Observations on epithermal mineralization in the Casposo and
Castaño Nuevo districts, San Juan, Argentina

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**Contents**

Summary and recommendations 3

Introduction 7

Background, and ore deposits of the region 7

Observations on the Casposo district 11
  - Paleosurface 11
  - Vein textures and alteration in the NW corridor 13
  - Veins north and NE of the NW corridor 15

Observations on the Castaño Nuevo district 18
  - Dome-centered advanced argillic alteration 18
  - Epithermal veins 20

Discussion 21
  - Casposo 21
  - Castaño Nuevo 23

Summary and conclusions 24
  - Casposo 24
  - Castaño Nuevo 25

Recommendations 26
  - Casposo 26
  - Castaño Nuevo 27
  - Regional 27

Qualifications 28
Summary and recommendations

Casposo

The main mineralized veins at Casposo now known occur in a NW-trending structural corridor that encompasses the Kamila pit, which hosts the Aztec, B and Inca veins. Mineralization is present from ~2500 to ~2300 m elevation; the Inca 1 veins extend to the SE at greater depth. Recent exploration by Troy has extended this mineralization to the SE with the discovery of the blind Inca 2 vein; the top of mineralization is over 200 m deep, within the andesite below an elevation of ~2200 m; the top of mineralization lies below the SE-dipping unconformity. To the NW, veins extend into the Mercado and Panzón area, making this NW corridor over 2 km in strike extent; further to the NW the veins are cut by a post-mineral dike. Further NW post-mineral rocks cover the area up to the Julieta veins, which outcrop over 4 km NW of the Panzón veins; thus the total length of this corridor is nearly 7 km, with over half of this corridor untested. E-W and N-S veins are also present north of the Kamila, with some of these tested only to maximum depths of ~130 m. The E-W veins are the earliest mineralized structures, formed during weak N-S extension, as indicated by structural studies, followed by E-W extension during formation of the N-S and NW-trending veins. Discovery of the Natalia vein east of the N-S fault that was earlier thought to be the eastern boundary to veins indicates further potential to the east.

Several veins in the district have illite as a gangue mineral or in a near-by alteration halo, and some have adularia also in an alteration halo. In the area of the surface projection of the Inca 2 vein, there is illite as well as adularia in a strongly silicified zone of alteration. These observations indicate a moderately high temperature (>200°C) boiling fluid in the veins. In the Mercado NW area there are laminated siliceous sediments that are now close to horizontal (within 10°), as well as minor occurrences at Panzón and Maya, that formed in open spaces at a shallow depth (perhaps <50-100 m) with an original horizontal orientation; their present position indicates little if any post-mineral tilting. Minor silica gel textures atop Rosarita hill, SE of the Inca 2 projection to the surface, are consistent with a low-temperature, shallow depth of formation.

Colloform textures in veins of the Kamila pit, as well as Inca 2, are consistent with a rapid cooling due to boiling. Previous studies as well a vein examination indicate multiple events of mineralization, both Ag- (and base metal)-rich as well more Au-rich (lower Ag: Au ratio). Besides numerous Au and Ag minerals, including Ag selenides, there are also minerals that indicate an intermediate sulfidation state (e.g., tetrahedrite), possibly due to periods of rapid boiling and cooling during mineralization.

The SE dip of the Inca 2 vein, as well as the general trend of vein lodes from the Kamila pit, matches the SE dip (>20°) of the andesite-rhyolite unconformity. The latter is likely pre-mineral in timing, consistent with the high angle of post-mineral dikes being in an original orientation. Such a pre-mineral tilt suggests that the unconformity may have influenced the level of mineralization, with upper limit of ore being deeper to the SE. If the tilting is pre-mineral, as the near-horizontal syn-hydrothermal laminated sediments suggest, the area of the north should be more deeply eroded. By contrast, at Mercado NW, and possibly Penzan and Maya, the textures suggest a shallow level of erosion; if these observations are correct, then a cross-fault with north-side down, north of the Kamila pit, is indicated.

Only by drilling through the horizon of potential high grades can a vein in the Casposo district be concluded to have been tested adequately, since the depth to relatively sharp tops of consistent ore zones can be as deep as paleo-temperatures of ~220°C, i.e., within the zone of illite stability,
and beneath the top of colloform-banded silica gels. The deep potential of veins in the district must be tested, given the vertical extent noted for good grade in the Inca 2 veins.

_Castaño Nuevo_

At Castaño Nuevo there are two principle veins, Dios Protégé outcropping at ~1625-1675 m elevation, and the San Agustin vein, with an upper outcrop at ~1840 m elevation. The better grades appear to be associated with the lower elevation vein. The best grades in both veins are typically related to brecciated vein margins with associated adularia. The potential for sufficient tonnage and grade to allow an open cut and trucking operation on these veins appears limited; the only target is for high-grade veins that would support underground mining. Stopes from historic mining are related to steeper portions of the normal faults that were dilated during dip-slip movement. Of the 27 holes drilled on these veins, none were deeper than 130 m vertical, meaning that the depth extent may not have been fully tested, particularly on the higher elevation San Agustin vein where shallow drilling did not intersect the high grades in outcrop. Given the high grades at ~1650 m elevation in the Dos Protégé vein, drill testing of the San Agustin vein to a similar elevation is warranted, i.e., ~100 m below the deepest level cut by previous drilling.

Further south a large area of alteration appears to be related to extrusion of a dacite dome in the Tertiary, with block and ash flows mapped over an area of 300 x 200 m. Based on previous mapping, the block and ash flows have been altered to residual quartz, silicic 2-3, with a halo of hypogene quartz-alunite and argillic alteration. Brecciated blocks include laminated lacustrine sediments that indicate paleosurface, implying a relatively shallow level of exposure at the top of this volcanic dome, ~2000 m in elevation. To the north ~1 km there is a horizon of chalcedony-replaced tuff that fills a channel at ~1850 m elevation, which overlies the San Agustin vein; given the erosion on the vein system, this chalcedony blanket most likely formed due to ground water table outflow of steam-heated water from the area of the dome. The chalcedony blanket indicates significant erosion of the veins, to the level of mineralization, prior to dome extrusion.

Early sampling indicates that the residual quartz has grades of 40 to 250 ppb Au, with one sample reporting 2 g/t Au, suggesting that this silicic lithocap may be mineralized. Even if this body is found to be largely barren, its occurrence indicates the potential for similar (Miocene age?) lithocap-related mineralization in this volcanic belt.

