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Regional Watershed Sustainability: water quantity, quality, and strategic management for the 5 Arequipa watersheds

Part 2: Water-Rock Geochemistry

Drs. Elizabeth Holley and Katharina Pfaff

1. Develop 5-watershed database for the Arequipa region

2. Identify current water-related problems within each watershed

   a. geochemical modeling of stream sediments to identify sources of sediments and metals

   b. geochemical model of rock-water interaction to identify the sources of metals and metalloids

3. Evaluate and recommend solutions

sustainability

Article

Tracking Sediment Provenance Applying a Linear Mixing Model Approach Using R's FingerPro Package, in the Mining-Influenced Ocoña Watershed, Southern Peru

Jorge Crespo [1,2,*], Elizabeth Holley [1], Madeleine Guillen [3], Ivan Lizaga [4], Sergio Ticona [3], Isaac Simon [5], Pablo A. Garcia-Chevesich [6,7] and Gisella Martínez [3]

geochemical modeling of stream sediments to identify sources of sediments and metals

Stream sediment sampling

a)

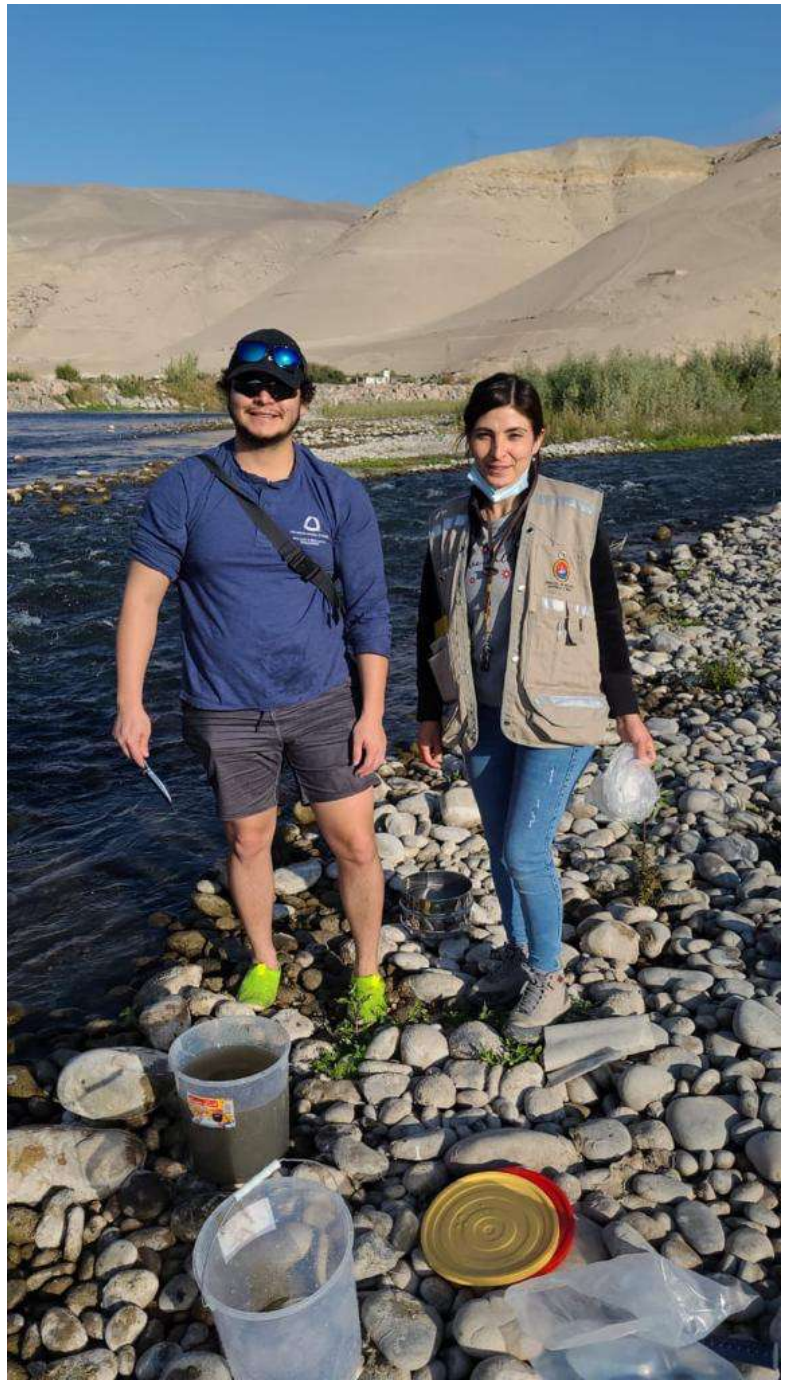
b)

c)

