# The San Francisco Gold-Silver-Copper Project, San Juan, Argentina – an example of a gold-rich intrusion-related tourmaline breccia system

# El Proyecto de Oro-Plata-Cobre San Francisco, San Juan, Argentina – Un ejemplo de mineralización aurífera relacionada a sistemas de brechas de turmalina.

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## 1. Abstract

Intrusion-related tourmaline breccias not obviously associated with porphyry copper systems are a subclass of tourmaline breccia that have not been widely reported in the academic literature. Intrusion-related tourmaline breccias are characterized by clusters of narrow, vertically-extensive downward-flaring tourmaline breccia pipes hosting a complex multi-element mineral assemblage (Au, Ag, Cu, Pb, Zn, Mo, Bi and W) with strong vertical zonation. Breccia clasts frequently exhibit decompressive shock textures and lack porphyry-type quartz veining. Exploration at San Francisco has defined a cluster of intrusion-related tourmaline breccia pipes, with drilling returning some of the highest gold-contents for this deposit style (i.e. 37m @ 6.3 g/t Au, 122 g/t Ag and 0.9 % Cu).

## Resumen

Brechas de turmalina relacionadas a intrusiones, sin clara asociación con sistemas de pórfidos de cobre, son una subclase de brechas que no han sido ampliamente documentadas en la literatura académica. Estas brechas de turmalina tienden a ocurrir agrupadas en *clusters*, exhibiendo morfología de chimenea (*pipe*), con gran extensión vertical y ensanchándose conforme aumenta la profundidad. En términos de mineralización, las brechas de turmalina se caracterizan por una compleja asociación polimetálica (Au, Ag, Cu, Pb, Zn, Mo, Bi y W) que revela una fuerte zonación vertical. Los clastos de las brechas usualmente exhiben texturas de descompresión y carecen de vetillas de cuarzo tipo pórfido. La exploración en San Francisco ha identificado un conjunto de brechas *pipes* de turmalina relacionadas a rocas intrusivas, cuyos resultados de perforación arrojaron leyes de oro comprendidas entre las más altas reportadas para este estilo de depósito (por ejemplo, 37 m @ 6,3 g/t Au, 122 g/t Ag y 0,9% Cu).

## 2. Introduction

Turmalina Metal's 3405 ha San Francisco property (the 'Project') is located at approximately 30° 50' S, 69° 36' W in San Juan province, Argentina: approximately 130 km northwest from the capital of San Juan and 55 km north-northwest from the town of Calingasta.

The project is located in the eastern foothills of the Andes mountain chain at an elevation of 2300 to 3200 m RL. Access to the project is by 20 km of dirt road from a graded provincial road.

To date five companies have conducted small scale mining or exploration at the project. The largest mine, the San Francisco de Los Andes ('San Francisco') mine, operated sporadically from 1941 to late 1970's (Lara, 2009). Subsequent local private companies and the Mines Department of Argentina conducted mapping, sampling and drilling campaigns at the project, with a total of 9 holes drilled for a total of 740m.

Turmalina Metals ('Turmalina' or 'the company'), a Canadian explorer listed on the TSX Venture exchange, entered into an option agreement on the project with two private land holders in late 2018. In 2019 Turmalina drilled ten holes at the San Francisco mine, intersecting multiple high-grade gold-copper-silver intersections (Table 1). This was

followed up by a comprehensive mapping and sampling program over the entire project area, which identified over 60 breccia occurrences. As of July 2020 the company was conducting a follow up drill program at San Francisco and several newly identified breccia targets.

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| 37 m @ 6.3 g/t Au, 122 g/t Ag & 0.9% Cu (8.7 g/t AuEq; SFDH-001) |
| 85 m @ 4.4 g/t Au, 109 g/t Ag & 0.8% Cu (6.6 g/t AuEq; SFDH-002) |
| Including 22 m @ 6.6 g/t Au, 86 g/t Ag & 1.5% Cu (9.5 g/t AuEq) |
| 51 m @ 3.6 g/t Au, 82 g/t Ag & 1.90% Cu (6.7 g/t AuEq; SFDH-003) |
| Including 26 m @ 5.5 g/t Au, 97 g/t Ag & 3.3% Cu (10.6 g/t AuEq) |
| 85 m @ 2.6 g/t Au, 88 g/t Ag & 0.6% Cu (4.3 g/t AuEq; SFDH-005) |
| Including 21m @ 5.0 g/t Au, 173 g/t Ag & 0.8% Cu (8.0 g/t AuEq) |
| 27 m @ 3.0 g/t Au, 124 g/t Ag & 0.4% Cu (4.8 g/t AuEq; SFDH-007) |

Table 1 – drill intersections from the Turmalina Metals 2019 drill program at San Francisco.