_Recommendations_

_Casposo_

- Conduct an orientation survey of the nature of the clay mineralogy zonation from hanging wall to footwall major veins, using SWIR (short wave-infra red) analysis; include surface traverses, e.g., over the projection of the blind Inca 2 vein. Based on these results and associated structural studies, extend surface traverses over areas of known veins and vein extensions, to determine the potential for vein continuation.
- All data collected on the surface and from drill core, geological, geochemical, mineralogical and geophysical, should be compiled into a single data base, and with new information on alteration added. Such a data base would provide the opportunity to integrate and interpret the geological, structural and vein history of known veins, including post-mineral changes. This information will allow exploration targets to be developed that best match known mineralized veins or fit a predicted environment of ore.
• Compile a table with vein characteristics, including nature of structures and their orientation, range of elevation of the veins as well as mineralization levels, vein textures and gangue mineralogy, sulfide mineralogy, paragenetic events, geochemical signatures (grades, Ag:Au ratios and variation, anomalous elements), grades in outcrop and vein widths, approximate elevation of the veins as well as alteration mineralogy, etc. Establish a relative order of priority for testing each vein set in the district.

• A greater density of surface sampling will provide more detail on grade variations to be expected at depth. For example, the Central vein at Cerro Norte should be channel sampled up the slope every ~5 m vertical to provide an indication of the vertical variability. Similarly, channels every 10 m across the Amanda vein will indicate the variability to be expected when the vein is drill tested. In addition, compare the grade results with the vein textures, here and elsewhere in the Casposo district, as epithermal veins in general, and Casposo in specific, can be highly variable in grade distribution.

• The tectonic evolution and structural framework of the district is better understood than most epithermal vein systems. Further structural studies should integrate other constraints, such as indicators of a horizontal position during hydrothermal activity, i.e., the laminated silica gels, as well as post-mineral movement. All veins, particularly those north of the NW trend, should have careful structural assessment to indicate the movement direction and the likely position and orientation (plunge) of dilation, as these should have the best potential for drill testing. Structural intersections have also been concluded to be conducive to width and grade development.

• Once the relative erosion levels of veins are estimated, from alteration, vein texture, grade and other indications, drill test each different vein set in order of priority to levels below evidence for silica gel deposition, e.g., colloform bands. This may be as much as 200 m or more vertical depth in areas of shallow erosion, i.e., where vein-hosted fault blocks when down-thrown rather than uplifted and eroded.

Castaño Nuevo

• The San Agustin vein at Castaño Nuevo should be tested to an elevation of ~1650 m, the elevation of good grades in the Dios Protégé vein, in zones of dilation and brecciation; such zones may have a plunge, rather than being vertical.

• Below the silicic lithocap at Castaño Nuevo, collect samples of silicic altered talus (chip sample over ~3-m radius silicic blocks, perhaps distinguishing silicic 2+ rocks, those brecciated and cemented, and quartz-alunite plus silicic <2 alteration in separate samples). If the results are positive (a significant portion, at least a quarter, greater than ~0.4 g/t Au), train samplers in rope safety and collect representative samples from the steepest silicic portions of the cliffs, to assess the potential of this body. Focus on structurally related feeders in the silicic core, as these tend to report the highest grades. If the results are positive, plan a drill program of angled holes to test the lithocap, working out from the structural feeder zones.

• Date the hypogene alunite in order to identify the age of the volcanism and hydrothermal activity, to help guide regional exploration for similar alteration styles and mineralization potential, not widely recognized in the Cordillera Frontal belt.
Regional

- Exploration targeting by prospectivity assessment is based on the quality, and relevance, of data input into the model. 1) Increasingly exploration is being conducted under cover, either post-mineral, or barren steam-heated alteration; in such cases, geochemical anomalies will not be present. 2) The ASTER survey interpretation needs reassessment, as the original interpretation suggested - incorrectly - that ASTER could detect feldspars; this brings into serious doubt the quality of the complete interpretation. The ASTER survey must be reassessed, both for project districts as well as for regional assessment by a geologist who also collects ground-truth samples. 3) Such prospectivity analysis will find styles of mineralization similar to known examples; an increasing proportion of discoveries will be of new styles in existing districts and new areas.

- Collect samples at the surface of different alteration mineralogy to use as ground-truth information to train the results from ASTER satellite images. Using a realistic mineral assemblage grouping, an experienced specialist should interpret ASTER anomalies, followed by a field check in the near-mine area, the district, and the region; feature to define include illite-related linear zones around veins, and alunite-dickite zones related to lithocaps, e.g., Castaño Nuevo for the latter. If pyrophyllite is confirmed (i.e., the original widespread ASTER anomalies are real) in an intrusive center, this suggest a sub-lithocap level of erosion, potentially to stockwork veinlets levels associated with porphyry systems.
Introduction

Peter Doyle, Vice-president, Exploration and Business Development of Troy Resources, requested the author to visit the Casposo mine in San Juan, Argentina, in order to comment on exploration near the Casposo and Castaño Nuevo projects. Two and a half days were spent in the field in and around the Casposo mine, plus a half day examining core from recent exploration drilling, and another day was spent in the field at Castaño Nuevo. Lectures on low-sulfidation deposits were also presented to the assembled geologists. In addition to Doyle, the visit was joined by the exploration team of Gustavo Sotarello, Irma Belvideri, Augusto Mol, Ezequiel Silva, Brendon Dean, Agustina Cocola, Ricardo Castro, Guillermo Romero, and Pedro Garcés, as well as mine geologists Oscar D’Orazio and Alejandro Rodriguez. A group from the Centre For Exploration Targeting (CET) University of Western Australia is also studying the Casposo district, including Steffen Hagemann, John Miller, and Arianne Ford, plus Ana Fogliata and Sebastian Grignola from the University of Tecumán. The author thanks members of this team for their information and discussion, and input to this report.

Background, and ore deposits of the region

The following background sections are largely taken from Doyle and Whitehouse (August 2011, NI 43-101 report), with minor amendments.

San Juan Province straddles three major north–south-trending ranges, the Cordillera Principal, Cordillera Frontal and Precordillera as well as part of the Pampean range (Sierras Pampeanas range). The Casposo project is located on the eastern border of the Cordillera Frontal, separated from the Precordillera to the east by the Rodeo-Calingasta–Uspallata Valley.

The Cordillera Principal extends along the Chile-Argentine border for ~1500 km. The main basement is formed by Permian–Triassic intrusive and volcanic rocks, of calc-alkaline affinity and andesitic to rhyolite composition, regionally known as the Choiyoi Group. These and younger sedimentary rocks of Jurassic and Cretaceous age have been thickened by compression and thrusting principally since the Late Cretaceous in a thin-skinned fold thrust belt.

The Cordillera Frontal comprises a basement of Carboniferous clastic sedimentary rocks to the west, intruded and overlain by Permian–Triassic volcanic and intrusive complex to the east. This complex consists of the same rock units as those in the Cordillera Principal, and was also uplifted with the Cordillera Principal. The Choiyoi Group hosts coeval mineralization, mainly porphyry Cu-Mo and Cu-Au deposits such as San Jorge and El Salado, and low-sulfidation epithermal Au deposits such as Casposo, La Cabeza and Castaño Nuevo (Fig. 1). Tertiary-age mineralization occurs at Poposa (high-sulfidation Au) and Paramillos (porphyry Cu-Mo) prospects.

