EVOLUTION OF THE POST-MINERALIZATION MARIANAS HYDROTHERMAL ERUPTION BRECCIA, CERRO NEGRO DISTRICT, PATAGONIA, ARGENTINA

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ABSTRACT

Cerro Negro project is one of the largest low sulfidation epithermal systems under exploration in the world. The deposit has a total resource estimation of ~6.7 Moz Au equivalent at 6 vein systems (www.goldcorp.com). The two Marianas veins (Mariana Central and Mariana Norte) represent about ~50% (3.3 Moz Au equiv.) of these resources, and they have the distinction of being discovered under a ~50 m thick post-mineralization hydrothermal eruption breccia event. The Marianas hydrothermal eruption breccia deposit extends over an area of about 0.5 km^2 and comprises a series of successive hydrothermal eruption breccia deposits interbedded with reworked volcaniclastic material of fluvio-lacustrine origin. These post-mineralization units were described in detail from selected drill-hole cores and correlated in two integrated cross sections in order to make an interpretation of the history of eruptive and sedimentary processes leading to concealment of the high grade precious metal veins. The main hydrothermal eruptive event is assigned to the latest mineralization stage. It is recorded in the breccia bodies with quartz-bearing banded fragments located just above dilatational structures. The fragments, up to 1 meter in diameter, were found as vein floats in the surface deposits and led to the discovery of the precious metal-rich veins. The reconstructed geometry of these breccias indicates that the eruption vents were located on the major dilatational faults hosting the epithermal veins. Most hydrothermal eruption breccias have been described in relatively young, poorly eroded terrains and active geothermal environments, where surficial and near-surficial features are preserved. Such shallow environment features are also preserved in the Jurassic rocks of the Cerro Negro district and consist of Au-Ag high grade epithermal veins, hydrothermal eruption breccias, and hot spring deposits. These rock types allow the reconstruction of entire volcanic–geothermal–epithermal system providing a unique model for the epithermal Deseado Massif region.

1. INTRODUCTION

Epithermal deposits form in the shallow parts of high-temperature hydrothermal systems. They are generally hosted by coeval and older volcanic rocks and/or underlying basement rocks and rarely by subvolcanic intrusions (Simmons et al. 2005). Shallow levels are characterized by several features including hydrothermal eruption breccias, sinter deposits, silicified finely laminated air-fall or lacustrine sediments, steam heated blankets and sheeted veins to the upper portions of some fissure vein system (Nelson and Giles 1985; Hedenquist et al. 2000; Corbett 2004; Simmons et al. 2005).

The Deseado Massif (southern Argentinean Patagonia) comprises a broad area of 60,000 km^2 with mainly Au-Ag low-sulfidation type epithermal deposits and numerous hot spring occurrences (Schalamuk et al. 1997; Guido and Schalamuk 2003; Echavarría et al. 2005; Fernández et al. 2008; Guido and Campbell 2011). These deposits are related to a widespread Middle to Upper Jurassic volcanic-hydrothermal event of andesitic to rhyolitic composition and calc-alkaline affinity grouped into the Bahia Laura Volcanic Complex (BLVC). This volcanic succession is part of the Chon Aike Silicic Large Igneous Province (Pankhurst et al. 1998), developed in Argentinian Patagonia to Antarctica, and interpreted as a diffuse extensional back-arc setting associated with opening of the South Atlantic Ocean (Richardson and Underhill 2002).

The region is an important gold and silver producer over the last 15 years (3 Moz of gold and over 40 Moz of silver; Páez et al. 2011) from four operational mines (Cerro Vanguardia, Martha, Manantial Espejo and San José). In addition, two new mines are under construction, including the Cerro Negro project, and more than 50 epithermal projects are undergoing different levels of exploration.

The Cerro Negro District is located at the western margin of the Deseado Massif and comprises ~26,500 ha of mining property 100 percent held by Goldcorp since December 2010. Based on resource calculations, Cerro Negro will become a promising gold producer in the Deseado Massif with significantly expanding reserves and resources.

At the northwestern part of the Cerro Negro District mineralization consist of steeply dipping low-sulfidation Au-Ag epithermal veins with exceptional widths and lengths (Eureka, San Marcos and the Marianas veins). The aim of this study is to recognize the mineralogical, textural and geological diagnostic features of the shallow epithermal environment represented by the two Marianas veins and the hydrothermal eruption breccia, and to recreate the evolution of the post-mineralization brecciation and sedimentary processes.

