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# Neutron activation analysis of Urartian pottery from eastern Anatolia

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A total of 275 pottery and clay samples from Urartian period sites in eastern Anatolia were analyzed by INAA. The pottery sample originates primarily from the fortress and Outer Town at Ayanis and also includes samples from nearby sites in the Lake Van basin. A small sample of pottery from Bastam, a contemporary Urartian fortress in northwest Iran, and Kef Kalesi, a site on the north shore of Lake Van were also analyzed. Ten distinct compositional groups were identified during the course of the analysis suggesting that pottery was produced at multiple locations throughout the Urartian Kingdom. In addition to identifying multiple production locales, we document the long-distance movement of pottery from the sites of Kef Kalesi and Bastam into the Van Basin and the movement of pottery from Ayanis to Bastam.

## Introduction

The Kingdom of Urartu brought an extensive mountainous territory in Turkey, Iran, and Armenia under highly centralized control from the 9th through the 7th centuries B.C.E. Under Urartian rule this region of Anatolia flourished as the state undertook impressive royal building programs, introduced irrigation-based agriculture on a large scale, created massive state-controlled storage facilities, imposed a state religion, and produced a distinctive style of art seen in bronzes and other objects of elite consumption.[1] Like some of the clearest examples of territorial states, Urartu flourished in an environment in which arable land was limited in scope, but stable in productivity, a situation that tends to strengthen the ability of elites to dominate the rest of the society.

To the extent that has been recovered to date, the Urartian archaeological record is largely known through excavations of fortified citadels. Scant attention has been paid to the domestic areas that surround these centers, although limited habitation areas were exposed by archaeologists working at the sites of Karmir Blur, Argišthinili, and Bastam. The fortress at Ayanis (ca. B.C.E. 673–630) located on the eastern shore of Lake Van, 35 km north of Tushpa (modern Van), the capital city of the Urartian Kingdom, offers an unparalleled opportunity to explore the larger urban environment at an Urartian site (Fig. 1).

Excavations at the Ayanis Fortress began in 1989 under the direction of Altan Çilingiroğlu.[2] Elizabeth STONE and Paul ZIMANSKY joined the excavation in 1997. Since then, work has been conducted in two different areas, designated as the "Fortress" and "Outer Town". The research design for Outer Town has focussed on understanding the distribution of people and institutions in the urban landscape of the highly centralized Urartian territorial state. One such way of addressing this question is by using instrumental neutron activation analysis (INAA) of pottery to examine the ties between residents in the Outer Town and the centralized government (e.g., the fortress). Excavations at Ayanis have yielded a substantial collection of pottery, most of which is a medium to coarse brown utilitarian ware. However, small quantities of the ceramics, referred to as red-polished Urartian ware, have been recovered from the fortress and various locations in the Outer Town. Pottery of this type tends to be rare and represents less than 10% of the total assemblage at the fortress. At an area in the Outer Town designated Pınarbaşı (just north of the Citadel), polished red ware comprises only 2% of the total pottery assemblage. At Güney Tepe, an Outer Town area east of the fortress, red ware pottery represents approximately 8% of the total ceramic assemblage.

Urartian ceramics, especially the red wares, are distinctive and visually appear similar throughout the empire. Determination of whether or not red ware pottery is the product of a centralized workshop(s) or the product of multiple dispersed workshops throughout the kingdom provides a means for evaluating the manufacture and distribution of red ware pottery within the kingdom. To address these questions 275 pottery and clay samples from the Ayanis fortress (Ayanis Kalesi) and Outer Town; the nearby Van Basin sites of Altıntepe (not to be confused with the larger site of the same name near Erzincan), Çavuştepe, Dilkaya, Karagünduz, and Van Kalise; Kef Kalesi, a site located on the north shore of Lake Van; and Bastam a contemporary fortress located in northwestern Iran were analyzed by INAA.

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A small sample of white-slipped medium-brown and fine buff-orange pottery from the Fortress and Outer Town was also analyzed by INAA. It was anticipated that we cold gain insight into the origin of these distinctive pottery types through chemical analyses.

## Experimental

*Sample preparation*

The INAA was conducted at the Archaeometry Laboratory at the University of Missouri Research Reactor (MURR). The ceramics were prepared for analysis using standard MURR procedures.[3] Pieces of each sherd were burred with a silicon carbide burr to remove painted or slipped surfaces and adhering soil. Burred samples were washed with deionized water and ground in agate mortars to a fine powder. The powdered samples were then oven-dried at 100 °C for 24 hours. Portions of approximately 150 mg were weighed and placed in small polyethylene vials used for short irradiations. At the same time, 200 mg of each sample was weighed into high-purity quartz vials used for long irradiations. Along with the unknown samples, reference standards of SRM-1633a (Coal Fly Ash) and SRM-688 (Basalt Rock) were similarly prepared, as were quality control samples (e.g., standards treated as unknowns) of SRM-278 (Obsidian Rock) and Ohio Red Clay.

