*University of Utah*
UNDERGRADUATE RESEARCH JOURNAL

# Environmental Conflict and Water Quality in Nambija, Ecuador

**Kate Nicponski**
**Faculty Mentor: Bill Johnson**
**Department of Geology and Geophysics**
**12.14.2018**

## 1. Abstract

In July 2018, a group of students from the University of Utah traveled to Ecuador as part of a learning abroad program to research water quality and associated environmental impacts of mining in the country. The Nambija River in southeast Ecuador is a characteristic example of mining operations and visual effects of resulting contamination on the surrounding environment. Water samples were collected along the Nambija River to teach students how to gather, analyze and interpret data. The purpose of this report is to characterize the geochemical qualities of the Nambija River and quantify local mercury and trace metal contamination due to artisanal gold mining in the Nambija Mineral District.

## 2. Introduction

Artisanal mining is an important source of livelihood for rural communities worldwide, especially in developing countries. In Ecuador, Artisanal and Small-scale gold mining is one of the oldest and most traditional forms of mineral extraction (Sánchez-Vázquez et al. 2016). According to a United Nations case study in 2012, Ecuador has over 1,349 artisanal operations of which 1,069 are gold operations. In 2002, artisanal and small-scale gold mining generated 65% of the direct employment within the broader artisanal mining sector in Ecuador (60,000 of 92,000 jobs) and by 2005, small scale mining was responsible for 75% of the 5 tons of national gold production (Spiegel, 2012).

The Zamora-Chinchipe Province, located in in the Paquisha canton in the south east of Ecuador is one of the most economically highly valued areas for artisanal gold mining in the Country (Sánchez-Vázquez et al, 2016). Mining activities in the Zamora-Chinchipe area extend as far back as colonial and pre-colonial times. However, it was not until the 1980's that there was extensive growth in artisanal mining to the Nambija Mineral District (Ramírez et al, 2003). As shown in Figure 1, the Nambija Mineral District is located east of Zamora in the Ecuadorian Amazon.

Like most active artisanal mines in Ecuador, mining operations in the Nambija Mineral District have been performed in a rudimentary manner, without any technical guidance. Gold in the Nambija occurs primarily in vugs and veins within and close to skarn bodies developed on volcano-sedimentary rocks (Markowski et al. 2006). Afterwards, the gold is recovered through gravimetric concentration and amalgamation with mercury. The resulting residues are deposited in the ground or discarded to nearby streams. (Carling et al, 2013). In addition to gold, the remaining sulfur-rich polymetallic ore contains high concentrations of Mn, Cd, Pb, As, Cu and Zn. Inadequate management of mine tailings results in the discharge of toxic cyanide effluents and sediments highly enriched with Hg and other metals into the Nambija River.

Nambija mining concessioners worked with learning abroad students to navigate the area and select 6 optimal water sampling sites (Figure 2). The principal objective of the study was the characterization and geochemical evaluation of local mercury and trace metal contamination of the Nambija River due to artisanal gold mining in the Nambija Mineral District.