2. CERRO NEGRO DISTRICT

The Cerro Negro veins lies within an Upper Jurassic thick volcanic sequence of the BLVC. The volcanic sequence was dated by U-Pb on zircons at 159-156 Ma (Lopez 2006). The stratigraphic sequence begins with andesitic lava flows interbedded with dacitic ignimbrites. These rocks are intruded by andesitic and dacitic subvolcanic bodies and overlain by late rhyolitic lava domes, flows and pyroclastic equivalents. The volcanic succession is topped by widespread fluvio-lacustrine and volcaniclastic deposits (Fig.1). During the last stages of BLVC volcanism a large hydrothermal system (~15 km^2 surface area) developed in the Cerro Negro area, expressed as low-sulfidation veins and breccias, regional hydrothermal alteration and surface hot spring manifestations (Lopez 2006).

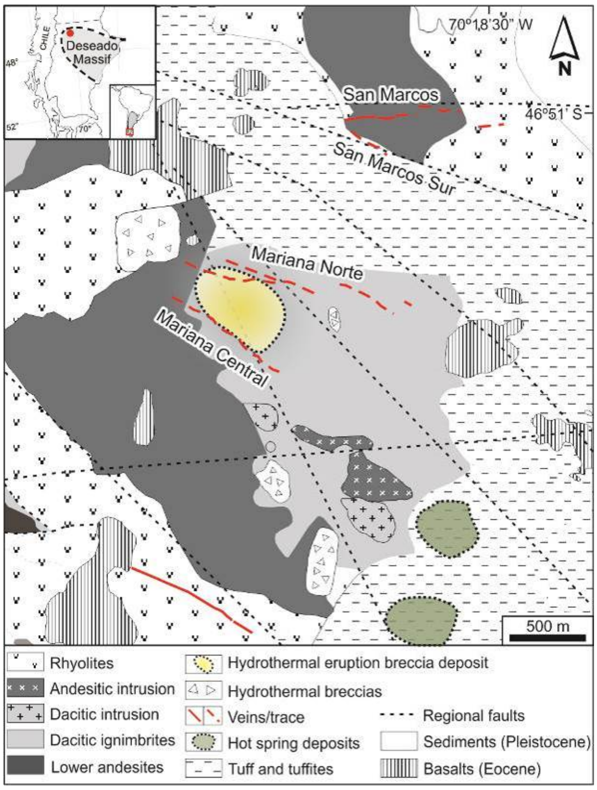

Figure 1: Geological map of the Marianas veins area with the location of the hydrothermal eruption breccia and hot spring.

3. THE MARIANAS SHALLOW EPITHERMAL SYSTEM

The Marianas epithermal vein system is located in the central part of the Cerro Negro District and is characterized by mineralized structures occupying major normal faults and/or splays at the limits of a NNW striking half-graben structure. The veins are hosted in andesites and are capped by hydrothermal eruption breccias and volcaniclastic deposits leaving surface expression restricted to few outcrops and quartz-bearing floats (Permuy Vidal et al. 2012; Fig. 2).

The two Marianas veins (Mariana Central and Mariana Norte) represent about ~50% (3.3 Moz Au equiv.) of the proven resources. These veins have the distinction of being discovered under a ~50 m thick post-mineral hydrothermal eruption breccia event as a result of a fence drill program below the vein floats.

3.1. Vein paragenesis

The Marianas vein systems are composed of quartz Au-Ag bearing epithermal veins characterized by several mineralization stages with crustiform-colloform banding textures and minor breccias. Carbonate replacement textures are observed locally but are not closely related to mineralization.

Eight mineralization stages were described and grouped into four main episodes. The first episode (E1 or high grade episode) is composed of crustiform-colloform banding textures and minor breccias with decreasing content of adularia, clay minerals (mainly smectites), quartz after fibro-radiated minerals (zeolite group minerals and/or truscottite) among quartz (after amorphous silica and/or chalcedony). High grade Au-Ag mineralization is related to early clay-sulfide rich bands or spots (“ginguro bands”), and/or disseminated in quartz bands. The second episode (E2 or barren episode) is the most voluminous, and consists of massive quartz, breccias and veinlets (fine comb quartz [amethyst variety] and carbonate pseudomorphs) with minor amounts of adularia and zeolites. E3 consists of massive calcite with comb quartz filling in the remaining open space, emplaced as veinlets or breccias with crosscutting relationships with respect to earlier stages. The fourth episode (E4) appears preferentially in Mariana Norte vein and consists of WNW-trending veining composed of a locally hematite stained quartz (after chalcedony and amethyst variety) and colloform banding with disseminated sulfides. Finally, E4 is composed by clay-rich matrix milled breccia with rounded clasts of rocks of the previous stages and locally displays erratic high silver contents associated with a dark Ag-sulfosalts-rich matrix.

