Mineralization Styles & Metal Zonation in Polymetallic Epithermal Systems
Santa Cruz Province, Argentina

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V Congreso Internacional de Prospectores y Exploradores
Patagonia - Southern Argentina & Chile, an Emerging Precious Metals Region

• Exploration discovery history in the last 30 years.
• A significant, new Au + Ag + Base Metal Province.
• Geological Setting – Massive extensional regime hosting many Au Ag epithermal deposits
• Modern deposit discoveries of 0.5 Moz to 5.0 Moz gold equiv.
• Last five years have doubled the number of new mineralized systems.
• New concepts, new technology have contributed to Discovery record: remote sensing; geophysics; new concepts
• Potential for future discovery in the geological province
Regional Overview

San Julian

Puerto Deseado

Las Heras

Cerro Bayo
28Moz Ag, 0.3Moz Au

San Jose
35Moz Ag, 0.5Moz Au

Eureka
1.4Moz Au, 24Moz Ag

Cerro Negro
0.9Moz Au

Martha
5.7Moz Ag

Manantial Espejo
38Moz Ag, 0.6Moz Au

Cerro Vanguardia
4.5Moz Au, 57.7Moz Ag

Vetas Sulfuro
0.2Moz Au

Cerro Moro
>1Moz Au/Ag???

Mirasol Resources
Claudia project

MINE LOCATION

Advanced Project

Mineral Occurrence

Major Town

Jurassic Volcanics

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Recent Discovery History

**First Exploration Stage**

- 1960s-1970s Fabricaciones Militares investigations
- 1980s SEGEMAR identifies and samples Cerro Vanguardia veins (Genini, et.al.), Cerro Moro
- Provincial Mining Reserves formed
- 1989 Freeport discovers Fachinal, Patagonian Chile (Tippett, Cruzat, Nasi, Moya, et.al.)
- 1989 Bond/Lac discover Manantial Espejo
- 1991 Volcan Hudson erupts (Chile) -2 metres of ash
- 1993 Newcrest discovers Eureka-Cerro Negro, La Paloma (Nano, Heenan, Smit)
- 1995 Yamana discovers Martha
- 1996 WMC discovers La Cantera, Tranquilo (Bajada)
- 1997 Minera Andes discovers Cerro Saavedra - Huevos Verdes (San Jose)

**Second Exploration Stage**

- 1998 MIM drills ore grade at Cerro Negro
- 1998 AnglogoldAshanti production commences at Cerro Vanguardia
- 2006 Freia vein discovered, San Jose
- 2007 Exeter drills ore grade at Cerro Moro
- 2008 Andean Resources drills ore grade at Eureka
Mineralization Styles & Metal Zonation in Polymetallic Epithermal Systems, Santa Cruz

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**Mine Location**

- **Major Town**
- **Jurassic Volcanics**

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**Mirasol Resources Claudia project**
Simplified Volcanic Stratigraphy

- **Resurgent rhyolite dome/flow/ air fall pyroclastics / epiclastic & Lacustrine rocks**

- **Late Chon Aike/early Matilde flows domes & Dykes rhyolite > andesite**

- **Quiescence/extension erosion/plant communities**

- **Massive rhyolite ignimbrite outpourings, minor dykes/domes, rhyolite > rhyodacite/dacite > andesite**

- **Flood basalts- andesitic volcanic centers**

- **Continental quartz & volcanic sandstone**

**Time Periods:**
- **JURASSIC**
- **CRETACEOUS**
- **TRIASSIC-CAMBRIAN**

**Locations:**
- **El Quemado**
- **Bajo Grande**
- **La Matilde**
- **Chon Aike**
- **Bajo Pobre**
- **Roca Blanca**
Stratigraphic timing of mineralization

Post mineral dome (rhyolite)

Altered synmineral dome (rhyolite>andesite)

Sinters - Chon Aike quiescence prograde base of Matilda

Epithermal veining hosted in dilatant structures in Chon Aike / Bajo Pobre / Roca Blanca / Triassic sequences

Mineralization late Chon Aike to Early Matilde event - Quiescence / change in character of volcanism
Santa Cruz epithermal model

*Polymetallic Ag-Au to quartz-ginguro Au-Ag epithermal*

- **Silica** kaolinite +/- dickite
- **Hydrothermal eruption breccia**
- **Water table SiO₂ flooding** Opaline/chalcedonic silica
- **Proximal sinter**
- **Vent mounds**
- **Passive replacement**

- **Zones over km’s (lateral outflow)**
- **Zones over 100m’s (up flow)**

**Advanced Argillic?**

**Polymetallic Ag-Au Epithermal**

- Smectite
- Illite

**Quartz-Ginguro Au-Ag Epithermal**

- Low sulphidation
- Low → Intermediate sulphidation

**Low sulphidation**
Paleosurface Model

- Water table silica
- Ejecta pebble
- Algal Sinter
- Replacement silica
- Silica Cap
- Eruption Breccia
- Vent Mound
- Mudcracks

