Copper Sources, Metal Production, and Metals Trade in Late Postclassic Mesoamerica

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Copper ore sources exploited during the Late Postclassic Period (1300 to 1521 A.D.) were located by means of lead isotope analyses of copper ores from 15 deposits in West Mexico, Oaxaca, and Veracruz and of 171 copper artifacts from nine Mesoamerican archaeological sites in West Mexico and in southern, central, and northeastern Mesoamerica. West Mexican ores provided copper metal for most artifacts from the west Mexican settlements of Atoyac and Urichu, as well as for some artifacts from Aztec towns, Huastec centers, a Maya site, and settlements in Oaxaca and Chiapas. West Mexico was not marginal to Mesoamerican events but played the primary role in the production and distribution of copper and bronze artifacts, one of Mesoamerica's key exotic goods.

Metal artifacts first appeared in Mesoamerica in the west around 650 A.D. Metallurgy was introduced from South America by a maritime route. West Mexico contains the most varied array of ore minerals available to ancient Mesoamerican smiths, including copper carbonates and sulfides, arsenopyrite, argentite, and silver sulfosalts. Cassiterite, the tin oxide ore, occurs in a southwestern extension of Mexico's Zacatecas tin province. West Mexican metalworkers focused primarily on fashioning ritual and sacred objects throughout the 900-year history of this technology. Before 1200 A.D., they used copper, principally for bells but also for small cold-worked implements. After 1200 to 1300 A.D., they produced copper-arsenic bronze, copper-tin bronze, and copper-silver alloys, not only for their golden and silvery colors but also to optimize the design and functionality of objects previously made in copper. Bells and elaborate tweezers as well as needles, awls, and other tools from this time appear at other Mesoamerican sites (*1*–*4*). Here, we present lead isotope data that demonstrate that many of these artifacts were produced in the west Mexican region.

Geochemical and Archaeological Context

Lead isotope (LI) analyses can be used to identify ore sources for artifacts made from copper and copper alloys (5) by matching the isotopic signatures of ore lead to those of the artifacts. The isotopic composition of ore lead is a function of the age and chemistry of the source rocks. Lead is present at analyzable concentrations in all copper artifacts. Because LI compositions are not altered during ore smelting, they provide a means of identifying the ore sources for the artifact metal. We followed the geological convention of plotting $^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ in creating LI fields (6). We omitted $^{207}Pb/^{204}Pb$ from the plots because these values vary only slightly in our samples, as expected with ores related to Mesozoic and younger magmatism, and add little information.

LI data are most effective in excluding certain deposits as likely source areas. Positive source identification is more difficult because not all deposits can be sampled. The level of confidence in identifying sources depends on whether regional geologic formation processes have resulted in clearly delineated LI fields, as well as on the number of deposits analyzed. We considered a deposit or mining region to qualify as a potential source when the artifact signature fell within the ore field. To determine whether the deposit could have been exploited by ancient Mesoamerican metalworkers, we evaluated its physical characteristics (size, accessibility, associated archaeological remains), regional archaeology, and historical evidence for mining. The design and composition of the artifact allowed us to narrow possible sources further. Where artifact designs and compositional types concentrate in particular geographical areas, we assumed that these objects may have been produced in or near those areas (*7*). Where artifact fields overlap, we used such information to determine which deposit or region constituted the more plausible metal source.

We analyzed 121 ore samples (*8*) from 15 copper deposits in Jalisco, Michoacan, Veracruz, and Oaxaca (Table 1) (9). Jalisco and Michoacan lie in the heart of the west Mexican metalworking zone. Ores in Veracruz and Oaxaca (Fig. 1) provided geographical breadth. Moreover, both regions supported state-level societies in the pre-Hispanic era, and copper artifacts have been excavated in or near both. Also, in Oaxaca, a local copper-gold alloy casting technology developed after 1200 A.D.; its relation to West Mexico's earlier copper-based metallurgy is unclear.

The ore isotopic fields (Fig. 2) are typical of continental arc deposits, plotting near the Stacey-Kramers reference line (*10*). The data used to construct some fields in Fig. 2 [Autlán, Ayutla, Oaxaca (Los Ocotes and El Taviche), and Veracruz (the Las Minas deposits)] represent groupings of individual mines in each area to simplify the

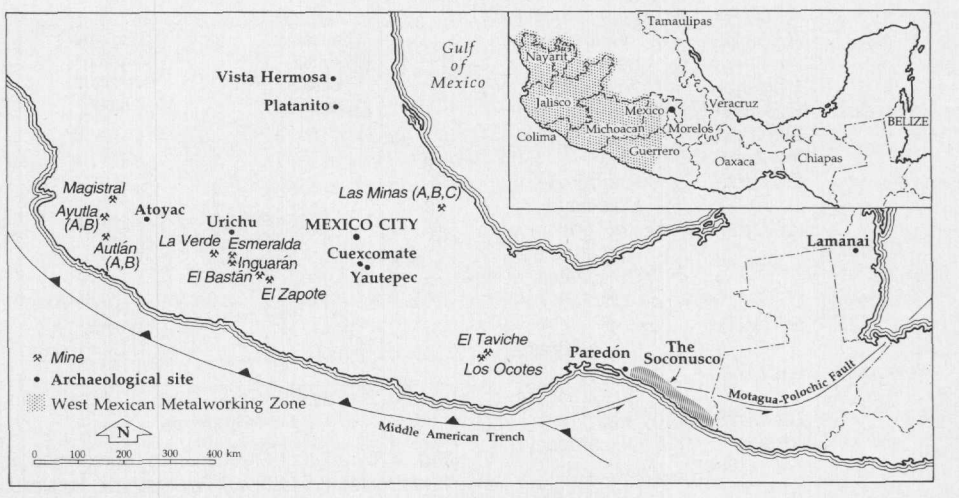

Fig. 1. Mesoamerican copper mines and archaeological sites.

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