Fig. 1. a) San Juan province and adjacent areas, showing the location of principal ore deposits and prospects.
The Precordillera comprises a series of north–south ranges, covering ~1000 km north–south and 100 km east–west, formed during large-scale tectonic compression since the Jurassic and culminating in the Miocene. The ranges in San Juan Province comprise Paleozoic limestones and clastic sedimentary rocks.

East of the Precordillera, the Pampean and Transpampean Ranges (Sierras Pampeanas) are composed of Precambrian and Paleozoic granitic and metamorphic rocks. Uplift occurred along Tertiary Laramide-style high-angle reverse faults. These ranges host minor Precambrian mineralization and, within the Precordillera, some Tertiary-aged deposits, associated with calc-alkaline to alkaline volcanic and sub-volcanic centers of Miocene-Pliocene age (for example, Nevados del Famatina, porphyry and high-sulfidation Cu-Au deposits, and Gualcamayo).

**Background on the Casposo district**

The Cordillera Frontal in San Juan Province is underlain by marine sedimentary rocks (shales, sandstones and conglomerates) of the Carboniferous La Puerta Formation. These sedimentary sequences are overlain by a thick intrusive and volcanic sequence assigned to the Permian–Triassic Choiyoi Group. Basal andesitic volcanic flows, tuffs and breccias are the main subsurface unit at Casposo and are overlain by rhyolite, rhyolite-dacite flows and dacitic ignimbrite flows. The volcanic units dip to the east at 15º to 20º and are cross-cut by north–south, east–west and northwest–southeast-trending structures. Rhyolite and andesite dikes that trend north–south transect older rock units.

The Casposo gold–silver mineralization is hosted in both the rhyolitic and underlying andesitic units, where it is associated with banded quartz–chalcedony veins. Adularia in the main veins returned an age of 280±0.8Ma (K/Ar), close to the published dates for the andesite unit. Post-mineralization dikes of rhyolitic (Kamila area), aphanitic-felsic and trachytic (Mercado area) composition commonly cut the veins. These dikes are up to 30 m thick, and typically have a steep dip and are oriented north–south.

Mineralization at Casposo occurs along a 10 km long west–northwest to east-southeast-trending regional structural corridor; the main Kamila vein system forms a sigmoidal set 500-m long near the center (Fig. 2). The Mercado vein system is the northwest continuation of Kamila, and is separated from Kamila by an east–west fault. A series of east–west-striking veins (Cerro Norte and Oveja Negra systems) splay off these major sets to the east and northeast.

Metallurgical studies using Qemscan (4 samples including the Aztec, B and Inca 2 veins plus a bulk sample) report pyrite, electrum (AuAg), argentite (Ag₂S), native Ag, naumannite (Ag₂Se), pyrargyrite (Ag₃SbS₃), freibergite ([Ag₆Cu₃Fe]₁₂Sb₄S₁₃) and polybasite (Ag₁₈Sb₂S₁₁). Minor sulfides reported include chalcopyrite (CuFeS₂), Cu-Sb-Ag sulfosalts (some listed above), Bi minerals, sphalerite (ZnS) and galena (PbS), as well as possible pyrrhotite (FeS)(ALS Ammtec, August 2011, May 2012). There is also major quartz, adularia, and white mica as well as clay minerals in these samples.

The NI 43-101 report notes an early sulfide assemblage, represented by base metal sulfides including low-Fe sphalerite, chalcopyrite and galena. The sulfides form clotted aggregates that are distributed along and near the base of very fine-grained quartz-rich bands. A middle assemblage is dominated by sulfosalts with native metal alloys and minor base-metal sulfides and selenides. Besides electrum and native silver, the silver-bearing minerals include tetrahedrite-tennantite, argentotennantite, antimonpearcite, pyrargyrite, acanthite, and naumannite; the accompanying sulfides and selenides include chalcopyrite, galena and
clausthalite. Pyrite was not identified with this assemblage. This sulfosalt episode partially to completely mantles minerals belonging to the early base metal-sulfide stage. The final stage consists of sulfosalts, silver selenide and silver sulfide plus native silver that is hosted in microveinlets within either of the previous two assemblages. Acanthite is the only silver-bearing mineral, which marks the most significant mineralogical difference between this stage and the preceding sulfosalt-rich stage.

Fig. 2. Geology and structure of the Casposo district, showing the main NW-trending corridor hosting the Kamila and Mercado vein deposits, as well as E-W and N-S vein prospects to the NE, many with initial drill testing.
The Aztec and B veins in the Kamila pit are now being mined; the Inca 1 vein is present to the SE of Kamila and will be mined from underground, now under development. Further SE, the blind Inca 2 vein was recently discovered, hosted within the andesite (Fig. 3). The vein does not continue into the overlying rhyolite, although alteration is present at the surface along projection of the structure. The contact between the andesite and overlying rhyolite dips at ~20° to the south; the top of the high-grade mineralization has a similar southerly plunge (Fig. 3); the vein is cut by high-angle felsic dikes.

Fig. 3. NW to SE long section through the Inca 2 vein, showing the southerly dip on the rhyolite-andesite contact, with the andesite hosting the well-mineralized vein. Early andesite dikes are cut by the vein, which was then cut by several N-S trending dikes that are thought to have intruded soon after vein formation.
Observations on the Casposo district

Many of the veins were examined at the surface, and a few in drill core intersections. The following preliminary observations may be relevant to determining the depth below paleosurface as well as the degree of post-mineral tilting.

Paleosurface

Finely laminated siliceous deposits, typically with a near-horizontal orientation, were recognized first in the Mercado NW area (Fig. 4). The very fine laminations are typically not colloform, typical of silica gel accumulating on the wall of a fracture, but appear to have deposited in an open space; such accumulation of colloidal gels would have had an original horizontal orientation. The presence of apparent cross-bedding (Fig. 4d) suggests a sub-aqueous deposition (and remobilization). The presently horizontal (Fig. 4a-b) to slightly south-dipping laminations (Fig. 4c), deposited during hydrothermal activity, indicate little if any post-mineral tilting.

Fig. 4. Laminated siliceous sediments, Mercado NW, lithified, a-b) with near-horizontal orientations. c) Mercado NW, slight tilt (<10° to ~south) to laminations. d) Mercado NW, probable cross-bedded laminations.

The right-angle contacts between laminations and the wallrock, locally with colloform bands on the wall (Fig. 5a), indicate that silica colloids may have been depositing from a laterally flowing liquid in the fracture, rather than from a stagnant liquid, as the latter would have resulted in a
concave-upward contact. That the silica deposits were gel-like is indicated by their local deformation prior to lithification (Fig. 5b).