## 3. Geology

### *3.1. Regional Geology*

There are three major north–south-trending ranges in San Juan Province. These are, from west to east, the Cordillera Principal (Permian–Triassic calc-alkaline intrusives and andesitic to rhyolitic volcanics of the Choiyoi Group), the Cordillera Frontal (Carboniferous clastic sediments basement rocks of the Agua Negra Formation, intruded and overlain by Permian–Triassic volcanics and intrusives), and the Pre-cordillera (Palaeozoic limestones and clastic sediments in a basin and range terrain).

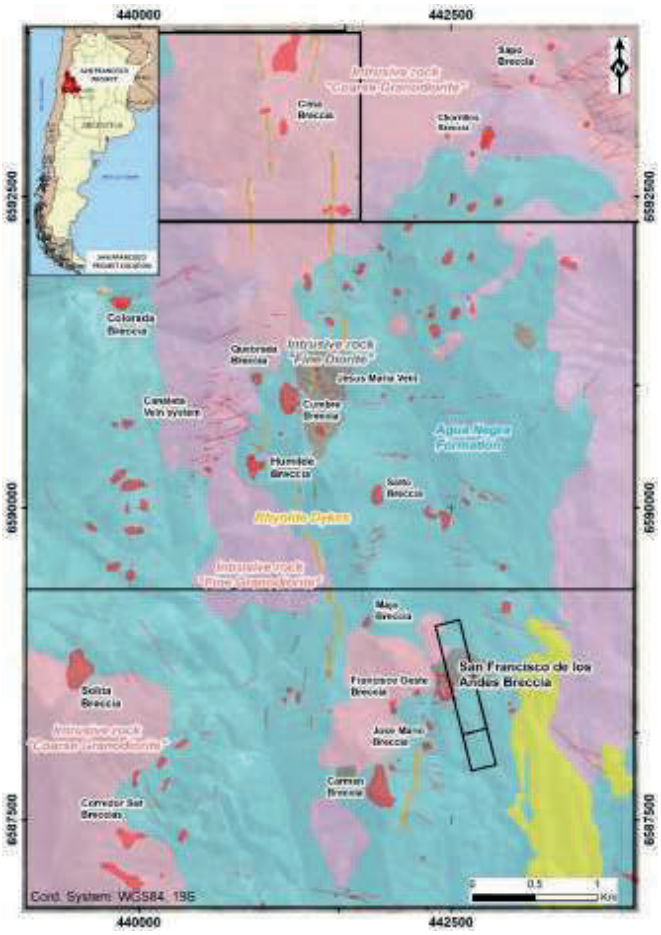


Figure 1 – Geology of San Francisco project area.

### *3.2. Project Geology*

The San Francisco Project is located on the eastern border of the Cordillera Frontal, with Late Permian diorite, granodiorite and quartz monzonite intrusives of the Colanguil Batholith emplaced into Carboniferous-Permian shallow marine quartzites and shales of the Agua Negra Formation (Llambias and Malvicini 1969). The Colanguil batholith has a strike length of over 40 km, and is part of a regional magmatic suite that is known to widespread tourmaline breccia polymetallic mineralization. The Colanguil batholith and Agua Negra formation are cut by Permian rhyolite dykes that post-date mineralisation in the area (Wyck, 2008).

*3.2.1. Agua Negra Formation*

The oldest rocks in the project area are dark grey arenites and siltstones of the Carboniferous Agua Negra Formation. The formation has been metamorphosed to shales and quartzite and, in close proximity to younger intrusives, contact metamorphosed to hornfels.

*3.2.1. Plutonic Rocks*

The Agua Negra Formation has been intruded by a late Permian feldspar-phyric biotite-quartz monzonite pluton. This plutonic phase varies from monzonite and quartz monzonite to granite, and the pluton contains small blocks/rafts or plugs of feldspar-phyric diorite to granodiorite. All of these units have been mapped as a single map unit by pervious workers (Figure 1; Wyck, 2008).

*3.2.1. Andesite Dykes*

Andesite dykes up to 5 meters width are present throughout the project area. The dykes cross cut both the intrusives and hornfelsed sediments.

*3.2.1. Rhyolite Dykes*

Distinctive, reddish weathering aphyric rhyolite dykes up to 10 meters truncate all intrusive rocks and associated quartz veins and tourmaline breccias.

