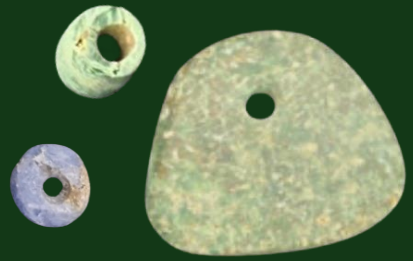
Archaeology and Material Science: Sacred Stone or Clever Fakes?

An Analysis of Ecuadorian Culture



Our story starts with a journey…

Archaeological dig site for pre-columbian Ecuador society artifacts

Beads and tools being made

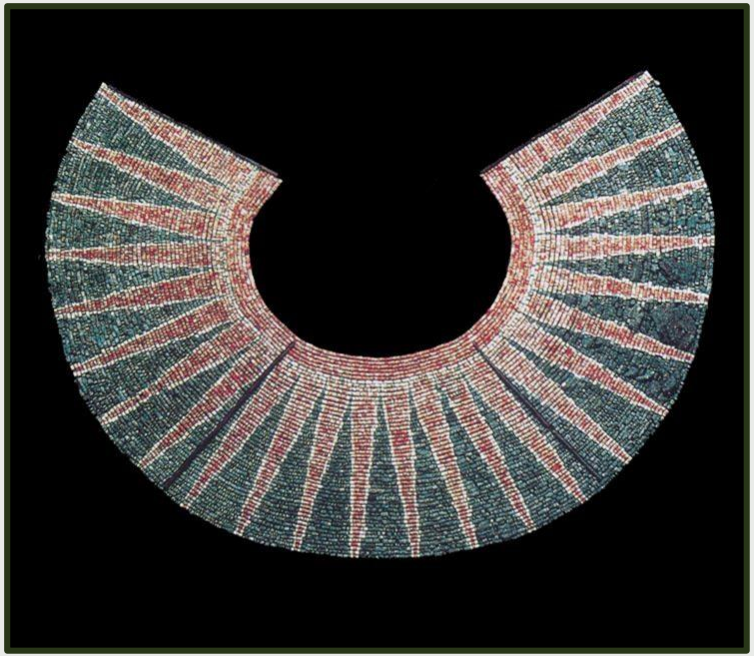
Urn discovered in an Ecuador farm

Historical Context

Guangala
200 B.C.E. - 800 C.E.

Manteño
800 C.E. - 1540 C.E.

The Green Stone



Necklace made of greenstone beads

Lords of Sipan Tomb

Moche Culture, Peru, 400 B.C.E.

Shimada, 2009

Lords of Sipan Tomb

Guangala Beads and Tools

Our Samples

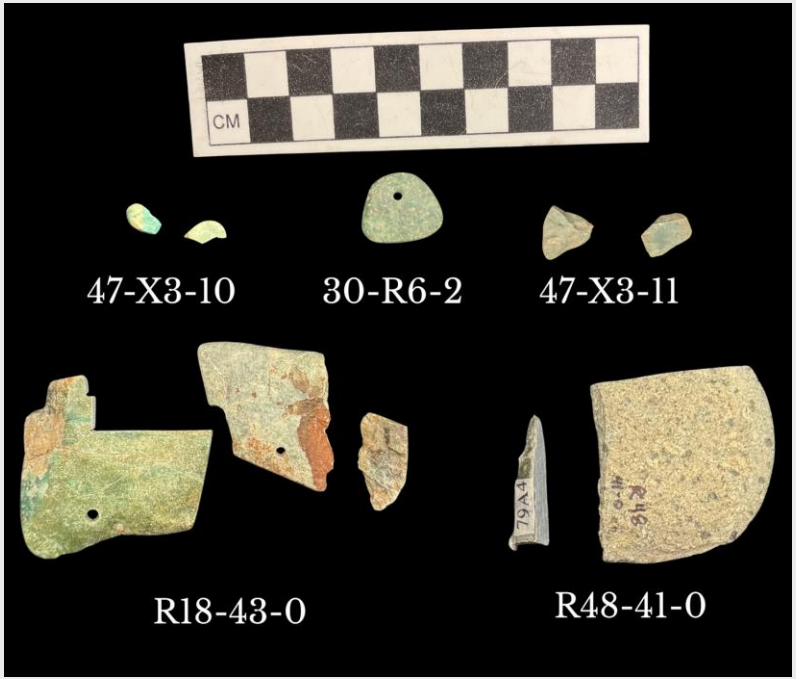
The archeological site used for our samples (Site 47)