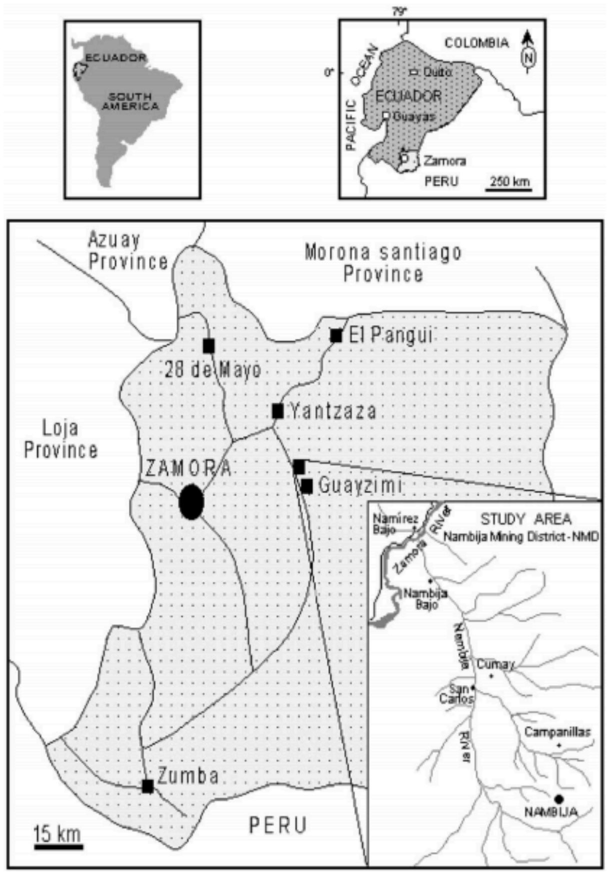


Figure 1. Map of the Location of the Nambija Nambija River and mine

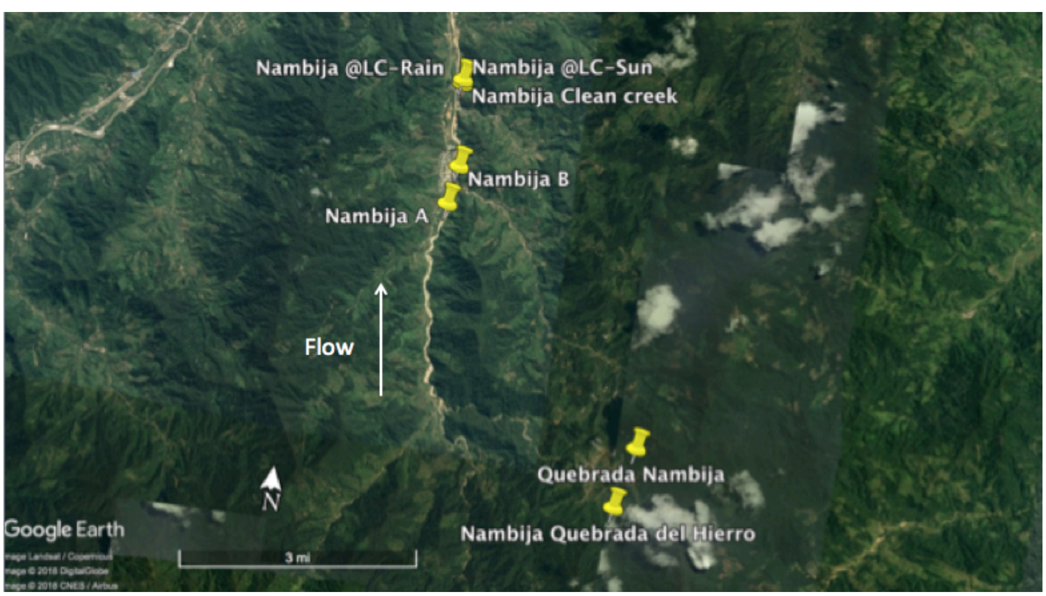


Figure 2. Sampling Locations down the Nambija River

## 3. Methods

3.1 *Water Sample Collection Overview*

Water samples were collected at 6 sites along the Nambija River transect to characterize stream chemistry. These sites are located upstream of the Nambija mine, downstream of the mine and in a nearby clean creek tributary for comparison. Samples were collected in low-density polyethylene (LDPE) or fluorinated high-density polyethylene (FLPE) bottles using a peristaltic Geopump. 20% hydrochloric acid was used to clean all LDPE and FLPE bottles before sample collection. 0.45 µm cartridge filters were attached to the Geopump for the collection of filtered samples.

To ensure quality samples representative of the Nambija, a clean hands-dirty hands protocol (Radtke, 1997) was used at all times of the sampling process. Field working class members assigned to the "Clean Hands" task oversaw of all operations involving equipment that contacts the sample. Members assigned to "Dirty Hands" handled all operations involving contact with potential sources of contamination. Once collected, all samples were shipped to the United States and analyzed within 2 months at the University of Utah, Freddrick Albert Sutton building Labs.