## 4. Economic Geology

Two styles of mineralization occur within the property: gold-silver-copper mineralized tourmaline breccia pipes and gold-silver or copper-gold mineralized quartz veins.

### *4.1. Tourmaline Breccias*

Recent mapping by the company and previous workers has defined 62 breccia outcrops on the property. Several breccia pipes have supported small scale mining, with the most significant being the San Francisco de Los Andes breccia pipe.

The tourmaline breccias on the property are typically circular to ellipsoid in plan shape, and range from <10m to over 200m in diameter.

Within the breccia pipes angular sedimentary and/or igneous clasts are hosted in a quartz-tourmaline-pyrite-chalcopyrite matrix. Mineralization is typically focused on the margins of the breccia pipe while the adjacent wall rocks are typically strongly sericite altered with abundant margin-parallel sheeted quartz-tourmaline-sulphide veins.

The breccia pipes typically have an "inverted carrot" morphology, with pipes increasing in width with depth, with vertical extents of greater than 500 meters above their source pluton.

Clasts and matrix composition, alteration and mineralization styles all vary with depth, with the San Francisco breccia pipe being considered an example of a breccia pipe top, while the Chorrillos breccia is considered to be an example of the base of a breccia pipe.

*4.1.1. The top of a breccia pipe: the San Francisco Breccia*

The San Francisco de Los Andes breccia pipe is 20m wide on surface and 70m long, with drilling indicating that the pipe becomes wider at depth. The breccia has been emplaced into hornfelsed quarzitic sediments of the Agua Negra formation.

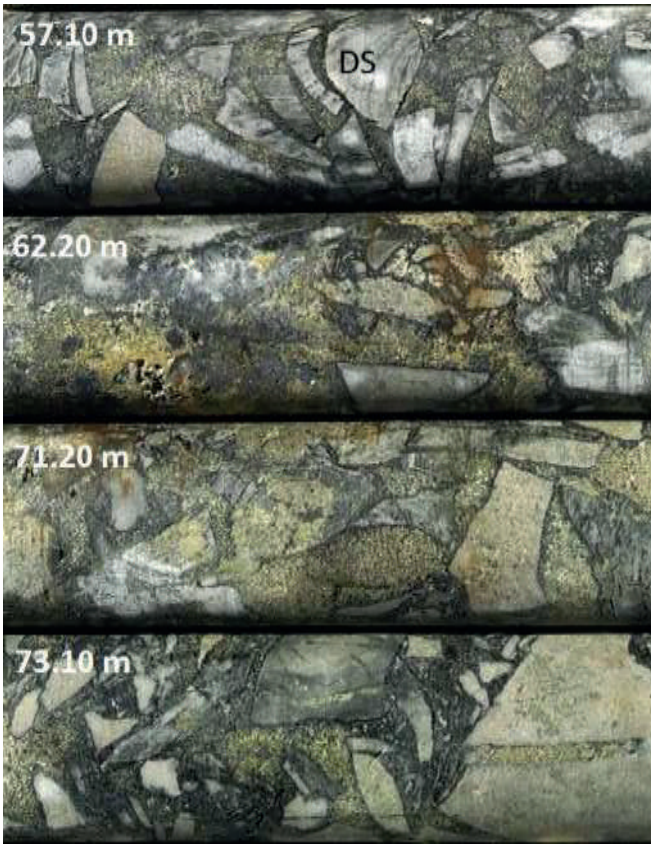


Figure 2 – Photographs of shallow breccia mineralisation from drill hole SFDH-005, San Francisco de Los Andes breccia pipe. Sericite-altered sedimentary clasts set in a sulphide-tourmaline matrix. 'DS' – curvilinear decompressive shock textures.

Within the breccia angular sericite-altered clasts of only the Agua Negra formation are supported in a pyrite-quartz-tourmaline-arsenopyrite-chalcopyrite-galena-sphSalerite-bismuthinite matrix (Figure 2). Polymetallic mineralisation (Au-Ag, Cu-Pb-Zn & Bi) is strongly zoned over distances of 10's of meters.

*4.1.2. The base of a breccia pipe: the Chorrillos Breccia*

The Chorrillos breccia pipe is elliptical in plan, approximately 90m wide on surface and 100m long. The breccia pipe has been emplaced into a biotite granodiorite that contains common tourmaline rosettes, miarolitic cavities and magmatic breccias. Within the breccia pipe angular sericite- or albite-altered granodiorite clasts are hosted in a tourmaline-quartz-chalcopyrite-pyrite matrix (Figure 3; Motton, 2019), with Cu-Mo mineralisation focused on the margins of the breccia pipe.

