# From Micrometers to Kilometers: Integrating Spatial and Chemical Datasets in the Study of Metal Production in the South Caucasus c. 1500-500 BC

Nathaniel Erb-Satullo[1]

[1] Department of Anthropology, Harvard University (nsatullo@fas.harvard.edu)

Landscape-scale survey data are rarely combined with chemical and microscopic analyses in archaeological research. Here, I present two case studies integrating data with widely varying spatial scales to address questions about metal production and consumption in South Caucasus c. 1500-500 BC.

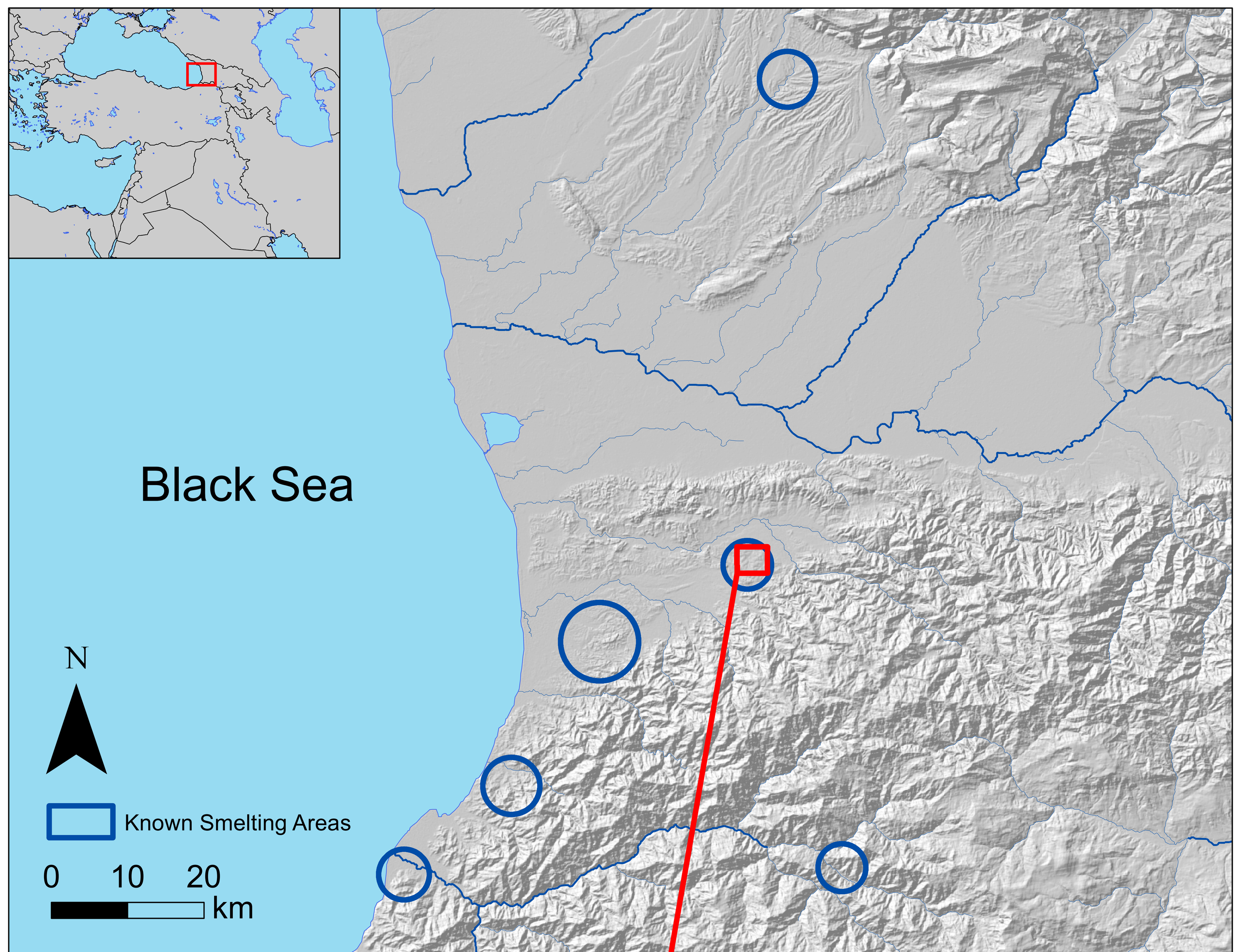


Figure 1. Map of the eastern Black Sea region (modern western Georgia), showing areas of known metal production.

