"GEOLOGICAL AND GEOCHEMISTRY PROSPECTING OF ZAMORA TOPOGRAPHICAL SHEET (E 1: 50.000)"

Carranco L. Andrés & Ruiz M. Grace

Instituto Nacional de Investigación Geológico Minero Metalúrgico

2015

ABSTRACT

This study presents the results of analysis and interpretation of geological and geochemical prospection in the area that covers the Zamora topographic sheet, scale 1: 50 000, Southeastern of Ecuador, to determine mineral occurrences.
Useful field observations, with laboratory assays for rock samples: thin section, wholerock geochemical analysis (major elements XRF, minor elements ICP-OES and rare earth elements REE) and fire assay, were necessary to discriminate the alkaline (Triassic?) and calcalkaline (Jurassic) volcanism, and to define the economic geology (<40 ppb Au; <67,30 ppm Ag; <43 375 ppm Cu; <1 165 ppm Pb; <1 165 ppm As; 47,32 ppm Sb; <3 772 ppm Zn). In addition, sampling of stream sediments, preparation and chemical analysis (ICP-OES) for subsequent exploratory analysis of spatial data and geostatistical treatment, were developed to determine anomalies of 11 elements (Hg, Au, Ag, As, Cu, Sb, Zn, Co, Mo, Ni and Pb). The analytical-graphical method of Lepeltier (modified) and the ordinary kriging interpolation method were applied.
Two zones with possible mineral potential (Tzunantza and Nanguipa) were defined from the correlation profiles of geochemical anomalies (As-Sb-Hg-Ag-Zn-Pb-Co and Au-Hg±As±Sb-Cu±Mo-Zn-Co, respectively) with geology (phreatomagmatic breccias and skarns, both related to porphyry). This study recommends to follow up these two areas. A detailed study is suggested with geochemical soils and geophysical surveys to delimit the areas of mining interest.

INTRODUCTION

The main objective is to analyze and interpret the geology and geochemistry in the area covered with the topographic sheet (HT) Zamora, scale 1: 50 000, to determine mineral occurrences and geological-mining potential of the study area.
The HT Zamora (E 1: 50 000) is located in Southeastern of Ecuador, in the province of Zamora Chinchipe. It is found mainly in the canton Zamora, and a small area in the cantons Centinela del Condor and Nangaritza (*Figure 1*).
The main hydrographic axis conforms the Zamora River that receives contributions from the central and outer slopes of the Cordillera Real. It is one of the sources of the Santiago River and tributary of the Marañon River, part of the upper Amazon basin.