Collection of rock samples

Created in ArcGIS

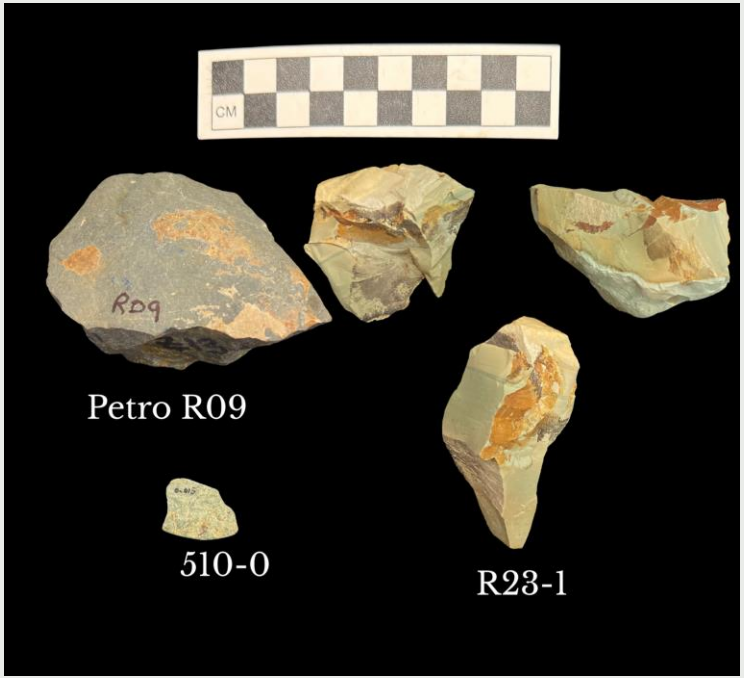
Our Artifacts

Finished beads found in Ecuador



Pendants, axe, and in-process beads found in Ecuador

Our Rocks

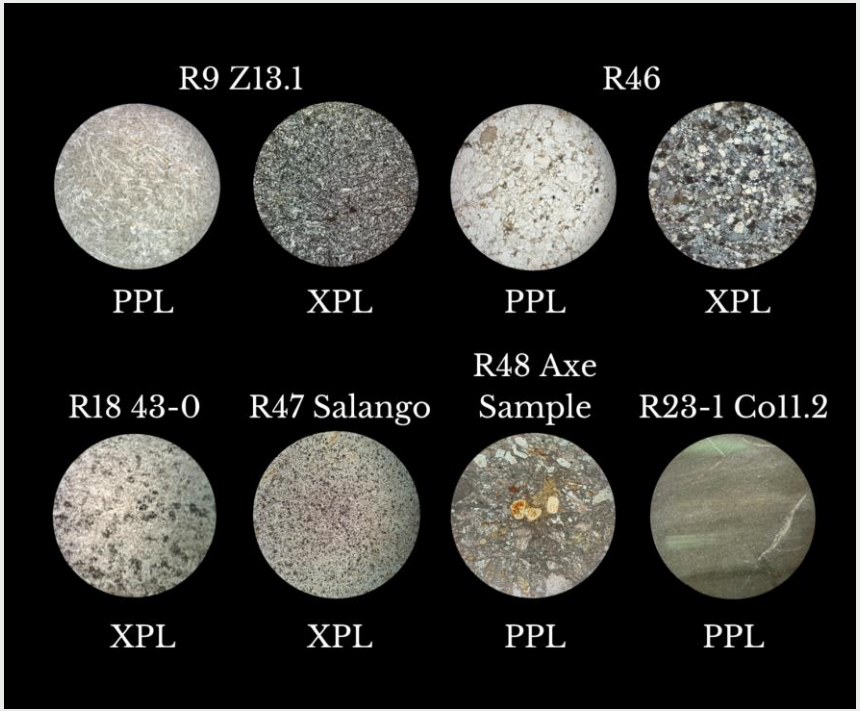


Outcrop samples and transported materials obtained to sample the geology local to the region

Petrographic Microscope

- Geologic identity
- Thin sections
- Plane-polarized light (PPL)
- Cross-polarized light (XPL)
- Birefringence

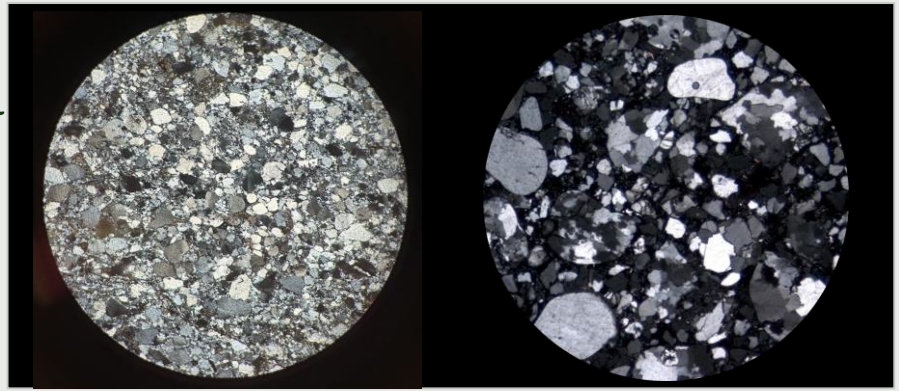
Leica Microsystems



Results

- R48 Axe matched the local rock of R23-2
- R23-1. Coll.2 is a welded tuff

R46 (local rock)