## The Organization of Metal Production

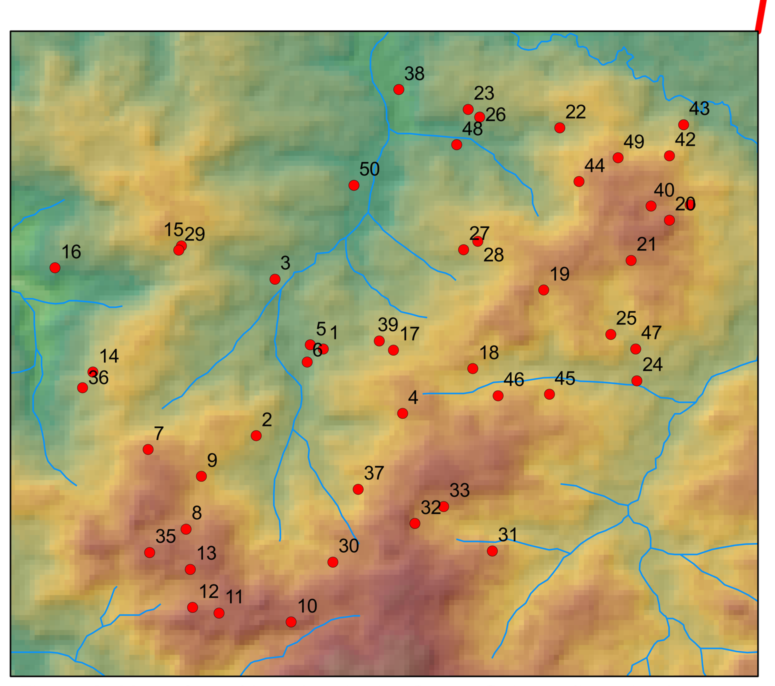

Figure 2. Map of smelting sites in the Supsa-Gubazeuli production area with site numbers.

Figure 3. Metal smelting site (Site 14 in figure 2). Sites are characterized by large amounts of metallurgical slag and other debris, visible in the foreground.

My colleagues and I have identified and mapped 50 copper smelting sites in the Supsa-Gubazeuli area of western Georgia. Smelting sites are numerous, dispersed, and individually small scale, but the aggregate scale of production was massive. Chemical and microscopic analysis shows that metalworkers used copper ores with varying suites of associated minerals (figure 4). This is likely due to geological zonation in the ore deposit. I used high-throughput qualitative portable X-ray fluorescence analysis (pXRF) to dramatically increase the sample size and examine spatial patterns in ore usage.

