

Geology of Carmen de Andacollo Deposit

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Abstract. The Carmen de Andacollo Copper Mine is located in the Coastal Range of central Chile, Coquimbo Province. Carmen de Andacollo deposit has “hybrid” features with elements of Porphyry Copper and Stratabound deposits. The structural domain model consists of the following main faults, sorted by relative age from the oldest to the youngest: 1) Syn-Mineralization: Carmen Fault and Hermosa-Twila-Andacollo Set. 2) Post-Mineralization: NS and NE Faults. Six big configurable lithology groups were identified: Lower Volcanic Unit, Upper Volcanic Unit, Intrusive Rocks Unit, Breccia Unit, Undifferentiated Rocks, and gravels. Nine mineralization events associated with nine alterations events have been described. The mineralization/oxidation zones at Carmen de Andacollo are controlling influence on the Cu grades. From top to bottom in the profile the major mineralization zones are: Gravel, leached zone and oxide, strong and weak secondary enrichment and primary zone.

Keywords: Geology, Andacollo Mine, Cretaceous Deposits, Stratabound and Porphyry Copper Deposits.

1. Location

The Carmen de Andacollo Copper Mine (Teck Resource Limited) is located in the Coastal Range of central Chile, Coquimbo Province, Region IV, in central Chile at 30°15'S latitude and 17°10'W longitude. The property is adjacent to the town of Andacollo, approximately 55 km southeast of the city of La Serena and 350 km north of Santiago. Access to the Andacollo property is by paved roads from La Serena. The property is located near the southern limit of the Atacama Desert at an elevation of approximately 1,000 meters.

2. Geology

Carmen de Andacollo deposit can be classified according its features of mineralization, alteration as a “hybrid” deposit. East of the Hermosa Fault this has features of Porphyry copper whereas to the west of the Hermosa Fault, this has features of Stratabound deposits due to the presence of pyroclastic rocks which controlled the emplacement of mineralization (Herrera et al, 2011).

2.1. Structures

The structural domain model consists of the following main faults, sorted by relative age from the oldest to the youngest: 1) Syn-Mineralization: a) Carmen Fault. b) Hermosa-Twila-Andacollo Set (+NW Faults). 2) Post-Mineralization: a) NS Faults (Re-activation of Hermosa +

channels for Mercury Solutions). b) NE Faults (the later that cuts all previous + Supergene Mercury?)

2.1.1. Carmen Fault

The Carmen Fault is a North-West trending sub-vertical fault that roughly approximates the south boundary of the high-grade Cu mineralization. This fault is considered the oldest of the faults and physical evidence of the fault is limited. The existence of the fault is based on changes in Cu grade and Hg grade. A visual review of the grades on either side suggests that while there is definitely a decrease in grades south of the fault, it is not a definitive hard boundary. As this is one of the earlier faults that is either pre or syn-mineralization the use of a soft boundary across this fault is considered appropriate.

2.1.2. Hermosa-Twila-Andacollo Fault Set (Main Mineralizing Event)

The Hermosa and Andacollo faults are interpreted as faults that have had more than one movement event. For the main mineralizing event they are considered to have been part of a duplex with the Twila Fault. The Hermosa Fault in many places in the central, area represents the location of a significant vertical change in the Tuff location. In the areas that there is Andesite between the Tuff and the fault it is high grade (similar to Tuff). This has been reviewed and drillholes shows definite Andesite between the Tuff and the fault and a sharp drop in grade after the fault. For this reason it is considered that the Hermosa fault is the hard mineralization boundary, not the lithology boundary and the Hermosa fault is deliberately not always in the same position as the sub-vertical offset in the Tuff. Otherwise, the Hermosa fault has been cut and displaced by the NE Faults. Its trend bends to east close to Carmen Fault. East of the Twila and Andacollo is very low grade. The Andacollo fault in the detailed fault mapping is shown as a group of three faults over a distance of 5m. The base of the middle fault is an obvious hard boundary. There are a large number of North-West trending faults mapped that correspond to the North-West Porphyry orientation. These are considered to be plumbing source for the main Copper mineralizing event. These faults are not considered to significantly offset the lithology or other faults.

2.1.3. North-South Fault Set

There are numerous small scale North-South faults mapped. These are considered to be synchronous with the North-South Porphyries. There are none of these smaller scale North-South faults in the main structural framework.

There may have been re-activation along the Hermosa and Andacollo faults during this event. There is strong evidence that this event reactivated north-south systems and Andacollo-Hermosa, causing significant normal displacement (some places up to 200 m), post-secondary enrichment. The structural model has been updated with the Tres Perlas Fault, Central Fault and Central II Fault. They were interpreted using historical bench and drillcore logging. These new fault is located towards the east of the Central Fault and it has been responsible for generating geotechnical instability in west wall of phase 1 hypogene.