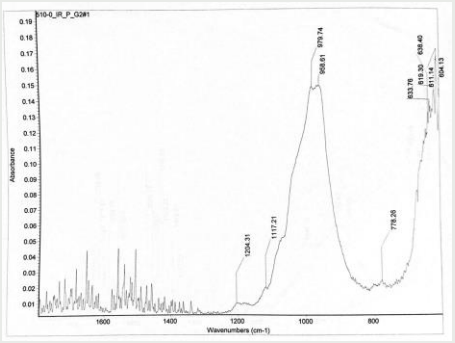


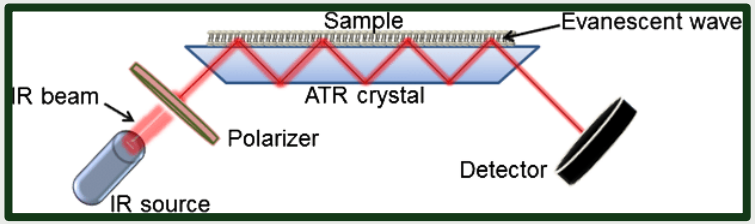
R46 40x XPL

Quartz Arenite

Geological Digressions, 2021

Fourier Transform Infrared Spectroscopy - Attenuated Total Reflectance (FT-IR-ATR)

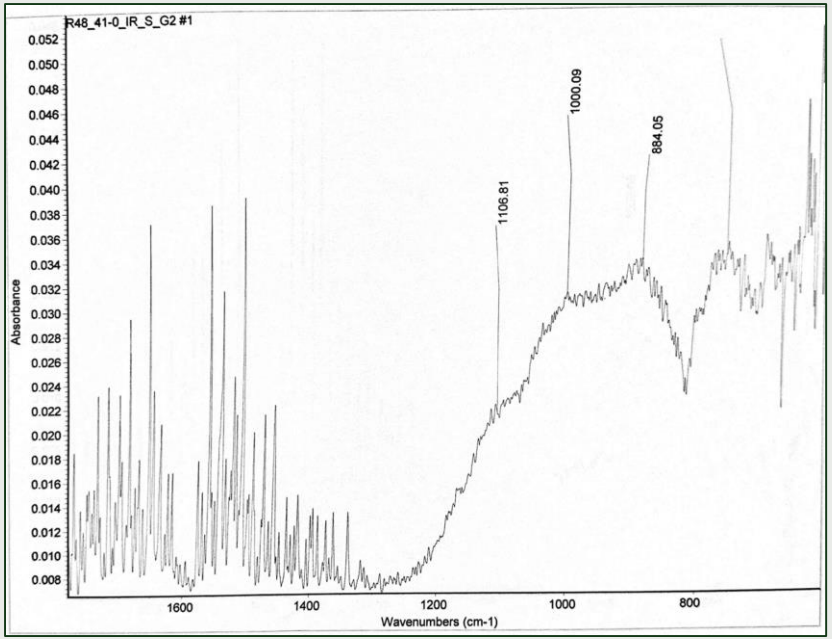




The way FT-IR-ATR works (Ausili et al., 2015)

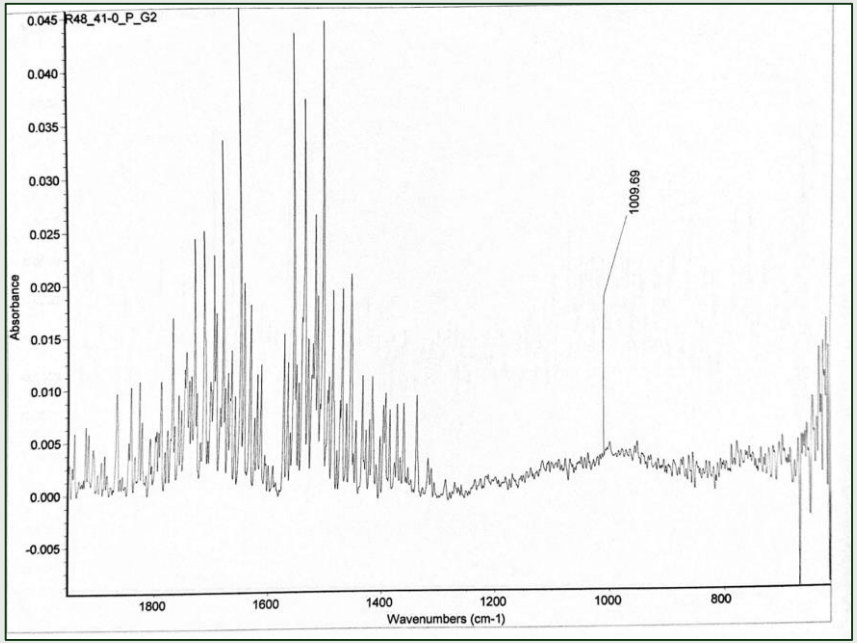
Selecting Spectra

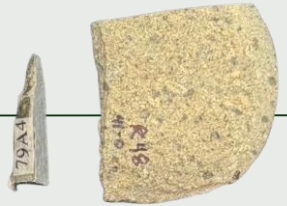
Solid R48



vs.