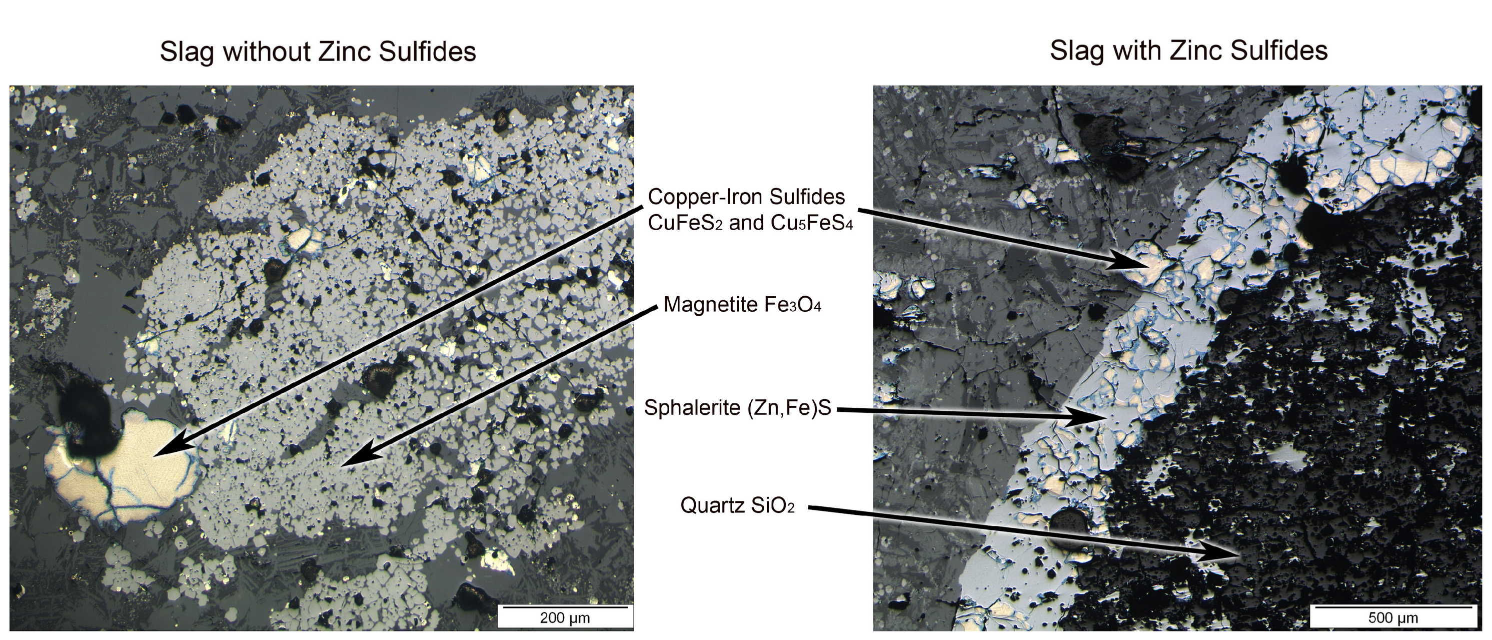


Figure 4. Microscopic images of metallurgical slag, showing partly melted fragments of ore and associated minerals. The ore fragment on the left contains no zinc sulfide, while the sample on the right has abundant zinc sulfide. In both cases, the copper ore is a sulfide compound.

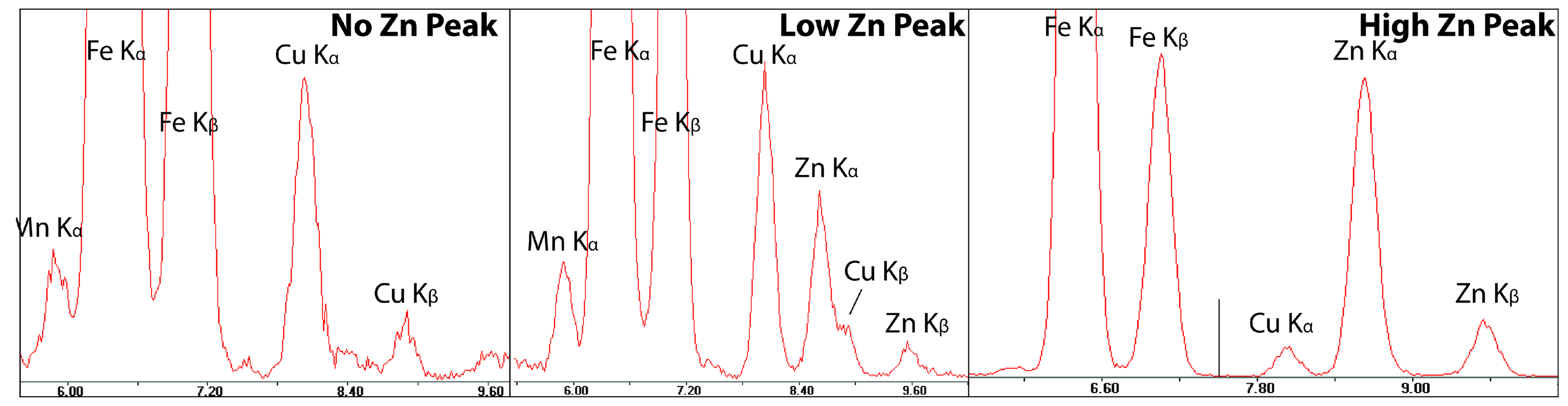


Figure 5. Parts of the pXRF spectrum showing Zn characteristic X-ray peaks. The spectra shown were taken from typical No Zn, low Zn, and high Zn slags. Note the relativel sizes of the Zn and Cu Kα peaks.