Mining Geology Research Group

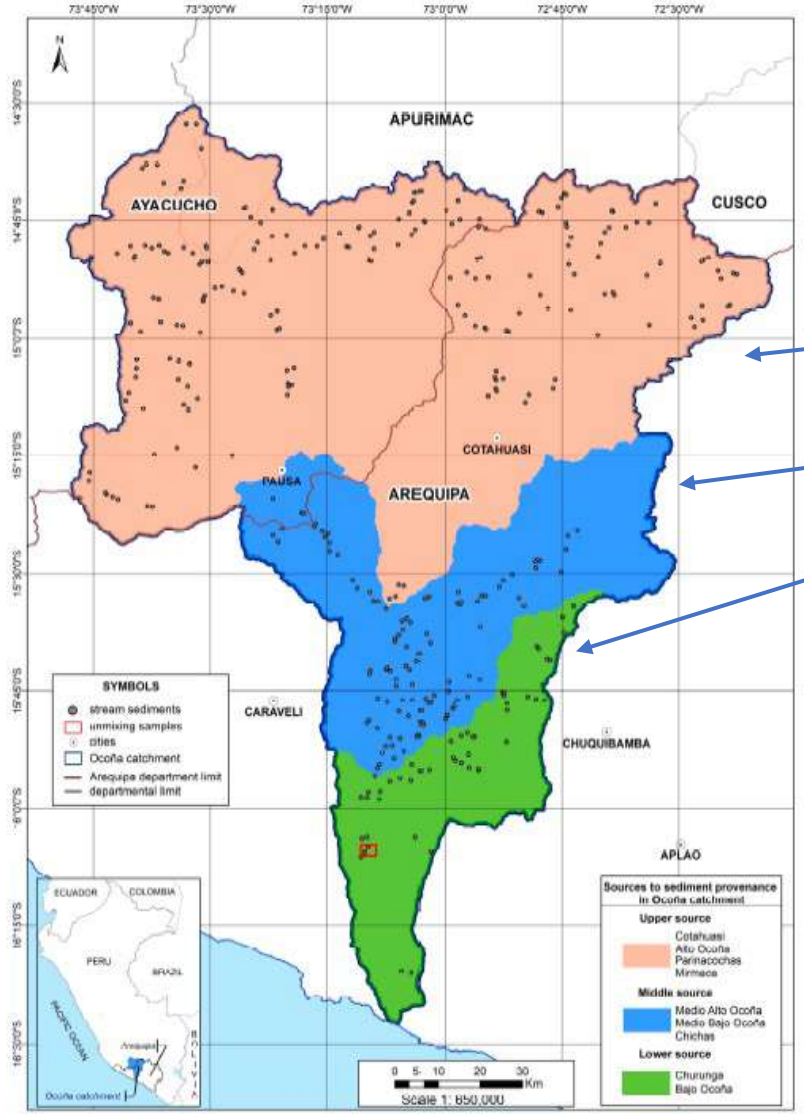
Mine tailings sampling

Majes-Camana Basin



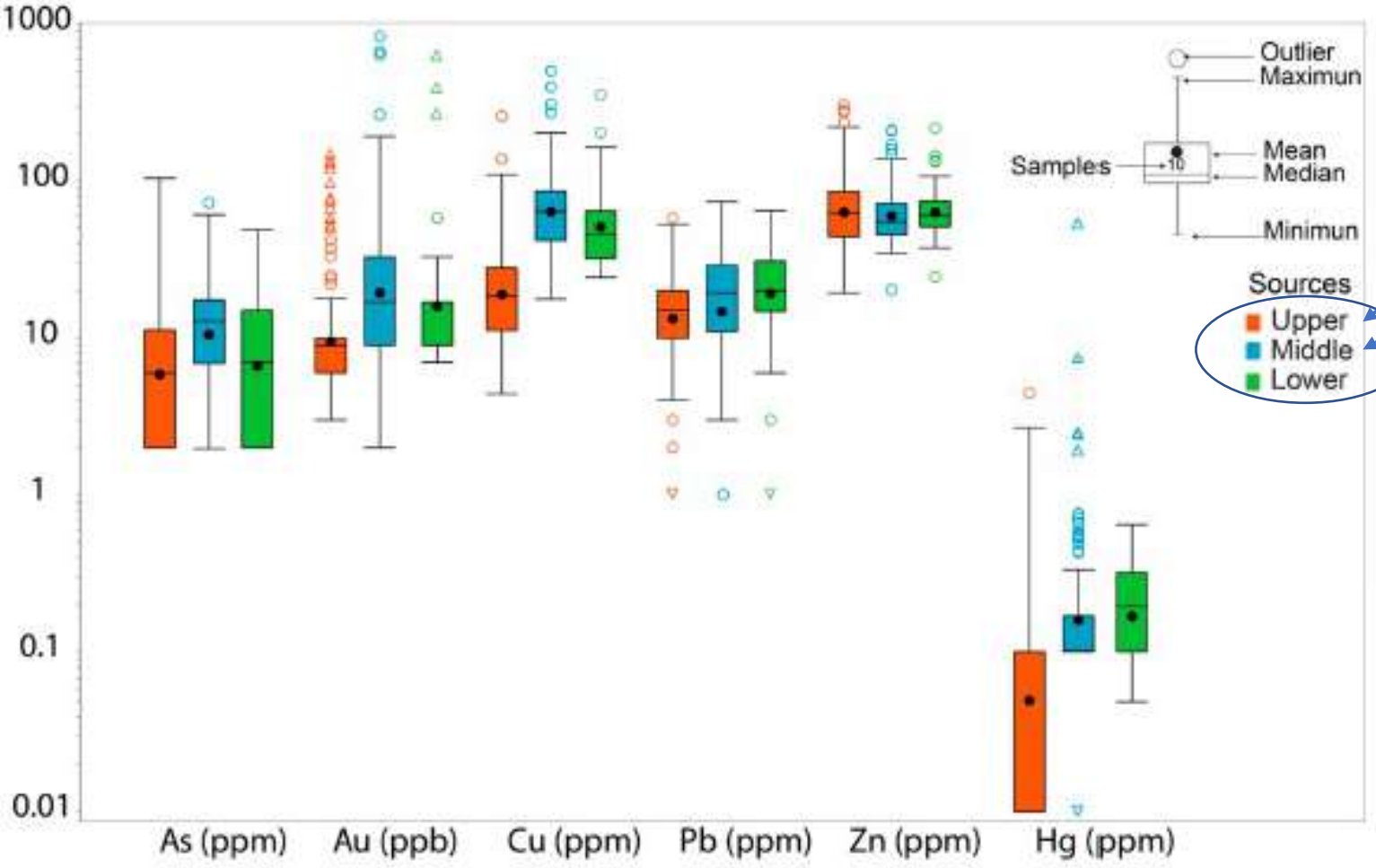
Camana river

Ocoña Watershed



- Stream sediment geochemistry
- Compare
  - Alto Ocoña
  - Medio Ocoña
  - Bajo Ocoña