Powder R48



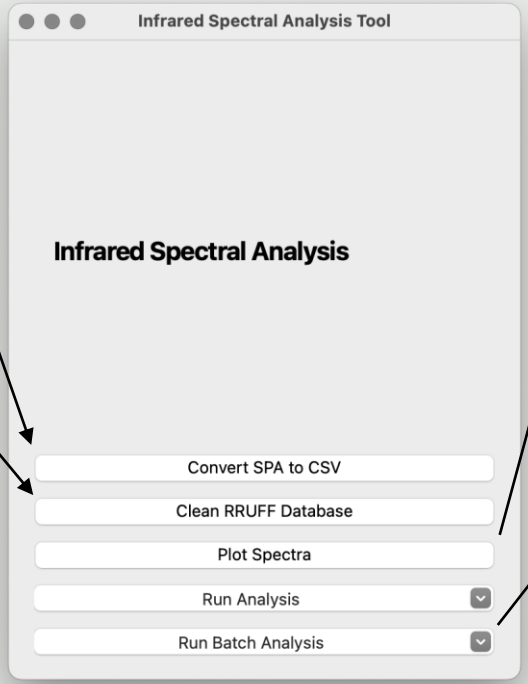


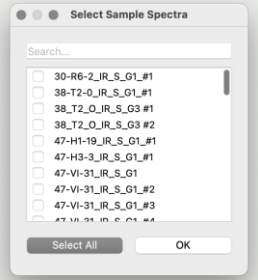
Sample R48, greenstone axe

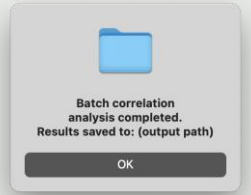
Samples being ground with a mortar and pestle

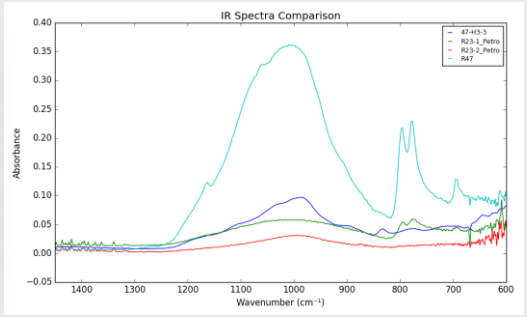
Statistical Analysis

RRUFF







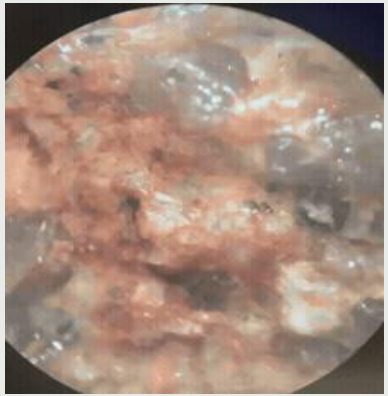


outputs > batch_correlation_results_20250724_141538.csv > data

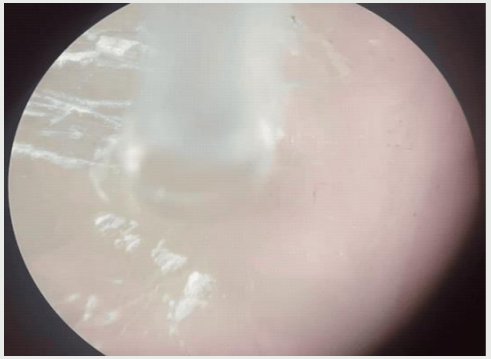
	Sample	Reference	Pearson R	Spearman Rho
2	30-R6-2_IR_S_G1_#1	Actinolite	0.7176522513683189	0.881295437326133
3	30-R6-2_IR_S_G1_#1	Albite	0.4901756848405308	0.4847821490667409
4	30-R6-2_IR_S_G1_#1	Beryl	0.41086681314264506	0.3883848060071539
5	30-R6-2_IR_S_G1_#1	Calcite	-0.47176580491025594	-0.5223129899840586
6	30-R6-2_IR_S_G1_#1	Dolomite	-0.3084733525050181	-0.4369803257674559
7	30-R6-2_IR_S_G1_#1	Jadeite	0.8378108468479157	0.8516089726822387
8	30-R6-2_IR_S_G1_#1	Lizardite	0.6253433310698707	0.8824654961657041
9	30-R6-2_IR_S_G1_#1	Malachite	0.5893313798751562	0.6647515746658678
10	30-R6-2_IR_S_G1_#1	Microcline	0.4984966236958275	0.5205123431606479
11	30-R6-2_IR_S_G1_#1	Muscovite	0.8608089022065699	0.8027753159166795
12	30-R6-2_IR_S_G1_#1	Orthoclase	0.5443799439164616	0.5672296766838392
13	30-R6-2_IR_S_G1_#1	Paragonite	0.9116864694646446	0.934883691299187
14	30-R6-2_IR_S_G1_#1	Phlogopite	0.7625762854061586	0.720023944036347
15	30-R6-2_IR_S_G1_#1	Quartz	0.20496048864169858	0.24685564836603738
16	30-R6-2_IR_S_G1_#1	Sanidine	0.5105731317796403	0.5188523144479638
17	30-R6-2_IR_S_G1_#1	Turquoise	0.3164469553608385	0.2478794832741633

Two correlation coefficients calculated in batch
Pearson's (r) and Spearman's (ρ)