## Results

•Qualitative analysis of Zn and Mo content show that metalworkers at different sites used ores with differing chemical and mineral compositions. This is true even for sites with similar radiocarbon dates.

•Data suggest that there was little coordination in mining activities. Metalworkers at each site were probably collecting their own ores, each with a slightly different suite of associated minerals.

•The spatial pattern of large quantities of small-scale independent production sites differs dramatically from contemporary copper production in neighboring regions.

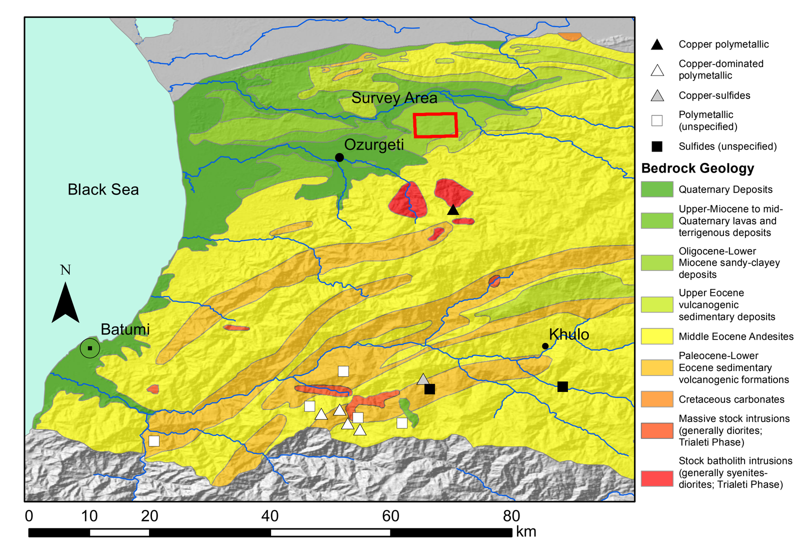


Figure 6. Geological Map of western Georgia with known sulfide deposits. Copper deposits are associated with intrusions into Eocene andesites. Geological data from Nazarov (1966).

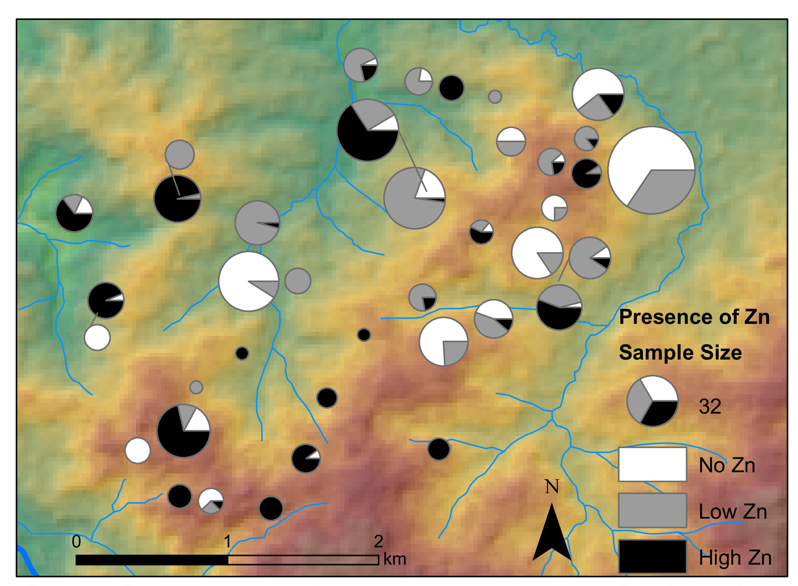


Figure 7. Presence of zinc (Zn) in slags at smelting sites. Pie charts show the proportion of slags at that site with no Zn peak, a small Zn peak, and a large Zn peak in the pXRF spectrum (figure 5). Size of pie charts is proportional to the total number of samples analyzed at that site. Combined sample size: 684