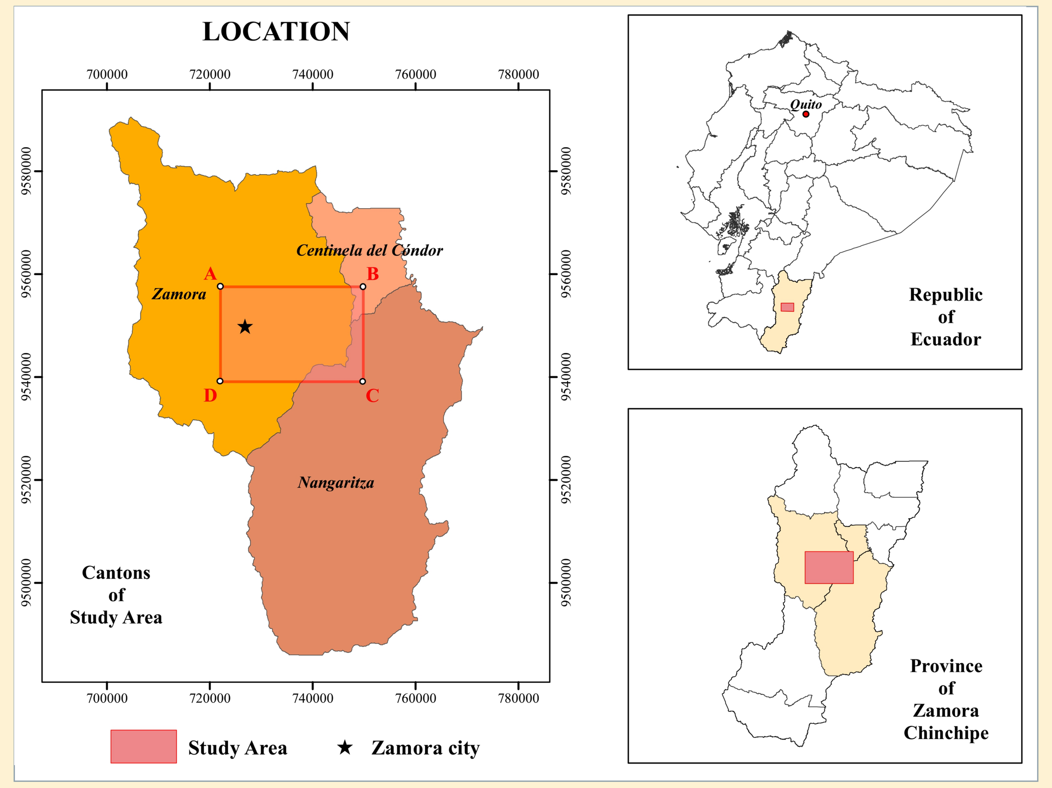


Figure 1: Location of the study area.

METHODOLOGY

Geological mapping
Petrographic analysis of thin sections and samples using the polarizing microscope OLYMPUS BX51 and the OLYMPUS S2X16 stereomicroscope respectively were developed.
By applying Igpet06 (Igneous petrology software, version 2006), whole-rock geochemical data was analyzed and interpreted. In addition, the Chemical Laboratory of INIGEMM conducted the following analysis:
Mineralogical analysis by X-ray Diffraction (XRD)
Analysis of major elements by X-ray Fluorescence (XRF)
Scanning 32 elements by Optical Emission Spectrometer with Inductive Coupling Plasma (ICP-OES).
Analysis of Rare Earths, uranium and thorium by Mass Spectrometer with Inductive Coupling Plasma (ICP-MS).
Determination of gold by fire assay.
Furthermore, spectral analysis with a portable infrared mineral analyzer (PIMA), using the ASD equipment Hi-Res FieldSpec 4, were performed.
Finally, the geological map was printed on the topographic base at 1: 50 000, in the system of Universal Transverse geo Mercator (UTM), World Geodetic System 1984 (WGS84), zone 17S.
Stream sediment sampling
This sampling was made based on the methodology used in PRODEMINCA (2000), which followed the following protocol:
A total of 351 samples, representing an average sampling density of 1 sample per 1.5 km2 were obtained.
Prioriced samples first and second order drains were taken at the junction of the gorges, at a distance of 50-100 meters. Areas with lower current strength that allowed the accumulation of finer sediments were sought.
Samples were first sieved through a 10 mesh BSI (2 mm) and then through a 80 mesh BSI (177 microns), with a minimum amount of water (about 2 liters).
The obtained material was decanted for 15-20 minutes, and then approximately 200 g was transferred to a previously numbered Kraff sheath for transport and storage.
The samples were dried in the open to avoid losing any volatile element and later were sent to chemical laboratories for analysis.
Phase results
Information processing and a geostatistical treatment of geochemical data using ArcGIS 10.2.1, were developed, with the consequent integration