- kaolinite +/- alunite
- SiO$_2$ kaolinite +/- dickite
- Hydrothermal Eruption breccia
- Water table SiO$_2$ flooding (thermal bulge)

Proximal sinter
Vent Mounds
Passive Replacement

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Paleosurface Model – Water table Silica (Silica Cap)

Silica replacement at paleowater table – Extensive areas associated with district hydrothermal up flows
Paleosurface Model – Water table Silica

Feeder structure – multiphase breccia  
Jasperoidal SiO2 - hematite

Pervasive replacement – chalcedony / opal. Rock textures preserved
Hydrothermal Eruption breccia

Proximal sinter Vent Mounds Passive Replacement

Water table SiO2 flooding (thermal bulge)

SiO2 kaolinite +/- dickite kaolinite +/- alunite

Concentric silica layers on ejecta pebbles & Wispy algal silica bands

Paleosurface Model – Proximal Sinter
Paleosurface Model – Vent mounds environments

Shallow aqueous. Vents mounds & stromatolites

Hummocky ground

Bioturbation
Paleosurface Model - Replacement

Hydrothermal Eruption breccia
Proximal sinter
Vent Mounds
Passive Replacement
Water table SiO2 flooding (thermal bulge)
SiO2 kaolinite +/-dickite
kaolinite +/-alunite
Desiccation cracks - Ephemeral lakes & shallow outflow zones
Polymetallic Ag-Au Epithermal

Ag : Au → 100s to 1000s

Wallrock vein breccia – hydrofractured wallrock, chalcedonic silica flooding rare pyrite – Kaolinite alteration of clasts.

Ag-Au chalcedony-adularia sulphide breccias – fine grained pyrite-marcasite-arsenopyrite rare Fe poor sphalerite-acanthiteargentite – Illite alteration

Ag-Au Colloform quartz ginguro veins – Early pyrite. Galena, Fe poor sphalerite, acanthiteargentite, electrum, tetrahedrite. Illite-sericite – Chloritie carbonate gangue

Ag-Au crustiform polymetallic veins – crustiform-colloform sulphide margin largely barren core. Early cubic pyrite. Galena, Fe poor sphalerite, chalcopyrite, electrum, polybasite, acanthiteargentite, tetrahedrite.

Ag crustiform polymetallic veins – Early cubic pyrite. Galena, Fe poor sphalerite, chalcopyrite, tetrahedrite, proustite pyargyrite, native silver minor electrum. Quartz adularia vein – illite smectite overprint
Polymetallic Ag-Au Epithermal

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Wallrock vein breccia
Polymetallic Ag-Au Epithermal

Ag-Au chalcedony-adularia sulphide breccias
Polymetallic Ag-Au Epithermal

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Smectite-Illite

Muscovite

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Polymetallic Ag-Au Epithermal

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Quartz adularia vein – illite smectite overprint

Smectite-Illite Muscovite

Ag crustiform polymetallic vein
Quartz-Ginguro Epithermal

Ag : Au 1 → 100

Mixed sulphide oxide facies, jasperoidal silica, fine grained pyrite marcasite phases. Mixing of oxidized meteoric and mineralized reduced fluids in structures

Colloform chalcedony veins with jasperoidal bands. Hematite dominated minor pyrite. Anomalous Au/Ag.

Chalcedonic fine saccharoidal quartz, ghosted wallrock clasts, acanthite-argentite clots – top of ore zone

Felted bladed textures and ginguro, chalcedony>adularia/illite, fine pyrite, acanthite-argentite, electrum and native Ag/Au – main ore zone

Colloform crustiform quartz and coarse bladed textures. Pyrite rare galena & sphalerite, acanthite-argentite, native Au/electrum – typically base of ore zone
Quartz-Ginguro Epithermal


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Jasperoidal silica (hypogene hematite) $\rightarrow$ chalcedony pyrite. Mixing oxidized and reduce fluids. 10’s ppb Au 1 – 20 ppm Ag
Quartz-Ginguro Epithermal

Mixed sulphide oxide facies, jasperoidal silica, fine grained pyrite marcasite phases. Mixing of oxidized groundwater and mineralized reduced fluids in structures.

Colloform chalcedony veins with jasperoidal bands. Hematite dominated minor pyrite. Anomalous Au/Ag.

