The new power of provenance tracers

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Provenance tracers help historians and archeologists catch a glimpse of the economic development of societies going back several millenias. Minor and trace elements can be found in artifacts because (1) metallurgy was unable to remove them, which is the case of refractory platinum group elements (2) they are part of the metallurgical processes (Pb in Ag), or (3) alloying improves the original mechanical properties of the metal, such as Cu in Ag and Au coinage and Sn in bronze. Less commendable additions, such as Cu to Ag, were also repeatedly used for monetary debasement. Refractory trace elements can be used to classify mints around the world, but require careful assessment of how they survived through metallurgy and coinage. Radiogenic isotopes are less affected by process, and have been used with mixed success. Lead isotopes in particular have attracted interest, mostly because Ag was commonly extracted from PbS ores (Iberian Peninsula), but other sources of Ag exist, such as sulfosalt, which require that exotic Pb is added to the ore for Ag purification. Reminting may also obscure provenance evaluations. An enormous but largely untapped source of information consists in transforming raw Pb isotope data into Pb model ages and U/Pb and Th/U ratios, which indicate the origin of ores in specific tectonic provinces, occasionally with unsuspected precision. Likewise, Os isotopes carry potential for guiding studies on the provenance of Au.

Stable isotopes of Cu and Ag demand a different approach. Silver isotopes can be used for coinage, and Cu and Sn isotopes for bronze. The isotopes of these elements reflect the conditions under which the ores formed, typically hydrothermal (high-temperature) vs supergene (low-temperature). Although these isotopes do not unambiguously reveal which particular ore deposit was actually mined to produce a given artifact, ab initio calculations and Cu and Ag isotopes can tell the geological nature of source ores. Combining Cu, Ag, and Sn with Pb isotopes hence provides a not yet exploited source of information about metal sources.

The use of isotopes, notably Pb, in sediments has also been used to assess the environmental impact of metals (Portus, Naples). Harbor sediments capture the history of pollution, typically the dissolution of Pb pipes from urban water distribution systems, and can be used as a index of urban development (Naples, Ephesus) and a record of major events such as volcanic eruptions and military misfortunes.