GEOLOGY

Ecuador is characterized by being in a subduction zone sub-orthogonal Nazca plate under the South American Plate. This generate the uplifting of the Andes, wich is comprised of two main ridges: Cordillera Occidental (West) and Cordillera Real (East).
Cordillera Real has metamorphic rocks of Paleozoic age in contact with igneous rocks product of a Mesozoic magmatism and volcanism at East. In the Amazon region, it is the Subandean Zone characterized by active thrust faults that raise the entire Cretaceous sedimentary sequence and deposits quaternary back-arc basin known as Oriente Basin.
From West to East, metamorphic rocks of medium-high level: quartz-feldspar gneiss, micaceous and migmatites (Sabanilla U.) and low-grade: phyllite and schist quartz-sericitic (Isimanchi U.) emerge in tectonic contact with sedimentary volcanogenic rocks: siltstones, tuffs, breccias and local andesitic lavas (Yacuambi U.) deposited in a marginal basin related to Misahuallí volcanic arc comprised of basaltic andesite-dacitic lavas, tuffs and breccias (La Saquea U.). Intrusive rocks predominate: granodiorites, granites, diorites (Zamora batholith), which affect volcaniclastic/volcanic and sedimentary rocks: tuffs, breccias and andesite, with levels of limestones and shales (Piuntza U.) deposited in a basin related to rift, generating metasomatic rocks as epidote and garnet skarns. Overlying sedimentary rocks: quartz sandstones, black shales and limestones micritic (Hollin & Napo Fms.) on the lower slope of the Zamora river.
As volcanism within the study area two major volcanic events have been characterized. The first, are consisting of alkaline rocks with tholeiitic affinity, is tectonically related to a rift (Piuntza U.). The second, are compound by calc-alkaline rocks, is related to a tectonic environment of volcanic arc (La Saque and Yacuambi U.). In the diagrams rare earth normalized Primitive Mantle generally are observed in lithophiles, elements whith too large ionic radius (LIL). The rocks of the La Saquea and Yacuambi U., have negative Nb peaks suggesting a tectonic subduction. In the rare earth diagrams normalized to chondrites observed an enrichment in light rare earth elements, unlike Piuntza U.
Hydromagmatic (phreatomagmatic) breccias: polymictic, linked by a magmatic milled clast matrix and siliceous cement, often accompanied by mineralizing fluids, supported by sub-rounded to rounded clasts. In addition, it presents young igneous material (accretionary lapilli), sinter clasts and matrix injection clasts.
Hydrothermal breccias: monomictic, linked by a siliceous cement and matrix, rich in plagioclase and sometimes adularia. Product replacement by hydrothermal processes are generally supported by subangular / angular clasts. The predominant hydrothermal alteration in these gaps is argillic, sericitic, chloritic and silicification of the clasts, and as many presents disseminated sulphides mineralization.
There is significant evidence of mineralization which is related to various post-batholith tabular bodies, dikes varying from andesitic to rhyolitic porphyry, granite stocks, hydrothermal breccias, and others (*Figure 2*).

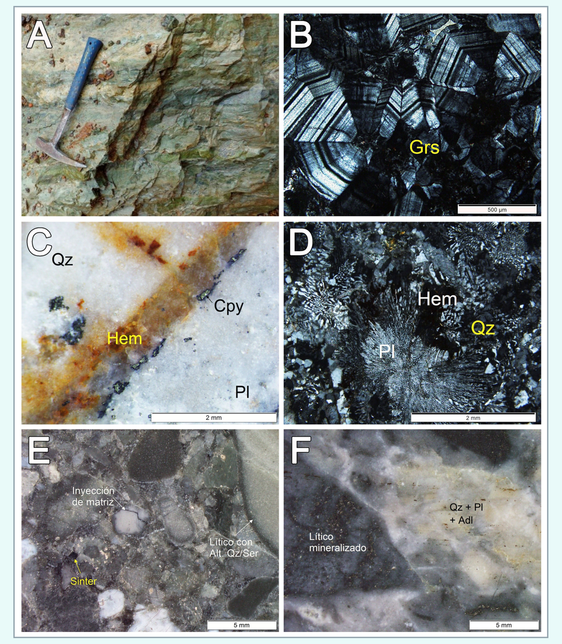


Figure 2: Photomicrograph of rocks with occurrences of economic mineralization.

A. Epidote skarn.

B. Garnet (grossular) skarn in thin section.

C. Chalcopyrite with halos of chalcocite in the edge of a quartz veinlets with oxides in andesite porphyry.

D. Rhyolite porphyry with myrmekite texture in thin section.

E. Phreatomagmatic breccia

F. Hydrothermal breccia. Abbreviations: Adl adularia, Cpy, chalcopyrite, Grs grossular, Hem hematite, Pl, plagioclase, Qz quartz (Whitney & Evans, 2010).