*Instrumental neutron activation analysis*

At MURR, INAA of pottery and clays consists of two irradiations and a total of three gamma counts.[3,4] Short irradiations involve a pair of samples being transported through a pneumatic tube system into the reactor core for a 5-second neutron irradiation using a neutron flux of $8\cdot10^{13}$ $n\cdot cm^{-2}\cdot s^{-1}$. After a 25-minute decay, the samples are counted using a high-resolution germanium detector for 720 seconds. This count yields data for elements associated with short-lived radionuclides: Al, Ba, Ca, Dy, K, Mn, Na, Ti, and V. For the long irradiation, bundles of 50 or 100 of the encapsulated quartz vials are irradiated by a neutron flux of $5\cdot10^{13}$ $n\cdot cm^{-2}\cdot s^{-1}$ for 24 hours. Following the long irradiation, samples are allowed to decay for 7 day, and then are counted for 2,000 seconds (the "middle count") on a high-resolution germanium detector coupled to an automatic sample changer. The middle count yields determination of elements associated with medium half-life radionuclides: As, La, Lu, Nd, Sm, U, and Yb. After an additional 2-weak decay, a second count of 10,000 seconds is carried out on each sample. This measurement permits quantification of elements based on long-lived radionuclides: Ce, Co, Cr, Cs, Eu, Fe, Hf, Ni, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr.

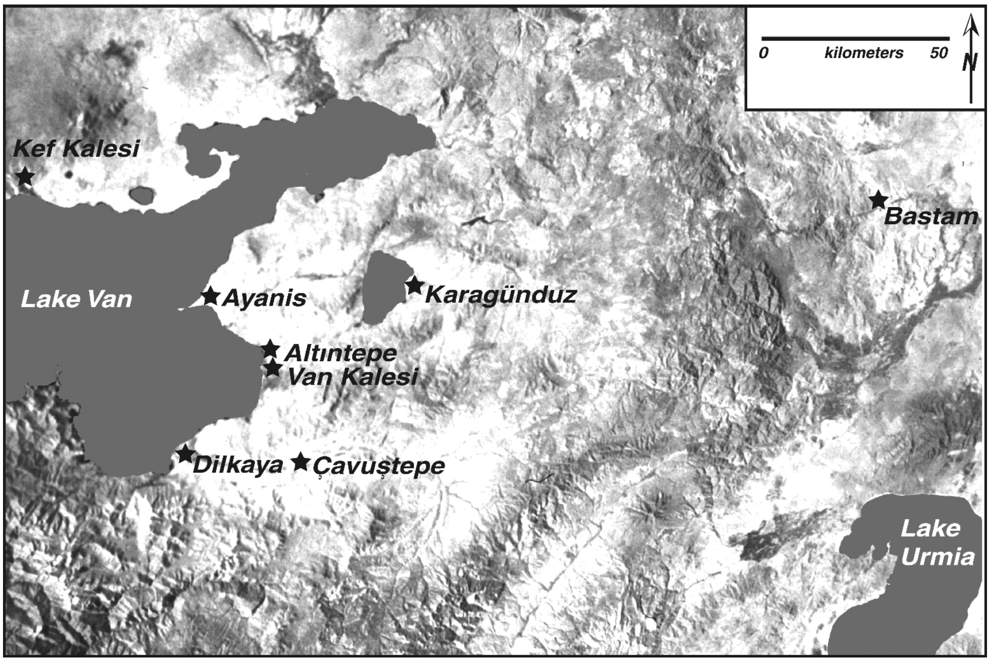


*Fig. 1.* Map of Eastern Anatolia showing sites discussed in the text and major physiographic features

*Quantitative analysis of the chemical data*

As is customary in ceramic provenance studies at MURR,[3–5] parts-per-million (mg/kg) data were converted to base-10 logarithms of concentrations. Use of log concentrations compensates for differences in magnitude between major elements, such as Al, on the one hand, and trace elements, such as the rare earth or lanthanide elements (e.g., La, Ce, Sm, Dy, and Yb) on the other hand. Transformation into log base-10 values also yields a more nearly normal distribution for many trace elements.