4. HYDROTHERMAL ERUPTION BRECCIA

The Marianas veins system are truncated by post-mineralization units over an area of about 0.5 km^2 and comprises a series of successive sub-horizontal hydrothermal eruption breccia deposits of interbedded with reworked volcaniclastic material of fluvio-lacustrine origin. At the surface the breccia expression consists of a horseshoe shaped topographic depression of 600 m long by 350 meters wide filled by several blocks and fragments of up to 2-3 meters dispersed over 1 km^2 area in a circular pattern (Fig. 2; 3A). These clasts are composed of altered host rocks (mostly andesites and minor tuffites and rhyolites), crustiform to colloform banding vein fragments just above the hided fissure veins, and possible hot spring travertine blocks in at higher margins (Fig. 2).

All these post-mineralization package were described in detail from selected drill-holes and correlated in two integrated cross sections (A-A’ and B-B’; Fig. 2) in order to interpret the evolution of the explosive and sedimentary processes the deposits of which were hiding the high grade precious metal veins hosted in andesite volcanic rocks. A wavy contact separates the andesite host from the post-mineralization package reaching ~100 meters between both vein systems. Post-mineralization deposits are divided in several facies including: lower breccia facies; upper breccia facies; volcaniclastic deposits and ash-fall deposits.

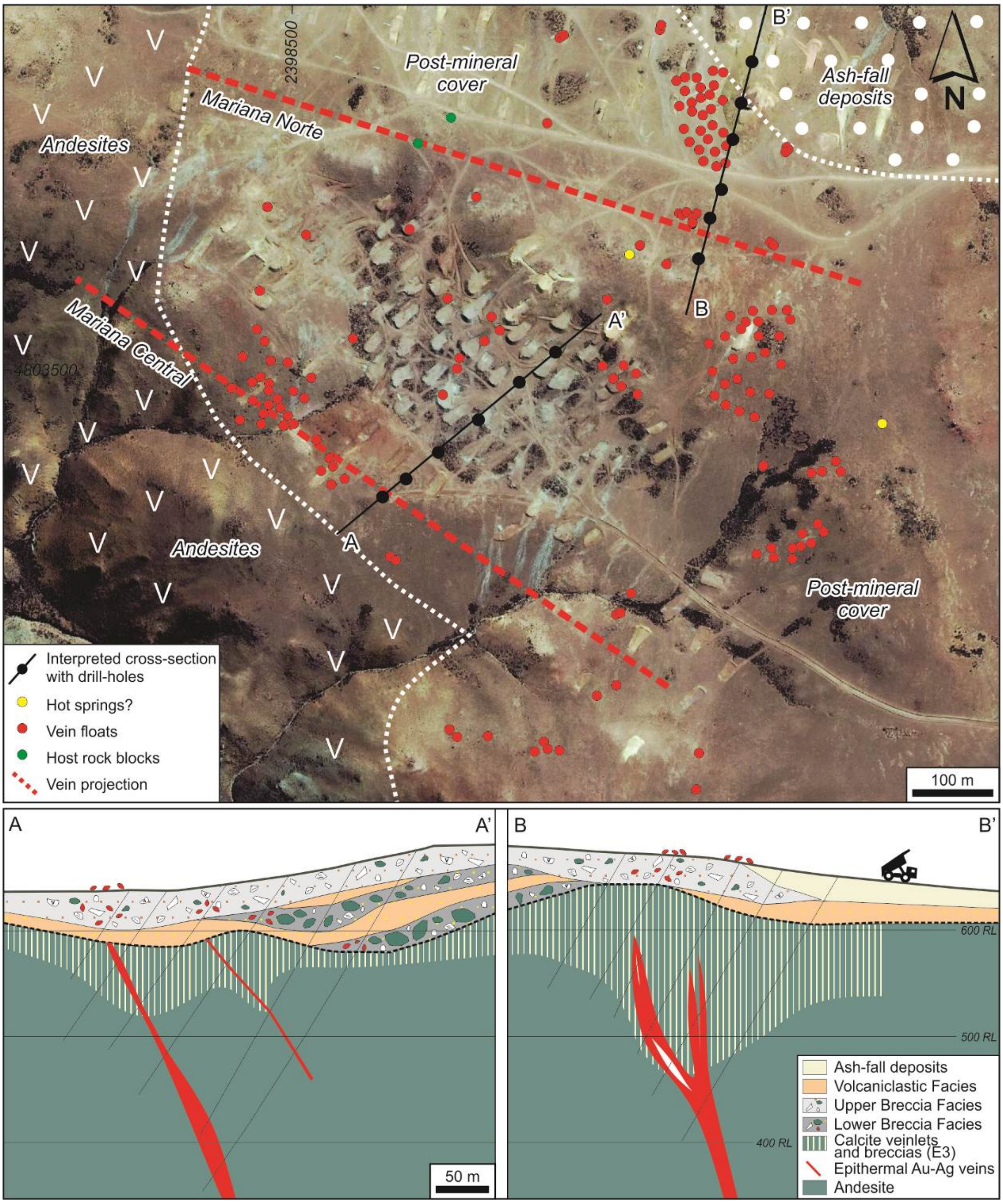

Figure 2: Top: plan view of the Marianas area with the hydrothermal eruption breccia surface features and the selected cross-sections for interpretations. Bottom: Interpreted sections along the post-mineralization hydrothermal eruption breccia deposits.