GEOCHEMISTRY

Samples of river sediments were analyzed in the laboratories of INIGEMM for 35 elements by ICP-OES, from which 11 were considered (Hg, Au, Ag, As, Cu, Sb, Zn, Co, Mo, Ni and Pb) for their respective geostatistical analysis and interpretation.
The geostatistical process (*Figure 3*) begins with the exploratory data analysis, in which first the normality is verified with statistical measures. Subsequently a trend analysis, is performed, in which the predominant direction of each element and its isotropic or anisotropic behavior is observed. Then, the structural analysis of the sample to observe semivariograms spatial correlation of data is performed.
With the above analysis it was possible to choose the best theoretical geostatistical model. The best curve fitting the experimental variogram to theoretical variogram is observed for each element.
For this, in all cases the kernel does not exceed 50% of the value of the plateau and combined between them is less than the variance requirement, since over 50% if there are many errors in data collection, processing, analysis chemical, etc.
Finally, the validation of the methods is performed by using the cross-validation, in which a curve of theoretical regression it is compared with a curve regression predicted, the estimated curves have some variation in slope compared to the theoretical curves due to prediction errors.
Modified Method Lepeltier, where it is possible to analyze the graphic concentration (ppm) was used to define anomalies - cumulative frequency and can establish populations; in this case. For all classes, elements 9 were obtained.

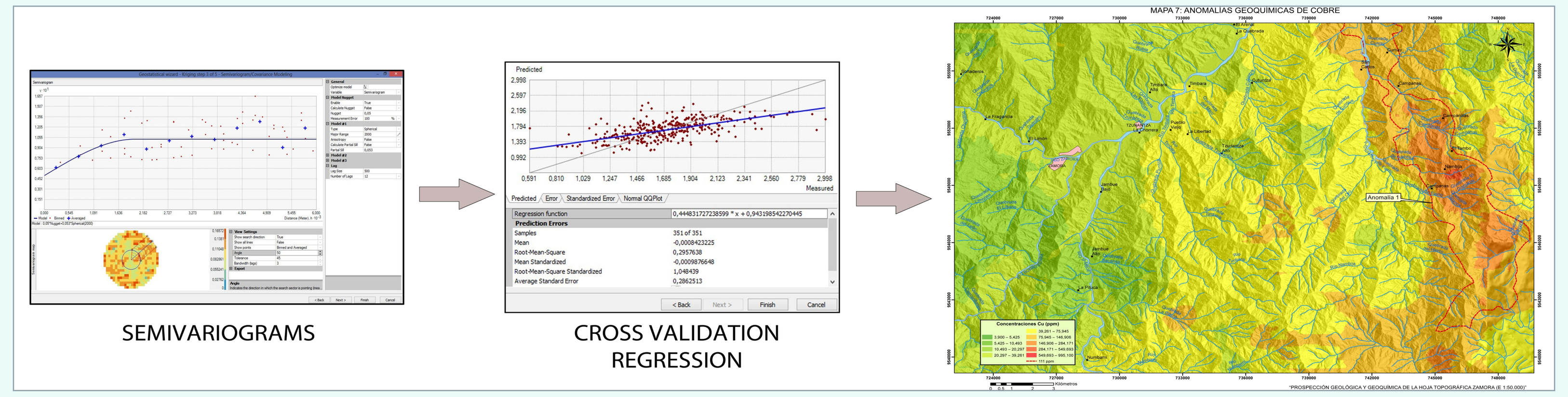


Figure 3: Statistical process whose end result is the prediction map of geochemical anomalies.

RESULTS

According to abnormalities of the analyzed elements, two regions of interest were defined. In these region, four profiles have been developed, allowing to relate the variation of the concentrations of the elements according to the geology observed in the field.