The main goal of quantitative analysis of the chemical data is to recognize compositionally homogeneous groups within the analytical database. Chemical groups are assumed to represent geographically restricted sources. The location of sources or source zones may be inferred by indirect means such as the "criterion of abundance"[6] or arguments based on geological and sedimentological characteristics.[7]

Potential compositional groups can be formulated initially by using non-compositional information (e.g., archaeological context, decorative attributes) or from application of pattern-recognition techniques to the chemical data. Principal components analysis (PCA) is one of the most commonly used statistical techniques in INAA to recognize patterns (e.g., subgroups) in chemical data sets. The validity of groups formulated by PCA can be confirmed directly through bivariate elemental concentration plots. A statistic known as Mahalanobis distance (or generalized distance) can be used to describe the separation between groups or between individual points and groups on multiple dimensions. Mahalanobis distance takes into account variances and covariances in the multivariate group and is analogous to expressing distance from a univariate mean in standard deviation units. Like standard deviation units, Mahalanobis distances can be converted into probabilities of group membership for each individual specimen.[5,8]

## Results

The analyzed Urartian ceramics could be subdivided into a core compositional group, Ayanis-1 and several smaller groups, Ayanis-2, Ayanis-3, Ayanis-4, Ayanis-5, Ayanis-6, Ayanis-7, Kef Kalesi, Bastam, and Ayanis Kalesi. Thirty-two ceramics could not be assigned to any of the compositional groups. Two of the six clay samples analyzed have high nickel, chromium, and cobalt values. These samples are considered outliers, and are not included in projections of the data.

A biplot (Fig. 2) derived from PCA of the Urartian data set variance-covariance matrix shows that the two major axes of variation in the data (Principal Components 1 and 2) express enrichment in Ni, Cr, and other transition metals as well as Ca, together with dilution of rare earth elements and Cs, Hf, Th, U, and Zr. The most striking differences in the data set, however, are based on variation in Ca concentrations. Figure 3, a bivariate plot of Cs and Ca base-10 logged concentrations demonstrates that the analyzed sample can be subdivided into high-calcium and low-calcium groups to facilitate data analysis. The samples of analyzed clays have both high-calcium and low-calcium concentrations. This suggests that differences between the high-calcium and low-calcium pottery do not result from the addition of non-plastics (e.g., temper) to clays used to manufacture pottery. Instead, this implies that both high-calcium and low-calcium clays were consumed by potters working in the Lake Van basin.

*Low-calcium pottery*

Ceramics in the low-calcium group form five compositional groups, Ayanis-1, Ayanis-2, Ayanis-3, Ayanis-5, and Kef Kalesi. Membership probabilities based on the first eight principal components obtained from PCA of the variance-covariance matrix of the 164 specimen low-calcium data set support the proposed group structure. The first eight principal components account for more than 91% of total variance in the data, thus probabilities should be similar to probabilities that would be obtained if all 33 dimensions were used in the Mahalanobis-distance calculations. Probabilities of membership for Ayanis-2, Ayanis-3, and Kef Kalesi could not be calculated because of the small sizes of these two groups, however, the distinctiveness of these two groups from Ayanis-1 is obvious from inspection of numerous bivariate projections of the data (Fig. 4). Samples assigned to the Ayanis-2, Ayanis-3, and Kef Kalesi groups are so distinct that most specimens fall outside the 0.001% Mahalanobis distance probability level for membership in Ayanis-1. All unassigned samples in the low-calcium group have less than 1% probability of membership in Ayanis-1.

When Mahalanobis distance probabilities are simultaneously calculated for Ayanis-1 and Ayanis-5, several specimens in Ayanis-1 exceed 1% probability of membership in the Ayanis-5 group. This is most likely a consequence of the small number of samples included in Ayanis-5 and the apparent heterogeneity of this group.