Ocoña Watershed



- Inverse distance weighting (IDW) of stream sediment geochemistry

Alto Ocoña

Medio Ocoña

Bajo Ocoña

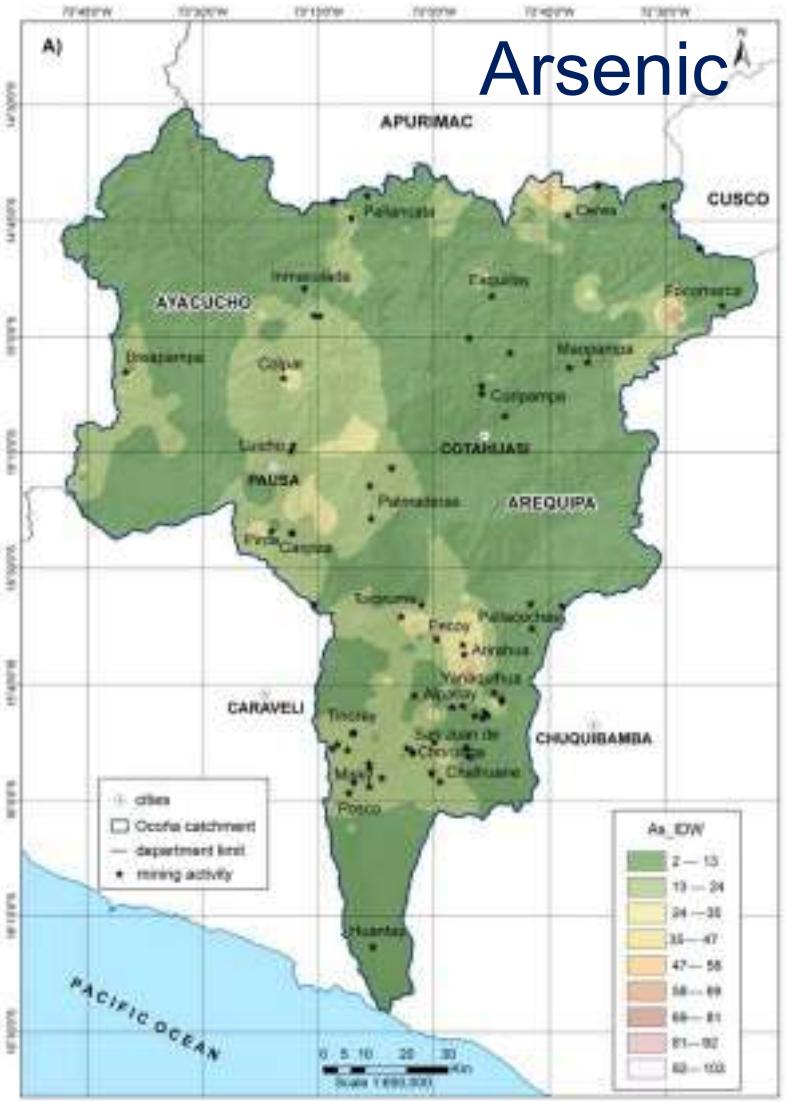
- All areas contain high metals

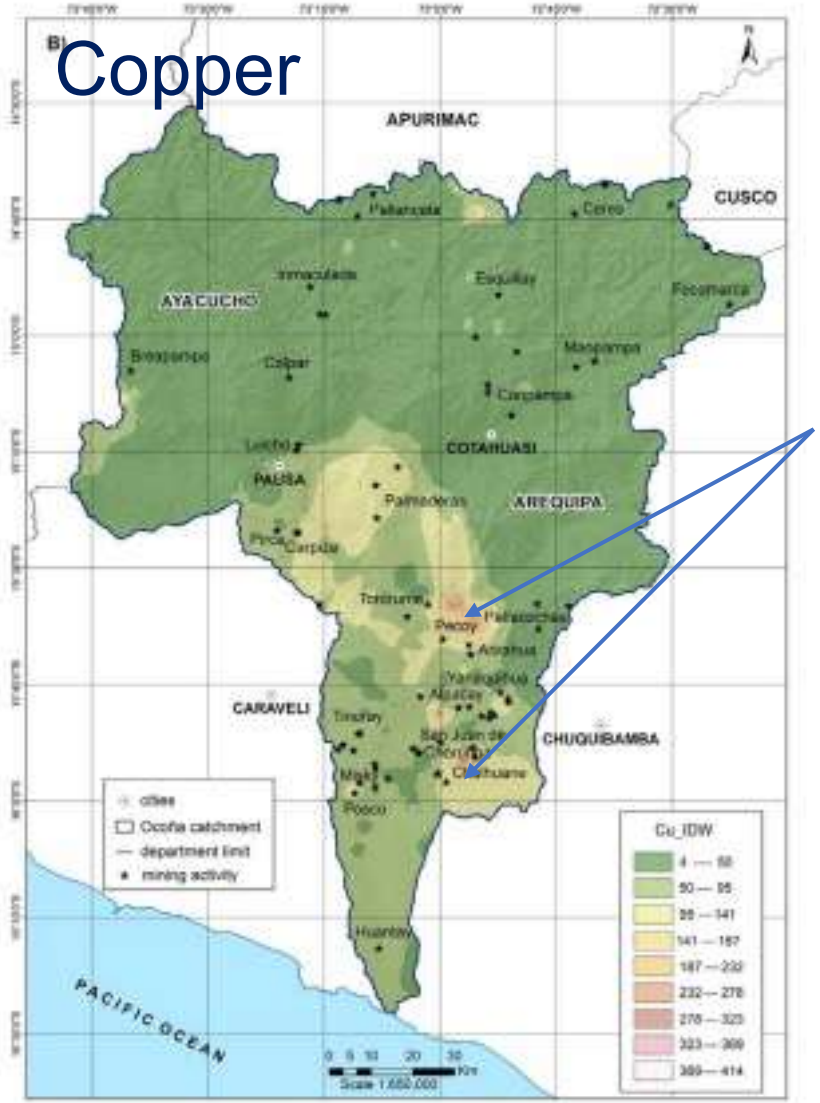
Alto Ocoña: highest Zn,Pb

Medio Ocoña: Au,Au,Cu,Hg

Bajo Ocoña: highest median Pb,Hg

Ocoña Watershed



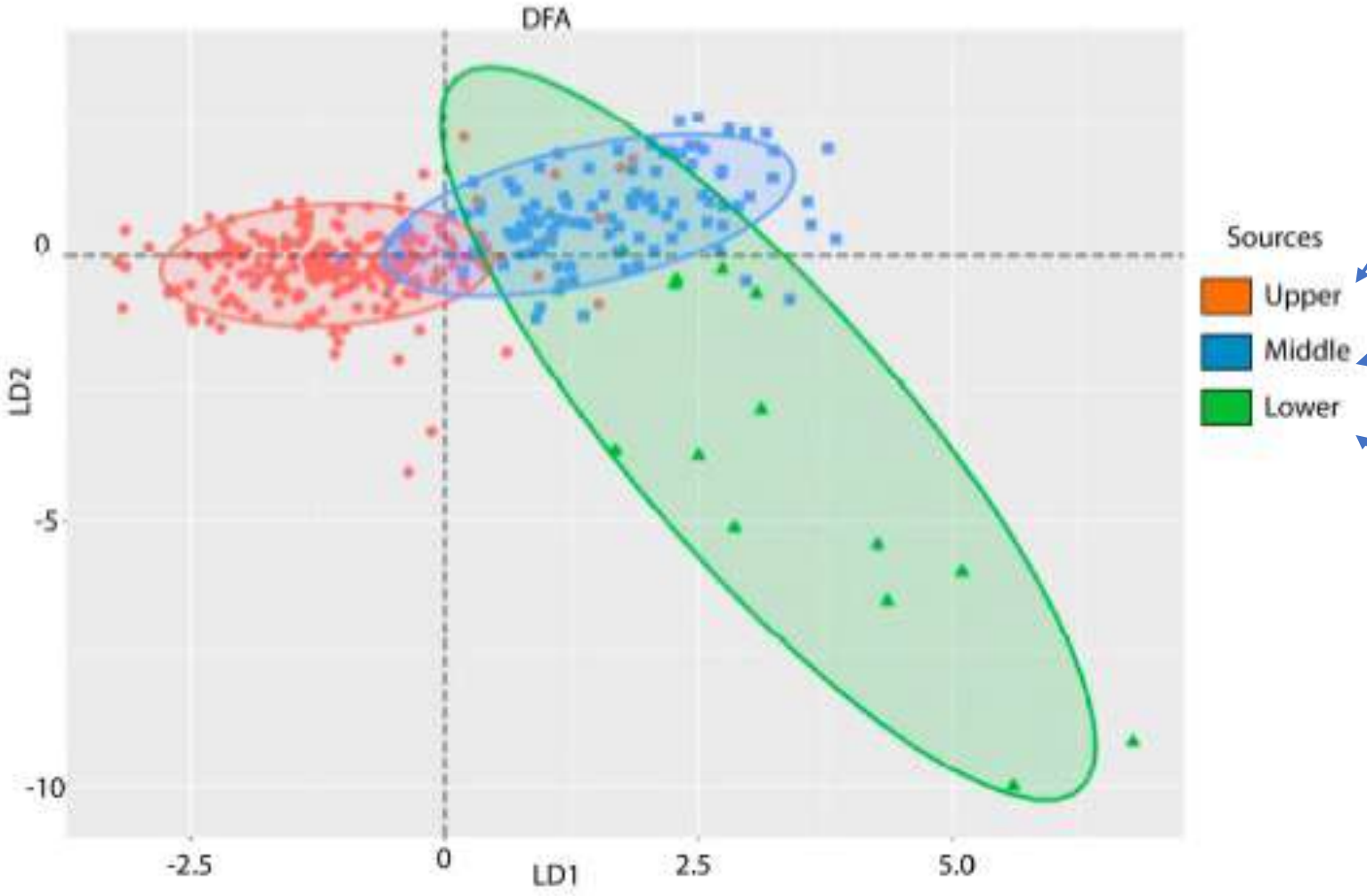


- Areas with mineral deposits and artisanal mining have high metals in rivers

  Pecoy, Arihua, Tororume, Chalhuane

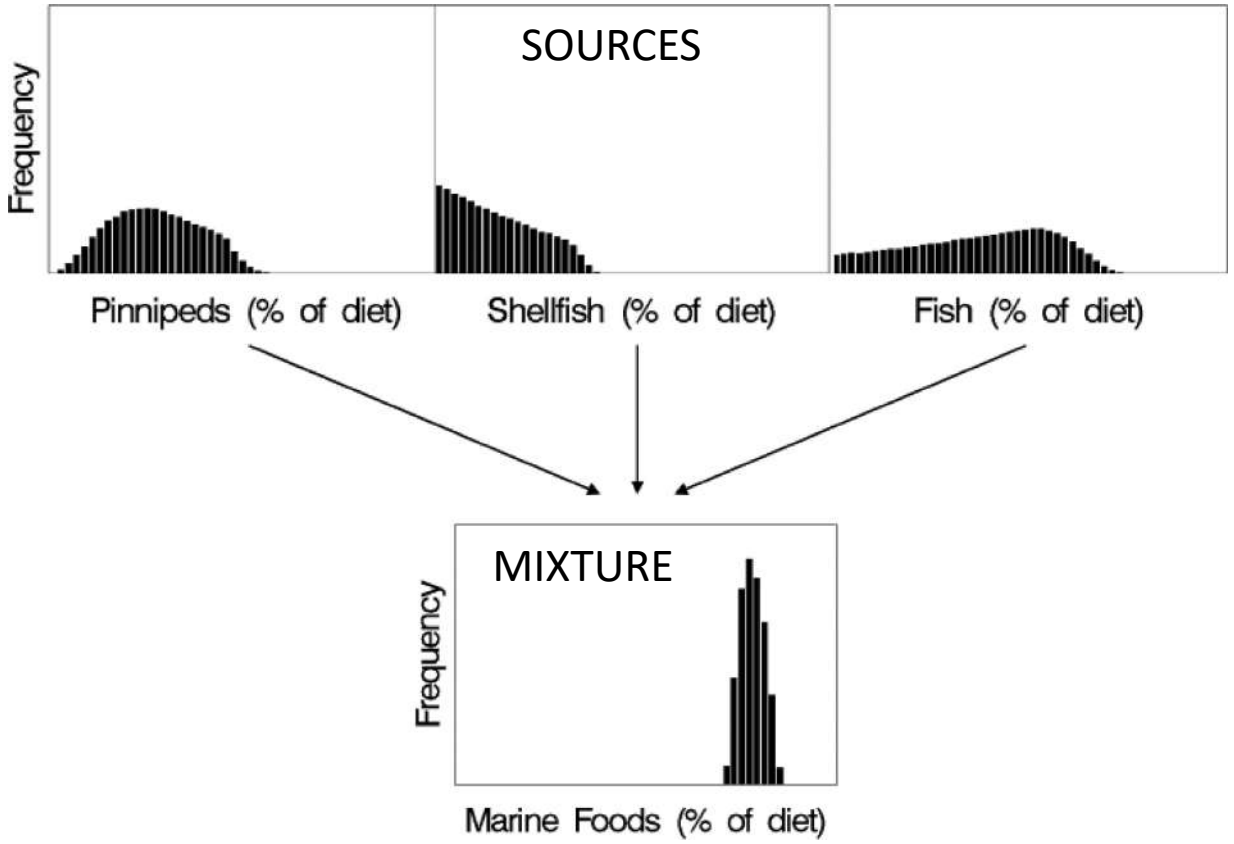
Cu concentrations in the stream sediments up to 504 ppm

Ocoña Watershed