Profile A
SW-NE (*Figure 4*), in the Cordillera de Tzunantza, it shows a similar behavior of Sb, Hg and Ag elements in the Piuntza creek sector, where a small body of diorite is affected by local faults, which intrudes andesitic tuffs of Piuntza unit containing 10,71 ppm Ag; 1 309 ppm Cu; 1 729 ppm Zn; 207,4 ppm As and 53,06 ppm W.
Moreover, anomalies of As, Co, Zn and Pb elements have similar curves in the area of Timbara river where it crop out andesite aphanitic and tuff having Propylitic alteration, also belonging to the Piuntza unit, and it is affected by diorite and rhyolite dikes with propylitic alteration containing 4,12 ppm Ag; 2 918 ppm Zn and 37,87 ppm W.

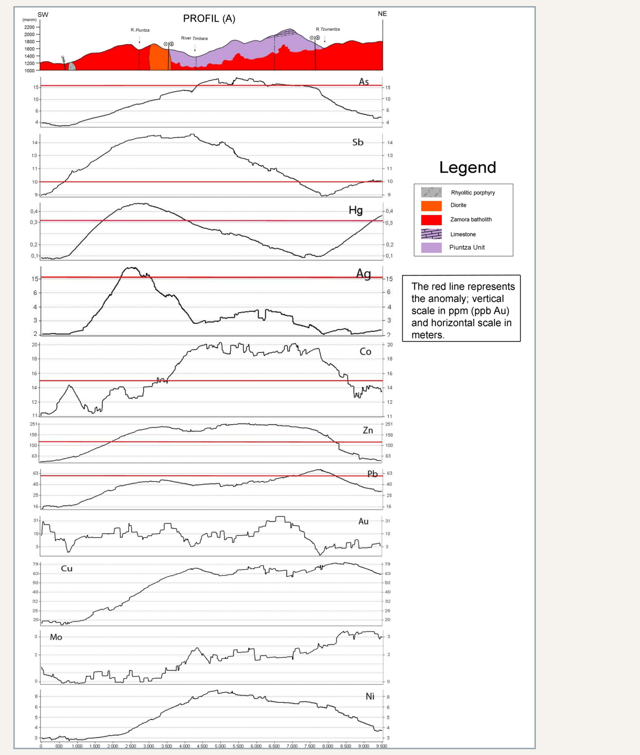
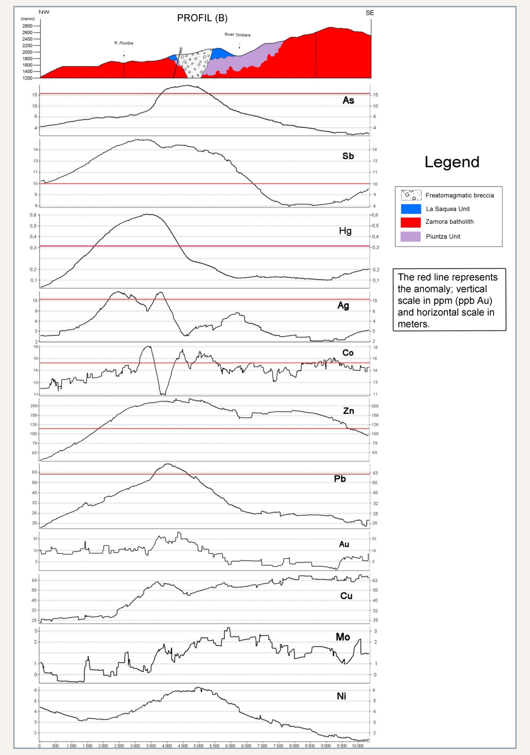


Figure 4: Correlation profil (A).



Profile B
NW-SE (*Figure 5*), in the Cordillera de Tzunantza, shows a more uniform behavior, mainly among Timbara and Piuntza streams, and anomalies of the elements such as As, Sb, Hg, Ag, Zn, Pb and Co.
In this sector, rhyolitic tuffs are observed with argillic alteration, belonging to the La Saquea unit, together with a body of phreatomagmatic breccias with clasts exhibiting phyllic and argillic alteration, the same that is affected by a thrust fault. Underlying volcanic breccias belonging to the Piuntza unit containing 3,4 ppm Ag.