The Panzón vein outcrops 180 m west of Mercado NW, and has at least one outcrop of similar laminated siliceous accumulation (Fig. 6a). The massive quartz vein at Maya outcrops about 600 m SSE of Mercado NW, and WNW of the Kamila pit ~300 m; one outcrop of finely laminated sediments is present in the locally colloform-banded vein (Fig. 6b), with a slight dip to the west, likely due to post-mineral tilting (or possible westward rotation due to listric down-faulting?).

![Fig. 5. Mercado NW. a) Irregular walls of an open space with fine laminations that extend to the wall; this suggests that there may have been lateral flow in the fracture, rather than the laminations forming from silica colloids settling from a stagnant liquid, as the latter should develop concave upward features near the wall. b) Finely laminated sediments (pen tip), locally deformed (scratcher tip), indicating that the laminated material was gel like, with deformation prior to lithification.](image)

![Fig. 6. Finely laminated siliceous sediments. a) Panzón outcrop, near-horizontal laminations in fracture cutting a silicified fragmental (brecciated) rock. b) Maya occurrence of laminated sediments in fracture cutting massive colloform-banded quartz vein (left); orientation of laminations have a <10° tilt to the west.](image)

These siliceous sediments appear to have been deposited in horizontal laminations as a silica gel in open spaces. Although the depth below the paleowater table can not be quantified by these features, the presence of open spaces plus the low-temperature conditions that would favor the formation of amorphous silica colloids suggest that this feature formed under shallow conditions, probably <100 m, or even <50 m. This is consistent with the massive silicification atop Rosarita hill, SE of Kamila, where dense cryptocrystalline quartz, deposited at low temperature, has replaced the rhyolites (Fig. 7).
Vein textures and alteration in the NW corridor

Within the NW vein corridor that hosts Mercado (and extensions) to the NW and Kamila (and the Inca vein extensions) to the SE, veins that outcrop or are present in the pit are typically massive cryptocrystalline in appearance (Fig. 8), with banding on a local scale; alteration where visible is dominated by illite, indicating paleotemperatures of \( \geq 200^\circ\) C, i.e., implying depths of \( \sim 150\) m below the water table in a hydrostatically pressured vein.

To the SE veins do not outcrop, but there is a silicified ridge in rhyolite (Fig. 9a) over the surface projection of the blind andesite-hosted Inca 2 vein (Fig. 3). Phenocrysts in the moderately silicified rhyolite are altered to adularia (Fig. 9b), with illite alteration increasing in a halo, outward from the main ridge (Fig. 9a). A single short traverse in the hanging wall up to the surface projection of the vein showed this clear zonation of mineralogy up to the silicified zone,
and it is likely that traverses (using hand lens and SWIR) will identify mineral zonation elsewhere.

Fig. 9. a) Along strike of the surface projection of the blind Inca 2 vein, looking SE over 1 km to Rosarita hill beyond the mill; foliated rhyolites here are moderately silicified, hence the ridge. The vein at depth widens where it changes direction, from SE to ESE beneath the figures with orange vests. b) Altered rhyolite over the Inca 2 vein, with feldspars altered to adularia and abundant illite after phyllosilicates.

Fig. 10. a) Inca 2, CA11-332, 276.0 and 276.9 m, andesite hosted; 12 g/t Au, 1560 g/t Ag, acicular quartz-sulfide after sulfide-poor quartz. Early colloform banded quartz (low Ag:Au ratio), brecciated, with later banding of sulfosalts. b) Inca 2, CA11-301, 448.8 m, ~1950 m, lowest elevation vein; brecciated wallrock with quartz-adularia, 2.5 g/t Au, 653 g/t Ag. c) Inca 1, CA08-08, 250 m; 7.2 m at 108.7 g/t Au, 4423 g/t Ag (with Sb>As, Cu >1 wt%, Mn ~1 wt%; 34 ppm Te, up to 177 ppm Se, Pb+Zn ~0.5 wt%). Early sulfide-rich, brecciated vein, cemented by sulfide-poor banded quartz-adularia.
Beneath the surface projection of the Inca Extension and Inca 2 vein (Fig. 9a), drill holes intersected the SW-dipping vein, hosted by andesite. The rhyolite-andesite contact dips ~20° to the south (Fig. 3), with the top of the mineralized Inca 2 vein within the andesite, following this contact. Pre-mineral andesite dikes are cut by the veins, whereas ~N-S felsic dikes cut the veins along faults with a small degree of offset of the contact (Fig. 3).

Fig. 11. Mercado NW. a) Brecciated colloform clasts cemented by a massive quartz matrix. b) Cross-cutting vein events, i.e., due to syn-hydrothermal changes in stress orientation.

Veins north and NE of the NW corridor

Away from the NW corridor that hosts the Kamila and Mercado deposits and their extensions to the SE and NW, respectively, there are ~E-W and ~N-S veins that outcrop to the north and NE of the NW-trending veins. The mineralogy and textures of the outcropping veins are variable, as are the Au grades in outcrop and at depth, the latter where drilled.

The Aurora and Casposo Norte veins (Fig. 2) are located 2.5-3 km north of the Kamila pit, and are oriented ~N-S and ~E-W, respectively. The Aurora vein (Fig. 12) dips steeply west and consists of massive quartz and in places dominant (post-quartz) calcite; there is local brecciation, weakly developed banding, and patches of bladed calcite, largely pseudomorphed by quartz. Grades include the best channel sample of 1.5 m at 7 g/t Au, and selective chip samples up to 9 g/t. The andesite host in the hanging wall has been demagnetized; a late mafic dike locally follows the vein and cuts across it. The nearby Casposo Norte vein, with E-W veins cut by the N-S stage, returned variable, spotty grades at the surface, with channel results up to 9 g/t Au. The outcropping vein is dominated by calcite, which is pre-, syn-, and post-quartz vein deposition; the quartz shows banded textures, in part because of the cyclic deposition of calcite (Fig. 13). The area was drilled with RC (20) and diamond (15) holes to a depth of ~120 m; there was reportedly less calcite at depth than at the surface. Diamond results in 7 of 15 holes returned 1 to 3 m at 2.2 to 4.6 g/t Au, with 4 of 20 RC holes showing similar results. This contrasts with outcrop results of 4.7 to 8.8 g/t Au equivalent (Ag: Au ~1:1), with spotty high grades (up to 19.8 g/t over 1 m).

The Cerro Norte area consists of three ~E-W veins ~1 km NE of the Kamila pit. In contrast to the Aurora and Casposo Norte veins, the vertical Central vein of Cerro Norte (Fig. 14a) shows better banding and less calcite overall, and the degree of quartz pseudomorphs after bladed calcite is more complete (Fig. 14b). There are grades up to 10 g/t Au over 0.5 m; in drill holes
there are reasonable grades over good thicknesses (e.g., 8.6 m of 6.9 g/t Au in CN-12-13) in a zone of dilation at ~76 m drill depth, raising the question of the potential for similar zones, here and in other veins in the Casposo district where fault movement led to dilation.