- Linear discriminant analysis identifies three potential sources
  - Alto (Cotahuasi, Alto Ocoña, Parinacochas, and Mirmaca
  - Medio (Medio Alto Ocoña, Medio Bajo Ocoña, Chichas, Secocha)
  - Bajo (Churunga and Bajo Ocoña)

Ocoña Watershed

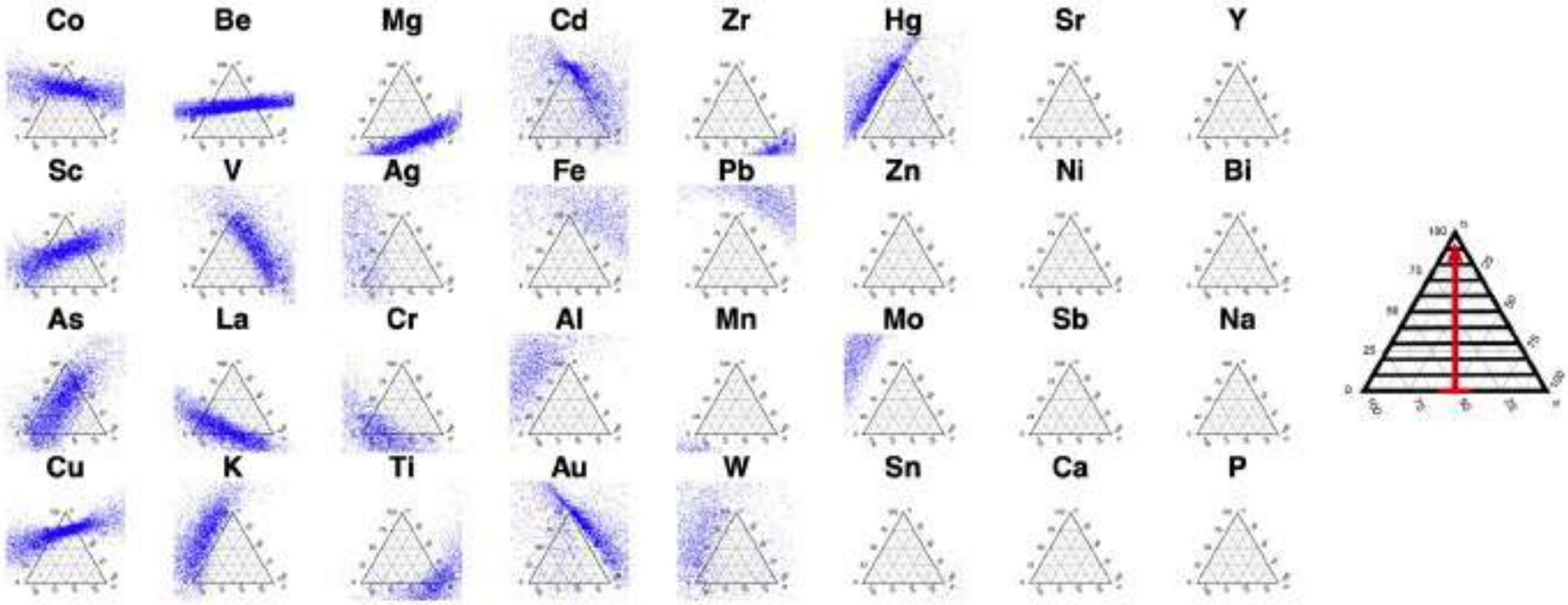


Phillips et al., 2014

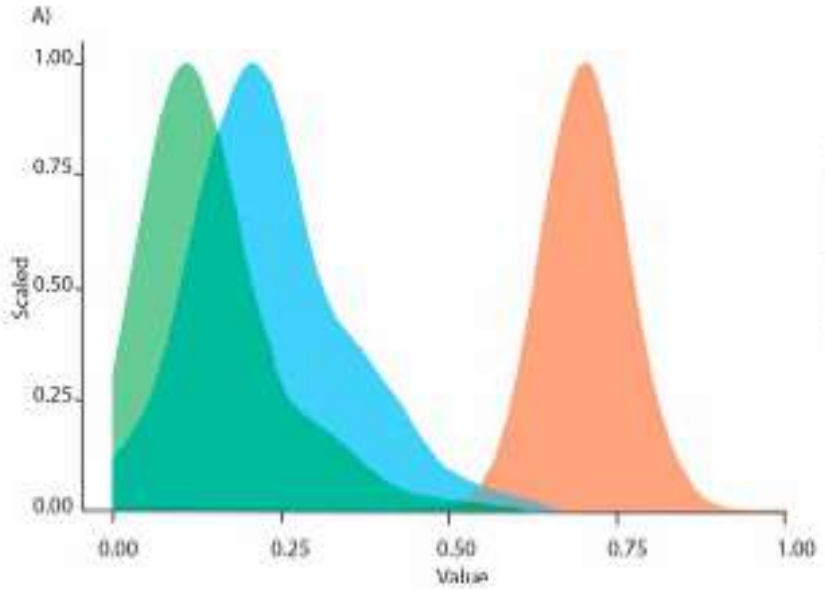
- Bayesian mixing models
- Developed for ecological food web studies
- Use sophisticated statistics to estimate proportional source contributions to a mixture
- We applied the modeling method to stream sediments: estimate the source contributions to the mixed sediments in Bajo Ocoña