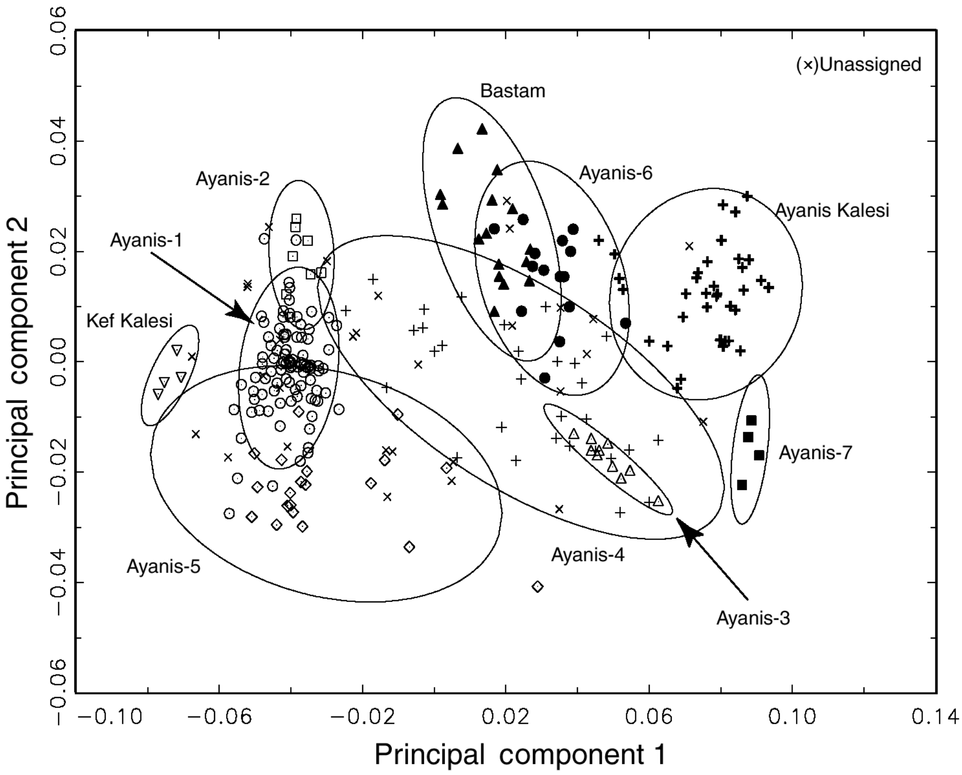


*Fig. 2.* Biplot derived from PCA of the variance-covariance matrix of the Urartian ceramics and clays data. Ellipses represent 90% confidence level for membership in the groups

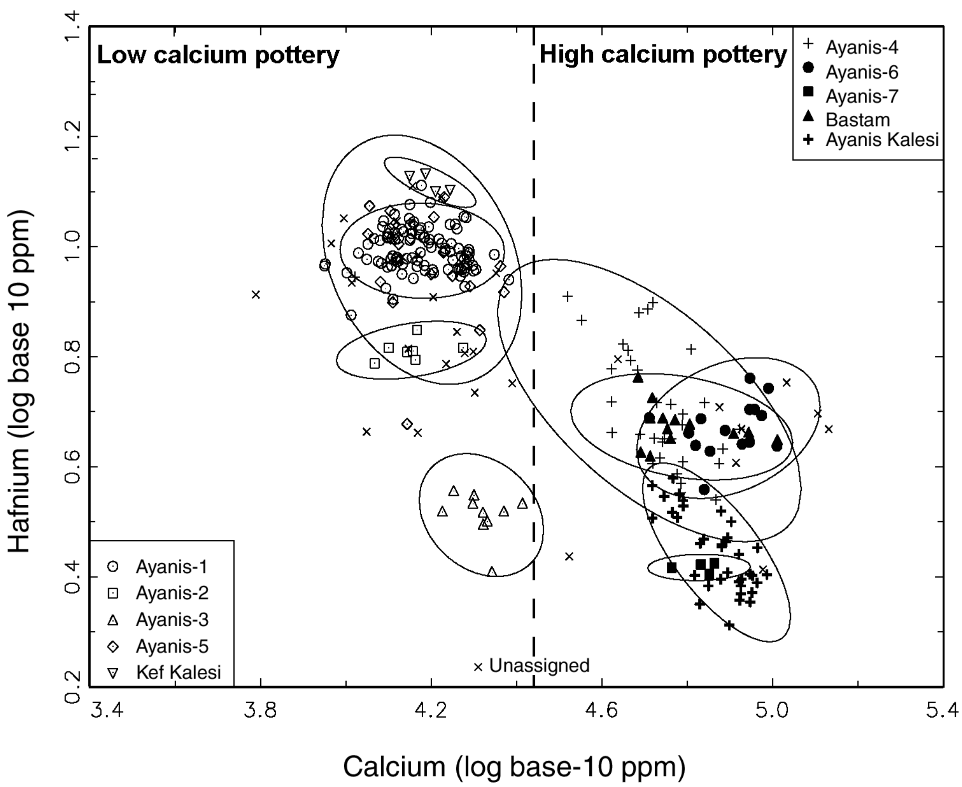


*Fig. 3.* Bivariate plot of calcium and hafnium concentrations in the Urartian ceramic data set showing basic the basic distinction between the high-calcium and low-calcium group. Ellipses represent 90% confidence level for membership in the groups