*3.2 Field Parameters*

A YSI field probe was used to measure temperature, dissolved oxygen (DO), conductivity, barometric pressure and pH at each of the 5 sample sites. The probe was calibrated for conductivity, pH, and DO at the beginning of each sampling period.

*3.3 Ion concentrations*

Filtered samples for major anions and cations were collected in 30mL LDPE bottles and were analyzed by ion chromatography (IC). Samples were filled to the top bottles to preserve redox-sensitive ions such ammonia/nitrate and sulfide/sulfate.

*3.4 Trace element concentration*

For trace element sample preservation, 2.4% nitric acid was added to 30ml LDPE bottles prior to sample collection. Filtered and unfiltered samples were collected to distinguish the particle-bound trace element species from the dissolved species. Bottles were filled to the neck to avoid loss of preservation acid. Samples were analyzed for 47 elemental concentrations using an inductively coupled plasma mass spectrometry (ICP-MS) for both filtered and unfiltered samples.

*3.5 Total and methyl mercury*

For mercury sample preservation, 1% HCL was added to 250ml FLPE bottles prior to filtered and unfiltered sample collection. Bottles were filled to the neck to avoid loss of preservation acid. Total mercury samples were prepared using in-bottle BrCL oxidation, and methyl mercury samples were distilled prior to analysis. Both THg and MeHg concentrations were analyzed using a Brooks Rand Model 3 cold vapor atomic fluorescence spectrometer (CVAFS).

*3.6 Alkalinity*
Filtered samples were collected in 125mL LDPE bottles with no headspace at each site. Alkalinity was measured in the lab through titration, using a known concentration of sulfuric acid.

*3.7 Total suspended solids and particle sizes.*
Unfiltered samples were collected in 250mL LDPE bottles. Total suspended solids concentrations were analyzed gravimetrically by difference between filter mass before and after passage of 50 mL of sample. A Particle Size Analyzer identified the size distribution of the particles in each sample.

## 4. Results

The sample collected at Quebrada Nambija (upstream of the mine) displays a specific conductance value of 40.1 μS/cm. Specific conductance values of samples taken downstream of the mine show modest variation ranging from 74.6 to 84 μS/cm. Temperature values increase steadily upstream to downstream from 14°C to 20°C.