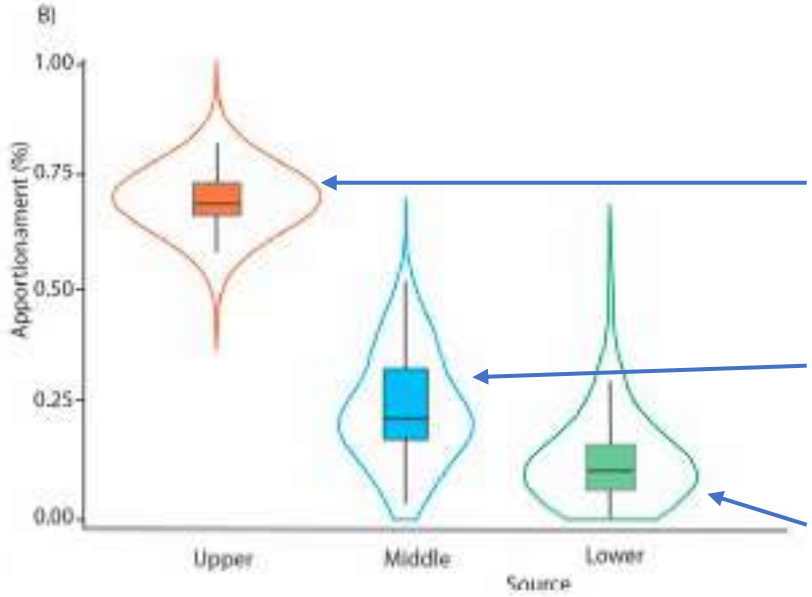
Ocoña Watershed

- Tracer selection

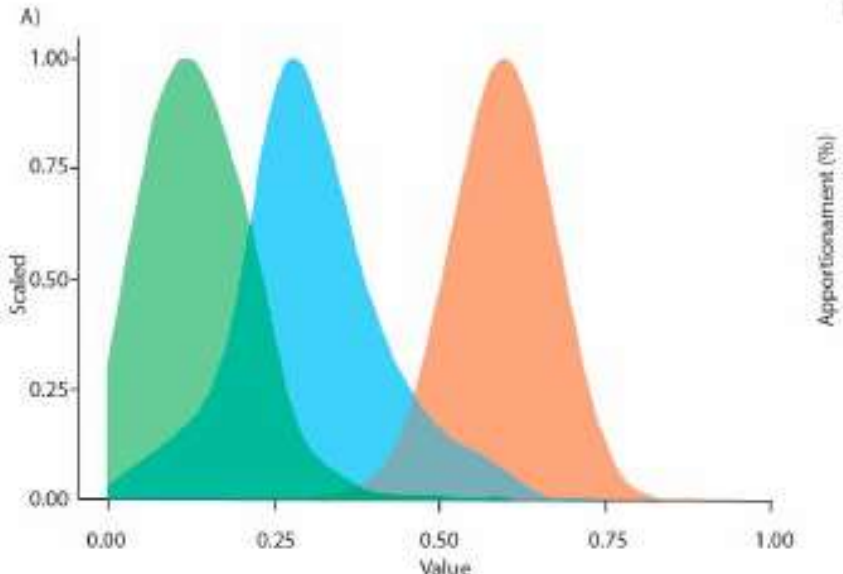


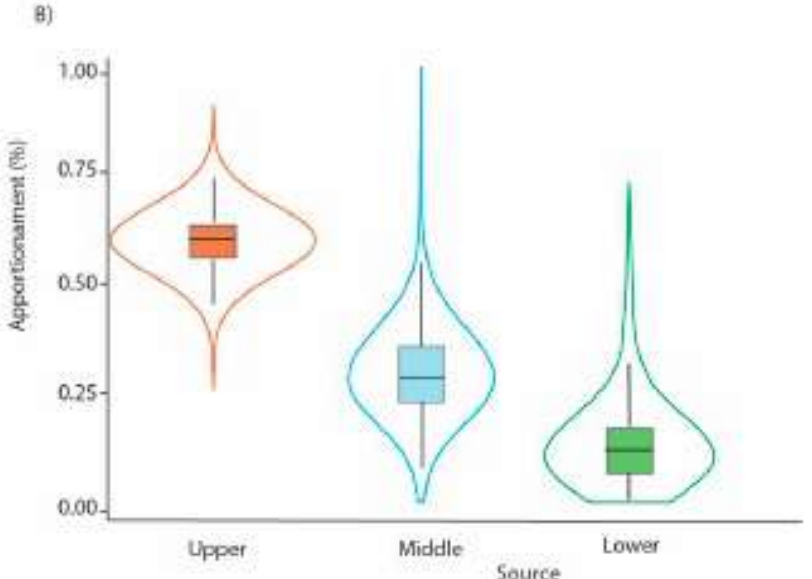
Ocoña Watershed





- Bayesian modeling identifies proportional contribution from each source
- Alto (Cotahuasi, Alto Ocoña, Parinacochas, and Mirmaca
- Medio (Medio Alto Ocoña, Medio Bajo Ocoña, Chichas, Secocha)
- Bajo (Churunga and Bajo Ocoña)

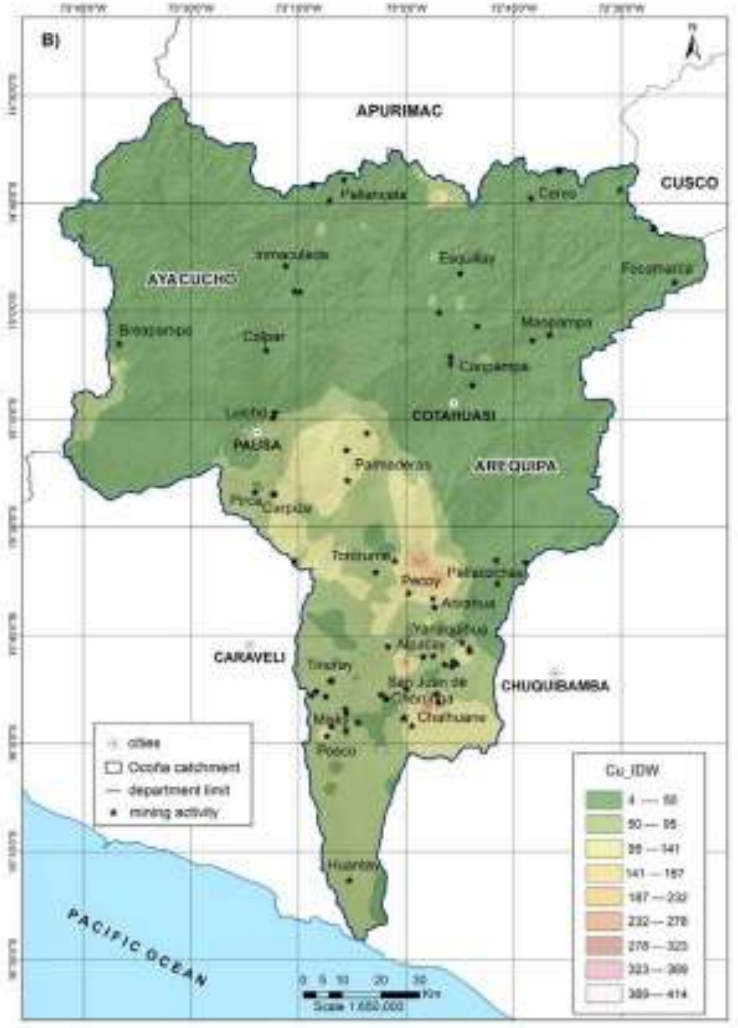




Conclusions on stream sediment modeling

- Fingerprinting of sediment and metal sources in the watershed
- Most most sediment originates from Alto Ocoña
- Most metals come from sites with mining activities / geological exploration in Medio Ocoña