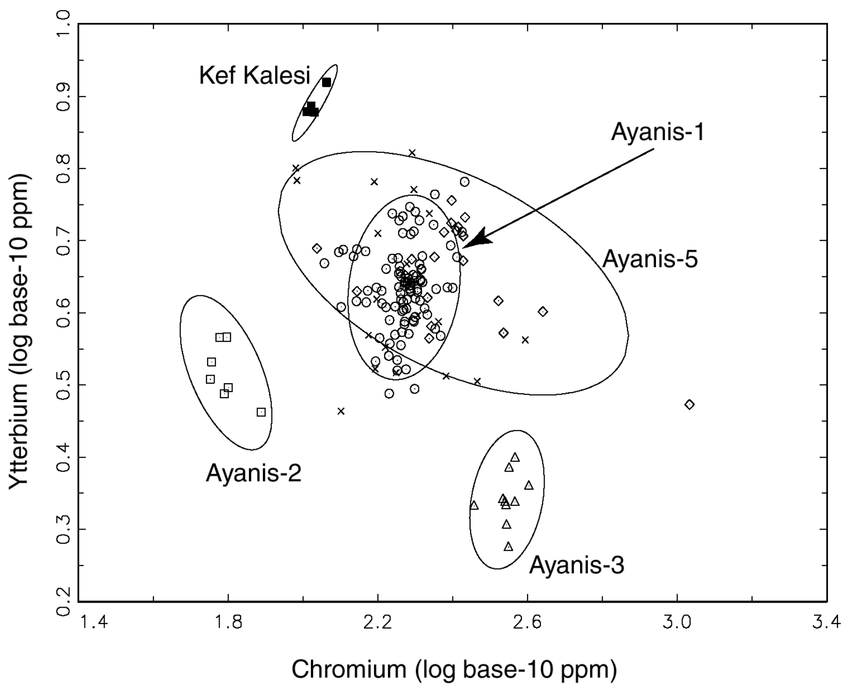


*Fig. 4.* Bivariate plot of chromium and ytterbium concentrations for the low-calcium pottery. Ellipses represent 90% confidence level for membership in the groups

It is possible that samples assigned to Ayanis-5 may actually comprise multiple subgroups. In most projections of the data, lower concentrations of Al and Cs and higher concentrations of Ni tend to discriminate the samples assigned to Ayanis-1 from samples assigned to Ayanis-5 (Fig. 5). It is likely that pottery assigned to Ayanis-5 are local to the Van Basin and that derivation of clays from higher and lower Al/Cs/Ni parent materials is what makes them distinct from Ayanis-1 pottery. Petrographic analysis of the pottery indicated that the addition of temper (or other non-plastics) to clays was not responsible for the differences observed in these two groups.

It is possible to further divide the Ayanis-1 group into two subgroups designated “1a” and “1b” based on small differences in Ba and Ca concentrations. Ayanis-1a is comprised almost exclusively of pottery from the Outer Town and Ayanis-1b is comprised of pottery primarily from the Ayanis fortress and outlying sites (Fig. 6). The chemical differences between Ayanis-1a and Ayanis-1b are subtle and may result from several factors including, wide-spread chemical continuity in clay resources throughout the Lake Van basin, selection of clays from similar resources, or differences in processing clays for ceramic manufacture. Mahalanobis distance probabilities support the division of Ayanis-1 into two subgroups. Samples designated “unassigned Ayanis-1” in Fig. 6 had either low probabilities of membership in the subgroup 1a or 1b, or had high probability of membership in both subgroups. It seems likely that, had we larger samples of pottery from the non-Ayanis Van Basin sites, it might have been possible to distinguish the pottery made at each of these sites. If so, this would demonstrate that although red polished ware, sometimes called “palace ware” although physically indistinguishable between sites, was made at each of the fortresses, and not all produced at a single center in the Van Basin (the capital at Van perhaps) and distributed to the satellite sites.

Given the number of specimens assigned to the Ayanis-1 and Ayanis-5 groups and because the vast majority of these samples are from Ayanis and nearby sites, we can infer that these groups represent locally produced red ware pottery. The distinctness of the pottery assigned to the Ayanis-2 and Ayanis-3 groups (Fig. 4) seems to suggest that pottery assigned to these groups were imported to Ayanis from other Urartian sites. This assumption is not unreasonable when we consider that one of the six specimens analyzed from Kef Kalesi, a site located on the opposite side of Lake Van from Ayanis, clearly has membership in the Ayanis-1 group. Additional analysis of pottery from other major Urartian sites is necessary to test the idea that pottery assigned to the Ayanis-2 and Ayanis-3 groups was imported to Ayanis.