Figure 5: Correlation profil (B).

Profile C
NW-SE (*Figure 6*), at north of the Cordillera de Nanguipa. In the area of Campanas Hg, Au and Cu anomalies were observed, outcrops of granodiorite intrusive rocks composition by Zamora batholith, sometimes with presence of local dacitic dikes and argillic alteration with normal faults.
In the Campanillas mine sector, there are also Au, Mo, Cu and Zn anomalies. Breccias and andesite were observed, affected by propylitic alteration with levels of garnet skarn (grossular) containing 67,3 ppm Ag; 43 375 ppm Cu; 555 ppm Zn and 672,7 ppm Mo, intercalated with fine tuff belonging to Piuntza unit in a evident N-S structural control and discordant contact with porphyritic andesites and rhyodacitic breccias of La Saquea unit.

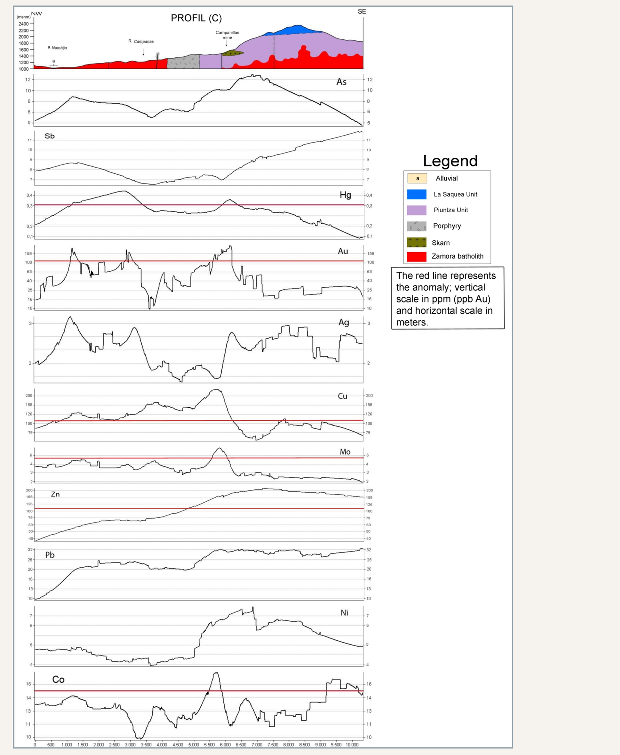
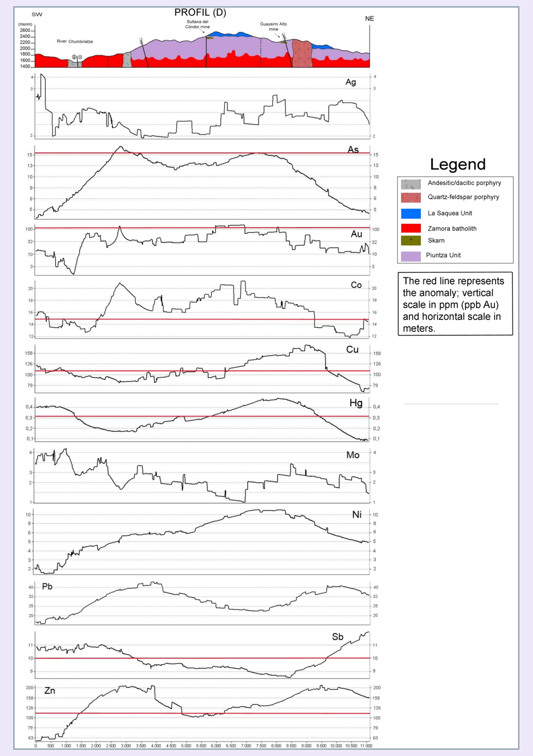


Figure 6: Correlation profil (C).