Fig. 12. Aurora vein outcrop, ~N-S, dips west, at contact of rhyolite with andesite. a) Massive quartz with calcite (locally bladed) leached out. b) Massive quartz vein, locally brecciated, cut by late veinlets; minor banding present.

Fig. 13. Casposo Norte outcrop, ~E-W vein with up to 70 vol% calcite at the surface, decreasing with depth (tested with 35 drill holes). b) Contorted banded quartz with interstitial calcite, later massive quartz, and late calcite (left).

Fig. 14. Cerro Norte Central. a) Near-vertical E-W vein, looking west. b) Vein with banded texture, combination of massive to laminated quartz and intergrowths of calcite, either pseudomorphed or now leached.
The Amanda vein, which curves from ~E-W to WNW to the west, is located 500 m to the NE of the Kamila pit (Fig. 15a), with well-developed thick quartz bands in outcrop and a paucity of calcite; there are local colloform bands as well (Fig. 15b). The vein follows the trend of a magnetic low anomaly that reflects the corridor of alteration associated with the vein. Early samples (1997) had values up to 3.8 g/t Au vein, but more recent selective chips returned grades up to 7 to 10.9 g/t.

The Lucia vein is located ~1 km north of the Kamila pit, and has a general ~NNE trends that projects north to the Ladera area, similar to the trend of Oveja Negra vein to the Aurora vein (Fig. 2). The Lucia vein returned highly variable results, with 10 of 25 channels reporting 2.2 to 11.7 g/t over 0.3 to 3.6 m widths. Two of 11 drill holes returned 10 and 12 g/t over 0.3 and 1.6 m vein widths, whereas other vein intersections had 0.3 to 1.8 g/t grades, all at 30 to 60 m depths. The veins are exhibit variable textures, from massive to banded quartz, locally with colloform textures (Fig. 16a). The high-grade vein intersection in LS-11-10 has quartz after bladed calcite as well as acicular textures of unknown origin and late colloform bands (Fig. 16b); above this interval there is adularia in fractures, but without grade.

Fig. 15. Amanda vein, ~E-W with steep dip to south. a) Looking ~SW over vein, with waste dump from Kamila pit beyond. b) Banded, locally colloform textures in carbonate-poor vein outcrops.

Fig. 16. Lucia vein, ~NNE, dip to the NW. a) Outcropping vein, local brecciation and open-space fill by colloform banded quartz. b) LS-11-10, 33.5 m; 1.6 m at 10 g/t Au and 15 g/t Ag (20 m deeper in LS-11-11, grades are 2 g/t Au). Acicular growths of quartz (replacing another mineral?) after pseudomorphed bladed calcite; late minor colloform bands in open spaces; adularia occurs above this interval in fractures, without appreciable mineralization.
Observations on the Castaño Nuevo district

Dome-centered advanced argillic alteration

In the southern part of the Castaño Nuevo district there is a large area of advanced argillic alteration which may overprint the San Agustín vein, the latter being part of the historic mined veins; Tenke Mining Corp. drilled 9 RC (2120m) holes up to ~400 m deep in the area in their search for epithermal and porphyry mineralization. The advanced argillic alteration is centered on a volcanic dome (Fig. 17a) that features proximal outcrops of block and ash flows (Fig. 17b; A. Cocola, pers. commun., 2012). Based on mapping and observation of talus blocks on the lower slope of the dome (Fig. 17a), the core of alteration is dominated by residual quartz with a strong silicic alteration, silicic 2 to 3 (moderate to extreme), as well as local vuggy quartz textures after lithic tuffs, some with a block and ash texture (Fig. 17b). In addition to fragmented residual quartz there is also evidence for finely laminated siliceous sediments with local graded lenses of clastic material (Fig. 17c, d); these are typical of lacustrine sediments in acid crater lake settings, and thus define the paleo ground water table.

Fig. 17. Dome south of Castaño veins. a) Talus block of silicic alteration, derived from the lithologic horizon that forms a steep cliff on the north margin of the dome. b) Silicic 3 (strongest) alteration of a block and ash flow; the volcanic deposit was located in a proximal position to a dome undergoing collapse. c) Fragmental talus block with various lithologies and alteration styles, including (closeup, d) finely laminated crater lake sediments; colloidal silica accumulated in an acid lake, locally with lenses of detrital material, indicating the paleosurface.
Fig. 18. Samples from top of the dome. a) Residual quartz with a vuggy texture after phenocrysts. b) Quartz (silicic 2) plus hypogene (finely crystalline) alunite after phenocrysts (locally identified as natroalunite by PIMA).

Fig. 19. a) View ~S to top of lithocap ~1 km away, showing erosional gully (now along the ridgetop) filled by a (block and ash?) tuff that was silicified by chalcedony, i.e., an aquifer that provided a channel for ground water table outflow of steam-heated water from the dome hosting the lithocap; outcrop of N-S vein cutting andesite can be seen to the left, on the next hill. b) Silicified tuff with block and ash texture. c) Closeup of chalcedony replacement.
Samples collected during mapping show typical textures of residual quartz, due to leaching, with a vuggy texture after the original phenocrysts of the host dacite (Fig. 18a). There also occurances of crystalline hypogene alunite replacing feldspar (Fig. 18b) in quartz-alunite alteration; PIMA analysis of the alunite indicates that it is Na rich, i.e., likely formed at higher temperature than if the sample were K rich.

Rock chip sampling was conducted on a 100 x 100 m (locally 50 m) grid by Tenke; recent mapping showed that the best Au anomalies are associated with an area ~300 x 200 m of block and ash flow that was altered to residual quartz, the typical host of mineralization in a lithocap environment. Six of the samples of residual quartz ranged from 40 to 260 ppb Au, with one sample returning 2 g/t Au. The residual quartz has a halo of quartz-alunite alteration, or where pyrite oxidation caused supergene leaching of alunite, a friable granular silicic alteration.

North of the dome, overlying an area of epithermal veins, there is a horizon of chalcedony silicification (Fig. 19a) that appears to have replaced a block and ash flow (Fig. 19b) that accumulated in an erosional gully. The blocks are altered to kaolinite, formed in a steam-heated environment at and above the paleo ground water table. The matrix is replaced by chalcedony (Fig. 19c), formed where the vapor condensate flowed laterally away from the source.