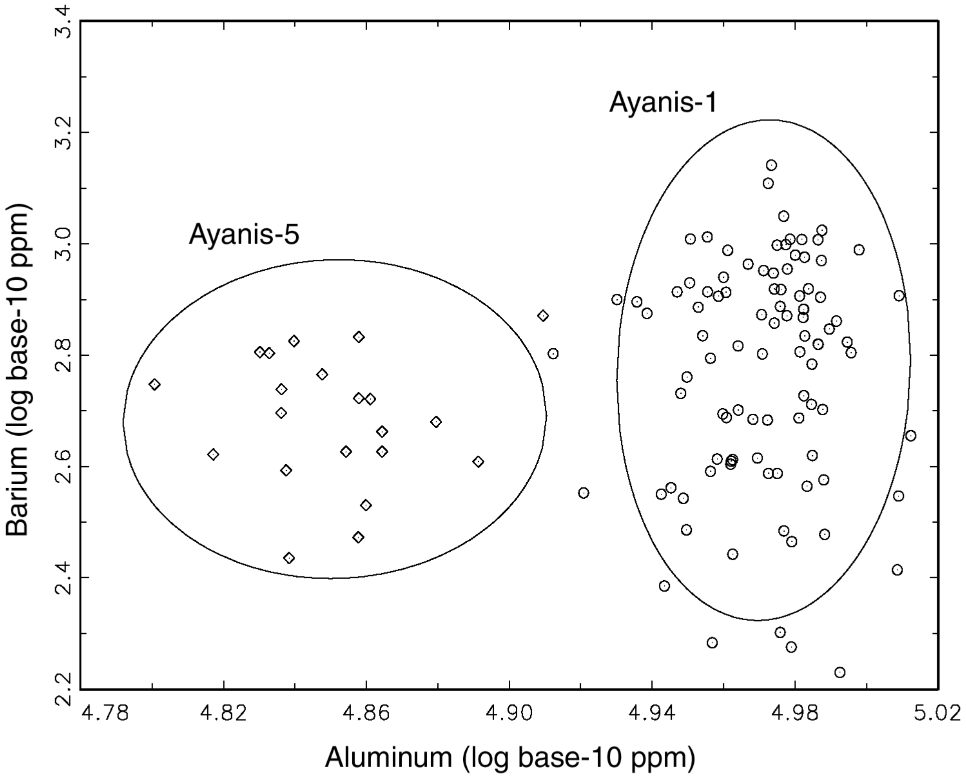


*Fig. 5.* Bivariate plot of aluminum and barium concentrations showing the separation of Ayanis 1 and Ayanis 5. Ellipses represent 90% confidence level for membership in the groups

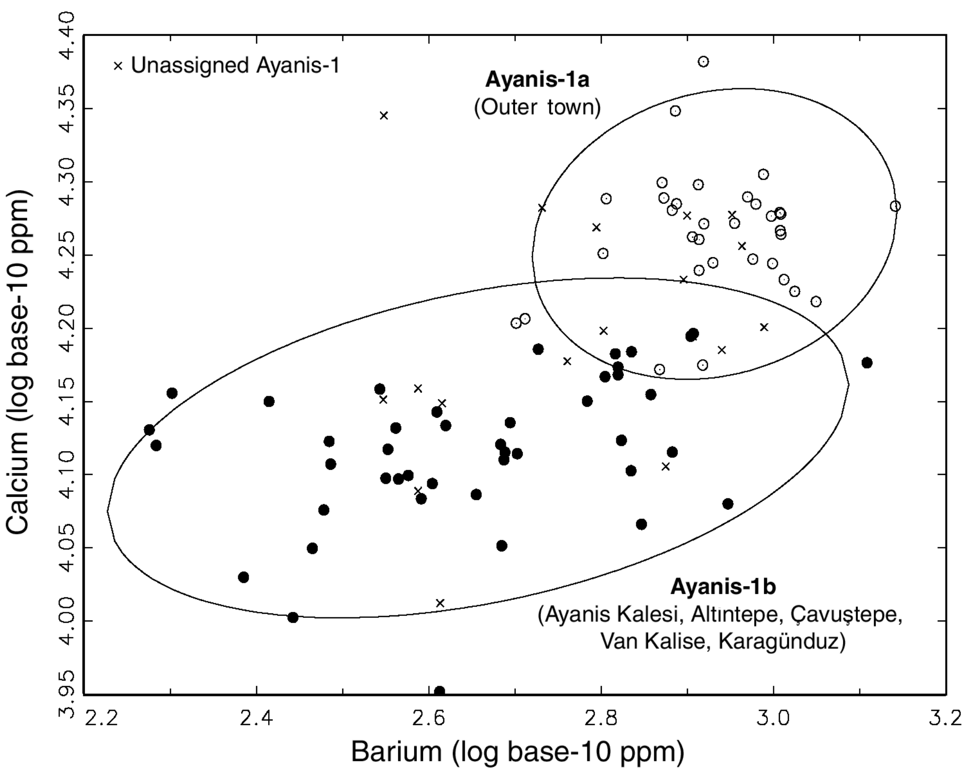


*Fig. 6.* Bivariate plot of barium and calcium concentrations showing the division of the Ayanis 1 core group into two subgroups Ayanis 1a and Ayanis 1b. Ellipses represent 90% confidence level for membership in the groups

*High-calcium pottery*

Ceramics classified as high calcium form five compositional groups, Bastam, Ayanis Kalesi, Ayanis-4, Ayanis-6, and Ayanis-7 (Fig. 7). Twelve ceramics were unassigned to any of the high-calcium groups. Group membership probabilities are based on the first eight principal components obtained from PCA of the variance-covariance matrix of the 111 specimen low-calcium data set. These eight components account for more 91% of total variance in the data. Probabilities of membership for Ayanis-7 could not be calculated because of the small sizes of this group, however, the distinctiveness of this group is obvious from inspection of numerous bivariate projections of the data. When samples in the Ayanis-7 group are projected against the remaining four high-calcium groups, all specimens fall outside of the 1% Mahalanobis distance probability level for membership in those groups.