Acid Test



Block of Granite



Block of Calcite ($CaCO_3$)

Calcite - 0.1 M

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

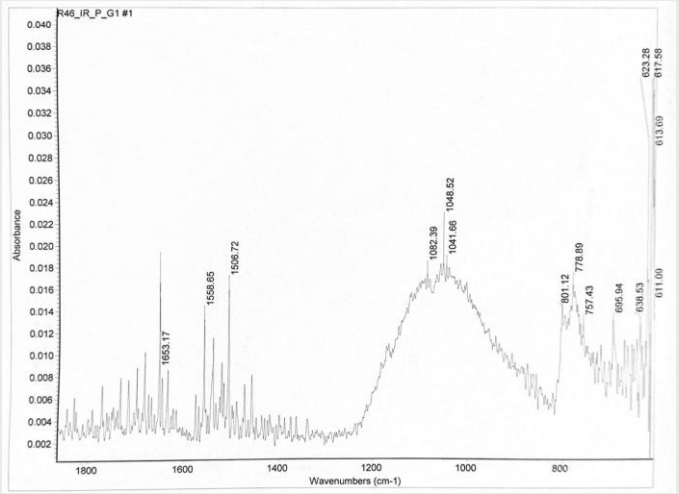
Malachite - 3.0 M

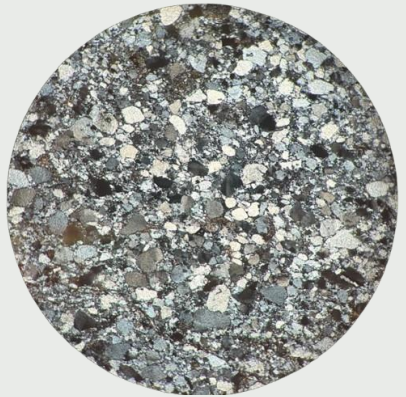
$$Cu_2CO_3(OH)_2(s) + 4HCl(aq) \rightarrow 2CuCl_2(aq) + 4H_2O(l) + 2CO_2(g)$$

Dolomite - 1.0 M

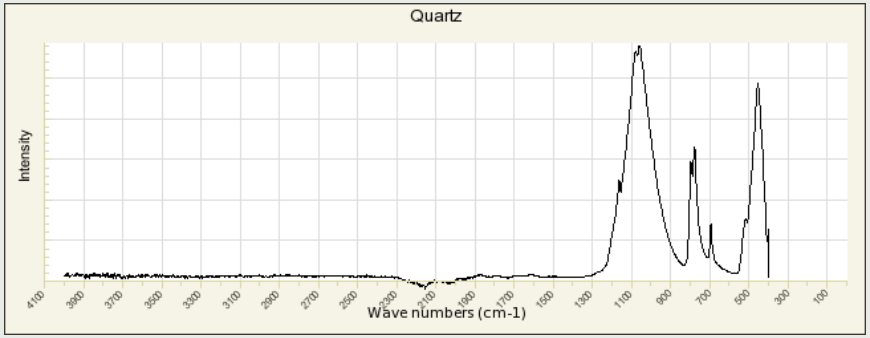
$$CaMg(CO_3)_2(s) + 4HCl(aq) \rightarrow CaCl_2(aq) + MgCl_2(aq) + 2H_2O(l) + 2CO_2(g)$$