- Erosion and sediment control practices necessary for areas where human activities such as mining contribute pollutants to the watershed



Controls on Acid Rock Drainage Generation in Arequipa, Peru

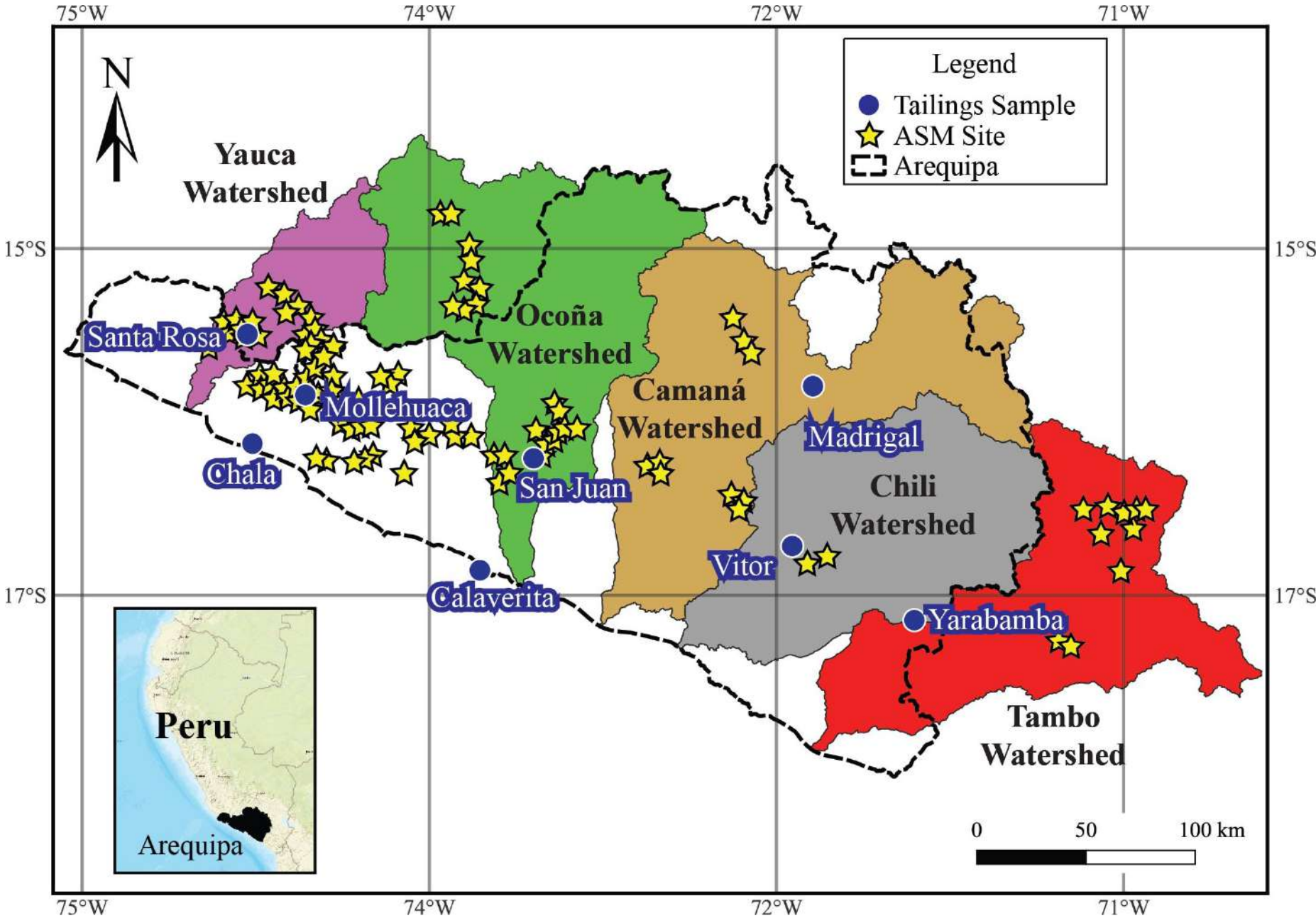
geochemical model of rock-water interaction to identify the sources of metals and metalloids

Acid Rock Drainage

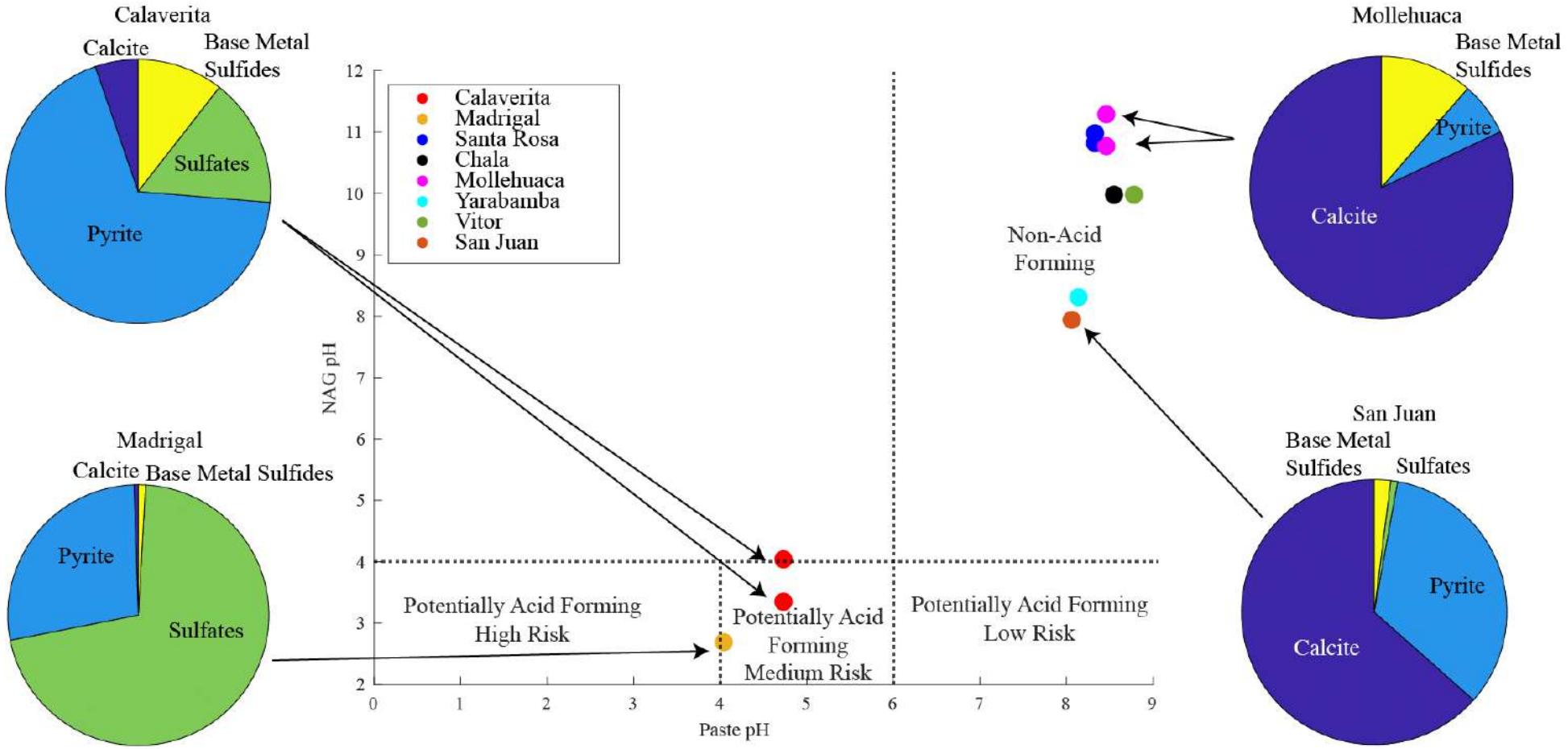
- Occurs from oxidation of sulfides like pyrite
- Detrimental to surrounding water quality due to low pH and elevated metal(loid) concentrations