Profile D
SW-NE (*Figure 7*), at south of the Cordillera de Nanguipa. In the area of the headwaters of the Chumbiriatza river, the Sb, Zn and Co elements present anomalies, outcrops two bodies of andesitic / dacitic porphyry with argillic alteration containing 1 064 ppm Cu, emplaced in the granodiorite Zamora batholith, presence of transform faults and the contact of the batholith with volcanic breccias of Piuntza unit affected by reverse faults were observed.
Between Sultana del Condor and Guaysimi Alto mines, there are anomalies of Au, Co, Cu, Hg and Zn. In these sectors outcrops volcanic breccias and porphyritic andesites with sub-propylitic to propylitic alteration containing 3,33 ppm Ag; 15,12 ppm W and 204,7 ppm V, with levels of epidote and garnet skarn belonging to the Piuntza unit controlled by N-S faults.

Figure 7: Correlation profil (D).

MINING POTENTIAL

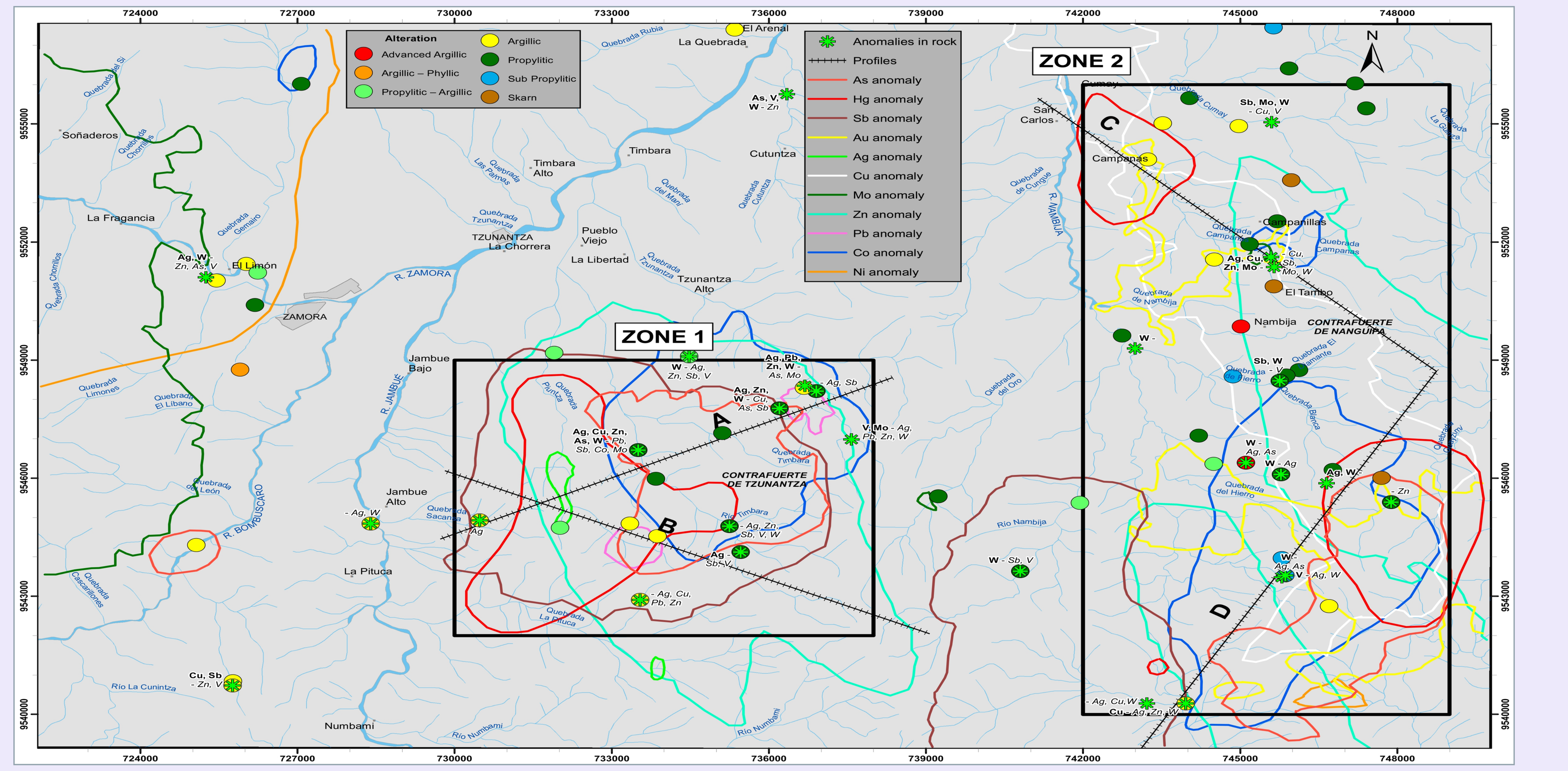


Figure 8: Mining potential and correlation profiles.

We have identified two areas with possible mining potential (*Figure 8*), the same as they were defined by analyzing anomalies of each element studied, correlated with the geology of the sector.
Zone 1
In Cordillera de Tzunantza, it can be seen that Pb-Zn-As and Cu-Mo elements have a high positive correlation. Dendrogram shows a strong association Zn-Pb due to the high similarity. On the other hand Cu-Mo strong association was also observed due to the high similarity between them.
Zone 2
In Cordillera de Nanguipa, it can be seen that the elements do not have a high correlation. It has been demonstrated in other studies detailed in the Campanillas mine that according to PRODEMINCA (2000), dendrogram shows associations Mo and Cu-Zn-Pb forming clusters 1 and 2.
On the other hand, Au and Ag elements have high similarity between them, so that in the analysis they are considered as different clusters (3 and 4 respectively).

CONCLUSIONS