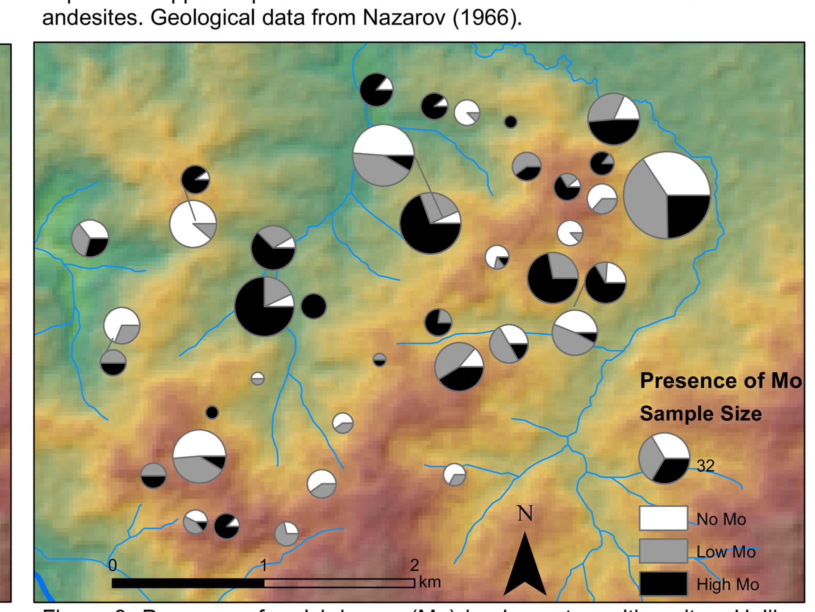


Figure 8. Presence of molybdenum (Mo) in slags at smelting sites. Unlike Zn, no Mo sulfides were not identified through microscopy, but Mo is known to associate with copper-bearing minerals in this regions, so the presence of Mo in the slags certainly derives from the ore. Pie charts show the proportion of slags at that site with no Mo peak, a small Mo peak, and a large Mo peak in the pXRF spectrum. Size of pie charts is proportional to the total number of samples analyzed at that site. Combined sample size: 684