**Epithermal veins**

The Dos Protégé and San Agustin veins were mined over 100 years ago on a small scale. Outcrops of both veins show features typical of low-sulfidation epithermal veins, with colloform banding (Figs. 20a and 21a) and abundant adularia, the latter commonly being the first mineral to deposit following hydrothermal brecciation and high-grade gold mineralization (Figs. 20b and 21c). Acicular textures are present locally (Fig. 21b), and along with the colloform banding caused by accumulation of silica gel, indicate rapid cooling, likely due to boiling and vapor loss. The pressure loss following hydrothermal brecciation most likely triggered such boiling; this is also consistent with the abundance of adularia that cements the breccia fragments, as loss of CO2 during boiling causes a pH increase that shifts the fluid-mineral equilibria from illite to adularia stability.

![Fig. 20. Dios Protégé vein, at an elevation of ~1625 to 1675 m elevation. a) Colloform-banded vein textures. Fluid inclusion study (A. Coca, pers. commun., May, 2012) suggests high temperatures of >330° C and low salinity, <1wt% NaCl equivalent; co-existing liquid and vapor-rich inclusions homogenized at ~260-270° C, in quartz with adularia as cement to breccias. b) Same vein zone, with brecciated vein margin with cockade texture, adularia first formed after brecciation; sample 12053, 12.8 g/t Au, 7.4 g/t Ag.](image-url)
Fig. 21. San Agustin vein, top at ~1840 m elevation, tested on surface and in drilling to a level about 100 m deep. a) Brecciated vein cemented by adularia, later finely banded quartz (similar to observations at Dos Protoge). b) Acicular growth of quartz and adularia, with massive quartz bands. c) High-grade brecciated vein, cemented by adularia. d) Brecciated vein from area of workings, with over 80 m of relief on veins, from summit into valley.

The San Agustin vein outcrops atop a hill (frontispiece) at an elevation of ~1840 m, and continues to outcrop into the valley about 80 m lower (Fig. 21d). At the highest elevation the vein is massive and poorly brecciated; grades are ~1.3 g/t over 1.7 m vein width. At lower elevations about halfway down the slope (Fig. 21d), a brecciated vein (Fig. 21c) returned 6.5 g/t Au and 11.2 g/t Ag, but shallow drilling below the outcrop did not intersect these grades, suggesting that the ore shoots may have a plunge. Recent drilling has cut the vein to a level down to ~1740 m elevation, ~100 m below its shallowest outcrop, but ~75 m above the top of the level of mineralization of the nearby Dos Protégé vein. The textures of the veins in outcrop, with colloform bands associated with brecciated veins, are typical of gold mineralization in low-sulfidation deposits (e.g., Fig. 10c) around the world.

The degree of post-mineral tilting or fault offset is not well known in Castaño Nuevo, but if there has been relatively little displacement between the original level of these two veins, there may be potential in the San Agustin vein below the deepest level tested by drilling.
Discussion

Casposo

The southerly tilt of the andesite-rhyolite contact over the Inca 2 vein (Fig. 3), as well as the similar southerly tilt on the upper limit of high-grade mineralization in the vein, may be due to two factors: 1) the vein formed when the contact was near-horizontal, with a horizontal upper limit to ore, beneath the contact; in this case, the dikes would have been vertical if intruded soon after mineralization, i.e., before subsequent tilting, or 2) tilting of the contact occurred early, with the top of the subsequent vein formation dipping to the south, perhaps reflecting the position of the contact. In this case, the dikes may be close to their original orientation.

The question of whether the dikes intruded vertically a flat-lying andesite-rhyolite contact and were then tilted, or the tilting pre-vein and dike, was put to John Miller, who wrote (pers. commun., 2012) that he is "not sure if 1) the overall steep west dip of many of the post-mineralisation dykes is a primary feature (i.e., they intruded along a pre-existing W-dipping trend instead of being vertical - there are a lot of structures with this dip direction, although most have shallower dips compared to the dykes, i.e., 55 to 70 degrees) or 2) the dykes were originally vertical and the W-dip reflects post-mineralisation tilting of the sequence."

Miller further notes that "I've only spent about 12 days onsite and ...we lack basic orientation data on the dykes in many areas. Some of the dykes definitely intruded up pre-existing faults and so their orientation doesn't reflect sigma 3. The Aurora vein is a good example if this. However, the dykes cross cutting Inca don't appear to have utilised a pre-existing fault and may have been originally vertical and then tilted. However, much of the orientations of these dykes are from drilling (they need to drill to the southeast to really constrain these properly). Having a flat-lying stratigraphy and then tilting everything post-mineralisation is quite possible, and a neat model. The only problem (from a structural view) that I have with the volcanic units being flat and then tilted to the east post-mineralisation is that back rotating everything by 15 to 20 degrees would mean Lucia and other many faults, that currently have 'normal' 60 to 70 degree dips for extensional faults, would be close to vertical."

In addition to the structural constraints discussed by Miller above that may favor a pre- rather than post-hydrothermal tilting, an observation that bears on this interpretation are the relatively flat-lying laminated siliceous sediments, which are near horizontal in Mercado NW to <10° dip to the west in the case of Maya. This observation support option 1 above, that the stratigraphy was tilted to the east or SE prior to hydrothermal activity and deposition of the laminated sediments, followed by intrusion of dikes - some along pre-existing structural paths. Also, if the east to SE dip were post-hydrothermal, and this was tilted back to the west, the slightly west-dipping sediments at Maya would become even steeper; rather, assuming that the original sediments were horizontal, their west dip may indicate a slight listric movement on a post-mineral, east-dipping fault. The timing and degree of tilting in the district also is relevant to the steep veins to the east and NE of the NW corridor.

Clearly the preliminary observations on structural and lamination features need to be bolstered with more measurements, particularly to consider the timing of tilting, not just overall but in multiple blocks and at several times, pre-, syn- and post-mineral. Such an understanding may be critical to exploration targeting in the future.

The Inca 2 veins at depths of 200 to 300 m have some similarities with veins in Mexico that feature multiple events (e.g., La Guitarra, San Sebastian). Several deposits there have shallow breccias with fragments of sulfide-rich material, with higher Ag and base metal contents,
cemented by sulfide-poor quartz veins with a lower Ag:Au ratio than the sulfide-rich vein clasts; locally such sulfide-rich veins are encountered in situ at greater depths. At Casposo, in Inca 2, there is evidence for sulfide-rich fragments to be cemented by sulfide-poor material (Fig. 10c), but also the reverse, sulfide poor material to be brecciated and cemented by sulfide-rich material (Fig. 10a). These observations may indicate an even greater vertical interval of ore potential that has been presently recognized, i.e., >200 m. This interval (Fig. 3) in a given vein will also be affected by the degree of post-mineral tilting and block faulting.

The erosional level can be indicated by characterization of temperature-sensitive clays that are stable at <150 to ~300° C. This mineralogy can be determined by SWIR (short-wave infrared spectra), and enable zonation patterns to be determined over known veins (for the Inca 2 vein, e.g., as done in the Waihi district; Fig. 22), and then used in exploration in the district.