2.1.4. North-East Fault Set

There is a major North-East fault set mapped in the northern supergene Phase 9 of the pit. Three major faults have been interpreted in this orientation and these faults show significant offset of the Lithology. The southern two of these faults dip to the NW and the northern fault dips towards the SE. This is considered the youngest of the major faulting events and crosscuts earlier events including the Cu mineralization. This interpretation is the basis for the use of a hard boundary across these faults however the small number of drillholes across the faults makes it difficult to justify numerically. The Hg mineralization shows continuity related to the North-East direction and the North-South fault set so it is possible that the Hg-mineralizing fluids were plumbed through the system via both of these fault sets. Five NE faults were interpreted southwards from the deposit. All of them dip towards NW. They have been interpreted cutting all faults around with a 5-10m vertical offset.

2.2. Lithology

Six big configurable lithology groups are identified (figure 1).

2.2.1. Lower Volcanic Unit

It corresponds to a volcanic sequence mainly formed by andesitic flows and auto-breccias with smaller interspersed tuffs and volcanoclastic rocks. Lithologies included in this unit are Coarse Porphydic Andesite (APG), Microporphyritic Andesite (AMIC), Medium Porphyric Andesite (APM), Fine Porphyric Andesite (APF), Andesitic Breccia (BXA) and Aphanitic Andesite (AAF).

2.2.2. Upper Volcanic Unit

It mostly corresponds to pyroclastic rocks that are distributed accordingly on the Lower Volcanic Unit. From an economic point of view, the current work acknowledges the permeability of its texture, which greatly favoured the invasion of hypogene mineralizing solutions, as a fundamental characteristic of this Unit. Lithologies defined in this Unit are Crystalline Tuff (TBC), Vitreous Tuff (TBV), Trachytic Lava (LTR), Lithic Tuff (TBL) and Volcanoclastic Rock (VCL).

2.2.3. Intrusive Rocks Unit

They cut all previous stratified units. They correspond to

stock and dikes of riolitic, granodioritic, dacitic and andesitic composition. The first group of these lithologies, predominant orientation NW, is directly related to alteration-mineralization events which gave rise to the ore: Medium Dacitic Porphyry (PFB) and Coarse Dacitic Porphyry (PFD). The second lithology group is represented by Riolitic Porphyry (PFA), traditionally called “Culebron Porphyry” and Andesitic Porphyry (PFC) both of predominant orientation N-S, they are considered post-mineralization and are usually waste.

2.2.4. Breccia Unit

The lithologies included in this Unit are Hermosa Breccia (BXX), Hydrothermal Breccia (BXH), Magmatic Breccia (BXM) and Fault Breccias (BXF).

2.2.5. Undifferentiated Rocks

Lithologies, whose current characteristics do not allow their classification, these include Obliterated Rock (R.O.) and Triturated Rock (R.T.).

2.2.6. Gravels

Overload of recent sediments of natural origin, formed by semi-consolidated polymictic fragments. They overlay all units described above.

2.3. Alteration

Three big “Alteration Domains” have been established: a) Late magmatic Alteration Domain: This is divided in 3 alteration events: Potassic Alteration (secondary biotite or potassic feldspar), propylitic and albitic. b) Phyllic Alteration Domain divided in Main Phyllic and Late Phyllic events, and c) Argillic Alteration Domain, which considers the events of Intermediate Argillic and Supergene Argillic alterations.

2.4. Sulphide Mineralization

Nine mineralization events related to nine alterations events have been described, divided in 3 domains:

a) Primary Mineralization in Late magmatic Domain: chalcopyrite-bornite (traces), magnetite-chalcopyrite and chalcopyrite-molybdenite, related to Potassic Alteration with dominating Secondary Biotite; chalcopyrite-bornite related to Potassic Alteration with dominating Potassic Feldspar; chalcopyrite-magnetite-specularite-(bornite)-pyrite(?) associated with Albitic Alteration; pyrite, pyrite-chalcopyrite (traces), specularite-chalcopyrite (traces) and magnetite-chalcopyrite (traces) associated with Propylitic Alteration.

b) Primary Mineralization in Phyllic Domain: pyrite, pyrite-chalcopyrite associations in Main Phyllic Alteration; pyrite (coarse), and pyrite-chalcopyrite-tennantite-enargite-tetrahedrite associated with Late Phyllic Alteration.

c) Primary and Secondary Mineralization in Argillic Domain: pyrite-cinnabar, pyrite-tennantite-enargite, cinnabar and pyrite-tennantite-chalcopyrite in Intermediate

Argillic Alteration; chalcocite, chalcocite-(covellite) and supergene cinnabar (?) associated with Supergene Argillic Alteration.

2.5. Mineral Zones

The mineralization/oxidation zones at Carmen de Andacollo are a controlling influence on the Cu grades. From top to bottom in the profile the major mineralization zones are:

2.5.1. Gravel

This is generally considered to be recent transported sediments. There are a few instances where this material is (was) old waste dumps from historic underground mines. Any material in this zone that contains Cu grades has already been mined.