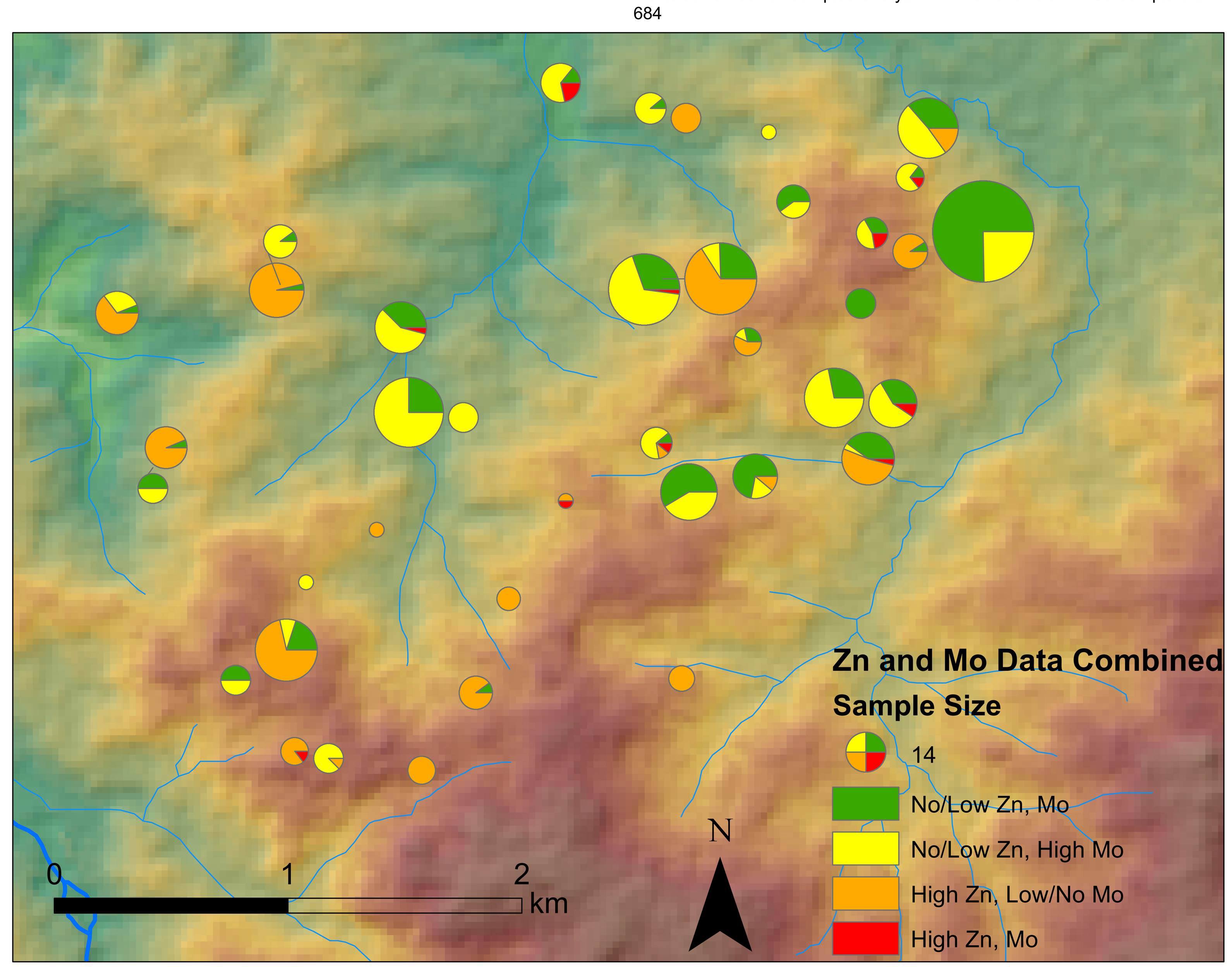


Figure 9. Map combining zinc and molybdenum data. Pie charts show the proportion of slags at each site with presence and absence of oth Zn and Mo peaks. Size of pie charts is proportional to the total number of samples analyzed at that site. Combined sample size: 684

## Spatial Patterns in Alloy Usage

•Chemical analyses from Abesadze and Bakhtadze (2011 [1988]) were incorporated into a spatial database to examine patterns in alloy usage.

•Results show that tin bronze was preferentially selected for specific types of artifacts, especially prestige items: items of body adornment (figure 12) and weapons (e.g. axes, figure 13).

•By contrast, agricultural implements (figure 11) were not made with tin bronze, suggesting that golden color, not only increased hardness, was a desired feature of tin bronzes.

•Comparison with raw copper ingots (figure 10) suggests that both tin and arsenic were intentionally added in discrete technological steps.

•Alloy selection shows spatial patterns, with tin bronze dominating in the north, and higher frequencies of arsenic bronze in the south.

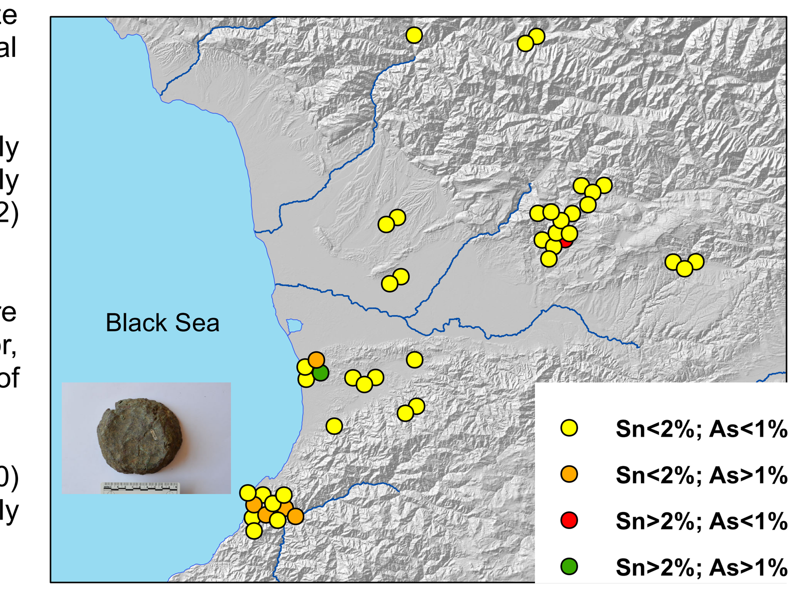


Figure 10. Map of alloy types for raw metal (ingots, drips, and ingot fragments) in western Georgia. Each point represents a single artifact, colored according to its chemical composition. Positions are approximate--ArcMap's disperse markers function was used to display different objects with the same findspot.