**Castaño Nuevo**

The epithermal veins are older than the dome-related lithocap and advanced argillic alteration, the latter being related to Tertiary volcanism in the region. The proximity of the two distinctly different mineralization types - with anomalous gold noted in silicic alteration of the lithocap - occurs in other districts around the world where tectonism has shifted between extension and arc-related activity; however, the more typical overprinting relation is for low-sulfidation veins to cut lithocaps due to a migration of arc activity such that an area is then put into back-arc extension. The large difference in age between the veins and the dome-related lithocap formation likely accounts for this atypical style of overprint.
Summary and conclusions

The Casposo and Castaño Nuevo districts are located in western San Juan Province, hosted by volcanic units of the Permian Choiyoi Formation which consist of an andesitic package overlain by rhyolitic rocks. The veins in both districts have been constrained to ~258 to 267 Ma, based on dating of pre- and post-mineral dikes as well as vein minerals, i.e., these epithermal veins are appreciably older than the Jurassic veins of the Deseado massif in Patagonia.

Casposo

The main mineralized veins at Casposo identified to date occur in a NW-trending structural corridor that encompasses the Kamila pit, which hosts the Aztec, B and Inca veins. Mineralization is present from ~2500 to ~2300 m elevation; the Inca 1 veins extend to the SE at greater depth. Recent exploration by Troy has extended this mineralization to the SE with the discovery of the blind Inca 2 vein; the top of mineralization is over 200 m deep, within the andesite below an elevation of ~2200 m; the top of mineralization lies below the SE-dipping unconformity. To the NW, veins extend into the Mercado and Panzón area, making this NW corridor over 2 km in strike extent; further to the NW the veins are cut by a post-mineral dike. Further NW post-mineral rocks cover the area up to the Julieta veins, which outcrop over 4 km NW of the Panzón veins; thus the total length of this corridor is nearly 7 km, with over half of this corridor untested. E-W and N-S veins are also present north of the Kamila, with some of these tested only to maximum depths of ~130 m; the E-W veins may be the earliest mineralized structures, formed during weak N-S extension, as indicated by structural studies. A subsequent major period of E-W extension occurred during formation of the N-S and NW-trending veins. A N-S fault to the east was suggested to be an eastern boundary to veins, but the Natalia discovery further east has changed this perception.

Many of the veins in the district were visited over three days. Several veins have illite as a gangue mineral or in a near-by alteration halo, and some have adularia also in an alteration halo. In the area of the surface projection of the Inca 2 vein, there is illite as well as adularia in a strongly silicified zone of alteration. These observations indicate a moderately high temperature (>200 C) fluid that was boiling in the veins. In the Mercado NW area there are laminated siliceous sediments that are now close to horizontal (within 10°), as well as minor occurrences at Penzan and Maya, that likely formed in open spaces related to brecciation; these sediments suggest a shallow depth of formation (say, <50-100 m), and also indicate little if any post-mineral tilting, as they formed in a near-horizontal orientation. Minor silica gel textures atop Rosarita hill, SE of the Inca 2 projection to the surface, are consistent with a low-temperature, shallow depth of formation.

Colloform textures in veins of the Kamila pit, as well as Inca 2, are consistent with a rapid cooling due to boiling. Previous studies as well a vein examination indicate multiple events of mineralization, both Ag- (and base metal)-rich as well more Au-rich (lower Ag:Au ratio). Besides numerous Au and Ag minerals, including Ag selenides, there are also minerals that indicate an intermediate sulfidation state (e.g., tetrahedrite), possibly due to periods of rapid boiling and cooling during mineralization.

The SE dip of the Inca 2 vein, as well as the general trend of vein lodes from the Kamila pit, matches the SE dip (>20°) of the andesite-rhyolite unconformity. The latter is likely pre-mineral in timing, consistent with the high angle of post-mineral dikes being in an original orientation; post-mineral tilt would result in some veins in the area needing to be tilted back to an unlikely (or less likely) orientation. Such a pre-mineral tilt might suggest that the unconformity played a
significant control on the level of mineralization, with upper limit of ore being deeper to the SE. If the tilting is pre-mineral, the area of the north should be more deeply eroded. By contrast, at Mercado NW, and possibly Penzan and Maya, there are textures suggestive of a very shallow level of erosion; if these observations are correct, then a cross-fault with north-side down, north of the Kamila pit, may be indicated.

Only by drilling through the horizon of potential high grades can a vein in the Casposo district be concluded to have been tested adequately, since the depth to relatively sharp tops of consistent ore zones can be as deep as paleo-temperatures of ~220°C, i.e., within the zone of illite stability, and well below the top of colloform-banded silica gels. Adequately test the deep potential of veins, since the district has shown that veins have the adequate grade and width to support underground mining.

**Castaño Nuevo**

At Castaño Nuevo there are two principle veins, Dios Protégé outcropping at ~1625-1675 m elevation, and the San Agustin vein, with an upper outcrop at ~1840 m elevation. The better grades appear to be associated with the lower elevation vein. The best grades in both veins are typically related to brecciated vein margins with associated adularia. The potential for sufficient tonnage and grade to allow an open cut and trucking operation on these veins appears limited, indicating that the only target is for high-grade veins that would support underground mining. Stopes from historic mining are related to steeper portions of the normal faults that were dilated during dip-slip movement. Of the 27 holes drilled on these veins, none were deeper than 130 m vertical, meaning that the depth extent may not have been fully tested, particularly on the higher elevation San Agustin vein where shallow drilling did not intersect the high grades in outcrop. Given the high grades at ~1650 m elevation in the Dos Protégé vein, drill testing of the San Agustin vein to a similar elevation is warranted, i.e., ~100 m below the deepest level cut by previous drilling.

Further south a large area of alteration appears to be related to extrusion of a dacite dome in the Tertiary, with block and ash flows mapped over an area of 300 x 200 m. Based on previous mapping as well as a brief examination of talus blocks, the block and ash flow has been altered to residual quartz that is silicic 2-3; there is a halo of hypogene quartz-alunite and argillic alteration. Breccia blocks incorporate laminated lacustrine sediments, the latter indicating paleosurface and implying a relatively shallow level of exposure at the top of this volcanic dome, ~2000 m in elevation. To the north ~1 km there is a horizon of chalcedony-replaced tuff that fills a channel at ~1850 m elevation, which overlies the San Agustin vein; given the erosion on the vein system, this chalcedony blanket most likely formed due to ground water table outflow of steam-heated water from the area of the dome, consistent with the evidence for a crater lake near the top of the dome. The chalcedony blanket indicates significant erosion of the veins, to the level of mineralization, prior to dome extrusion and alteration.