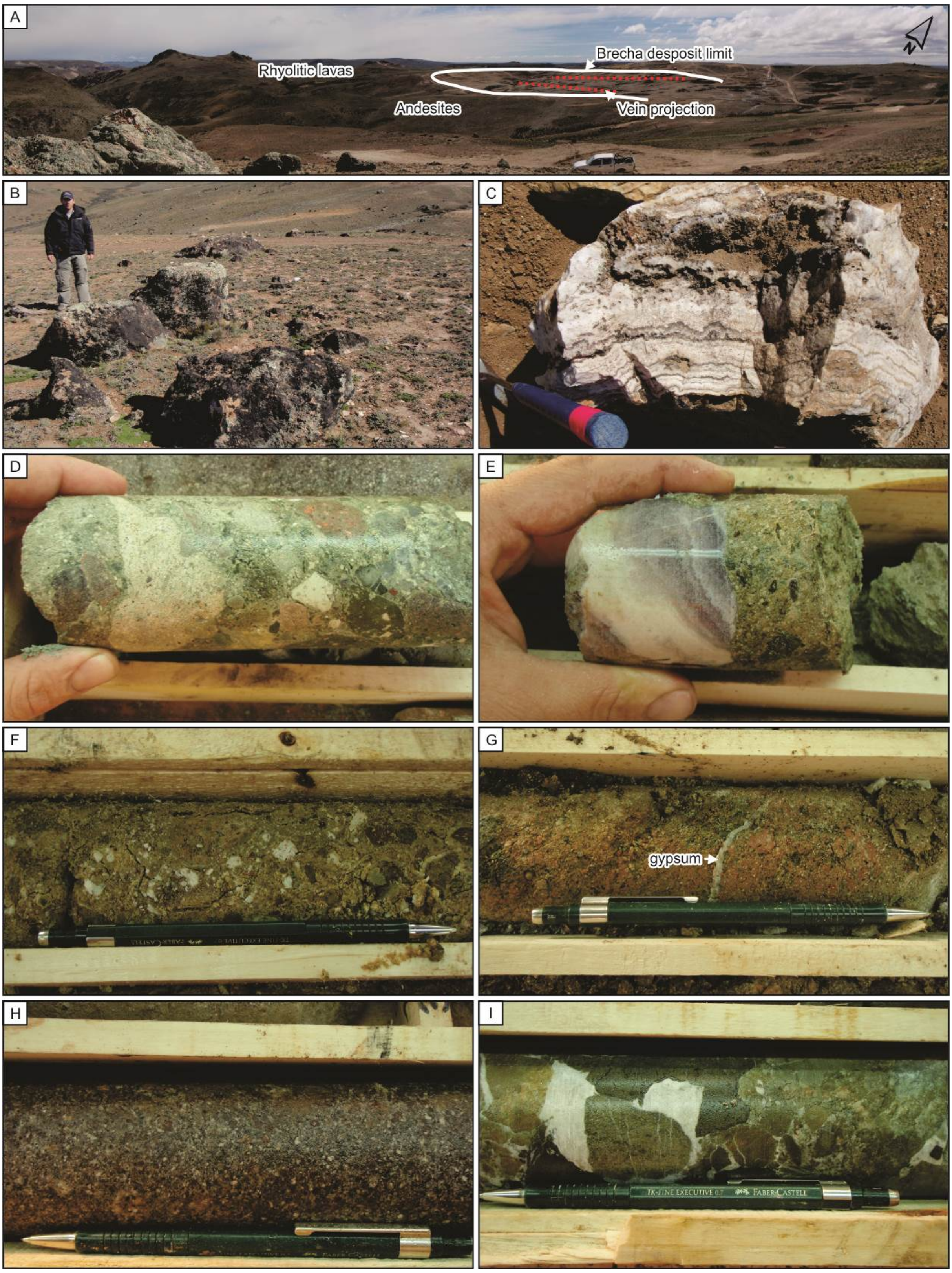

Figure 3: Mariana vein system and the hydrothermal breccia area. A: Regional view of the area. B: Larger blocks of the Upper Breccia facies lying on surface. C: Quartz crustiform-colloform vein fragments at surface. D: Polymictic breccias of Lower Breccia facies. E: Quartz colloform banded fragment on the Lower Breccia facies. F: Polymictic matrix supported breccia of the Upper Breccia facies. G: Gypsum veinlets in the matrix of the Upper Breccia facies. H: Volcaniclastic reworked facies. I: Calcite monomictic breccia corresponding to mineralization episode E3.

4.1 Lower Breccia Facies

These occur as two main lensoid shaped sub-horizontal deposits developed towards Mariana Central structures (A-A' section; Fig. 2) reaching 20-30 meters thick. Lower facies is dominated by polymictic matrix supported breccias with angular to sub-angular fragments of decimeters size, dominantly composed of hydrothermally altered andesites, less reworked volcaniclastic material and pyroclastic rocks (Fig. 3D) The matrix is composed of rock flour material, vug fills and fine veinlets of calcite (± manganoan calcite?) and greenish tinted clays (illite-smectite) of hydrothermal origin (Fig. 3 D, E). Frequently, the Lower facies contains abundant vein fragments of quartz massive to crustiform-colloform banded textures (Fig. 3E). The size of the fragments varies from a few centimeters on top grading to larger sizes just above the mineralized fissure veins.

4.2 Upper Breccia Facies

These develops a tabular shape deposit with a larger extension outcropping on surface and reaching ~40 meters depth at A-A' section above Mariana Central veins (Fig. 2). It consists of unsorted polymictic matrix supported breccias with angular to sub-angular fragments of up to few centimeters to decimeters size (Fig. 3 F). Clasts are composed mainly of pyroclastic rocks, minor andesite fragments and occasionally small vein material fragments and possible hot springs travertine blocks. The matrix is composed of comminuted rock fragments and hydrothermal clays (illite-smectite) frequently cross-cut by late fine gypsum veinlets (Fig. 3G).

4.3 Volcaniclastic facies

Tuffites are intercalated within the breccia facies, reaching 20 meters thickness in section B-B' (Fig. 2). These rocks are composed of reworked volcanic material in a purple coloured clastic matrix and a subtle calcite alteration (Fig. 3H).

4.4 Ash-fall deposits