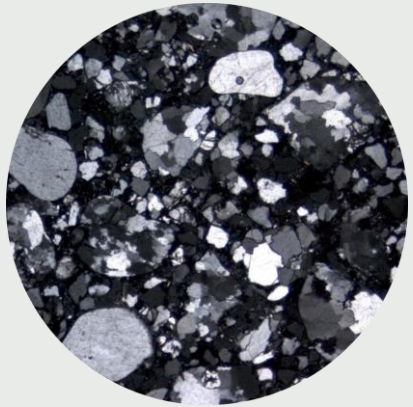
Results





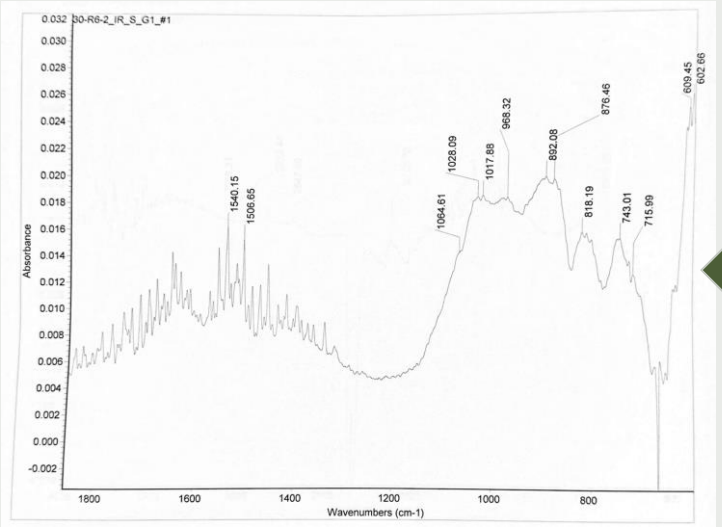
R46 40x XPL

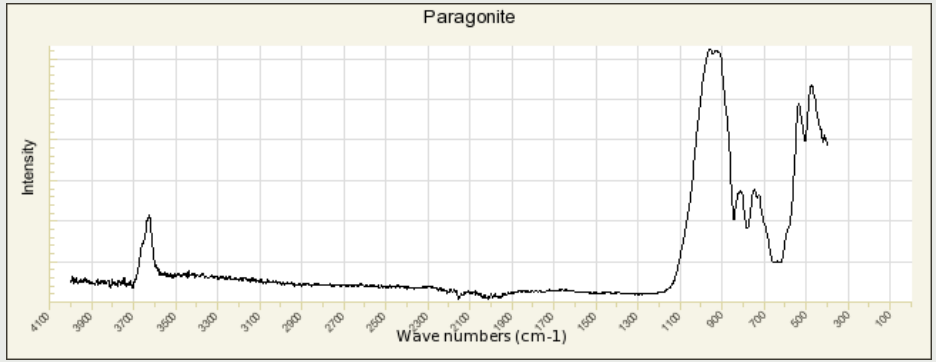


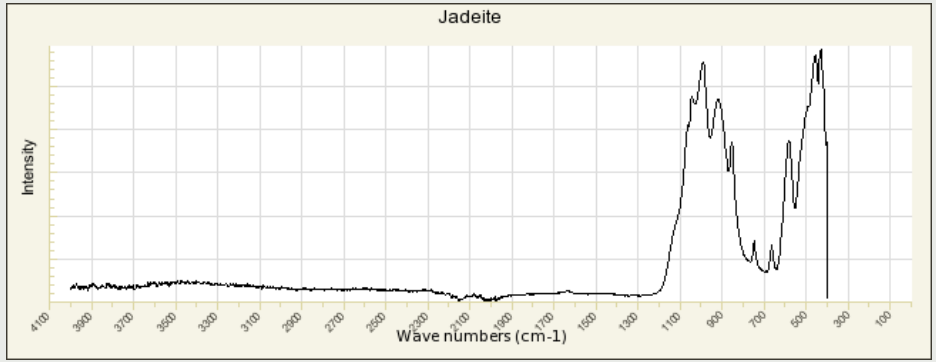


Quartz Arenite

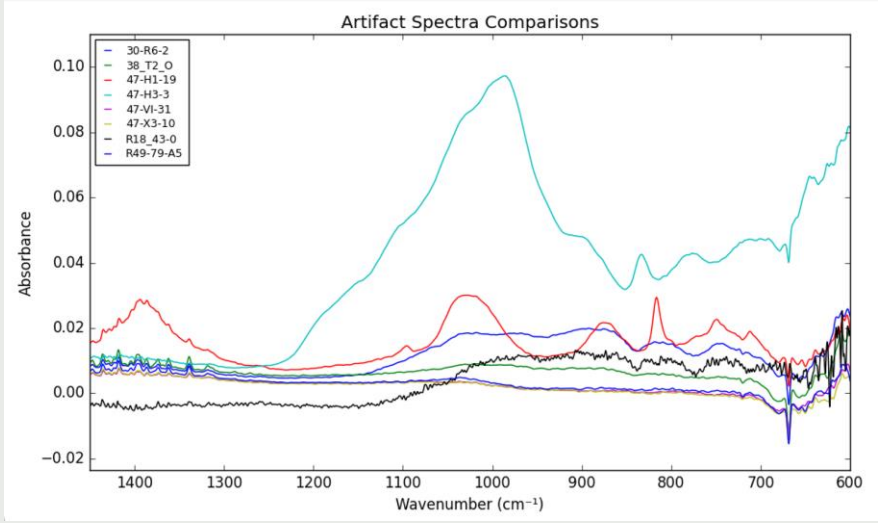
Results


30-R6-2_IR_S_G1_#1
Absorbance
Wavenumbers (cm-1)
1540.15
1506.65
1064.61
1028.09
1017.88
968.32
892.08
876.46
818.19
743.01
715.99
609.45
602.66

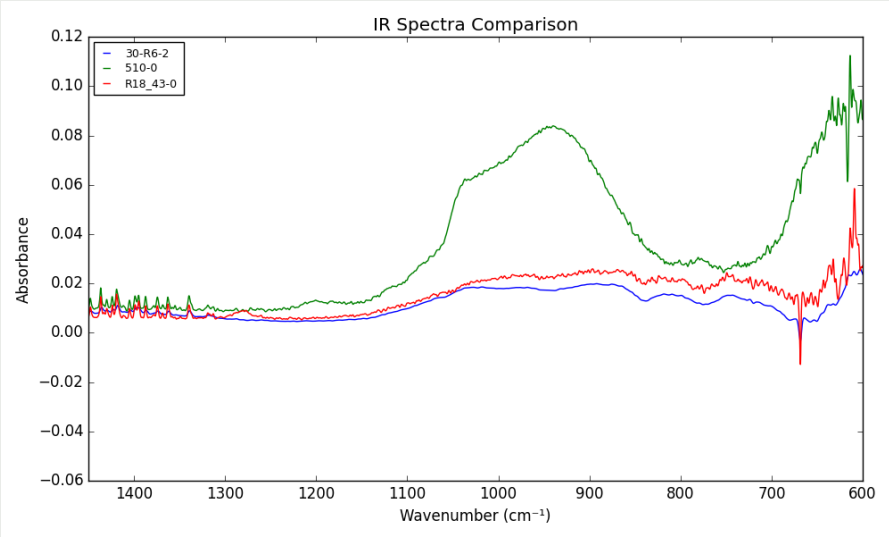

Paragonite
Intensity
Wave numbers (cm-1)