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Banded jasper chalcedony vein. 100’s ppb Au & 10 - 30 ppm Ag.
Quartz-Ginguro Epithermal


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Chalcedonic-fine saccharoidal silica – acanthite clots

Top of ore zone
Quartz-Ginguro Epithermal


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Main Ore Zone - Felted bladed textures Colloform Chalcedony with ginguro
Quartz-Ginguro Epithermal

- Mixed sulphide oxide facies, jasperoidal silica, fine grained pyrite marcasite phases.
- Mixing of oxidized groundwater and mineralized reduced fluids in structures.
- Colloform chalcedony veins with jasperoidal bands. Hematite dominated minor pyrite. Anomalous Au/Ag.
- Chalcedonic fine saccharoidal quartz, ghosted wallrock clasts, acanthite-argentite clots – top of ore zone.
- Felted bladed textures and ginguro, chalcedony>adularia/illite, fine pyrite, acanthite-argentite, electrum and native Ag/Au – main ore zone.
- Colloform crustiform quartz and coarse bladed textures. Pyrite rare galena & sphalerite, acanthite-argentite, native Au/electrum – typically base of ore zone.
- Crystalline & Saccharoidal quartz + coarse bladed textures typically poorly mineralized (may be ore grade in rare cases).
Cerro Vanguardia – Claudia System

- **Cerro Bayo**: 28 Moz Ag, 0.3 Moz Au
- **San Jose**: 35 Moz Ag, 0.5 Moz Au
- **San Julian**: 28 Moz Ag, 0.3 Moz Au
- **Las Heras**: 28 Moz Ag, 0.3 Moz Au
- **San Jose**: 35 Moz Ag, 0.5 Moz Au
- **Eureka**: 1.4 Moz Au, 24 Moz Ag
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- **Manantial Espejo**: 0.2 Moz Au
- **Cerro Moro**: >1 Moz Au/Ag??
- **Mirasol Resources Claudia project**: 38 Moz Ag, 0.6 Moz Au

**Mines and Locations**

- **Cerro Vanguardia**
- **San Jose**
- **Manantial Espejo**
- **Cerro Moro**
- **Eureka**
- **Cerro Negro**
- **Las Heras**

**Jurassic Volcanics**

**Major Towns**

- **Puerto Deseado**
- **San Julian**
- **Las Heras**
- **San Jose**
- **Cerro Bayo**

**Map Legend**

- **Mine Location**
- **Advanced Project**
- **Mineral Occurrence**
- **Major Town**
- **Jurassic Volcanics**
Cerro Vanguardia Pits
17.1Mt@8.2g/t Au, 105g/t Ag

Claudia District

Rio Seco
Laguna Blanca
Curahue

Claudia Sinters

Post Jurassic Cover
Volcanic Domes
Sinters
La Matilde
Chon Aike
Bajo Pobre

Outcropping Vein
Pit Outline
Mineralised Corridor
Claudia Tenement
Cerro Vanguardia Pits
17.1Mt@8.2g/t Au, 105g/t Ag

Cerro Vanguardia – Claudia District

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Rio Seco Qtz-Ginguro zone

- Jasperoidal banding in vein
- Throat Breccia
- Wispy Sinter
- Acanthite clots
- Ginguro Banding
- Water table silica
Cerro Vanguardia – Claudia District

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Laguna Blanca – Early Polymetallic to late Au Ag epithermal

Sphalerite galena mineralization
Zn & Pb > 1 %, Ag < 30 ppm

Overprint pyrite Ag +/- basemetal
+ 500 ppm Ag, Pb & Zn 100 – 1000 ppm

Crustiform Cqtz veining
Au 1 ppm / Ag 30 ppm low Pb Zn

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Epithermal Metal Zoning

Rock Chip Sampling
- Base metal + Ag/Au 300-500
- Antimony + Ag/Au <30 (approx.)
- Mercury + Ag/Au <30 (approx.)

- Post Jurassic Cover
- Volcanic Domes
- Sinters
- La Matilde
- Chon Aike
- Bajo Pobre

Outcropping Vein
Pit Outline

Basemetal ($^{Ag/Au}_{Au}$ = 300-500)
Sb ($^{Ag/Au}_{Au}$ ~< 30)
Hg ($^{Ag/Au}_{Au}$ ~< 30)
Cerro Vanguardia Au/Ag resource areas
Summary

• Mineralization late Chon Aike to early Matilde event.

• Common spatial association with altered rhyolite +/- dacite - andesite dykes & domes.

• Polymetallic Ag-Au to Quartz ginguro Au-Ag epithermal (Corbett) with Low to intermediate sulphidation (Hedenquist) character.

• Zone vertically over 100s of meters & laterally on a district scale over 10 km’s from proximal polymetallic Ag-Au to more distal quartz ginguro Au-Ag.

• Mineral district 10’s of km’s in diameter – Cerro Vanguardia 25kms (Co.Vanguardia-Claudia – 35-40kms).

• Zoning patterns are important exploration tools to help vector in poorly exposed large mineral systems.