Overlying all of the described facies in the B-B' section (Fig. 2) there appears fine ash-fall deposits interpreted as a post-breccia deposit.

4.5 Calcite veinlets and breccias

This breccia facies correlates with calcite veinlets and monomictic breccias of mineralization episode E3 (Fig. 3I). These rocks are disposed as a halo around mineralized structures near the lithological contact between the host rock andesites and the post-mineralization hydrothermal eruption breccia deposit (Fig. 2).

5. CONCLUDING REMARKS

The Mariana hydrothermal eruption breccia is a diagnostic feature of the shallow Jurassic volcanic-epithermal-geothermal environment in the Cerro Negro district. Facies reconstruction of the funnel-shaped breccia deposits reveals a brecciation cyclicity within syn-sedimentary pulses totalling a more than 50 meters thick deposit with the roots interpreted to be in Au-Ag high-grade mineralized veins. The first eruption was recorded in the lower breccia facies including two pulses separated by reworked material due to waning of cyclic main brecciation events. These facies locates mainly towards Mariana Central structures interpreted as the main conduits. Afterwards, another sedimentary cycle preludes a bigger eruption recorded in the the upper breccia facies with a larger extension covering Mariana Central and Mariana Norte systems and truncating previous deposits. Higher thicknesses points to both vein structures which probably were the conduits for this bigger eruption. Both breccia facies contains vein fragments evidencing a post-mineralization event. The whole package covers the mineralized veins and among some minor erosion processes it appears to record the Jurassic paleo-topography.

These types of eruptions are mentioned mainly in active geothermal environments such as Taupo (New Zealand) and Yellowstone (US). Nevertheless, Marianas fossil hydrothermal eruption main characteristics as shape, size and thickness indicate successive big-scale eruptions in agree with a huge hydrothermal system.

Low-sulfidation, hot spring type shallow gold deposits are enriched in precious metals with variable amounts of base metals. In that sense the Cerro Negro District high grade Au-Ag deposits are related to shallow epithermal features such as hydrothermal eruption breccias and hot spring deposits, representing a new model for the Deseado Massif province, and must be considered in further exploration of the region.

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