2.5.2. Leached Zone and Oxide

The Leached Zone is defined by the presence of Fe-Oxides without Cu-oxides or any sulphides. The Oxide Zone is defined by the presence of Fe-Oxides and Cu-oxides without any sulphides. These two zones were combined for the estimation. The logged presence/absence of Copper oxides did not create a visible correlation to the Cu grades. There were significant grades within material logged as Leach (i.e. no visible Cu oxides) that would make the separation of these zones questionable.

2.5.3. Strong Secondary Enrichment (ESEC1)

This zone is traditionally referred to as the Supergene Zone. It is defined by the presence of secondary Cu-sulphides, predominantly chalcocite, without the presence of chalcopyrite. While most drillholes showed this contact as a sharp contrast in CNCu there were some drillholes (~5%) that showed significant enrichment beyond this point. A second interpretation pass was needed displaying the CNCu value. If there was significant CNCu beyond the

logged contact then the contact was moved to the point at which there was a sharp decline in CNCu grade.

2.5.4 Weak Secondary Enrichment (ESEC2)

This zone is defined by the presence of Chalcocite and Chalcopyrite. The logging of small amounts of Chalcocite is inconsistent so this boundary contains significant amount of interpretation. It was considered that with the presence of Chalcopyrite, the dominant grade variability characteristics are the same as the Primary zone. This zone was used for defining Metallurgical characteristics.

2.5.5. Primary Zone

This zone is defined by the presence of primary minerals such as Chalcopyrite, Pyrite, Bornite, Tennantite, and no secondary Cu. PRIMC: Primary Zone featuring cavities. Rock fractures and cavities do not evidence or may be partially filled with gypsum. In the case of the latter, the roof of this area is called a “sulphate top” (TDSO₄). PRIMS: Primary Zone with no cavities. Rock fractures and cavities are completely filled with gypsum (±anhydrite). The roof of this area is called a “dominant sulphate top” (TDSO₄) and marks the end of supergene activity at the deposit. Top of carbonate – TCO₃: Surface that marks the upper limit of the area featuring fractures and veinlets filled with calcite. Water is noticeably less acidic under this limit than the water above the limit.

References

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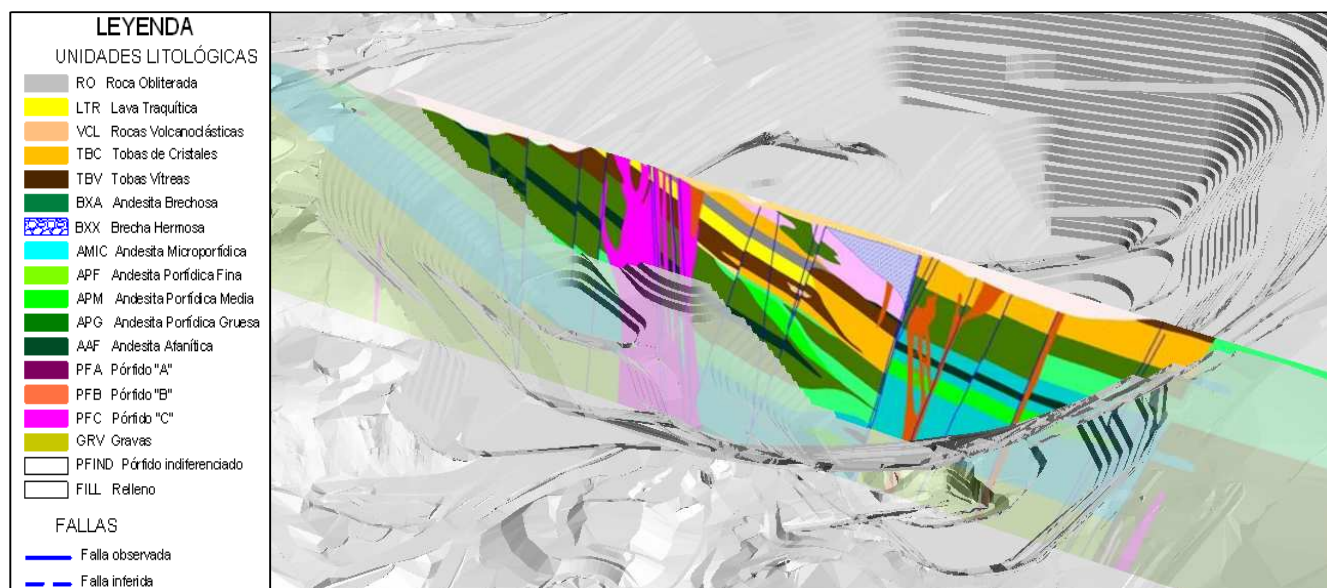


Figure 1. Section of lithology in final pit for Carmen de Andacollo Deposit.