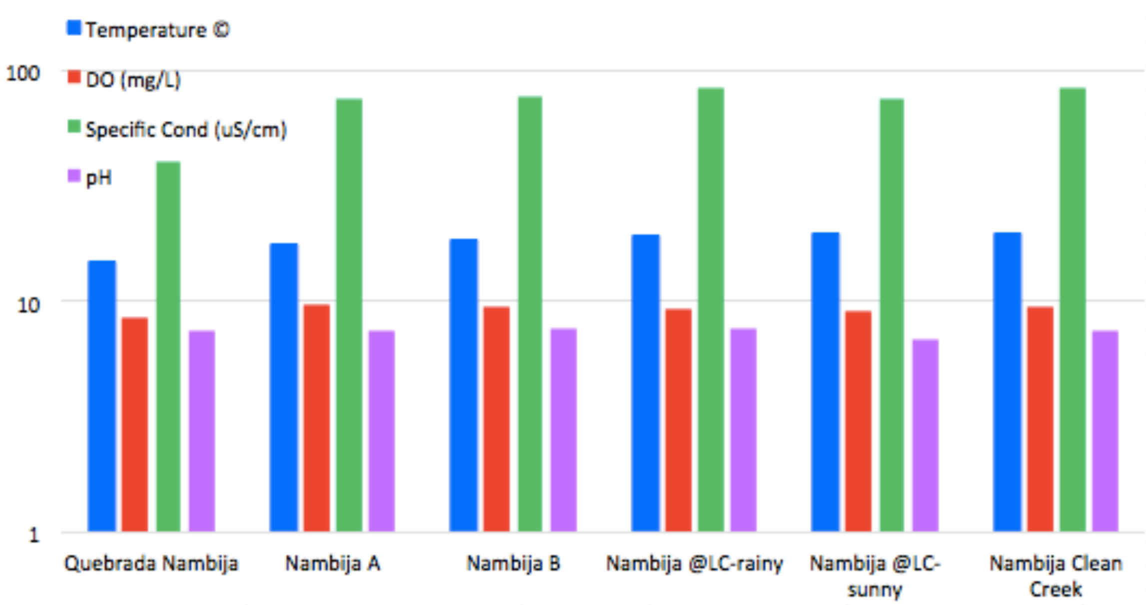


Figure 3. Nambija River Transect basic field parameters

Out of the 47 elemental concentrations analyzed, Manganese, Aluminum and Iron demonstrate concentration values that exceed the Maximum Containment Levels (MCL). These levels, established by the Environmental Protection agency, are surpassed at all four sampling sites downstream of the Nambija mine for each one of these elements. Samples taken at the Quebrada Nambija and Namijba Clean creek contain concentrations <0.5mg/L for all three metals. Concentrations of metals are randomly distributed along the downstream segment of the sampling transect. The majority of elements at each site are largely particle bound rather than dissolved (fraction that passed through the 0.45-[micro]m filter).