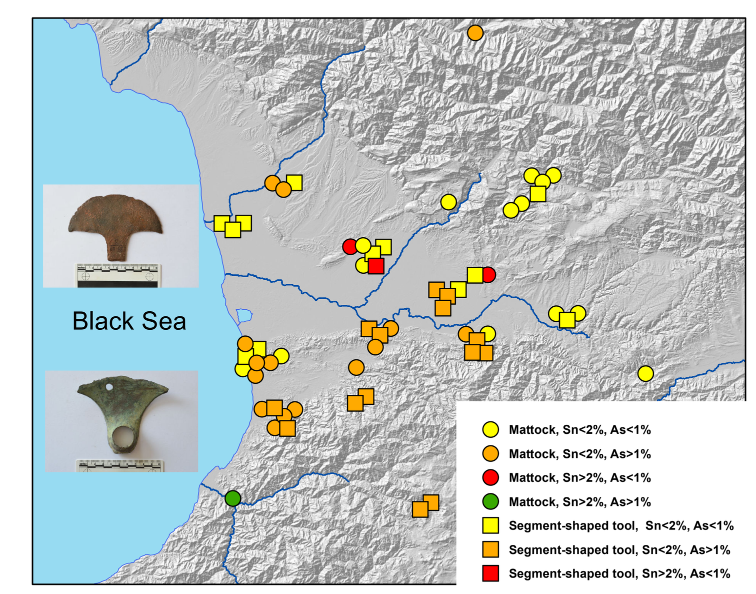


Figure 11. Map of alloy types for hoes and so-called "segment-shaped" tools in western Georgia. Each point represents an artifact, colored according to its chemical composition. Positions are approximate--ArcMap's disperse markers function was used to display different objects with the same findspot.

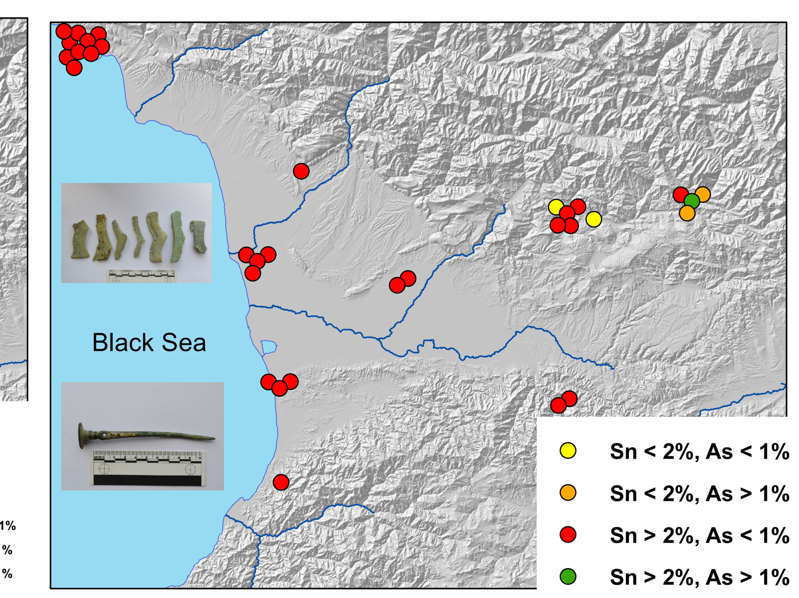


Figure 12. Map of alloy types for items of body decoration (belt buckles, pins) in western Georgia. Each point represents an artifact, colored according to its chemical composition. Positions are approximate--ArcMap's disperse markers function was used to display different objects with the same findspot.