Several anomalies were coincident in the areas of Tzunantza and Nanguipa, where the relation with geology makes possible to define the two areas of mineral potential.
According to the correlation profiles, it is deduced that the permeable lithology of Piuntza unit is favorable for hosting mineralization.
The final results obtained in Zone 1 (Tzunantza) suggest that the sector would be prospective for deposits type breccia pipe related to porphyry with a typical association of elements Cu±Au±Mo-Ag-Zn-Pb (McQueen, s / f)... Preserved? and maybe a epithermal deposit of high or low sulphidation.
The final results obtained in Zone 2 (Nanguipa) confirm the existence of a deposit of gold skarn related to porphyry Cu-Mo and Cu-Au, as mentioned in previous research in the sector; therefore it increase the reliability of the analysis performed in this investigation.

REFERENCES

Litherland, M., Aspden, J. A., & Jemielita, R. A. (1994). The Metamorphic Belts of Ecuador: Overseas Memoir of the British Geological Survey. Keyworth, U.K.
Mateus, A. (2011). Análisis Geoestadístico por el Método de Kriging Ordinario Aplicado a Muestras de Sedimentos Fluviales en el Distrito Minero Azuay. Tesis de maestría no publicada, Universidad San Francisco de Quito, Quito, Ecuador.
McQueen, K. G. (s/f). Ore deposit types and their primary expressions. En C. Butt, M. Cornelius, K. Scott, & I. Robertson, Regolith Expression of Australian Ore Systems (1 ed., págs. 1-14). Bentley, Western Australia: CRC LEME.
PRODEMINCA. (2000). Depósitos Porfídicos y Epi-mesotermales Relacionados con Intrusiones de la Cordillera del Cóndor: Evaluación de Distritos Mineros del Ecuador (1ra ed., Vol. 5). Quito, Ecuador: UCP Prodeminca Proyecto MEM BIRF 36-55 EC.
Romeuf, N. (1994). Volcanisme jurassique et metamoriphisme en Equateur et au Perou. Thèse de doctorat, Universite de Droit, d'Economie et des Sciences d'Aix-Marseille, Faculte des Sciences et Techniques de St-Jérome, Marseille, France.
Sillitoe, R. H. (1985). Ore-related breccias in volcanoplutonic arcs: Economic Geology, v. 80, p. 1467–1514.