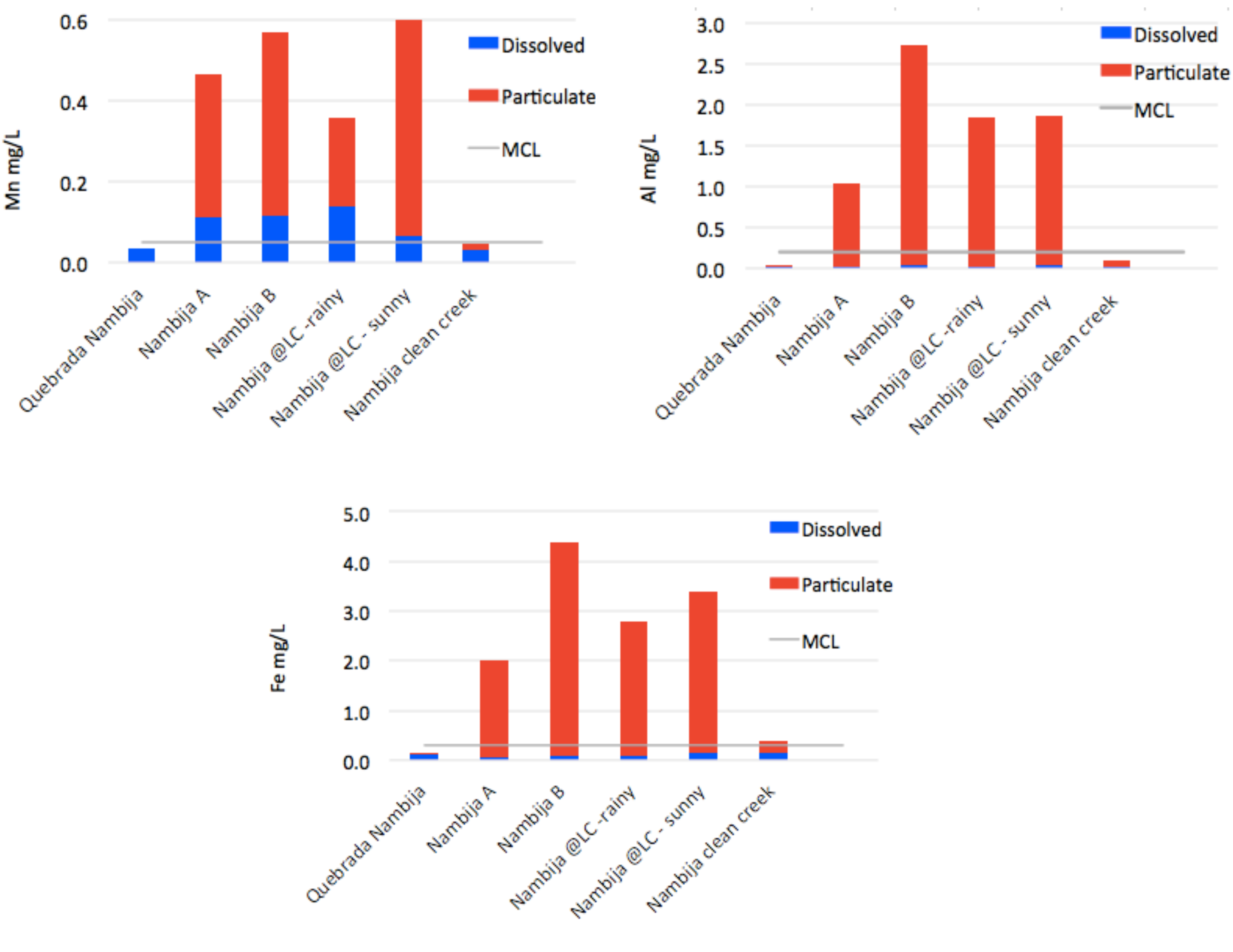


**Figure 4. Nambija River Transect trace element concentrations (Mn, Al, Fe)**

Total and methyl mercury concentrations are below 0.5ng/L for samples taken at Quebrada Nambija. Total Mercury concentrations for the downstream sampling sites range from 302.22 ng/L to 1442.13 ng/L. Methyl mercury concentrations range from 0.06 to 0.15 at sites down stream of the mine.

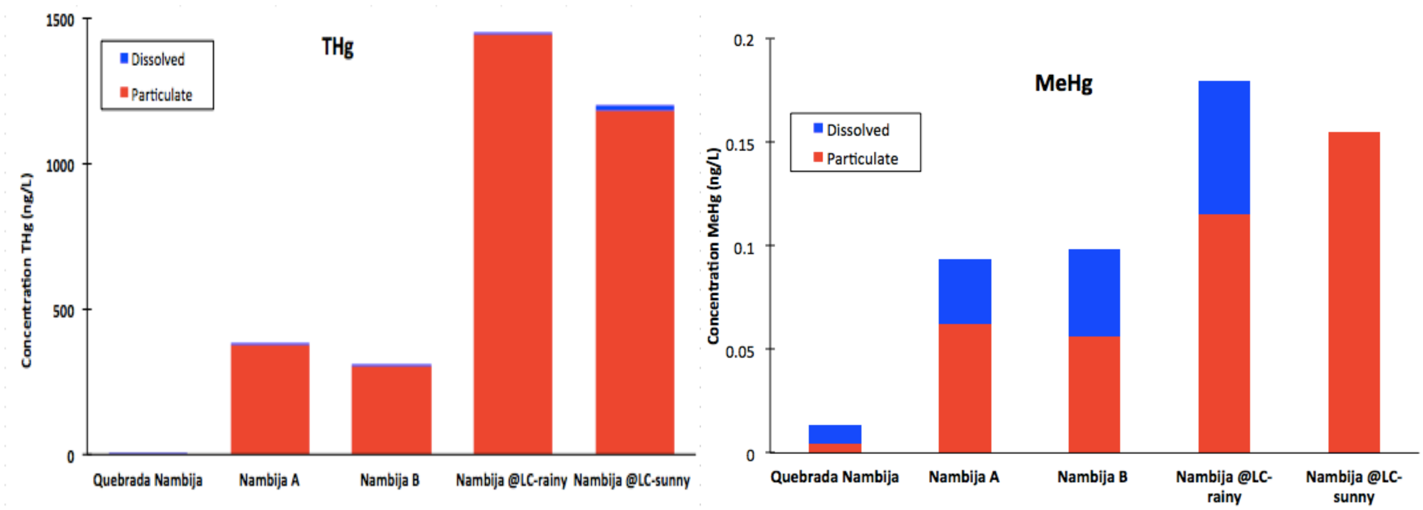


**Figure 5. Nambija River Transect Total and Methyl Mercury concentrations**

## 5. Discussion

Temperature Differences measured using the field probe are due to elevation differences at each sampling site. Conductivity increase from sites upstream to downstream is due to higher concentrations of dissolved solids and possibly the addition of metals from the mining processes. The majority of the 47 elements measured did not exhibit concentrations exceeding that of maximum contaminant levels, but can still be considered threating to the surrounding environment.