Ten of the fourteen samples from the site of Bastam (NW Iran) comprise the core of the Bastam compositional group. Of the remaining four samples from the site of Bastam, two are unassigned high-calcium, one is unassigned low-calcium, and one ceramic is assigned to the Ayanis-1 group. Four samples non-local to Bastam are included in the Bastam reference group, three originate from the Outer Town, and one is from the fortress (Ayanis Kalesi). Although the Bastam reference group is small, this is nonetheless clear evidence for the two-way exchange of pottery between Bastam and Ayanis.

Most pottery assigned to Ayanis-4 (~75%) originates from the Outer Town. The remaining samples originate from the fortress and other sites in the Van Basin. Ayanis-4 is relatively heterogeneous and it is possible that additional sampling would indicate that it consists of two or more subgroups.

All pottery in the Ayanis Kalesi compositional group is typologically defined as "Ware-3", a medium ware ceramic with white slip. Pottery in this group is morphologically similar in shape and has similar decorative markings. Two-thirds of the ceramics in the Ayanis Kalesi compositional group are from the fortress. The remaining samples are from Outer Town contexts. At this point in our study, it is unclear whether pottery assigned to this group was locally produced at Ayanis or whether it was imported. Additional sampling and research is necessary to determine the distribution of this pottery type in other Urartian sites, as well as non-Urartian sites given that it is possible that this ware was not produced by Urartian craftsmen.

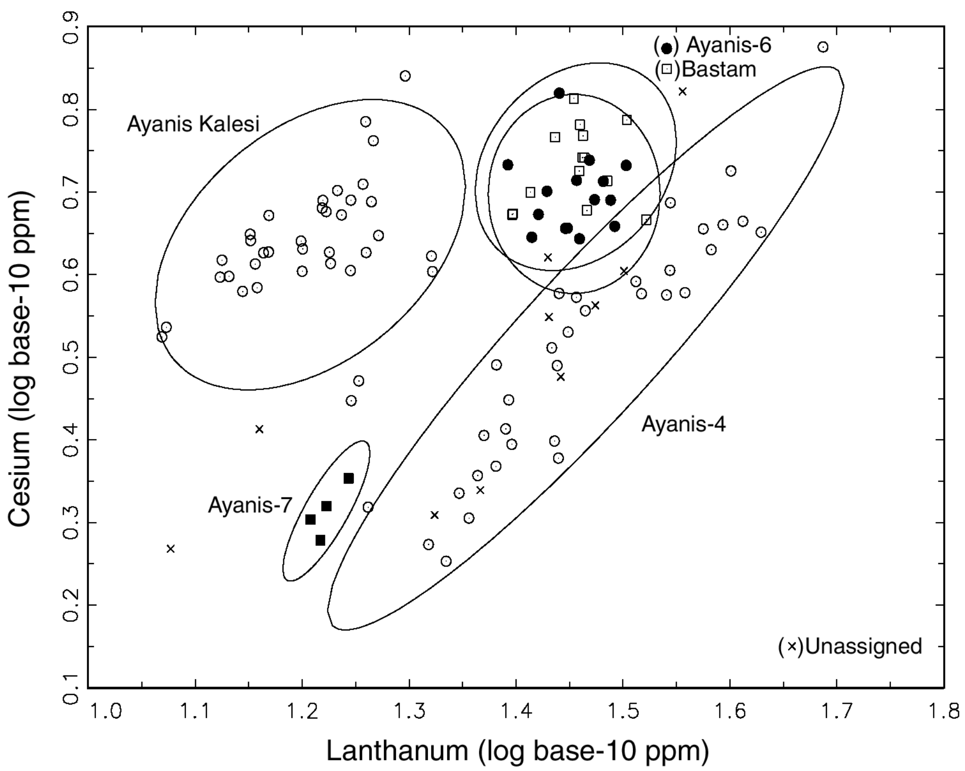


*Fig. 7.* Bivariate plot of lanthanum and cesium concentrations for the high-calcium ceramics. Ellipses represent 90% confidence level for membership in the groups

Fine buff-orange pottery comprises the Ayanis-6 and Ayanis-7 groups. Morphologically and stylistically these vessels are different from other Urartian ceramics and can best be compared to pottery from Assyrian sites in northern Syria like Tell Ahmar. Given the uniqueness of these vessels, it is probable that Urartian craftsmen did not produce them. This raises the question of where do these ceramics originate? Whereas pottery in the Ayanis-7 group is relatively distinct from the other chemical groups and thus its provenance is unknown at this time, pottery assigned to Ayanis-6 can only be differentiated from the Bastam reference group on the basis of Cr (Fig. 8). Although chemically these ceramics are similar to the Bastam pottery, the lack of any analogous wares and shapes from the greater Bastam area of northwest Iraq and/or southern Armenia make it unlikely that the Ayanis-6 pottery derived from there.