Jadeite
Intensity
Wave numbers (cm-1)

Comparative Analysis

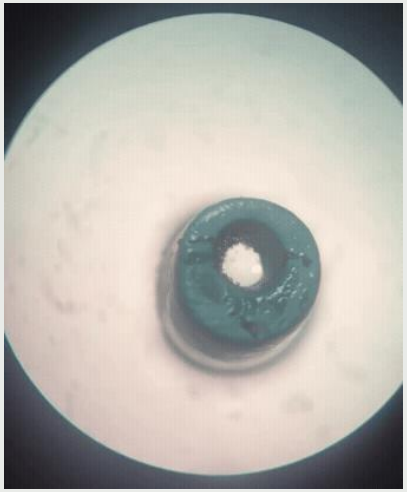


All Artifacts

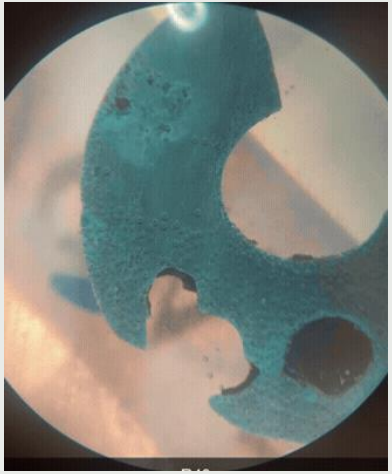


Pendants and Fragments

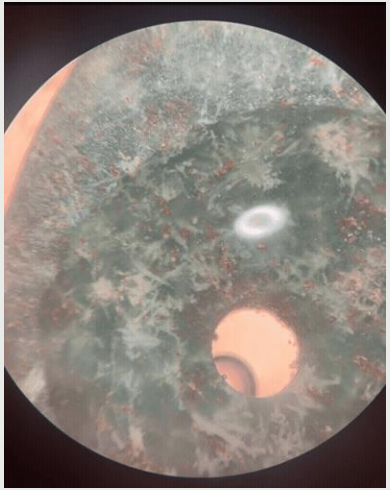
Acid Test Results



R47-H1-19



R49-79-A5



30-R6-2

Geology of Ecuador

47-V1-31
Turquoise

47-H1-19
Malachite

Artifact

30-R6-2

38-T2-0

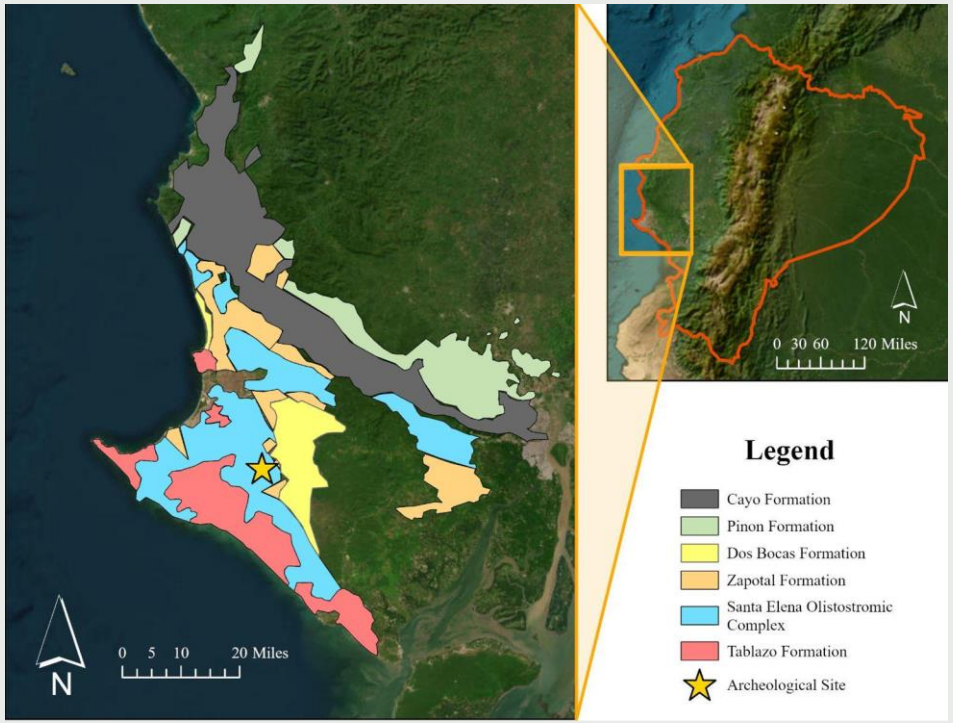
47-H3-3

Local Rock

510-0

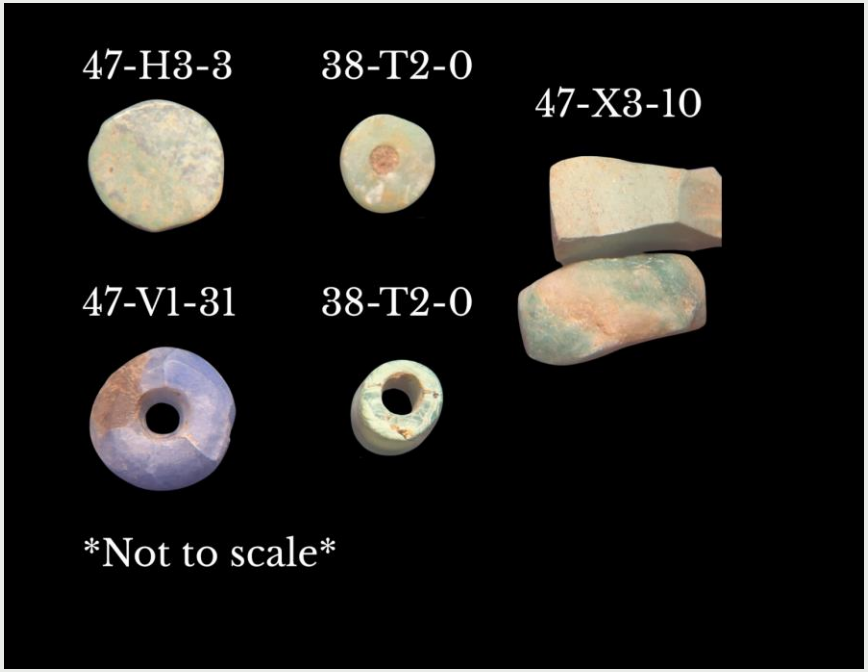
R46

R47



Map of Geologic Formations of Coastal Ecuador

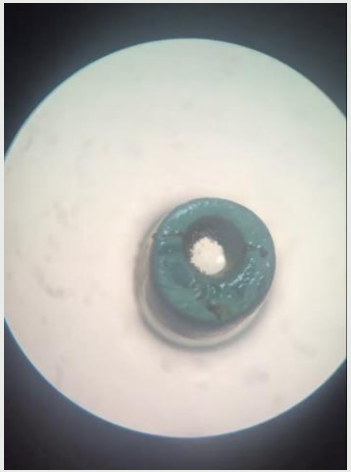
The Guangala and Manteño

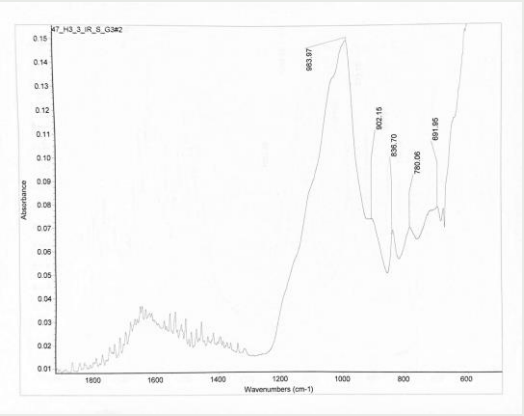


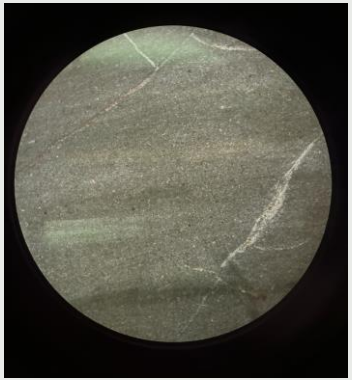
- Values in Guangala and Manteño society
- Bead production