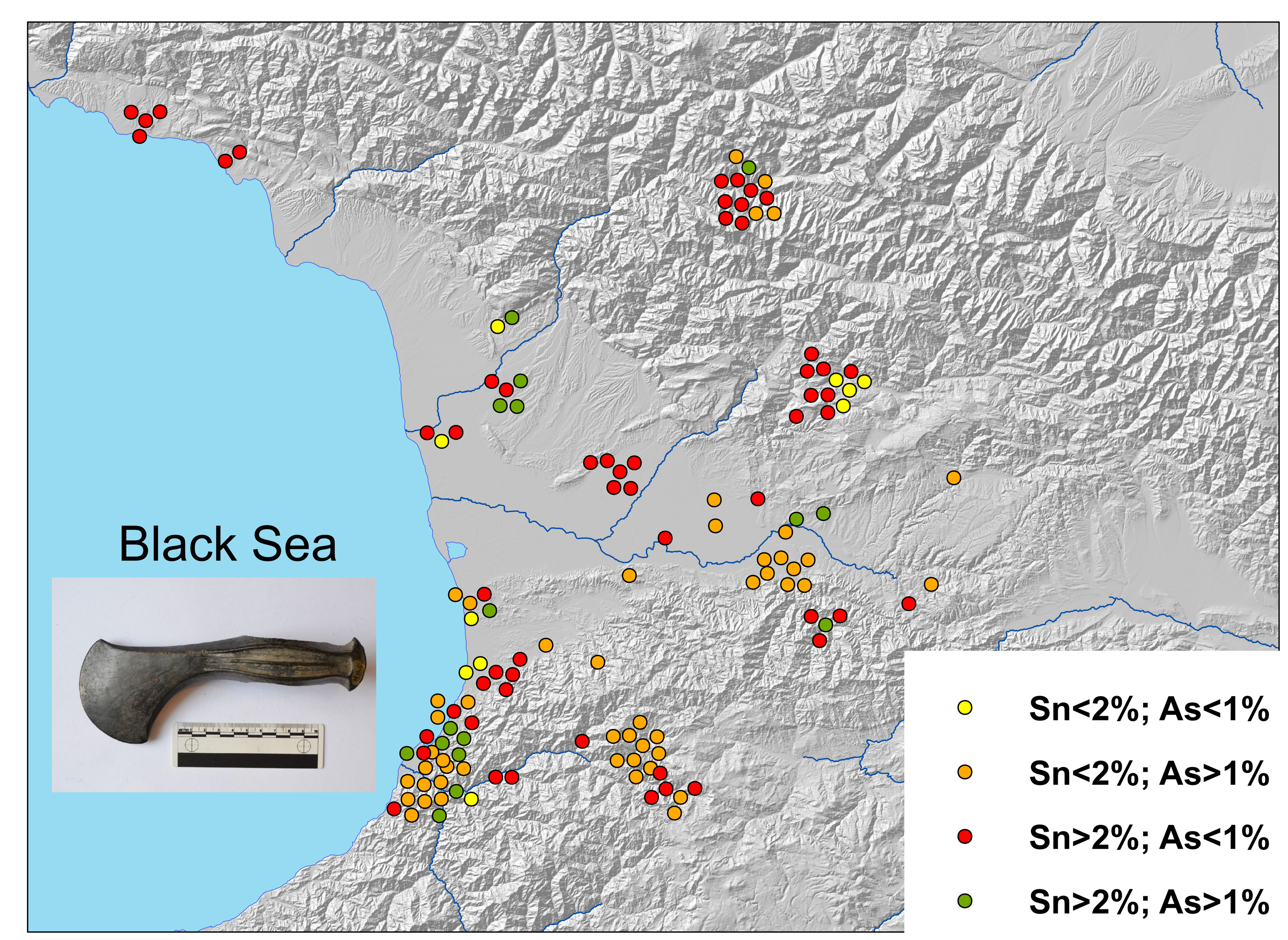


Figure 13. Map of alloy types for axes in western Georgia. Each point represents an artifact, colored according to its chemical composition. Positions are approximate--ArcMap's disperse markers function was used to display different objects with the same findspot.

## References

Abesadze, T., Bakhtadze, R., 2011 [1988]. Kolkhuri kulturis metalurgiis istoriisatvis (On the history of the metallurgy of the Colchis Culture) (in Georgian with Russian summary), Georgian National Museum, Tbilisi.

Nazarov, Y.I., 1966. Osobennosti Formirovaniya i Prognoz Glubinnykh (Skrytykh) Mestorozhdeniy Mednokolchedannoy Formatsii Yuzhnoy Gruzii (Particularities of Formation and the Prognosis of Deep (Hidden) Ore Deposits of Chalcopyrite formation of Southern Georgia), Nedra, Moscow.