Computational analysis of lead isotope ratios in artefacts and ores from China: tracing connections, quantifying ambiguity, and rethinking provenance

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Summary

This dissertation has explored the use of lead in ancient China. It combined archaeological case studies with methodological explorations. The research was driven by two linked challenges. One was the need to trace the movement of lead as a key resource in antiquity. The other was the difficulty of doing so because many Chinese lead deposits have overlapping isotopic signatures. To address these challenges, the study applied existing analytical methods in new contexts and developed frameworks to better understand isotopic ambiguity.

Chapter 1 introduced the background of the study, outlining the history of metallic lead in China and beyond, and reviewing the state of lead isotope research in Chinese archaeology. It set out the research problem, objectives, and significance, identifying two central themes: the provenance and circulation of lead in the sampled glass and glaze, and the overlap and indistinctiveness of lead resources.

Chapter 2 provided a methodological case study focusing on four lead–barium glass bi artifacts from the Warring States period (475–221 BCE) and Western Han dynasty (202 BCE–8 CE). Using chemical and isotopic analysis combined with kernel density estimates (KDE), this chapter demonstrated how statistical tools can be applied to evaluate possible raw material sources and reconstruct resource movements. The analysis highlighted the dominant role of South China as a source region for glass–making.

Chapter 3 extended the investigation to Han dynasty (202 BCE–220 CE) lead-glazed pottery. Through a combination of chemical composition and isotopic analyses, it explored the origins of the lead used in glaze production and compared these results with other archaeological objects. The findings revealed significant diversity in raw material procurement and raised questions about whether different products (bronze, glass and glaze) drew on distinct lead sources. The chapter also situated these observations within the broader context of Han imperial expansion and exchange, linking material patterns to historical developments.

Chapter 4 shifted the focus from specific case studies to the broader methodological problem of isotopic overlap among Chinese lead deposits. It introduced a risk–aware framework and constructed the Indistinctiveness Index to quantify the degree of ambiguity at the deposit level. This approach moved beyond static grouping strategies, providing archaeologists with a clearer view of where isotopic distinctions become blurred. The chapter demonstrated that geological zoning and ore–forming processes do not guarantee unique isotopic signatures, and it classified deposits according to levels of indistinctiveness. An appendix documented earlier attempts to group deposits directly by isotopic data.

Chapter 5 synthesized these findings and discussed their broader implications. It

argued that lead isotopes in artifacts are not like fingerprints that indicate absolute uniqueness. Instead, they are more like mitochondrial DNA, allowing researchers to trace lineages and relationships across overlapping populations. The chapter also reconsidered assumptions about proximity–based procurement, explored clustering approaches for artifacts, and compared cultural and natural lead signatures.

Overall, this dissertation explores a new pattern of lead isotope research. The focus is on making analysis more digital, more statistical, and more transparent. Instead of relying on intuition or visual inspection, it introduces quantitative tools that reveal the structure, distribution, and overlaps. In this way, vague assumptions become measurable evidence, and long–standing habits such as local procurement, linear links between geology and isotopes signatures, or scatterplot judgments are critically reassessed. The dissertation engages with concepts such as isotopes as markers of lineage rather than fingerprints of uniqueness and proximity–based procurement, seeking frameworks that link scientific results with archaeological interpretation. It shifts the focus from single–source attribution to mapping relationships and addressing isotopic overlap through the Indistinctiveness Index. This approach enhances the rigor of lead isotope analysis and offers archaeology a complementary basis for understanding resource use and social interaction.