Madrigal Tailings, Camaná-Majes-Colca Watershed, Arequipa

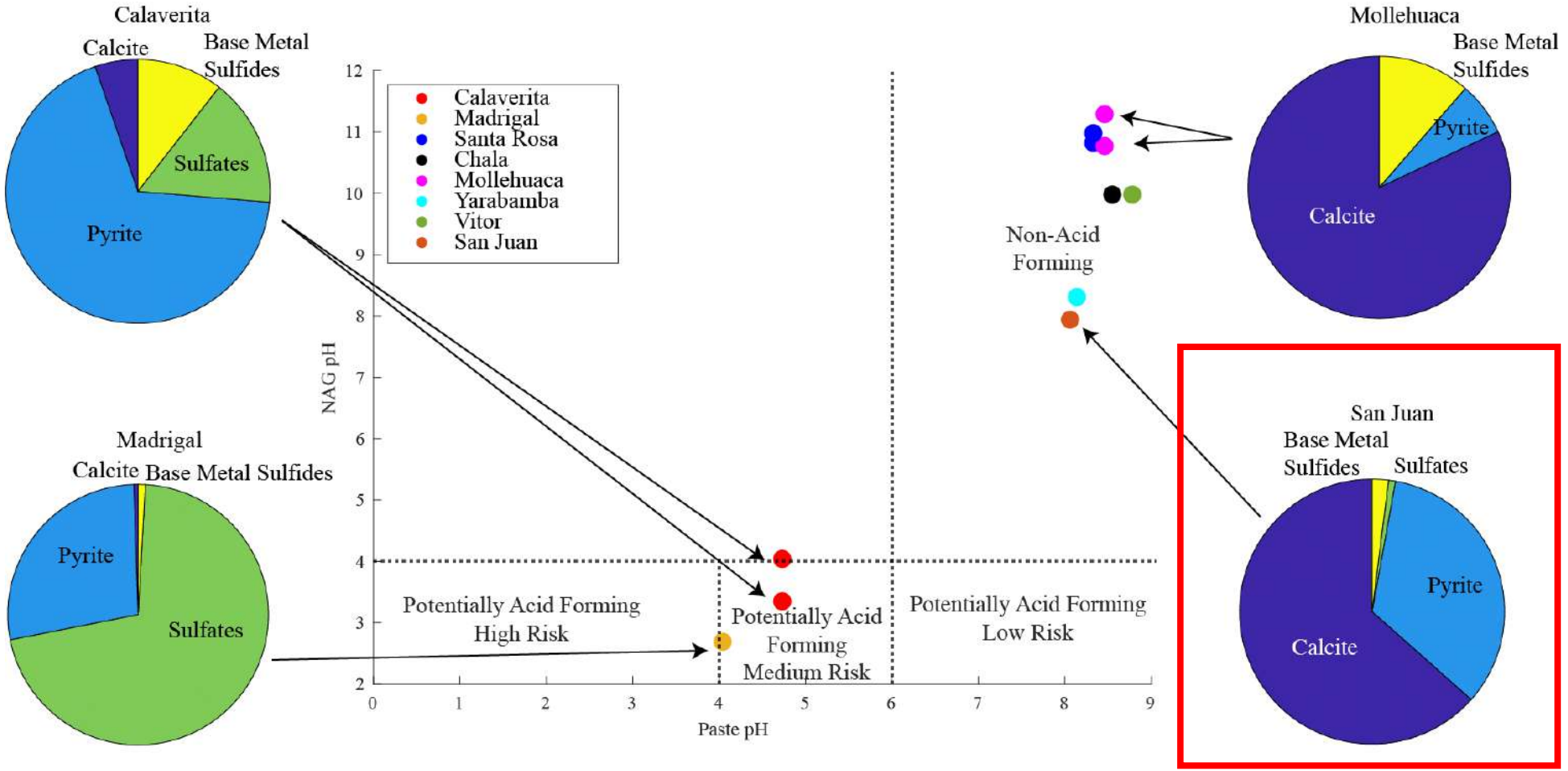
Artisanal and Small-Scale Mining



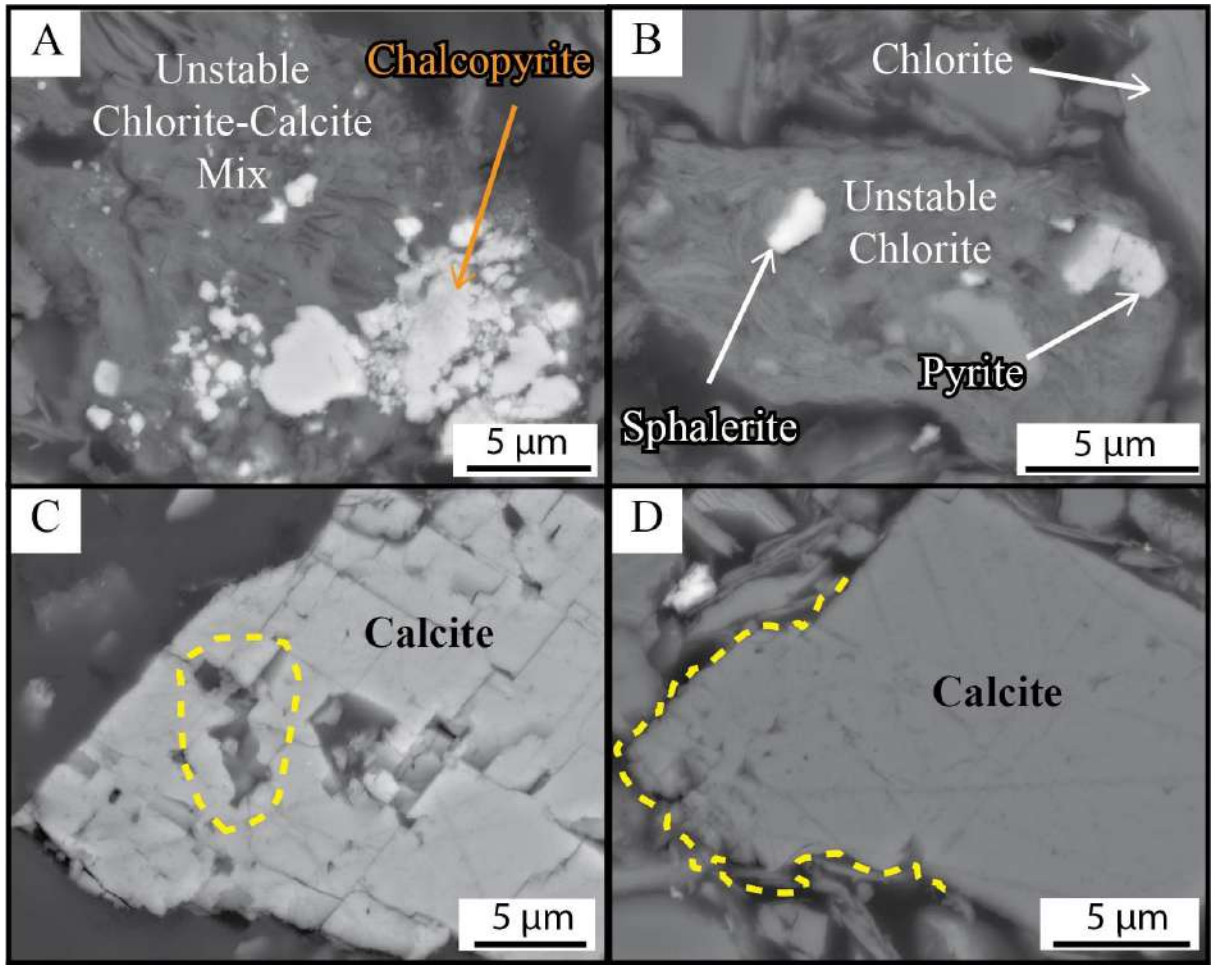
Mineralogical Controls

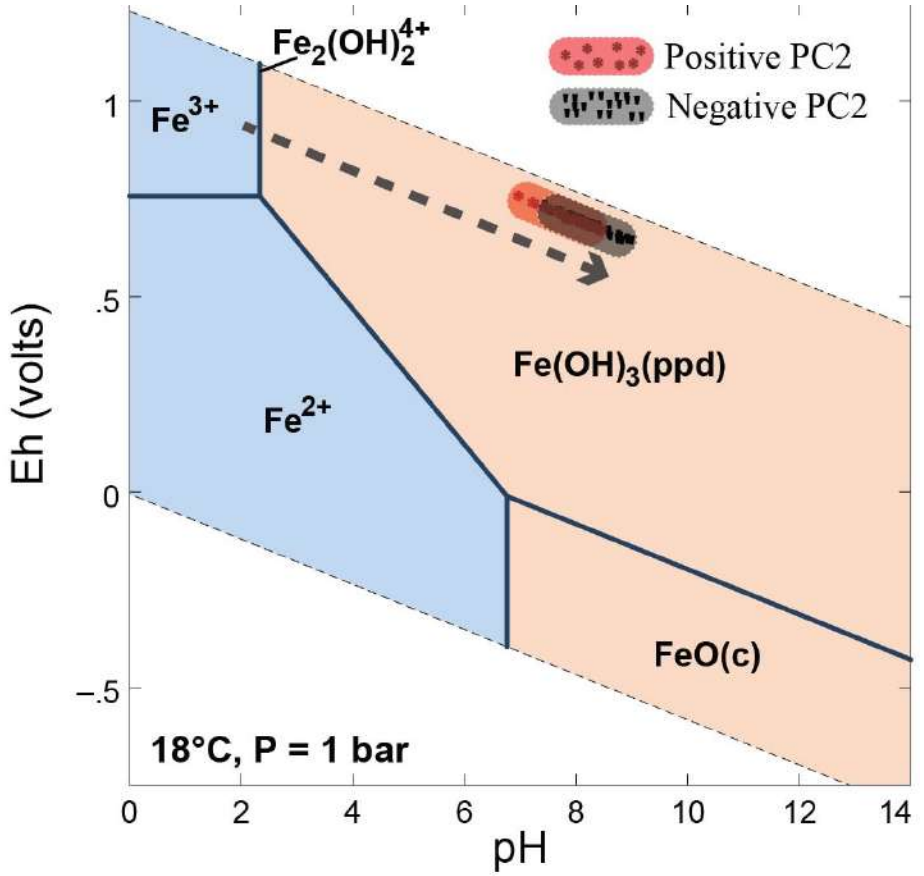


Mineralogical Controls



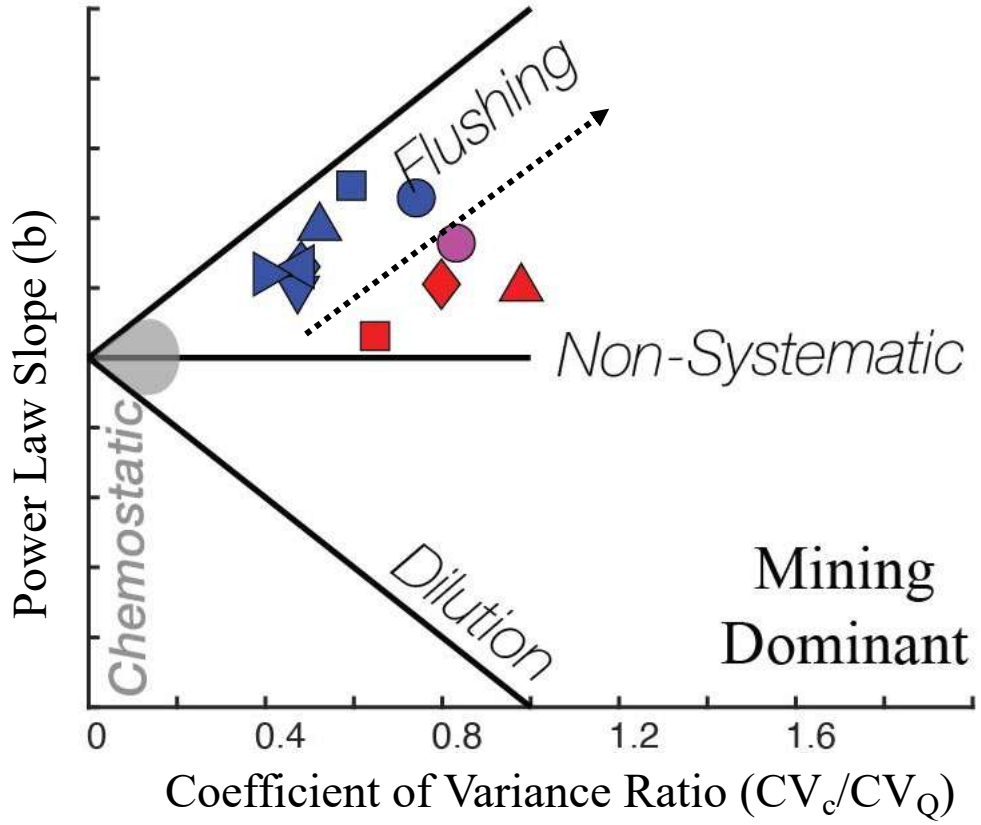
Mineralogical Controls – San Juan





Seasonal Controls– San Juan

- Positive slope (y-axis) is considered flushing
- Flushing – metal(loid) concentration increases with increasing river discharge
- X-Axis explains the variation of metal(loid) concentration



Conclusions on rock-water interaction

Acid rock drainage is related to mineralogy of mineral deposits being mined:

- Pyrite, base metal sulfides, and sulfates are responsible for acidic drainage that is dangerous to basin surface water
- Calcite and chlorite neutralize acidity and precipitants forming during acid-neutralization removes certain metal(loids) from solution

Seasonal changes, namely changes in river discharge impact water quality through incorporation of metal(loids). Therefore high-rain season in Arequipa is of concern.

Deposit types most like Madrigal and Calaverita (i.e. Epithermal deposits) are the most concerning in the five watersheds of Arequipa

Paper 1: Simon, I.S., Pfaff, K., et al., *Submitted* Geological and anthropogenic contributions of metal(loid)s in the artisanal and small-scale mining-impacted Ocoña watershed of Arequipa, Peru. Journal of Applied Geochemistry.

Paper 2: Simon, I.S., Pfaff, K., et al., *In Preparation.* Mineralogical Controls on Acid Rock Generation in Arequipa.

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Thank You! – !Muchas Gracias!

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