- Role in wider trade network & cultural implications
- Economic strategies

Methodology

- Multifaceted approach
  - Cross-validation of results
- Non-destructive analysis
- Destructive analysis

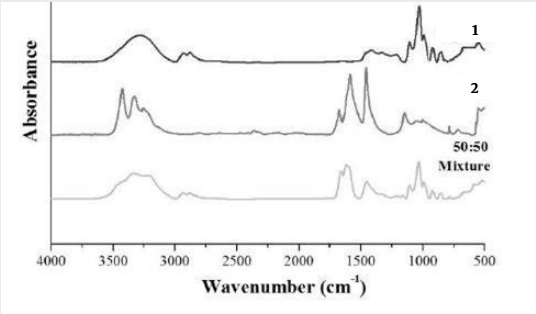






Discussion - Limitations

- Mixtures
  - FTIR-ATR Spectra
  - Correlation Analyses
- Weathering
  - Carbonate Layers
- Time
  - Only 2 weeks!



Example of mixtures with combined peaks, leading to more complicated spectra (Versino & Garcia, 2018)

Weathering Rocks (Day, 2016)

Conclusion

- Novel interdisciplinary approach
  - FTIR
- The origins of beads
  - Local materials
  - Other places
- Future warnings for archeologists

Acknowledgements

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Questions?