Nuclear Archaeometry Applications

Transactions of the American Nuclear Society

vol 49

4. Chemical Characterization of Sealing Clays from Fourth Millennium B.C. Sites in Iran,
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This research was undertaken to determine if significant chemical differences could be determined among the locally available unfired clays used to seal objects at several sites in lowland and highland Iran. If chemical compositional differences exist among the sealing clays from specific sites, these differences, along with seal iconographic data, would provide complementary evidence concerning inter-site trade in the sealed goods. The results of the chemical compositional study and the archaeological implications are reported in this paper.

By the mid to late fourth millennium B.C., the practice of sealing goods being stored or shipped had become common at most sites in Greater Mesopotamia. These sealings took the form of wet clay applied over knots on bales or the mouths of narrow necked jars; strings securing leather coverings of storage jars, door jambs, or locks; and other methods of closure. While the clay was still plastic, stamp or cylinder seals were impressed into the clay as marks of ownership. The process of unsealing these goods has left fragments of the seal impressed clays as important indicators of administrative activities at the sites. The iconography of the seal impressions and the seals themselves have been intensively studied and many parallels drawn between sites based on stylistic similarities. These stylistic similarities have been used to propose cultural contact and trade between different regions.

In this study, unfired clay objects and seal-impressed clays from five sites were examined. The sites were Susa, Tepe SharaFabad, and Tepe Farukabab in lowland southwestern Iran; Tal-e Malyan in the highlands of southwestern Iran; and Tepe Yahya in the highlands of southeastern Iran. Chemical analysis of the clays was carried out using instrumental neutron activation analysis for 25 elements, and mineral phase analysis was by x-ray diffraction. The clay objects were chosen from each site to represent objects that had a low probability of being trade items and therefore reflect the clays present in the vicinity of each site. The seal-impressed clays included jar stoppers, tag sealings, and other sealing types, which had the potential of having sealed items involved in inter-regional trade. In addition to these sealing types, door lock and storage jar sealings representing local sealing clays were also examined. In all, analyzed were: 78 sealings and 42 clay objects from Tal-e Malyan; 7 sealings and 26 clay objects from Tepe Yahya; 6 sealings and 11 clay objects from Tepe SharaFabad; 8 sealings from Susa; and 1 sealing and 11 clay objects from Tepe Farukabab.

The chemical data from the clay objects and the sealing clays were subjected to cluster analysis using average linkage clustering of a mean Euclidian distance matrix. The clusters formed separated the clays into groups that corresponded to the sites of recovery in almost all cases. All the Tepe Yahya samples were easily distinguishable from the other clays. The Tepe Farukabab and Tepe SharaFabad samples, with a few exceptions, were also readily distinguishable as discrete clusters. The Susa and Tal-e Malyan samples, however, were intermixed in two large clusters. X-ray diffraction data showed that all of the clays contained some calcite and/or dolomite. The calcium concentrations in the clays display a great deal of variability, indicating the possibility of dilution effects masking chemical differences. To minimize these dilution effects, the data for the samples from each site were fitted to their group mean and reclustering. The clustering of the fitted data resulted in near perfect separation into site-specific groups. Statistical tests of the validity of the groups, using Mahalanobis distance and Hotelling's T-square statistic, indicated that the samples in each group were assigned correctly at the 95% confidence level and that members of each group had a <1% probability of belonging to any of the other groups.

The Tal-e Malyan samples formed two distinctive clusters, using the unfitted data, which corresponded well with the area of the site where the samples were excavated. (The excavation at ABC and TUV are located about 1 km apart on the mound.)

The specificity of the clays to the area of excavation at the site is again related to differing carbonate contents (the distinction is greatly diminished when fitted data are used) and is believed to be a pre-depositional phenomenon related to sedimentation conditions in each area. Statistical tests showed the two groups of clays to be separated at the 95% confidence level.

The results of this research indicate that although iconographic parallels exist between Susa and Tal-e Malyan seals, little direct trade in sealed goods can be documented by the clay compositional data. While three or four sealing clays from Tal-e Malyan do not appear to be local to the site, they did not originate at either Susa or Tepe Yahya (postulated trading partners). In addition, the two area-specific groups at
Nuclear Archaeometry Applications

Tal-e Malayan indicate that the administrative activities associated with sealing and unsealing goods were localized in each area.