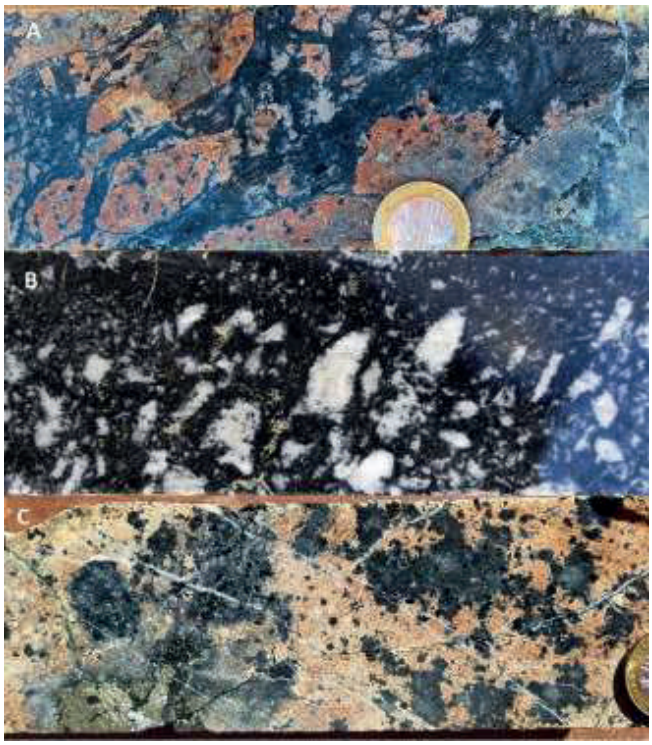


Figure 3 – Photographs of typical deep tourmaline breccia textures from the Chorrillos breccia pipe. A: Orthoclase-altered intrusive clasts set in a tourmaline-quartz matrix breccia. B: Eroded quartz clasts set in a tourmaline-chalcopyrite matrix. C: tourmaline rosettes and large miarolitic cavities filled by tourmaline-quartz-pyrite within the 'parent' granodiorite pluton.

### *4.2. Veins*

The project area hosts numerous 0.1 to 5 m wide quartz-limonite-hematite veins associated with sericite alteration. These veins are typically either Au-Ag or Cu-Au-Ag mineralized and several have supported small scale mining for gold.

## 5. Discussion

Intrusion-related gold-silver-copper tourmaline breccias are a sub-class of tourmaline breccia that have received less attention then 'porphyry-related' copper-molybdenum tourmaline breccias. Intrusion-related tourmaline breccias typically form clusters of downward-flaring narrow pipes above a source pluton (Kirwin et. al. 2018), and individual breccias commonly display a complex multi-element mineral assemblage (Au, Ag, Cu, Pb, Zn, Mo, Bi and W) with strong vertical zonation. In contrast porphyry-related tourmaline breccias display a relatively simple Cu-Mo mineral assemblage and flare upwards into breccias that can be over 1 km in width. Clasts in intrusion-related examples often display decompressive shock textures and lack porphyry-type quartz veining.

Given the strong vertical zonation it is important when exploring in an intrusion-related tourmaline breccia cluster to understand where a given breccia is located relative to the vertical zonation.

The shallow parts of intrusion-related tourmaline breccias are characterized by narrow shingle breccias (typically tens of meters wide) with sericite-altered clasts of country rock set in a sulphide-rich pyrite-quartz-tourmaline matrix with strong precious and base metal mineralization. Deeper zones are characterized by potassic alteration, +/- biotite and magnetite.

With increasing depth the breccia pipes become wider, clasts of intrusives become more common and mineralization grades from Au-Ag to Cu-Mo, with the highest grades typically focused on the inside margin of the breccia pipe.

The base of intrusion-related tourmaline breccias may be greater than 300m in diameter and is hosted in the source pluton which displays signs of volatile saturation, such as UST's, miarolitic cavities and tourmaline rosettes. The base of the breccias are characterized by orthoclase- or albite-alerted intrusive clasts hosted in a matrix that grades from hydrothermal (quartz-tourmaline) to magmatic (quartz-aplite) with increasing depth.

## 6. Conclusions

Intrusion-related tourmaline breccias may represent attractive high-grade Au-Ag-Cu

exploration targets and low development CAPEX opportunities that have not received significant attention from the exploration or academic communities.

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