Early sampling indicates that the residual quartz has grades of 40 to 250 ppb Au, with one sample reporting 2 g/t Au, suggesting that this silicic lithocap may be mineralized. Even if this body is found to be largely barren, its occurrence indicates the potential for similar (Miocene age?) lithocap-related mineralization in this volcanic belt.
Recommendations

Casposo

- Conduct an orientation survey of the nature of the clay mineralogy zonation from hanging wall to footwall major veins, using SWIR (short wave-infra red) analysis (e.g., TerraSpec); include surface traverses, e.g., over the projection of the blind Inca 2 vein. Based on these results and associated structural studies, extend surface traverses over areas of known veins and vein extensions, to determine the potential for vein continuation.

- All data collected on the surface and from drill core, geological, geochemical, mineralogical and geophysical, should be compiled into a single data base, and with new information on alteration added. Such a data base would provide the opportunity to integrate and interpret the geological, structural and vein history of known veins, including post-mineral changes. This information will allow exploration targets to be developed that best match known mineralized veins or fit a predicted environment of ore.

- Compile a table with vein characteristics, including nature of structures and their orientation, range of elevation of the veins as well as mineralization levels, vein textures and gangue mineralogy, sulfide mineralogy, paragenetic events, geochemical signatures (grades, Ag: Au ratios and variation, anomalous elements), grades in outcrop and vein widths, approximate erosion level below the paleo-surface, alteration mineralogy, etc. Establish a relative order of priority for testing each vein set in the district.

- A greater density of surface sampling will provide more detail on grade variations to be expected at depth. For example, the Central vein at Cerro Norte should be channel sampled up the slope (Fig. 14a) every ~5 m vertical to provide an indication of the vertical variability here, with individual samples on different vein textures, e.g., banded vs massive quartz. Similarly, channels every 10 m across the Amanda vein will indicate the variability to be expected when the vein is drill tested. In addition, compare the grade results with the vein textures, here and elsewhere in the Casposo district, as epithermal veins in general, and Casposo in specific, can be highly variable in grade distribution.

- The tectonic evolution and structural framework of the district is better understood than most epithermal vein systems. Further structural studies should integrate other constraints, such as indicators of a horizontal position during hydrothermal activity, i.e., the laminated silica gels, to establish vein orientations at the time of mineralization, as well as post-mineral movement.

- All veins, particularly those to the north of the NW trend, should have careful structural assessment to indicate the movement direction and the likely position and orientation (plunge) of dilation, as these should have the best potential for drill testing. Structural intersections have also been concluded to be conducive to width and grade development.

- Once the relative erosion levels of veins are estimated, from alteration, vein texture, grade and other indications, drill test each different vein set in order of priority to levels below evidence for silica gel deposition, e.g., colloform bands. This may be as much as 200 m or more vertical depth in areas of shallow erosion, i.e., where vein-hosted fault blocks when down-thrown rather than uplifted and eroded.
Castaño Nuevo

- The San Agustin vein at Castaño Nuevo should be tested below an elevation of ~1700 m, which is the elevation of good grades in the Dios Protégé vein, in zones of dilation and brecciation; such zones may have a plunge, rather than being vertical.

- Below the silicic lithocap at Castaño Nuevo, collect samples of silicic altered talus (chip sample over ~3-m radius silicic blocks, perhaps distinguishing silicic 2+ rocks, those brecciated and cemented, and quartz-alunite plus silicic <2 alteration in separate samples). If the results are positive (a significant portion, at least a quarter, greater than ~0.4 g/t Au), train samplers in rope safety and collect representative samples from the steepest silicic portions of the cliffs, to assess the potential of this body. Focus on structurally related feeders in the silicic core, as these tend to report the highest grades. If the results are positive, plan a drill program of angled holes to test the lithocap, working out from the structural feeder zones.

- Date the hypogene alunite in order to identify the age of the volcanism and hydrothermal activity, to help guide regional exploration for similar alteration styles and mineralization potential, not widely recognized in the Cordillera Frontal belt.

Regional

- Exploration targeting by prospectivity assessment is based on the quality, and relevance, of data input into the model. 1) Increasingly exploration is being conducted under cover, either post-mineral, or barren steam-heated alteration; in such cases, geochemical anomalies will not be present. 2) The ASTER survey interpretation needs reassessment, as the original interpretation suggested - incorrectly - that ASTER could detect feldspars; this brings into serious doubt the quality of the complete interpretation. The ASTER survey must be reassessed, both for project districts as well as for regional assessment by a geologist who also collects ground-truth samples. 3) Such prospectivity analysis will find styles of mineralization similar to known examples; an increasing proportion of discoveries will be of new styles in existing districts and new areas.

- Collect samples at the surface of different alteration mineralogy to use as ground-truth information to train the results from ASTER satellite images. Using a realistic mineral assemblage grouping, an experienced specialist should interpret ASTER anomalies, followed by a field check in the near-mine area, the district, and the region; feature to define include illite-related linear zones around veins, and alunite-dickite zones related to lithocaps, e.g., Castaño Nuevo for the latter. If pyrophyllite is confirmed (i.e., the original widespread ASTER anomalies are real) in an intrusive center, this suggest a sub-lithocap level of erosion, potentially to stockwork veinlets levels associated with porphyry systems.
Qualifications

I, Jeffrey W. Hedenquist, of Ottawa, Canada, hereby certify that:

- I am President of Hedenquist Consulting, Inc., incorporated within the province of Ontario. I am an independent consulting geologist with an office at 74 Greenfield Avenue, Ottawa, Ontario, K1S 0X7, Canada; telephone 1-613-230-9191.
- I am a graduate of Macalester College, St. Paul, Minnesota, USA (B.A, Geology, 1975), The Johns Hopkins University, Baltimore, Maryland, USA (M.A., Geology, 1978), and the University of Auckland, Auckland, New Zealand (Ph.D, Geology, 1983); I was awarded a Doctor honoris causa degree by the University of Turku, Finland, in 2006.
- I have practiced my profession as a geologist continuously since 1975, working as a researcher for the U.S. Geological Survey, the New Zealand Department of Scientific and Industrial Research – Chemistry Division, and the Geological Survey of Japan until the end of 1998. I have published widely in international refereed journals on subjects related to epithermal and porphyry ore-deposit formation and active hydrothermal systems. I consulted to the mineral industry and various governments as a New Zealand government scientist from 1985 to 1989, and I have been an independent consultant since January, 1999.
- I am a Fellow of the Society of Economic Geologists and have served in executive officer positions; I am also a member of the Geological Association of Canada (Mineral Deposits Division), Society of Resource Geology of Japan and the Geochemical Society. I was Editor of the 100th Anniversary Publications of Economic Geology and am Associate Editor of the journal, as well as an editorial board member of Resource Geology; I have previously served as editorial board member of Geology, Geothermics, Journal of Exploration Geochemistry, Geochemical Journal and Mineralium Deposita.
- This report is based on information provided to me by Troy Resources Limited, previous independent reports, and personal observations in the field.
- I have no direct or indirect interest in Troy Resources Limited, in the properties described in this report, or in any other properties in the region.
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