered to be the fault system responsible for the systematic domino-like deformation of stratigraphy. This fault system hosts several vein systems, such as the Aventurero, Rosario, Brieseida, Picacho, and Adularia veins – all important ore deposits in the district. Kinematic indicators in the Aventurero show local subhorizontal movements, so these faults are believed to have a late strike-slip component.

### N-S Faults

North-South striking faults and veins are developed in the underground mine, and in surface mapping in the northern part of the district. The fault-veins in the mine have no documented stratigraphic offset, but dip steeply eastward to vertical. Those exposed in the north district exhibit several tens of meters of west-side-down displacement, and locally contain fault-striations indicating dominantly dip-slip latest movement. The Belen and San José veins are good examples of ore deposits emplaced in these structures.

### NNE Fault-Veins

Several north-northeast to northeast striking veins are known in the district that have been some of the richest veins historically – the San Juan, Maria, Balvanera, Animas, and San Amado veins (some of which are faulted continuations) are examples of rich veins formed in these faults. Consideration of the regional stress-strain pattern, along with mapping in the mine, indicates that these veins are extension fractures with minimal offset. However, similar-striking faults further north in the district form the boundaries between several large fault blocks on which significantly different stratigraphic successions within the Ocampo andesite and Santa Eduvigis formation are preserved. Thus NNE-striking faults may actually form two sets separated in time – a hypothesis that needs more work to test completely.

### WNW-Faults

Although these faults are rare, the WNW-striking PGR Fault system is a key component to the ore district. This fault corridor consists of brittle faulting with hydrothermal breccias, and forms the control to the open pit mines where this system intersects the NW-striking veins and lesser N-S striking veins. The four open pits and past-productive Sta. Eduvigis vein occur along this fault-vein system, and the system has been traced for a total of 5 km from the Estrella Mine on the west to the Altagracia prospect area on the east. The fault system dips steeply to the south and it is believed to be an oblique dextral-normal fault.

In most of the mapped areas, stratigraphic contacts and bedding exhibit shallow to moderate dips, mainly to the east or northeast. At least locally, there is a slight angular discordance between bedding in units deeper in the stratigraphic succession (Ocampo Andesite, El Salto Formation) and the well-stratified rocks of the upper volcanogenic sequence. The best known example is in the northern part of the property where the basal contact of the upper volcanogenic sequence truncates intraformational contacts in the Ocampo Andesite, suggesting that a significant small hiatus occurs at the base of the upper sequence.

However, no angular discordance has been identified to date in the eastern part of the property, and the regional significance of the contact remains uncertain.

The underground mine area consists of numerous northwest trending faults that are cut by north to northeast trending faults. This produces a rhombohedral pattern of horsts and grabens. In the Northeast area there are a number of mineralized structures that include Brenda, Maria, JM, Rosario, Aventurero, San Juan, Las Animas and Santa Juliana.

## MINERAL DEPOSITS

The Ocampo district is an example of low-sulfidation / intermediate-sulfidation mineralization in the current understanding of the definitions (Albinson et al., 2001, White & Hedenquist, 1995). Mineralization consists of brittle fault-controlled hydrothermal breccias, veins, and veinlet swarms that are generally restricted to narrow semi-planar features. Discreet classic banded fissure veins are actually uncommon (although sometimes the highest grades). Single-stage to three-staged quartz-adularia-calcite veinlet swarms and vein stockworks are actually more common. Above 1800m most veins have a low sulfide content whether mineralized or not. At depth some of the veins change gradually to unmineralized massive quartz-calcite, while others change to a mixture of gangue with 5 to 15% sulfides – predominantly pyrite with lesser galena-sphalerite-chalcopryrite. The former are regarded as true low-sulfidation, and the latter as intermediate sulfidation veins.

All the major fault directions in the district are mineralized to some degree, creating a very complex but economically-favorable geometry. Where NW-striking veins such as Picacho intersect WNW-striking vein systems such as PGR, complex sheeted veinlet and sometimes stockwork patterns form deposits that are amenable to low-cost open pit extraction. Mineralization in the PGR open pit trend commonly occurs in linear and triangular-shaped bodies 8 to 70m wide that can be mined with a low cut-off grade and heap leached. Mineralization grading less than 0.5 gpt Au commonly consists of sparse veinlets in a weakly silicified matrix, although some complex hydrothermal breccias also comprise low-grade ores. The PGR trend has locally extensive zones of hydrothermal breccias that are also controlled by elevation and lithology – the volume between 1800 and 2100m elevation where hosted by San Ramon and Sta. Eduviges formations are favorable for thick zones of hydrothermal breccias and low-grade gold mineralization over open-pit mineable widths. Below 1800m and within the Ocampo Andesite, mineralization is most commonly characterized by veins and sheeted vein zones that form underground-mineable ores. The main underground mine is located where there is an intersecting system of NW, N-S, and NE-striking veins that can all be mined from a central spiral decline ramp.

The low sulfidation mineralization consists of early pervasive adularization, and open-space fillings of white to clear quartz – amethyst – adularia - calcite gangue with mineralized phases of pyrite – argentite – native silver - argentiferous galena – electrum – sphalerite – chalcopryrite (Crawford et al., 2002). Mineralization is seldom found in discreet fissure type veins at Ocampo. The structures that house the mineral zones of importance have a core of quartz breccia surrounded by varying degrees of quartz stockworks and silicification.

Commercial grade of gold-silver mineralization are presently known over a 700m vertical interval from 2150m to 1450m elevation, although no single ore shoot has been traced more than 450m vertically. Several ore shoots were exposed on surface and had clearly suffered some erosion, hence the ore shoots were probably more continuous than their present preservation. Consideration of the tilting of the post-mineral UVS tuffs suggests that the district has been tilted slightly to the east, and some of the extensive vertical extent may be due to the tilting.

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