Total mercury concentrations are considerably high but do not surpass that of the MCL set for mercury contamination by the EPA (2000 ng/L). Concentration values for MeHg, the most toxic and bio accumulative form of Hg, were comparatively lower than that of total mercury (by a magnitude of 3). Methyl mercury is produced in aquatic systems by sulfate- and iron-reducing bacteria in the presence of organic matter. A study done by P. Velasquez-Lopez indicated low methylation rates downstream of mining operations that used cyanide leaching for gold extraction. It was concluded in this study that there were potential negative correlations between cyanide and mercury methylation (Carling et al, 2013).

It is unknown whether or not the the Nambija mine uses cyanide leaching as a method for gold extraction in addition to mercury amalgamation. If so, this may be a possible explanation for low methyl mercury levels relative to total mercury concentrations in the Nambija River. Further research on this correlation is necessary to fully understand the controls on methylation in these mining areas. Suggestions for continued research include studying the influence of cyanide leaching on water quality, the addition of sediment, core and tailings sampling, and further water sample collection along the Nambija River transect.

References Cited

Carling, G., Diaz, T., Ponce, X., Perez, M., Nasimba, L., Pazmino, L., . . . Johnson, P. (2013). Particulate and Dissolved Trace Element Concentrations in Three Southern Ecuador Rivers Impacted by Artisanal Gold Mining. *Water, Air, & Soil Pollution, 224*(2), 1-16.

Spiegel, S. (2012). *Analysis of Formalization Approaches in the Artisanal and Small-Scale Gold Mining Sector Based on Experiences in Ecuador, Mongolia, Peru, Tanzania and Uganda: Tanzania Case Study*. United Nations Environment Programme

Radtke, D. (1997). *Techniques of Water-Resources Investigations of the United States Geological Survey,* Techniques of Water-Resources Investigations of the United States Geological Survey.

Sánchez-Vázquez, Espinosa-Quezada, & Eguiguren-Riofrío. (2016). "Golden reality" or the "reality of gold": Artisanal mining and socio-environmental conflict in Chinapintza, Ecuador. *The Extractive Industries and Society, 3*(1), 124-128.

Ramírez Requelme, Ramos, Angélica, & Brabo. (2003). Assessment of Hg-contamination in soils and stream sediments in the mineral district of Nambija, Ecuadorian Amazon (example of an impacted area affected by artisanal gold mining). *Applied Geochemistry, 18*(3), 371-381.

Betancourt, O., Narvaez, A., & Roulet, M. (2006). Small-scale gold mining in the Puyango River Basin, Southern Ecuador: A study of environmental impacts and human exposures. *Epidemiology, 17*(6), S432-S433.

Velásquez-López, P. C., Veiga, M. M., & Hall, K. (2010). Mercury balance in amalgamation in artisanal and small-scale gold mining: Identifying strategies for reducing environmental pollution in Portovelo-Zaruma, Ecuador. *Journal of Cleaner Production, 18*(3), 226-232.

Guimaraes, Jean Remy Davée, Betancourt, Oscar, Miranda, Marcio Rodrigues, Barriga, Ramiro, Cueva, Edwin, & Betancourt, Sebastián. (2011). Long-range effect of cyanide on mercury methylation in a gold mining area in southern Ecuador. *The Science of the Total Environment,409*(23), 5026-33.

A Muñoz, G & Pazmino, Isabel & Ayala, Diana & A Espinosa, P & Velasquez-Lopez, Patricio. (2014). Gravity concentration of gold in Nambija -Ecuador: The importance of process analysis for recovery success.

Markowski, A., Vallance, J., Chiaradia, M., & Fontboté, L. (2006). Mineral zoning and gold occurrence in the Fortuna skarn mine, Nambija district, Ecuador. *Mineralium Deposita,41*(4), 301-321. doi:10.1007/s00126-006-0062-x