## Conclusions

The INAA of pottery from Ayanis and other contemporary sites in Eastern Anatolia offers a glimpse into Urartian ceramic production and organization. Ten distinct chemical groups were identified, several of which are presumed to represent local ceramic production at Ayanis. Analysis of pottery from Kef Kalesi and Bastam permitted the identification of two reference groups that admittedly contain a small number of specimens. Nonetheless, we have clear chemical evidence for movement of pottery from Kef Kalesi to Ayanis. Likewise, there is trade of pottery between sites in the Van Basin and Bastam. Several of the red ware groups, (e.g., Ayanis-2, Ayanis-3, and Ayanis-4) may represent pottery that was imported to Ayanis from other Urartian sites. Two fine buff-orange chemical groups were identified (Ayanis-6 and Ayanis-7) during the course of this analysis, one of which is similar chemically but not typologically to pottery produced in northwest Iran or southern Armenia. We identified one compositional group in the analyzed sample of white-slipped pottery (Ayanis Kalesi), which suggests that this ware originated from a single source. Although pottery from the Ayanis and several nearby sites are compositionally similar, there is some basis for optimism that we can distinguish among pottery produced at Ayanis and pottery produced at nearby sites. In total, seven Urartian red ware pottery groups were identified by INAA. Based on our preliminary analysis, we suggest that these groups represent multiple pottery production locales throughout the Urartian Kingdom. Future analyses of Urartian pottery sites may permit us to refine the compositional groups identified in this study and perhaps identify the provenance of some of these pottery groups.

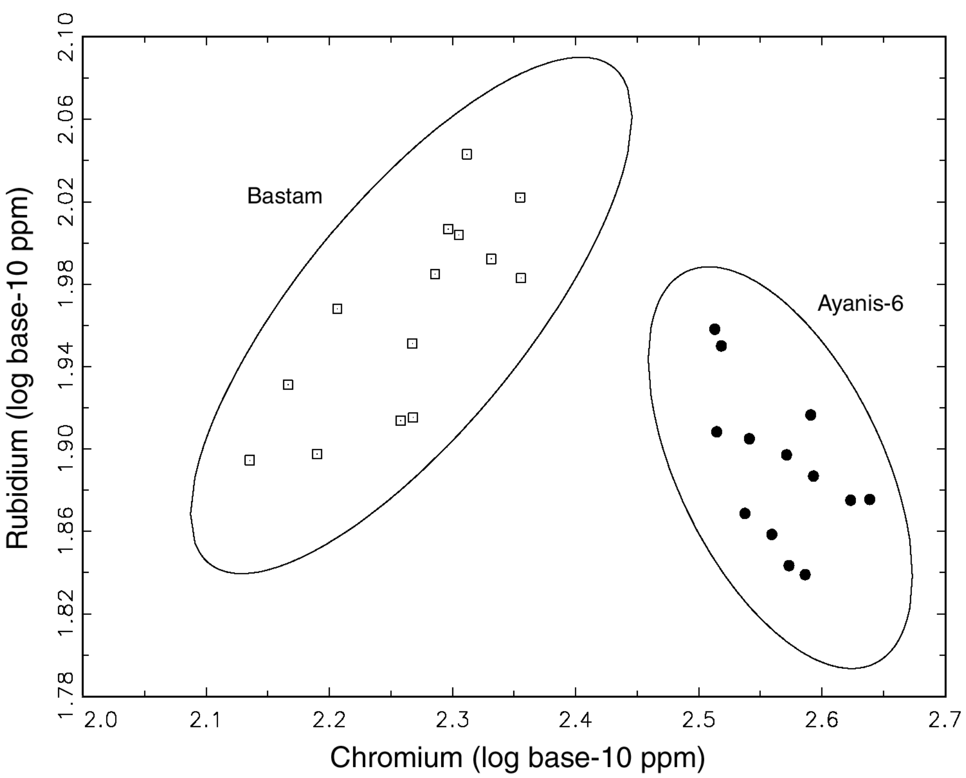


*Fig. 8.* Bivariate plot of chromium and rubidium concentrations showing separation of the Bastam and Ayanis-7 pottery. Ellipses represent 90% confidence level for membership in the groups

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